GEORGIA DOT RESEARCH PROJECT 18-06

FINAL REPORT

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

VOLUME III

Georgia Department of Transportation

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH

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16. Abstract: This volume is the third in a series. The other volumes in the series are FHWA-GA-20-1806 Volumes I through IV.

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 has 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 III

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Georgia Department of Transportation

In cooperation with
U.S. Department of Transportation Federal Highway Administration

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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APPENDIX D. BIOLOGICAL ASSESSMENTS

This appendix contains biological assessments for each of the 111 species covered in this report. The assessments include basic information on life history, abundance and conservation status, as well as an analysis of sensitivity to stressors that is used to assign species tolerance values for Total Effect Score calculation. Each assessment has been reviewed by at least one external expert and represents the best available scientific information at the time of compilation. However, the researcher team recommends reviewing and updating this information at least every five years, or sooner if new scientific research indicates a change in sensitivity classification is warranted for a species.

Species sensitivities are summarized below in Table 1. These values are incorporated into the Total Effect Score tool. Sediment sensitivity is on a 3-point scale, with each species assigned a value of either “intolerant” (1), “moderate” (2), or “tolerant” (3). Pollutant sensitivity is on a 5-point scale, with each species assigned a value of “extremely intolerant” (1), “very intolerant” (2), “somewhat intolerant” (3), “moderate” (4) and “tolerant” (5). The assignment of each sensitivity classification is based on the analysis of the effects of construction activities on biota in Chapter 6 (Volume I), and the species-level reviews presented in this appendix.

Noise sensitivity for fish species is classified as either "high" or "medium" based on the categories described in Chapter 6 (located in Volume I). All non-fish species were assigned to the “medium” sensitivity category, due to limited information, as discussed in Chapter 6 (Volume I). Recolonization potential is classified as high, medium or low. This potential is a characteristic of the species, and assumes the existence of a nearby population of potential colonists; if all individuals of an isolated population are extirpated, then recolonization will be impossible regardless of potential. Recolonization potential was assigned based on expert opinion of the authors and external reviewers based on species movement potential and propensity. Noise sensitivity and recolonization potential are *not* discussed further in the species-level accounts that follow.

Physical contact sensitivity is not shown in table 1, but is set at “medium” for fish (which are mobile) and mussels (which are usually relocated) and “high” for all other taxa.

Species that are considered critically endangered for purposes of calculating the MaxTES are listed as “CE” under “Overall Imperilment.” Critically endangered species include all species listed as endangered under the ESA as well as those species judged by the authors and external reviewers to be at high risk of extinction. For example, the undescribed Coosa madtom is now known only from the mainstem of the Upper Etowah River, so a single toxicity event could cause the species to go extinct. Average lifespan is based on expert opinion for short-lived species (those with maximum life spans less than 10 years). For long-lived species, it was assumed (1) that reported maximum lifespans represented the age of 95% mortality, and (2) that populations underwent exponential decay. Using these assumptions, the age of 50% mortality (the average lifespan) was approximated by dividing the reported maximum lifespan by three.

Table 1. Summary of species characteristics.

Group	Scientific name	Common name	Sed. Sens 3-pt	Pollut. Sen 5-pt	Noise Sensitivity	Recolon Potential	Overall Imperil	Avg. Life-span
Amphibians	*Gomphus consanguis*	Cherokee clubtail	2	3	med	high		2
Amphibians	*Cryptobranchus alleganiensis alleganiensis*	Eastern hellbender	1	3	med	low		9.9
Amphibians	*Ophiogomphus edmundo*	Edmund's snaketail	2	3	med	high		2
Amphibians	*Lithobates capito*	gopher frog	1	3	med	med		2.0
Amphibians	*Amphiuma pholeter*	one-toed amphiuma	2	3	med	med		5.3
Amphibians	*Cordulegaster sayi*	Say's spiketail	2	4	med	high		3
Amphibians	*Notophthalmus perstriatus*	striped newt	3	3	med	low		5.0
Crayfishes	*Cambarus speciosus*	beautiful crayfish	2	4	med	med	CE	2.5
Crayfishes	*Cambarus unestami*	blackbarred crayfish	2	4	med	med		2.5
Crayfishes	*Distocambarus devexus*	Broad River burrowing crayfish	3	3	med	low		5
Crayfishes	*Cambarus howardi*	Chattahoochee crayfish	2	4	med	med		2.5
Crayfishes	*Cambarus scotti*	Chattooga River crayfish	2	4	med	med		2.5
Crayfishes	*Cambarus extraneus*	Chickamauga crayfish	2	4	med	med		2.5
Crayfishes	*Cambarus cymatilis*	Conasauga blue burrower	3	3	med	low	CE	5
Crayfishes	*Cambarus coosawattae*	Coosawattee crayfish	2	4	med	med	CE	2.5
Crayfishes	*Cambarus doughertyensis*	Dougherty burrowing crayfish	3	3	med	low	CE	5
Crayfishes	*Cambarus fasciatus*	Etowah crayfish	2	4	med	med		2.5
Crayfishes	*Procambarus verrucosus*	grainy crayfish	3	3	med	med		2.5
Crayfishes	*Cambarus parrishi*	Hiwassee headwaters crayfish	1	4	med	med	CE	2.5
Crayfishes	*Cambarus strigosus*	lean crayfish	3	3	med	low		5
Crayfishes	*Cambarus georgiae*	Little Tennessee crayfish	2	4	med	med		2.5

Crayfishes	*Procambarus gibbus*	Muckalee crayfish	2	4	med	med		2.5
Crayfishes	*Cambarus truncatus*	Oconee burrowing crayfish	3	3	med	low		5
Crayfishes	*Cambarus harti*	Piedmont blue burrower	3	3	med	low	CE	5
Crayfishes	*Procambarus versutus*	sly crayfish	2	3	med	med		2.5
Crayfishes	*Cambarus englishi*	Tallapoosa crayfish	3	4	med	med		2.5
Fishes	*Alosa alabamae*	Alabama shad	2	4	high	med		4
Fishes	*Cyprinella xaenura*	Altamaha shiner	1	3	high	med		2
Fishes	*Percina antesella*	amber darter	1	3	med	med	CE	2
Fishes	*Enneacanthus chaetodon*	blackbanded sunfish	2	3	med	med		4
Fishes	*Etheostoma duryi*	blackside snubnose / black darter	1	3	med	med		2.5
Fishes	*Erimystax insignis*	blotched chub	2	4	med	med		2
Fishes	*Cyprinella caerulea*	blue shiner	1	2	high	med		2
Fishes	*Elassoma okatie*	bluebarred pygmy sunfish	2	4	med	med		1
Fishes	*Lucania goodei*	bluefin killifish	3	4	med	low		2
Fishes	*Pteronotropis welaka*	bluenose shiner	3	3	high	med		2
Fishes	*Cyprinella callitaenia*	bluestripe shiner	1	3	high	med		2
Fishes	*Percina kusha*	bridled darter	1	3	med	med	CE	2
Fishes	*Pteronotropis euryzonus*	broadstripe shiner	1	3	high	med		2
Fishes	*Notropis asperifrons*	burrhead shiner	1	3	high	med		3
Fishes	*Etheostoma scotti*	Cherokee darter	1	4	med	med		2.5
Fishes	*Etheostoma ditrema*	coldwater darter	1	3	med	low		2
Fishes	*Percina jenkinsi*	Conasauga logperch	1	3	med	med	CE	3
Fishes	*Macrhybopsis etnieri*	Coosa chub	1	2	high	med		2
Fishes	*Noturus sp. cf. munitus*	Coosa madtom	1	3	high	low	CE	4
Fishes	*Percina sciera*	dusky darter	2	4	med	med		3
Fishes	*Etheostoma etowahae*	Etowah darter	1	1	med	med	CE	2

Fishes	*Phenacobius crassilabrum*	fatlips minnow	2	5	high	med		2.5
Fishes	*Hemitremia flammea*	flame chub	1	3	high	low		1.5
Fishes	*Percina lenticula*	freckled darter	1	2	med	med		3
Fishes	*Percina aurolineata*	goldline darter	1	3	med	med		2
Fishes	*Etheostoma parvipinne*	goldstripe darter	2	3	med	low		2
Fishes	*Etheostoma chlorobranchium*	greenfin darter	1	3	med	med		3
Fishes	*Percina crypta*	Halloween darter	1	3	med	med		2
Fishes	*Notropis hypsilepis*	highscale shiner	2	2	high	med		4
Fishes	*Etheostoma brevirostrum*	holiday darter	1	3	med	med	CE	2.5
Fishes	*Acipenser fulvescens*	lake sturgeon	2	2	med	high		22.6
Fishes	*Hybopsis lineapunctata*	lined chub	1	4	high	med		2
Fishes	*Etheostoma chuckwachatte*	lipstick darter	1	3	med	med		2.5
Fishes	*Noturus eleutherus*	mountain madtom	1	2	high	low		4
Fishes	*Percina smithvanizi*	muscadine darter	2	3	med	med		2
Fishes	*Fundulus catenatus*	northern studfish	1	4	med	med		3
Fishes	*Ichthyomyzon bdellium*	Ohio lamprey	1	4	high	med		6
Fishes	*Percina squamata*	olive darter	1	2	med	med		3
Fishes	*Notropis ariommus*	popeye shiner	1	3	high	med		2
Fishes	*Moxostoma robustum*	robust redhorse	1	3	high	high	CE	12
Fishes	*Etheostoma rupestre*	rock darter	2	3	med	med		3
Fishes	*Notropis scepticus*	sandbar shiner	2	2	high	med		3
Fishes	*Moxostoma sp. 2*	sicklefin redhorse	2	3	high	high	CE	8
Fishes	*Notropis photogenis*	silver shiner	1	3	high	med		2
Fishes	*Percina tanasi*	snail darter	1	3	med	med		3
Fishes	*Ameiurus serracanthus*	spotted bullhead	3	3	high	med		5
Fishes	*Phenacobius uranops*	stargazing minnow	2	4	high	med		2

Fishes	*Fundulus bifax*	stippled studfish	1	4	med	low		4
Fishes	*Micropterus notius*	Suwannee bass	2	3	med	high		7
Fishes	*Etheostoma tallapoosae*	Tallapoosa darter	1	3	med	med		2.5
Fishes	*Percina aurantiaca*	tangerine darter	1	3	med	med		3
Fishes	*Chrosomus tennesseensis*	Tennessee dace	2	4	high	med		3
Fishes	*Etheostoma trisella*	trispot darter	2	3	high	high	CE	2
Fishes	*Etheostoma vulneratum*	wounded darter	1	3	med	med		3
Mussels	*Pseudodontoideus connasaugaensis*	Alabama creekmussel	1	3	med	low	CE	11.2
Mussels	*Medionidus acutissimus*	Alabama moccasinshell	1	3	med	low	CE	1.7
Mussels	*Elliptio arca*	Alabama spike	1	3	med	low		11.9
Mussels	*Alasmidonta arcula*	Altamaha arcmussel	2	2	med	med		5.1
Mussels	*Elliptio spinosa*	Altamaha spinymussel	1	3	med	low	CE	13.9
Mussels	*Utterbackiana heardi*	Apalachicola floater	2	3	med	med		4.0
Mussels	*Fusconaia masoni*	Atlantic pigtoe	1	3	med	low	CE	12.5
Mussels	*Medionidus parvulus*	Coosa moccasinshell	1	3	med	low	CE	1.7
Mussels	*Elliptio arctata*	delicate spike	1	2	med	low		10.9
Mussels	*Amblema neislerii*	fat threeridge	1	3	med	low	CE	16.5
Mussels	*Hamiota altilis*	finelined pocketbook	1	3	med	med		5.0
Mussels	*Pleurobema hanleyianum*	Georgia pigtoe	1	3	med	low	CE	12.4
Mussels	*Medionidus penicillatus*	Gulf moccasinshell	1	3	med	low	CE	1.7
Mussels	*Elliptio purpurella*	inflated spike	1	3	med	med		13.9
Mussels	*Pleurobema pyriforme*	oval pigtoe	1	3	med	med	CE	12.4
Mussels	*Elliptoideus sloatianus*	purple bankclimber	1	3	med	high	CE	13.9
Mussels	*Strophitus radiatus*	Rayed Creekshell	2	2	med	med		6.1
Mussels	*Ptychobranchus foremanianus*	rayed kidneyshell	1	3	med	low	CE	6.1
Mussels	*Toxolasma pullus*	Savannah lilliput	2	3	med	med		2.6

Mussels	*Hamiota subangulata*	shinyrayed pocketbook	1	3	med	med	CE	5.0
Mussels	*Pleurobema decisum*	Southern clubshell	1	3	med	med	CE	14.9
Mussels	*Alasmidonta triangulata*	southern elktoe	2	2	med	med	CE	5.1
Mussels	*Pleurobema georgianum*	Southern pigtoe	1	3	med	low	CE	12.4
Mussels	*Medionidus walkeri*	Suwannee moccasinshell	1	3	med	med	CE	1.7
Snails	*Leptoxis foremani*	interrupted rocksnail	1	2	med	med	CE	3
Turtles	*Graptemys pulchra*	Alabama map turtle	2	4	med	med		14
Turtles	*Macrochelys temminckii*	Apalachicola alligator snapping turtle	3	4	med	med		26.4
Turtles	*Graptemys barbouri*	Barbour's map turtle	2	4	med	med		14
Turtles	*Glyptemys muhlenbergii*	bog turtle	3	4	med	low	CE	9
Turtles	*Graptemys geographica*	Northern map turtle	2	4	med	med		14
Turtles	*Macrochelys suwanniensis*	Suwanee alligator snapping turtle	3	4	med	med		26.4

AMPHIBIANS

EASTERN HELLBENDER

Species

Eastern Hellbender, *Cryptobranchus alleganiensis alleganiensis*

Description

The Eastern hellbender is a fully aquatic, stream-dwelling salamander. It is relatively large compared to other salamanders, growing up to 74cm in total length (Fitch 1947; Petranka 1998). Its head and body are dorsoventrally compressed, while the tail is laterally compressed into a paddle. Eastern hellbenders generally walk or trot along the stream bottom on short, stocky legs, but can use their tails to swim quickly for short bursts to escape from predators (Smith 1907). Larvae possess external gills, but these are lost once an individual reaches approximately 10-13cm in length or 1.5 to 2 years old and are not present at all in adults (Bishop 1941; Nickerson and Mays 1973). Adults use their lungs in low oxygen environments, but mostly rely on cutaneous respiration (Jensen et al. 2007; Guimond and Hutchison 1973). The skin is generally brown, dark green, or gray in color with some dark brown or black spots, blotches or mottling on the dorsal surface. A horizontal fold of skin extends down each side of the body.

The genus *Cryptobranchus* contains only one other extant subspecies, the Ozark hellbender (*Cryptobranchus alleganiensis bishopi*). The next closest relatives of the Eastern hellbender are members of the genus *Andrias* which contains several species of giant salamanders native to China and Japan including the Japanese Giant Salamander (*Andrias japonicus*) and others which share a family (*Cryptobranchidae*) with the North American hellbenders (USFWS 2018a).

Life History

Eastern hellbenders nest under large, flat rocks in the late summer (USFWS 2018a; Jensen et al. 2007; Mayasich et al. 2003). Males inhabit burrows with downstream facing openings under these rocks and guard them against predators and conspecifics, occasionally excavating excess sediments. Females deposit eggs in a cluster on the substrate within the burrow between late summer and early October to be fertilized by the male. The 450 to 1100 eggs hatch within about two to three months. Males remain in the nest protecting the eggs from predators, including adult Eastern hellbenders, and aerating them by rocking back and forth to increase water circulation. After hatching, larvae rely at least partially on energy reserves from a yolk sac for a few months. Individuals reach maturity at approximately five or six years of age (USFWS 2018a; Jensen et al. 2007; Mayasich et al. 2003).

Eastern hellbenders feed primarily on crayfish, but will also consume small fish, insects, snails, and other amphibians (Dunn 2016; USFWS 2018a; Jensen et al. 2007; Keitzer et al. 2013).

Larval Eastern hellbenders rely more heavily on aquatic insect larvae than adults (Pitt and Nickerson 2006; Hecht et al. 2017).

Hellbender populations are found almost exclusively in cool, clear, fast streams with high levels of dissolved oxygen and unembedded boulder, cobble, and gravel substrates (USFWS 2018a). Adults require large, flat, partially embedded rocks, or, to a lesser extent, bedrock crevices or root wads, for shelter, foraging, and mating (USFWS 2018; Jensen et al. 2007). Larvae use interstitial spaces in unembedded gravel and cobble for refuge and feeding (USFWS 2018).

Numbers, Reproduction, Distribution

Eastern hellbenders range from northeastern Mississippi to southern New York (Jensen et al. 2007). Within this range, 570 historical populations have been identified (USFWS 2018a). As of 2018, 225 of these populations are extirpated. 126 are considered healthy by the U.S. Fish and Wildlife Service, and 219 are declining (USFWS 2018a). In Georgia, Eastern hellbenders are restricted to streams in the mountainous regions of the northeast part of the state (Jensen et al. 2007).

Eastern hellbenders have long lifespans and relatively long times until maturity (USFWS 2018a). Individuals are known to reach at least 25 to 30 years of age in the wild and in captivity, with reports of individuals surviving for over 50 years (Horchler 2010; Peterson et al. 1988; Taber et al. 1975).

Conservation

The Eastern hellbender has a global conservation ranking of G3T2 and a Georgia state ranking of S2S3. It is protected as Threatened in Georgia, but it has no federal protections. The primary threats to extant populations include sedimentation, water quality degradation, habitat loss (due to stream impoundment and gravel mining), disease, human collection (for the pet trade and for use as fishing bait), climate change, small population effects, and increased native and invasive predator abundance (Jensen et al. 2007; USFWS 2018a). Currently the main conservation efforts include habitat restoration, habitat protection, captive breeding, and stocking of captive-bred individuals back into streams with depleted or extirpated populations (USFWS 2018a).

Effects of Construction Activities

Sediment

The most recent species status assessment for the Eastern hellbender (USFWS 2018a) identified sedimentation as the most important stressor contributing to continued declines of Eastern hellbender populations. Pugh et al. (2016) analyzed habitat and occurrence data for Eastern hellbenders in western North Carolina and found that the strongest predictor of presence was local habitat characterized by "larger rocks, more bedrock, and less organic matter and fine sediments." Neto et al. (2019) analyzed microhabitat use of multiple life stages of Eastern hellbenders and found that their occurrence was associated with coarse substrate and low embeddedness.

While adults do maintain their burrows to an extent by excavating sediments, they mostly rely on existing crevices for shelter (Smith 1907). Adult males guard the nest during embryonic development and may maintain it free of fine sediments, though this has not been documented. Eastern hellbenders may be indirectly affected by a reduction in abundance of their prey base by a sedimentation event.

Based on the findings of Pugh et al. and Neto et al., the sediment sensitivity of the Eastern hellbender is categorized as intolerant (1).

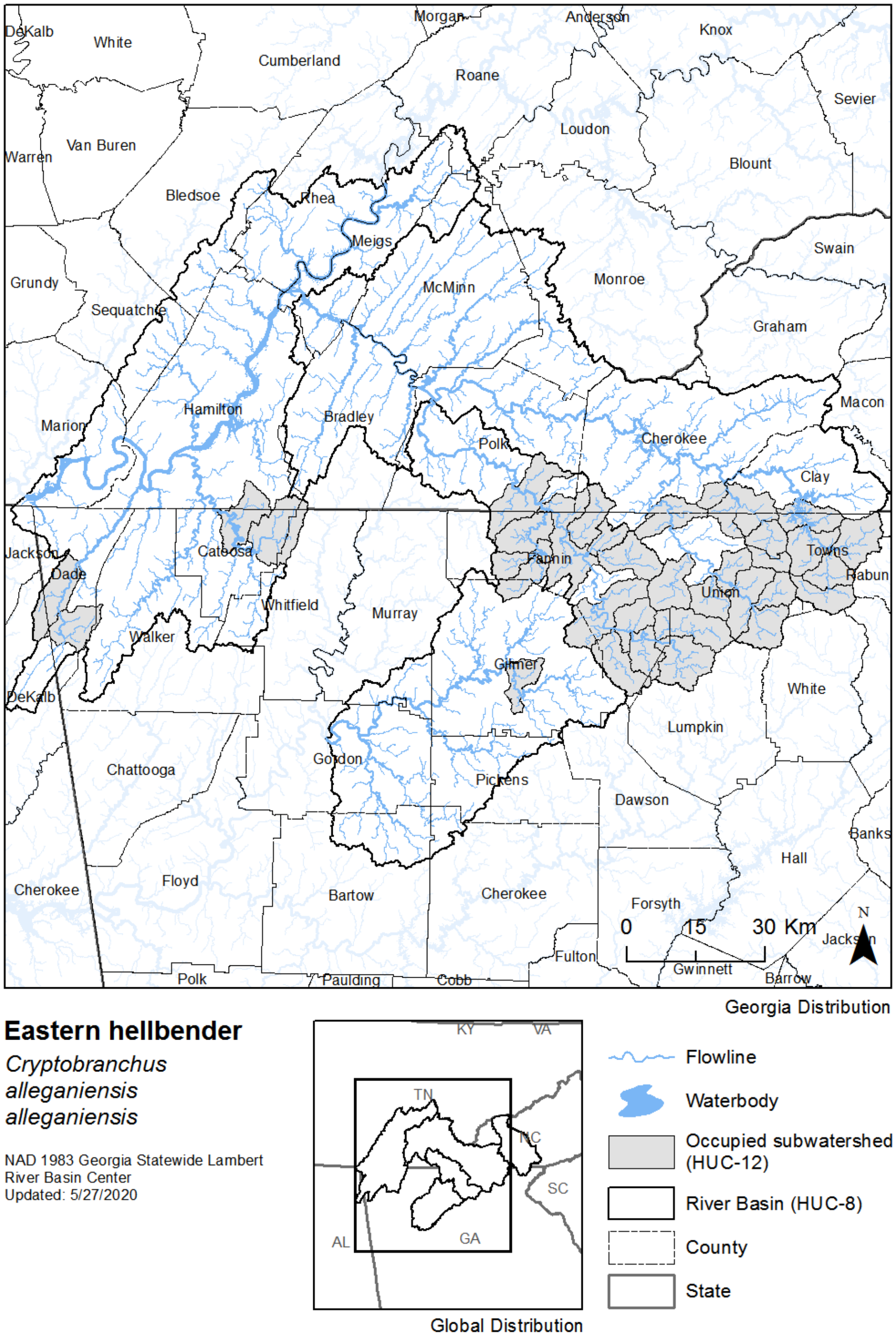
Pollutants

As part of a conservation assessment by the U.S. Forest Service, experts consistently cited "pollution" as a potential threat to hellbender populations (Mayasich et al. 2003). Keitzer et al. (2013) analyzed habitat characteristics of occupied sites and found that Eastern hellbenders preferred sites with low specific conductivity.

Eastern hellbenders rely primarily on cutaneous respiration, which serves as an exposure route for hydrophilic pollutants (e.g. metals). As a predatory species, the Eastern hellbender likely has a higher body burden of pollutants that bioaccumulate (e.g. organic compounds, hydrocarbons).

Based on the work by Keitzer et al. and the traits-related evidence, the pollutant sensitivity of the Eastern hellbender is categorized as somewhat intolerant (3).

Figure 1. Map. Range map of the Eastern hellbender.



GOPHER FROG

Species

Gopher Frog, *Lithobates capito*

Description

The adult gopher frog reaches a maximum of about 11cm in length and 151g in weight (Stevenson et al. 2007a; Palis and Fischer 1997). Adult dorsal coloration can range from brown or gray to "creamy white" with dark brown mottling, spots or bars. The ventral side is darkly mottled white or off-white with some yellow on the hind limb. Yellow brown ridges run from the hind limbs up to the eyes. The larval stage reaches a length of 84mm. Tadpole coloration is olive green with some dark spots scattered around the dorsal side (Stevenson et al. 2007a).

Life History

Gopher frogs migrate to ephemeral ponds, ditches, or borrow pits after heavy rains to breed (Stevenson et al. 2007a). Breeding ponds must be seasonally dry so that large, predatory fishes are excluded (Stevenson et al. 2007a). Adult males settle in shallow water and make a low-pitched, snore-like call, which can travel up to a quarter mile, to attract mates (Stevenson et al. 2007; Palis and Fischer 1997). Breeding season timing is variable depending on location and conditions (Stevenson et al. 2007a; Horan et al. 2011; Palis 1998; Palis and Fischer 1997).

Breeding has been documented between September and May (Horan et al. 2011; Palis 1998; Palis and Fischer 1997; Semlitsch et al. 1995). While the seasonal breeding range is large, the duration of a local breeding event is often restricted to less than two weeks (Semlitsch et al. 1995). Eggs are deposited in masses of up to 6000 individuals on stiff emergent vegetation near the surface in shallow water at the edges of the breeding pond (Palis 1998; Palis and Fischer 1997; Stevenson et al. 2007a). Larvae are herbivorous and emigrate from the pond as terrestrial juveniles between three and seven months after hatching (Palis 1998; Palis and Fischer 1997; Stevenson et al. 2007a). Post-larval gopher frogs are entirely terrestrial outside of the breeding season. Juvenile frogs mature in about two years after metamorphosis (Palis and Fischer 1997).

Gopher frogs are mostly reliant on gopher tortoise burrows for cover outside of the breeding season, though they have also been known to use logs, stumps, and small mammal and crayfish burrows to a lesser extent (Stevenson et al. 2007a; Wright and Wright 1949). They exhibit extreme site fidelity in their burrows, especially in drought conditions (Blihovde 2006). Adult and juvenile gopher frogs feed nocturnally on any invertebrates or smaller amphibians that pass by their home burrows (Stevenson et al. 2007a).

Numbers, Reproduction, Distribution

The gopher frog range extends from Alabama and Florida along the eastern coast to North Carolina (NatureServe 2020). In Georgia, gopher frog breeding populations continue to occur at multiple locations in the Upper, Middle, and Lower Coastal Plains regions of the state (Stevenson et al. 2007a).

Conservation

The gopher frog has a global conservation ranking of G3 and a Georgia state ranking of S2S3. It is protected as Rare in Georgia and it is petitioned for federal listing under the ESA.

The primary threat to gopher frog populations is habitat loss and fragmentation due to silviculture, human development, and fire suppression (Stevenson et al. 2007a). The habitat of the gopher frog relies on regular fires to maintain ephemeral pool persistence and vegetation community structure. Fire suppression has reduced the prevalence of these upland communities (Stevenson et al. 2007a). Roznik and Johnson found a higher density of gopher tortoise and small mammal burrows in fire-maintained habitats, meaning increased availability of shelter for juvenile and adult gopher frogs (Roznik and Johnson 2009). Due to their reliance on gopher tortoise burrows, reductions in population sizes of this reptile have possibly adversely affected the gopher frog (Stevenson et al. 2007a).

Attempts at conservation efforts include prescribed burning, though most sources suggest the frequency of prescribed fire is rarely sufficient to maintain the native vegetative communities preferred by gopher frogs. In North Carolina, experiments with stocking of larvae and construction of breeding pools are being conducted (Palis and Fischer 1997). The Nature Conservancy is attempting to restore damaged longleaf pine sandhill habitat in Florida, and the USDA is removing predatory fishes from breeding sites in Alabama (Palis and Fischer 1997).

Effects of Construction Activities

Sediment

Palis (1998) identifies “siltation from road run-off” as a threat to larval gopher frogs. In the final rule to list the congener *L. sevosa* as an endangered species, USFWS states that sediment from unpaved roads had degraded breeding sites in adjacent ponds (USFWS 2001).

With terrestrial juvenile and adult life stages, only the egg and larval stages of the gopher frog are susceptible to the effects of sedimentation from construction activities. Because the breeding ponds are located in seasonal wetlands disconnected from streams or rivers, the duration of any adverse effects of a sedimentation event will be prolonged by the lack of sediment flushing.

Based on the previous identification of roadway sediments as a threat, the sediment sensitivity of the gopher frog is categorized as intolerant (1).

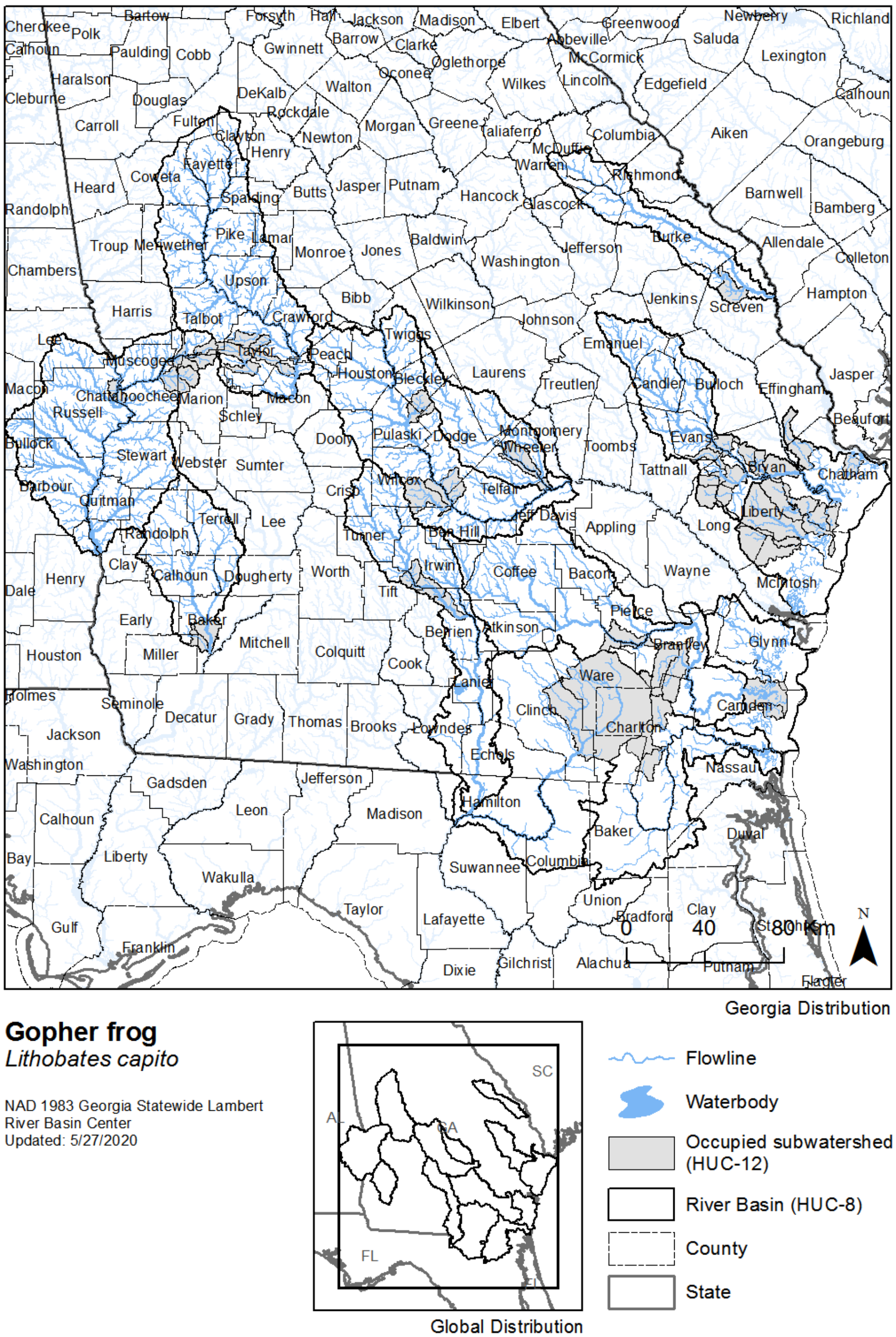
Pollutants

No lab or field studies investigating the effects of roadway associated pollutants on the gopher frog were found. A substantial body of toxicological research exists relating to the effects of individual pollutant compounds on species related to the gopher frog (e.g. (*L. chiricahuensis, L. clamitans, L. pipiens, L. sphenocephalus*). Taken together, this body of work has found that exposure to metals (e.g. nickel, zinc, lead, copper) and PCBs resulted in reduced growth and survival of early life stages, increased deformities, altered feeding and swimming rates, and altered sex ratios (Calfee and Little 2017; Chen et al. 2006; Glennemeier and Denver 2001; Jofré and Karasov 2008; Karasov et al. 2005; Karraker and Ruthig 2009; Kohl et al. 2015; Leduc et al. 2016; Relyea 2004; Rosenshield et al. 1999). Unfortunately, because these findings focused on individual compounds and species they do little to inform estimates of relative sensitivity to real-world mixtures of pollutants associated with stormwater runoff associated with stream-crossing structures. However, some studies did examine the relationship between urbanization and several congeners (wood frog, *L. sylvaticus;* Northern leopard frog, *L. pipiens;* American bullfrog, *L. catesbeianus*), finding that their occupancy was negatively correlated with urbanization (Clark et al. 2008; Guderyahn et al. 2016; Johnson et al. 2011).

The gopher frog is likely directly exposed to sediment-bound pollutants through ingestion of sediment during the larval life stage (Moeun 2018).

Based on the negative correlation of congener occurrence with urbanization, the pollutant sensitivity of the gopher frog is categorized as somewhat intolerant (3).

Figure 2. Map. Range map of the gopher frog.



ONE-TOED AMPHIUMA

Species

One-Toed Amphiuma, *Amphiuma pholeter*

Description

The one-toed amphiuma is a salamander with an elongated body shape and no external gills, though it retains one gill slit on each side. It reaches a maximum length of around 30cm. The four, diminished appendages each have one toe. The skin of the one-toed amphiuma is a flat, dark brown (Jensen and Owers 2007).

Life History

Little is known about the life cycle of the one-toed amphiuma (Jensen and Owers 2007; Means 1996). It likely lays eggs in the early summer like its congeners (*A. means*, *A. tridactylum;* Jensen and Owers 2007). Both congeners deposit eggs in burrows where one parent remains to guard the eggs from predation by crayfish, other amphiumas, and other predators (Fontenot Jr 1999; Gunzburger 2003; Smith and Secor 2017). Eggs likely hatch in late summer or early fall (Jensen and Owers 2007). Larvae of *A. pholeter* have not been observed (Jensen and Owers 2007), although congeners have very short larval stages persisting for a length of time on the order of weeks (Gunzburger 2003). One-toed amphiumas reach adulthood at about 2 years

(Petranka 1998). Adult *A. means* can reach an age of 16 years (David L. Haskins and Bryan 2020). Adults feed on clams, snails, earthworms, and arthropods (Jensen and Owers 2007).

One-toed amphiumas live in beds of liquid organic muck formed from decaying hardwoods within low gradient streams and periodically inundated floodplain wetlands (Jensen and Owers 2007; Means 1977). While congeners have been observed in more varied habitats, and even travelling over land after rain storms, *A. pholeter* has been collected exclusively in these muck bed habitats (Bonett et al. 2009). One-toed amphiuma can move through open water, but their locomotion in this medium is fairly limited compared to their preferred substrate (Bonett et al. 2009). Though amphiumas are capable of cutaneous respiration, especially for the elimination of carbon dioxide, they rely on their lungs as a primary source of oxygen, especially at warm temperatures when their metabolism is accelerated (Guimond and Hutchison 1974; Toews 1969).

Numbers, Reproduction, Distribution

The range of the one-toed amphiuma is restricted to southern Alabama, Mississippi, southwestern Georgia, and northern Florida. Within Georgia, the one-toed amphiuma has been observed only within waters of the Ochlockonee River Basin, though it may also occur in the Chattahoochee and Flint River systems (Jensen and Owers 2007; Means 1996). No population estimates for this species were found.

Conservation

The one-toed amphiuma has a global conservation ranking of G3 and a Georgia state ranking of S1. It is protected as Rare in Georgia, but it has no federal protections.

Threats to this species within Georgia include pollution from agricultural runoff, alteration of stream hydrology resulting from impoundment and wetland drainage, siltation, and predation and habitat degradation resulting from use of their organic muck habitats by feral hogs (Enge 2005; Jensen and Owers 2007). Little is being done to specifically protect the one-toed amphiuma and its habitat, possibly because so little is known about this amphibian.

Effects of Construction Activities

Sediment

Increased sediment inputs resulting from watershed development are considered a primary threat to habitat quality for the one-toed amphiuma (Enge 2005; Jensen and Owers 2007).

As an invertivore, the one-toed amphiuma may be indirectly affected by sediment via a reduction of macroinvertebrate abundance. Because adults engage in parental care of developing embryos, they may also remove fine particles following a sedimentation event; however, this has not been documented.

Because the one-toed amphiuma is most often found in areas with little water current, the duration of any adverse effects of a sedimentation event will be prolonged by the lack of sediment flushing.

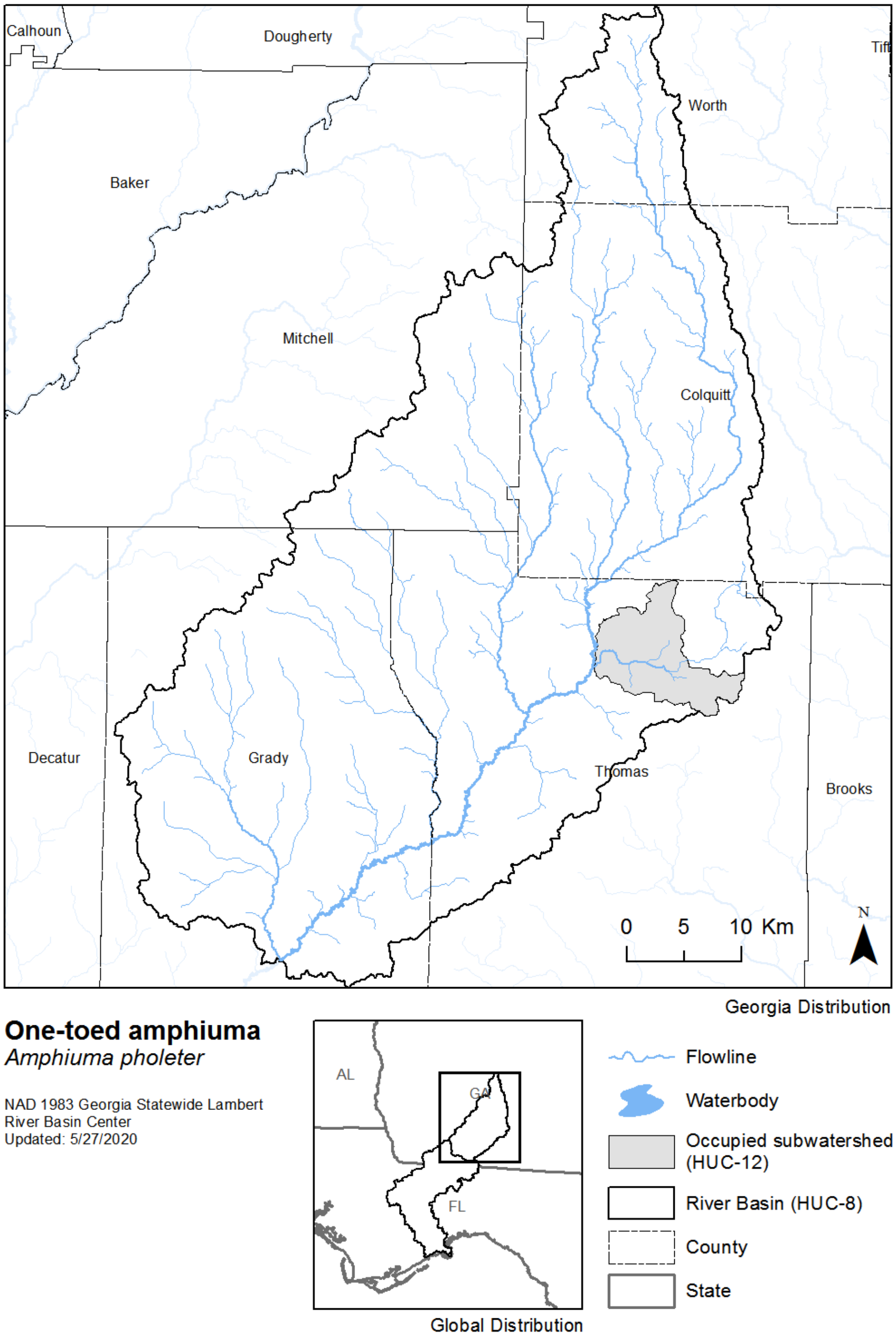
Based on the limited information available, the sediment sensitivity of the one-toed amphiuma is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of roadway-associated pollutants on the one-toed amphiuma were found. As a species that inhabits beds of organic materials, the one-toed amphiuma likely comes into direct contact with any pollutants bound to these materials. As a species that likely lays its eggs in burrows of soft sediment (like its congeners), the incubating embryos are likely exposed to sediment-associated pollutants.

Relying on the traits-based information, the pollutant sensitivity of the one-toed amphiuma is categorized as somewhat intolerant (3).

Figure 3. Map. Range map of the one-toed amphiuma.



STRIPED NEWT

Species

Striped Newt, *Notophthalmus perstriatus*

Description

The striped newt is a semiaquatic salamander that can be recognized by characteristic bright red lines on either side of the body (Stevenson et al. 2007b). These lines generally extend between the eyes and tail, where they may become more diffuse. Reaching a maximum length of around 10cm (4in) in total length, the striped newt is dark green or brown, sometimes with a row of red spots along the edges of the ventral side. The ventral side is yellow to silver in color, occasionally with black spots. Terrestrial juveniles, or efts, tend to have less conspicuous coloration. Larvae and paedomorphic aquatic adults are darker gray or brown in coloration with blotches of darker pigment, bushy gills and a laterally flattened tail for swimming (USFWS 2018b; Stevenson et al. 2007b).

The genus *Notophthalmus* contains two species in addition to the striped newt: the black-spotted newt (*Notophthalmus meridionalis*) and the eastern newt (*Notophthalmus viridescens*). Of these, only the eastern newt overlaps in range with the striped newt and can be distinguished by its lack of red lateral stripes (USFWS 2018b).

Life History

Between mid-winter and early spring, adult newts migrate to rainwater-fed ephemeral ponds to spawn (Dodd 1993; Jensen et al. 2008). Striped newts exhibit internal fertilization, after which females deposit eggs individually on aquatic vegetation over a period several months (Johnson 2002). Depending on the hydroperiod of the breeding pond, larvae follow one of two life cycle options. If water is abundant in the pond, larvae will remain in the pond and become paedomorphic adults until they spawn, after which time they metamorphose into terrestrial adults. If water is scarce, larvae will become terrestrial juveniles called efts. Efts reach maturity on land and become terrestrial adults. Larvae can develop lungs, lose their gills, and become efts within about three to six months of hatching (USFWS 2018b). Ponds must have a hydroperiod of between 4.5 and 6 months for an individual to complete metamorphosis (USFWS 2018b). If there is inadequate time to metamorphose before temporary ponds dry up, or in the coldest portions of the year, entire populations can hibernate in pond sediments (Bishop 1943). Adult striped newts can live for up to 15 years (Dodd 1993; De Magalhaes and Costa 2009). Aquatic adult striped newts are opportunistic hunters and will consume any small invertebrates they can capture as well as amphibian eggs (USFWS 2018b; Christman and Franz 1973). Little is known about the foraging habits of larvae and terrestrial adults (USFWS 2018b).

In Georgia, striped newts live in the pine sandhills of the southern parts of the state (USFWS 2018). Larvae and paedomorphs live in small, temporary ponds containing no large, predatory fish. These ponds are necessary for reproduction, but adults and efts inhabit the upland pine sandhill areas surrounding these ponds, reaching a distance of up to 1km from the ponds, though most remain within 700m. In dry conditions, terrestrial life stages find refuge under rocks and logs in the upland areas (USFWS 2018b).

Numbers, Reproduction, Distribution

The range of the striped newt spans across Northern Florida and parts of Southern Georgia (Dodd Jr and LaClaire 1995). Currently, there are 114 known breeding ponds, though 17 of these are almost certainly extirpated, and 57 additional ponds are potentially extirpated (USFWS 2018b). Since 2002, only three populations have been confirmed to be extant in Georgia (Stevenson et al. 2007b). Overall, current population distributions and sizes are poorly understood.

Conservation

The striped newt has been given a Georgia state rank of S2 (imperiled), and a global rank of G2G3 (between imperiled and vulnerable). This species is protected as Threatened in the state of Georgia.

The most important threat to the striped newt is loss of pine sandhill habitat due to replacement by agriculture, urban development, and pine plantations (Dodd Jr and LaClaire 1995; USFWS 2018b). Extended periods of drought might reduce the hydroperiod of ephemeral ponds to levels unsuitable for the newt’s life cycle. Fire suppression can also affect the plant community and persistence of ephemeral ponds, making them uninhabitable. Fragmentation of the terrestrial habitat surrounding the ponds can lead to reduced continuity between pond populations, adversely affecting resilience to local disturbance (USFWS 2018b).

Little protection is currently in place for striped newt habitat, especially on private lands (USFWS 2018b). Some success has been seen with reintroduction efforts and habitat restoration in the Apalachicola National Forest in Florida (USFWS 2018b).

Effects of Construction Activities

Sediment

Striped newts have consistently been found in ponds in sandy soils and with mud substrate (Dodd Jr and LaClaire 1995; USFWS 2018b). Chambers (2008) found no correlation between substrate composition and breeding site selection in the congener *N. viridescens.* Gates and Thompson (1982) found *N. viridescens* preferred breeding pools with mud substrate. Following a feeding study, Christman and Franz (1973) concluded that feeding by aquatic adult striped newts is based primarily on chemical cues; this suggests that increased turbidity is unlikely to adversely affect striped newt feeding success.

Because the breeding ponds are located in seasonal wetlands disconnected from streams or rivers, the duration of any adverse effects of a sedimentation event may be prolonged by the lack of sediment flushing.

Because the above research suggests that their breeding habitat is not sensitive to the presence of fine sediments, sediment sensitivity of the striped newt is categorized as tolerant (3).

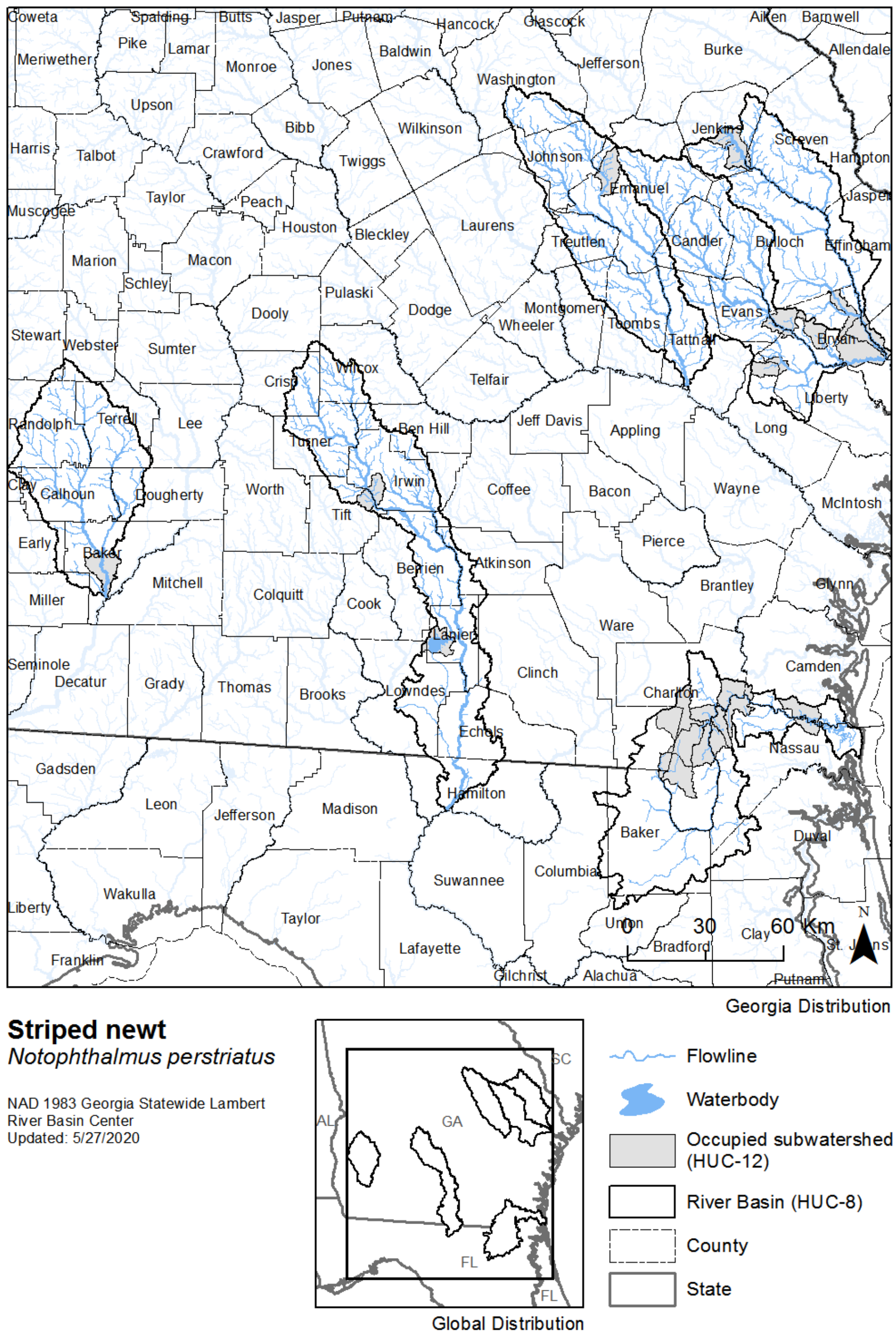
Pollutants

No lab or field studies investigating the effects of roadway-associated pollutants on the striped newt were found. When exposed to PAH-containing compounds, the congener *N. viridescens* exhibited reduced swimming speed, endurance, and righting ability (Bommarito et al. 2010).

Adult striped newts are primarily terrestrial, but do engage in opportunistic predation on aquatic inverts, which may serve as a dietary exposure route for roadway-associated pollutants. Early aquatic life stages of striped newts are more likely to experience exposure to pollutants and are likely to be more sensitive to those compounds. However, because breeding ponds in seasonal wetlands are not connected to fluvial systems, they are unlikely to contain substantial accumulations of roadway pollutants. Because the breeding ponds are located in seasonal wetlands disconnected from streams or rivers, the duration of any adverse effects of pollutants may be prolonged by the lack of flushing.

Based on the limited available information, pollutant sensitivity of the striped newt is categorized as somewhat intolerant (3).

Figure 4. Map. Range map of the striped newt.



CRAYFISHES

BEAUTIFUL CRAYFISH

Species

Beautiful Crayfish, *Cambarus speciosus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008l): The carapace color of the beautiful crayfish is orange-tan and the abdomen greenish. The edges of the rostrum and rear margins of the abdominal segments are reddish. The areola is wide with margins nearly parallel sided and well-developed cervical spines are present. The rostrum is narrow and tapers anteriorly. The claws can be quite large in relation to the body and there is a gap between the fingers of the claw when the fingers are closed. There is usually a tuft of setae at the base of the fixed finger of the claw. This species reaches a maximum total body length of about 90 mm (3.5 inches).

Life History

Schuster (2001) reported finding this species most commonly under slab rocks along the stream margin. The beautiful crayfish is primarily found under rocks in medium-sized streams where the currents are moderate to swift.

No diet studies for the beautiful crayfish were found; however, stream crayfish generally hide during the day and come out at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008l).

Male beautiful crayfish in reproductive condition (first form) were observed in April, September, and October. The smallest observed reproductive male was 56 mm (2.2 in). One female beautiful crayfish with eggs was observed in April. The smallest female carrying eggs was 61 mm (2.4 in) in length (Skelton 2008l).

Numbers, Reproduction, Distribution

The distribution of the beautiful crayfish lies entirely within Georgia (Simon 2011). Schuster (2001) delimited the range of the beautiful crayfish to the upper Coosawattee River basin, upstream of Carter’s Lake. Almost all of the watersheds where they have been found are part of the Blue Ridge physiographic province (Skelton 2008l).

Following surveys in 2001 (Schuster 2001) and 2013 (Skelton 2016), authors concluded that beautiful crayfish populations at surveyed sites are stable.

Conservation

The global conservation ranking status of the beautiful crayfish is G2 and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia and is not under federal protections. In Georgia, there are no protected populations of beautiful crayfish at the state level (Skelton 2008l).

The beautiful crayfish is vulnerable to extirpation due to its small range, habitat loss or alteration due to urbanization and associated stormwater, sedimentation due to poor land management or development practices, and competition with invasive crayfishes (Skelton 2008l).

Effects of Construction Activities

Sediment

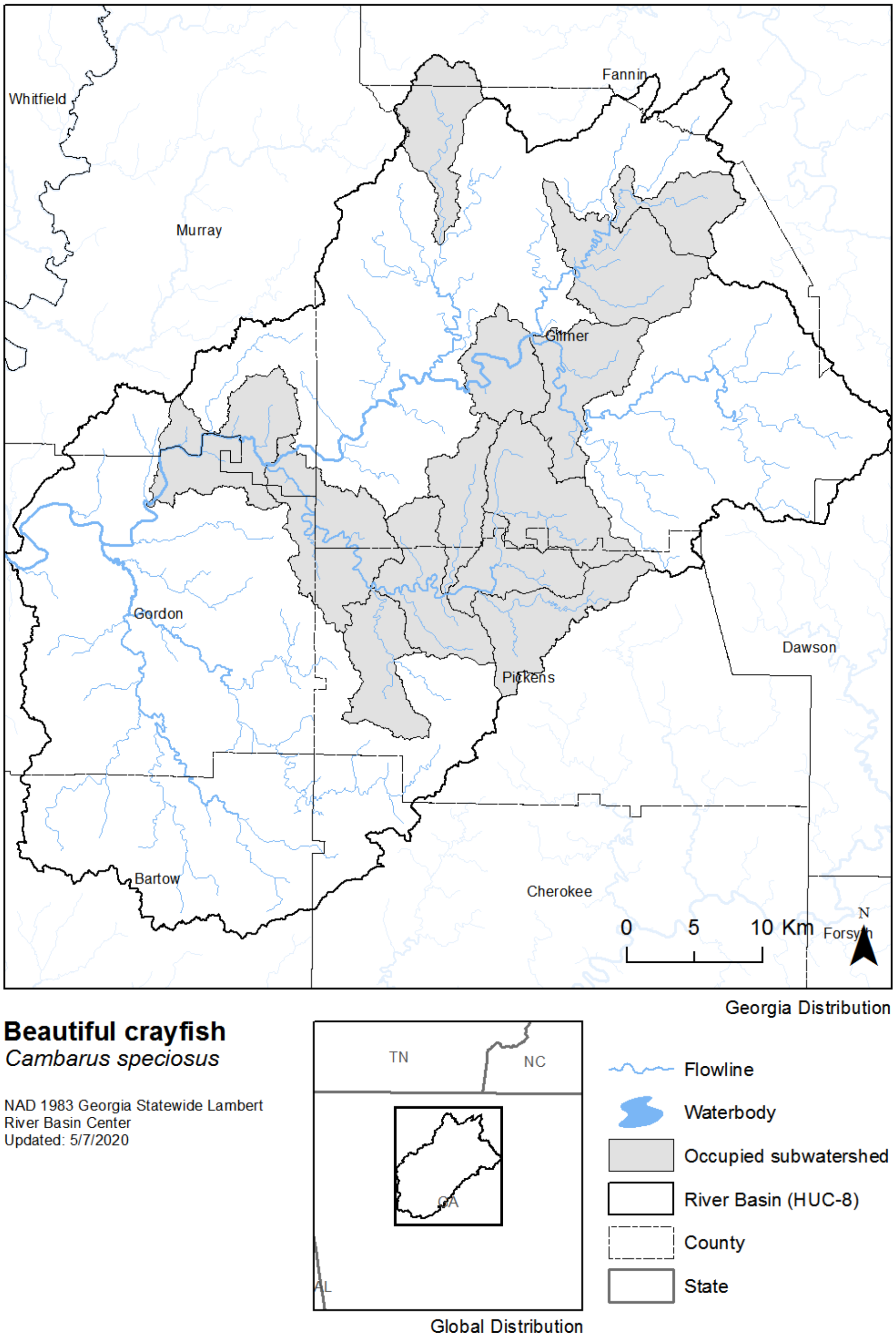
No lab or field studies investigating the effects of sediment on the beautiful crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

Due to limited information, the sediment sensitivity of the beautiful crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the beautiful crayfish were found. Open water crayfishes are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting. Due to limited information, the pollutant sensitivity of the beautiful crayfish is categorized as moderate (4).

Figure 5. Map. Range map of the beautiful crayfish.



BLACKBARRED CRAYFISH

Species

Blackbarred Crayfish, *Cambarus unestami*

Description

Reproduced from Georgia Department of Natural Resources (Skelton 2008j):

The overall color of the blackbarred crayfish is brownish with dark barring on the abdomen giving the impression of longitudinal stripes. The areola is wide and the rostrum tapers gradually. There are two rows of tubercles on the mesial margin of the palm. This species reaches a maximum total body length of about 80 mm (3.1 in).

Life History

The blackbarred crayfish is most often found under rocks in slow, moderate, and swift flowing mountain streams ranging in size from 0.1-0.5 m deep and 2-12 m wide and with coarse substrate (Hobbs 1981, Hobbs Jr 1989, Schuster 2001, Kilburn et al. 2014). The type locality is Daniel Creek in Dade County, Georgia and is described as a creek 15 feet wide and 1.5 feet deep flowing at a moderate velocity over bed rock and sand substrate with no plant growth and "crystal clear" water (Hobbs Jr 1989).

Male blackbarred crayfish in reproductive condition have been observed in April, May, October, and November. The smallest observed breeding male is approximately 54 mm (2.1 in). Female blackbarred crayfish carrying eggs were collected in April and May. Clutch sizes of two female blackbarred crayfish were 124 and 194 eggs, and egg diameters averaged 2.5 mm (0.1 in). The smallest observed female with eggs is 65 mm (2.6 in) (Hobbs 1981, Hobbs Jr 1989, Skelton 2008j).

Numbers, Reproduction, Distribution

The distribution of the blackbarred crayfish is limited to Georgia and Alabama (Simon 2011). More specifically, the blackbarred crayfish inhabits approximately 250-1000 km2 (100-400 mi2) of the Tennessee River System near Lookout and Sand Mountains in extreme northwestern Georgia and northeastern Alabama. This species has also been observed in the Little River system of the upper Coosa River in Georgia (Hobbs Jr 1989).

Conservation

The global conservation ranking status of the blackbarred crayfish is G2 and the Georgia state conservation ranking status is S3. This species is listed as threatened by the state of Georgia and is not under any federal protections. The blackbarred crayfish likely occurs in one protected area, Cloudland Canyon State Park (Skelton 2008j).

Although the range of the blackbarred crayfish is small relative to the ranges of other imperiled freshwater taxa (e.g. Warren Jr et al. 2000, Smith et al. 2011), Kilburn et al. (2014) concluded that the blackbarred crayfish has not experienced a loss of habitat or population declines.

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the blackbarred crayfish were found. However, a study of the closely related *C. obeyensis* provides some evidence for a slight positive relationship with percent fine sediment and percent pebble substrate (Johansen 2018).

Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

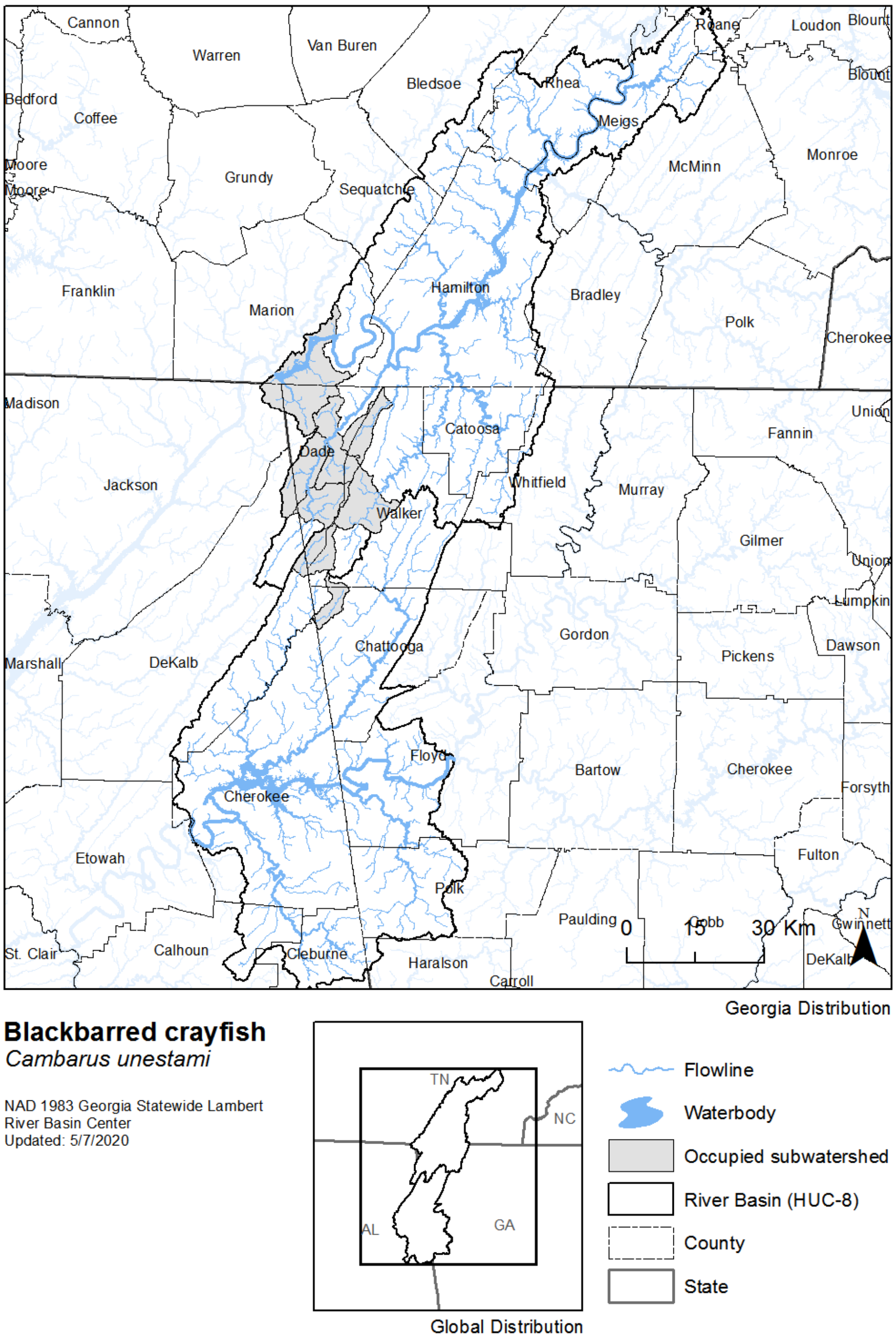
Due to limited information, the sediment sensitivity of the blackbarred crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the blackbarred crayfish were found. Open water crayfishes, especially riffle-dwellers, are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the blackbarred crayfish is categorized as moderate (4).

Figure 6. Map. Range map of the blackbarred crayfish.



BROAD RIVER BURROWING CRAYFISH

Species

Broad River Burrowing Crayfish, *Distocambarus devexus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008o): The overall color of the Broad River burrowing crayfish is tan to brownish with dark mottling. The areola is fairly narrow and the rostrum is wide, gradually converging anteriorly to a blunt point. The movable fingers of the claws are about the same length as the mesial margins of the palms of the claws. The abdomen appears narrower than the cephalothorax. This species reaches a maximum total body length of about 75 mm (3 in).

Life History

The Broad River burrowing crayfish is an obligate burrower that constructs burrows near surface water or areas where the water table is near the surface. However, one individual was observed inhabiting a burrow that did not extend beyond the water table (Skelton 2008o). Juveniles, and sometimes adults, are commonly found in ephemeral pools and streams during spring (Skelton 2008o). The burrows of primary burrowers are often complex with multiple chambers, passages, and openings to the surface marked by chimneys (Skelton 2008o).

No diet studies of the Broad River burrowing crayfish were found. The diet of burrowing crayfishes is not well understood; however, crayfish are generally considered to be opportunistic omnivores. Therefore, burrowing crayfish likely consume animal and plant material within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008o).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008o).

Primary burrowing crayfish are generally restricted to their burrows for most of their lives. Male crayfish, however, leave their burrows to seek mates during the reproductive season. Male Broad River burrowing crayfish in reproductive condition have been observed in April. A female Broad River burrowing crayfish carrying eggs was observed in April. Unlike stream crayfish, multiple juvenile cohorts of burrowing crayfish may be observed together (Skelton 2008o).

Numbers, Reproduction, Distribution

The distribution of the Broad River burrowing crayfish is limited to Georgia (Simon 2011). More specifically, this species has been collected from the Broad River watershed in northeastern Georgia counties of Elbert, Oglethorpe, Lincoln, and Wilkes (Skelton 2008o).

Conservation

The global conservation ranking status of the Broad River Burrowing crayfish is G1 and the state of Georgia conservation ranking status is S1. This species is listed as threatened by the state of Georgia and it is under no federal protections.

The Broad River burrowing crayfish is vulnerable to extirpation due to its small range and the susceptibility of burrows to land disturbing activities. In addition, changes to hydrology and land use within the range of this species may reduce ephemeral pool and stream habitat that may be important to the life cycle of this species (Skelton 2008o).

Effects of Construction Activities

Sediment

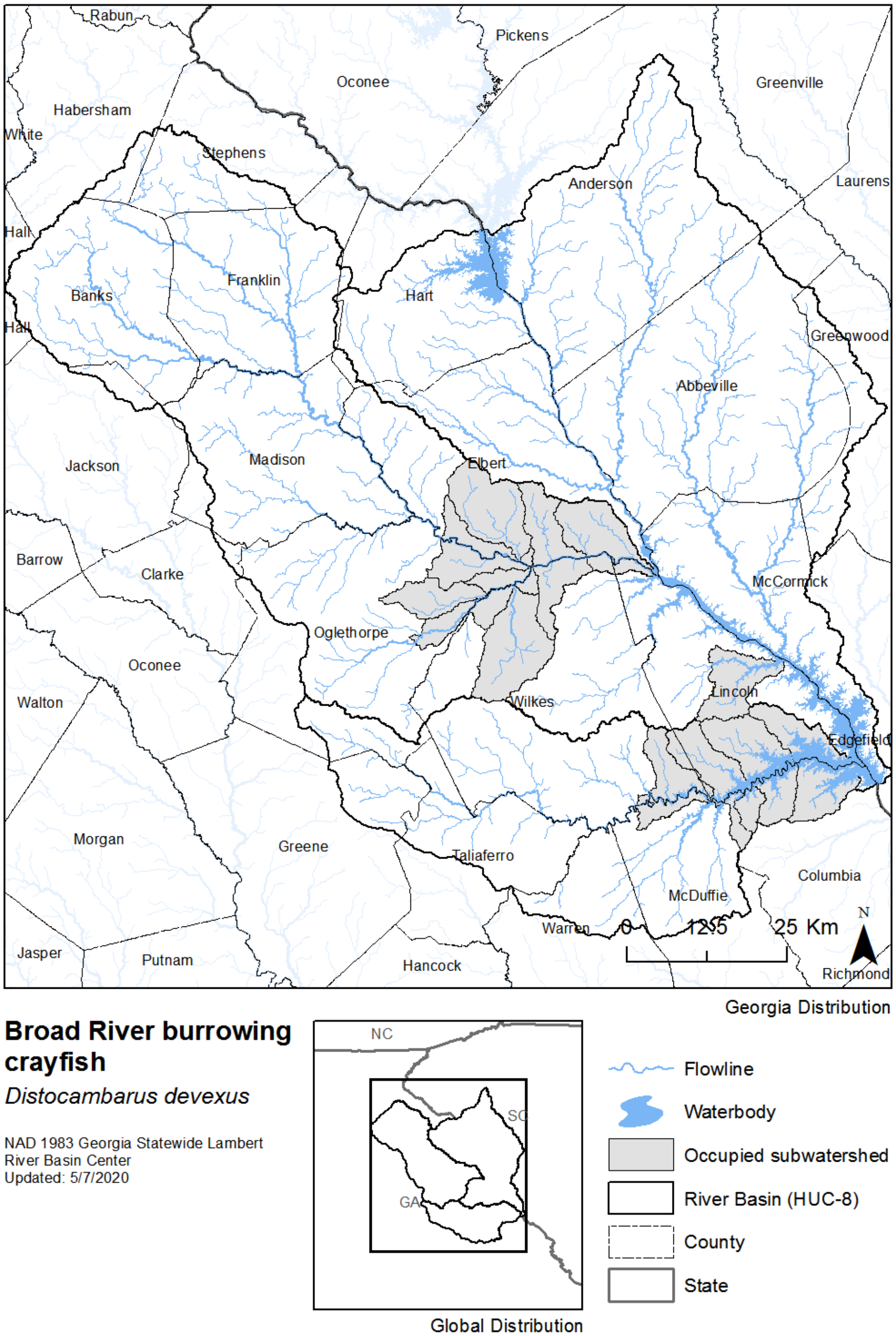
No lab or field studies investigating the effects of sediment on the Broad River burrowing crayfish were found. As a primary burrower, the habitat of the Broad River burrowing crayfish is isolated from sediment conveyed by surface waters. In the absence of an exposure route, the Broad River burrowing crayfish is unlikely to be adversely affected by elevated sedimentation. Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the Broad River burrowing crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Broad River burrowing crayfish were found. Because the Broad River burrowing crayfish is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants, relative to open water species, through both direct contact and its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the Broad River burrowing crayfish is categorized as somewhat intolerant (3).

Figure 7. Map. Range map of the broad river burrowing crayfish.



CHATTAHOOCHEE CRAYFISH

Species

Chattahoochee Crayfish, *Cambarus howardi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008i): The dorsal surface of the Chattahoochee Crayfish has bronze and bluish-green coloration on the claws, carapace, and on the abdomen. The areola is lavender-brown with hints of green. Thin orange-brown bands mark the separation of the abdominal segments and the joints of appendages. The center of the tail fades from green to yellow-brown posteriorly, and the sutures are a darker orange-brown. The areola is 3-5 times as long as broad and comprises 35-39 percent of the total length of the carapace. Not counting the tail, mature males range in length from 20-33 mm (0.8-1.3 in) and mature females range from 20–36 mm (0.8-1.4 in). Maximum total length of the species is about 77 mm (3 in).

Life History

The Chattahoochee crayfish is usually found under rocks in riffle habitats and has been collected from small tributary streams and the mainstem of the Chattahoochee River (Skelton 2008i).

No diet studies for the Chattahoochee crayfish were found. However, stream crayfish generally hide during the day and emerge at night to forage opportunistically on plant, animal, and detrital material (Skelton 2008i).

Male Chattahoochee crayfish have been observed in reproductive condition from May to October. Female Chattahoochee crayfish have been observed with eggs in late spring, which likely hatch in early summer. Two female Chattahoochee crayfish were observed with 20 and 42 eggs, which ranged in diameter from 2.2-2.3 mm (about 0.08 in) (Skelton 2008i).

Numbers, Reproduction, Distribution

The distribution of the Chattahoochee crayfish is limited to Georgia and Alabama (Simon 2011). Additional surveys may have identified occurrences of this species in North Carolina (Upper Broad, Yadkin-Pee Dee, Catawba, and Waterlee River watersheds) (Simmons and Fraley 2010) and South Carolina (Saluda and Enoree River watersheds); however, collections outside of Georgia and Alabama are still under scrutiny (NatureServe 2020). Within Georgia, the Chattahoochee crayfish has been collected in the Chattahoochee River system in Cobb, DeKalb, Douglas, Forsyth, Fulton, Hall, and Lumpkin counties. In Alabama, the Chattahoochee crayfish has been collected in the Halawakee Creek system (Skelton 2008i).

Conservation

The global conservation ranking status of the Chattahoochee crayfish is G3Q, and the state conservation ranking status is S2. This species is listed as threatened by the state of Georgia, and is not under any federal protections. In Georgia, some populations of Chattahoochee crayfish may be protected within municipal parks (Skelton 2008i).

The Chattahoochee crayfish is vulnerable to extirpation due to its small range, habitat loss and alteration by urbanization, sedimentation due to poor land management and development practices, and competition from invasive crayfishes (Skelton 2008). More specifically, the Chattahoochee crayfish is threatened by reduced water quality caused by urban development (e.g. road building, riparian buffer reduction, culvert installation, hydrological alteration, and increased stormwater pollution) throughout its range. Recent surveys identified declines in Chattahoochee crayfish populations associated with forest clearing, sedimentation, urbanization, and stream impoundments (Stanton 2006, Skelton 2008i).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Chattahoochee crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

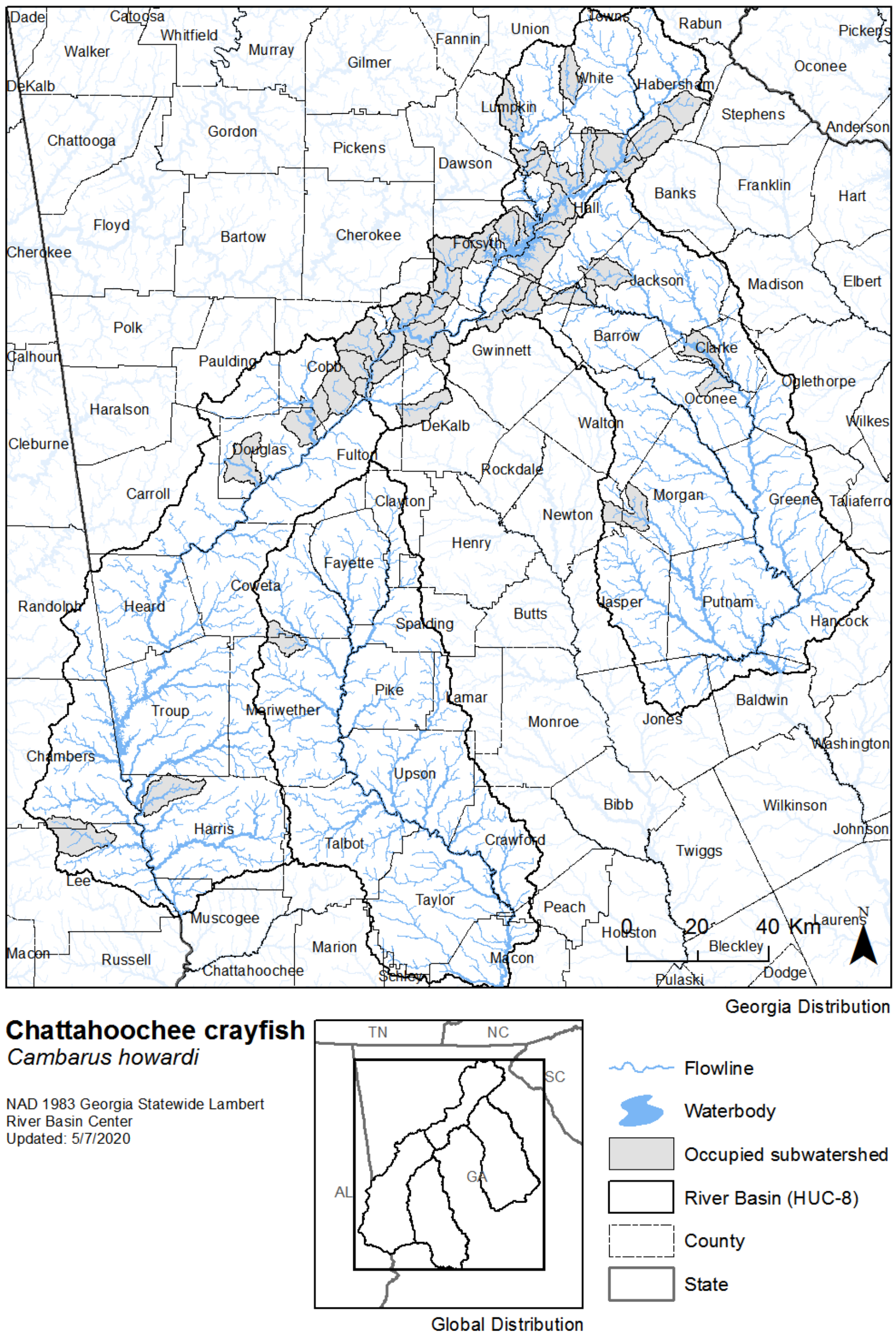
Due to limited information, the sediment sensitivity of the Chattahoochee crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Chattahoochee crayfish were found. Open water crayfishes, especially riffle-dwellers, are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information the pollutant sensitivity of the Chattahoochee crayfish is categorized as moderate (4).

Figure 8. Map. Range map of the Chattahoochee crayfish.



CHATTOOGA RIVER CRAYFISH

Species

Chattooga River Crayfish, *Cambarus scotti*

Description

Reproduced from the Georgia Department of Natural Resources (Skelton 2008k): The overall color of the Chattooga River crayfish is tannish to brown, although the margins of the rostrum and various tubercles are bright reddish. The claws are a dull greenish and there are two rows of tubercles on the mesial margin of the palm. The areola is wide and nearly parallel sided; there is one sharp cervical spine on each side of the carapace. The rostrum is fairly long and tapers gradually to a point. This species reaches a maximum total body length of about 90 mm (3.5 in).

Life History

The Chattooga River crayfish can be found in swift flowing water and under rocks or debris. The type locality of this species is Clarks Creek in northwest Georgia – a stream that is approximately 3 meters wide, 0.5 meters deep, and flows swiftly over a rocky substrate (Hobbs 1981, Skelton 2008k). Later surveys found that this species inhabits a range of stream sizes (width: 5-10m; depth: 0.1-1m) and velocities (“slow to moderate”) (Kilburn et al. 2014).

No diet studies for the Chattooga River crayfish were found. However, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008k).

Male Chattooga River crayfish in reproductive condition (first form) have been collected in March, April, May, September, and October, and range in size from 24.5mm to 41.8mm (Hobbs 1981). Female Chattooga River crayfish have been observed with eggs in April. Among four ovigerous females, clutch sizes ranged from 110 to 310, and egg diameters ranged from 2.1-2.3 mm (about 0.125 inch). The smallest observed female in reproductive condition was 62 mm (2.4 in) (Hobbs 1981).

Numbers, Reproduction, Distribution

The distribution of the Chattooga River crayfish is limited to Georgia and Alabama (Simon 2011). More specifically, the Chattooga River crayfish was historically observed in about 20 locations in the Chattooga River basin in Chattooga and Walker counties, GA, and the Coosa River in Calhoun, Cherokee, and St. Clair counties, AL (Hobbs Jr 1989). The Chattooga River crayfish has been collected 14 sites from Walker and Chattooga counties in Georgia, located within the Ridge and Valley physiographic province (Skelton 2008k).

Kilburn et al. (2014) suggest the Chattooga River crayfish populations are stable because they observed this species at 79% of 55 sites surveyed (Kilburn et al. 2014).

Conservation

The global conservation ranking status of the Chattooga River crayfish is G3 and the Georgia state conservation ranking status is S2. This species is considered threatened by the state of Georgia and is not under any federal protections. In Georgia, there are no known protected populations for the Chattooga River crayfish (Skelton 2008).

The Chattooga River crayfish is vulnerable to extirpation because of its small range, habitat loss and alteration due to urbanization, eutrophication likely due to nutrient runoff from agriculture, sedimentation due to poor land management and development practices, and introduction of non-native crayfishes (Skelton 2008k).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Chattooga River crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

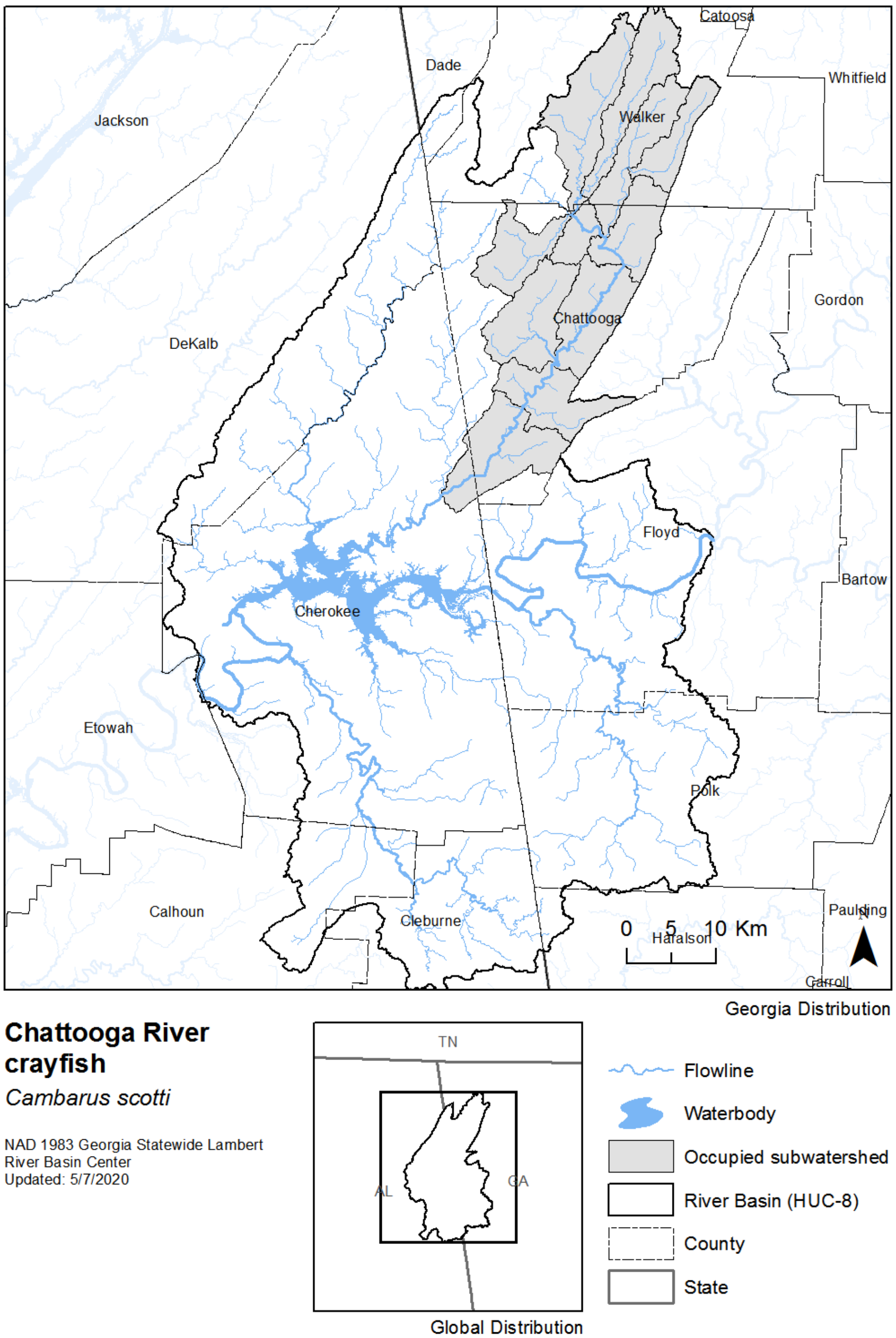
Due to limited information, the sediment sensitivity of the Chattooga River crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Chattooga River crayfish were found. Open water crayfishes are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Chattooga River crayfish is categorized as moderate (4).

Figure 9. Map. Range map of the Chattooga River crayfish.



CHICKAMAUGA CRAYFISH

Species

Chickamauga Crayfish, *Cambarus extraneus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008e): The Chickamauga crayfish has a mottled brown and tan carapace. The abdomen of this species has a striped pattern, consisting of a pale longitudinal stripe running down the middle and bordered by a dark stripe on the sides. Each of the dark stripes also has a light stripe along the sides. The maximum total body length of the Chickamauga crayfish is about 100 mm (3.9 in).

Life History

The Chickamauga crayfish is considered a stream crayfish (i.e. "open water crayfish") because individuals of this species are primarily found in slow- to moderately-flowing reaches of small streams near leaf packs, woody debris, or under rocks (Hobbs 1981, Skelton 2008e). Hobbs (1942) noted this species appeared to be restricted to small streams with shade and cover, free from the effects of erosion. This was contradicted by a later report by Hobbs (1981) who noted that while most Chickamauga crayfish specimens were collected from clear streams, "at least two localities [where Chickamauga crayfish was collected] the stream bed had an abundant silt cover and the water was carrying a heavy load of reddish brown, finely divided particulate matter." This species has been observed in a wide range of stream sizes, from small springs to South Chickamauga Creek (Skelton 2008e).

No diet studies on the Chickamauga crayfish were found. However, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008e).

Male Chickamauga Crayfish have been observed in reproductive condition in April, May, and October. Female Chickamauga crayfish with eggs or juveniles have not been observed. A mating pair was observed in late April (Skelton 2008e).

Numbers, Reproduction, Distribution

The distribution of the Chickamauga crayfish includes Georgia and Tennessee (Simon 2011). More specifically, the Chickamauga Crayfish has been observed in 15 locations in the South Chickamauga Creek system in Georgia and Tennessee. All collections of this species are in the Ridge and Valley physiographic province (Skelton 2008e).

Conservation

The global conservation ranking status of the Chickamauga crayfish is G2 and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia and it is not under any federal protections.

In Tennessee, populations of the Chickamauga crayfish are declining; however, in Georgia, limited sampling indicates that at least some populations are stable. The Chickamauga crayfish is vulnerable to extirpation because of its small range, habitat loss/alteration due to urbanization, sedimentation due to poor land management and development practices, and competition with invasive crayfishes (Skelton 2008e).

Effects of Construction Activities

Sediment

The Chickamauga crayfish was originally thought to inhabit only small, clear headwater streams (Hobbs 1942); however, later collections describe the species as inhabiting streams with at least occasional sediment pulses (Hobbs 1981). No lab or field studies that directly investigated the effects of sediment on the Chickamauga crayfish were found.

Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

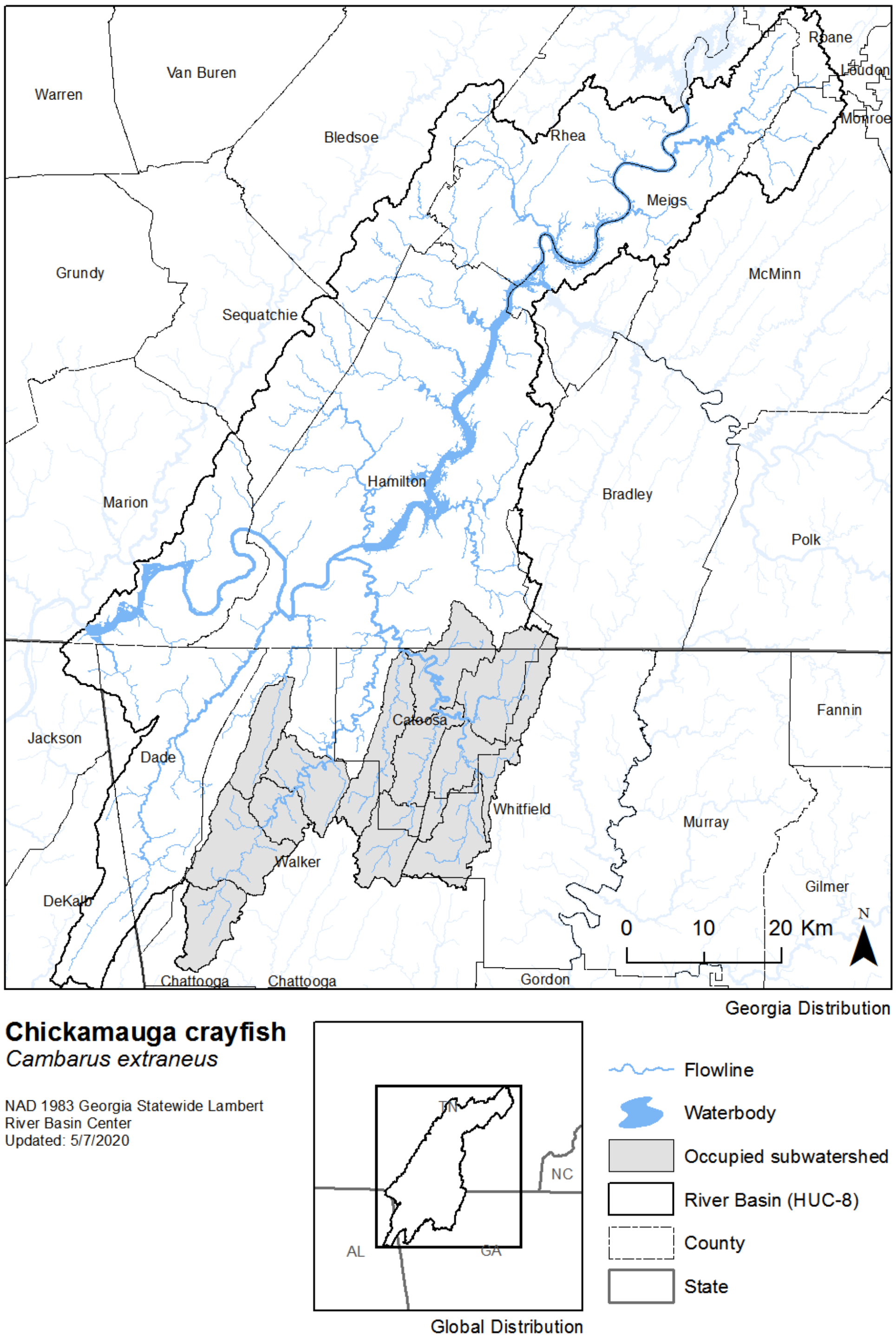
Due to limited information, the sediment sensitivity of the Chickamauga crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Chickamauga crayfish were found. Open water crayfishes, especially riffle-dwellers, are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Chickamauga crayfish is categorized as moderate (4).

Figure 10. Map. Range map of the Chickamauga crayfish.



CONASAUGA BLUE BURROWER

Species

Conasauga Blue Burrower, *Cambarus cymatilis*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008b):
The overall color of the Conasauga blue burrower is typically deep blue and the tips of the claws are orange. Specimens from the Hiwassee River system in Tennessee have more orange on the claws and may have an orangish wash on the cephalothorax. There are two rows of tubercles along the mesial margin of the palm. The areola is obliterated and the abdomen appears narrower and shorter than the cephalothorax. This species reaches a maximum total body length of about 75 mm (3 in).

Life History

The Conasauga blue burrower creates complex burrows in areas adjacent to streams. Burrows are also created in low areas where the water table is near the surface (Skelton 2008b).
No diet studies of the Conasauga blue burrower were found. The diet of burrowing crayfishes is generally not well understood; however, crayfish are generally considered to be opportunistic omnivores. Therefore, burrowing crayfish likely consume animal, plant, and detrital material

within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008b).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008).

A male and a female Conasauga blue burrower in reproductive condition were observed in April (Bouchard 1972). A female Conasauga blue burrower with 7 eggs, ranging from 1.9-2.0 mm (slightly less than inch) in diameter, was also observed in April (Skelton 2008).

Numbers, Reproduction, Distribution

The distribution of the Conasauga blue burrower includes Georgia and Tennessee (Simon 2011), but is limited to the portions of the Conasauga and Hiwassee River systems within the Ridge and Valley physiographic province. Collection sites include a neighborhood yard and a downtown site (although now paved; Skelton 2008).

In Georgia, there is only a single known population of Conasauga blue burrower that persist on state property, the Conasauga River Natural Area (Skelton 2008).

Conservation

The global conservation ranking status of the Conasauga blue burrower is G1 and the Georgia state conservation ranking status is S1. This species is listed as endangered by the state of Georgia and it is not under any federal protections.

The Conasauga blue burrower is vulnerable to extirpation because of its small range, degradation of habitat by urbanization of the surrounding watershed, and loss/degradation of habitat from associated land disturbing activates that could destroy burrows and alter hydrology (Skelton 2008b).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Conasauga blue burrower were found. As a primary burrower, the habitat of the Conasauga blue burrower is isolated from sediment conveyed by surface waters. In the absence of an exposure route, the Conasauga blue burrower is unlikely to be adversely affected by elevated sedimentation.

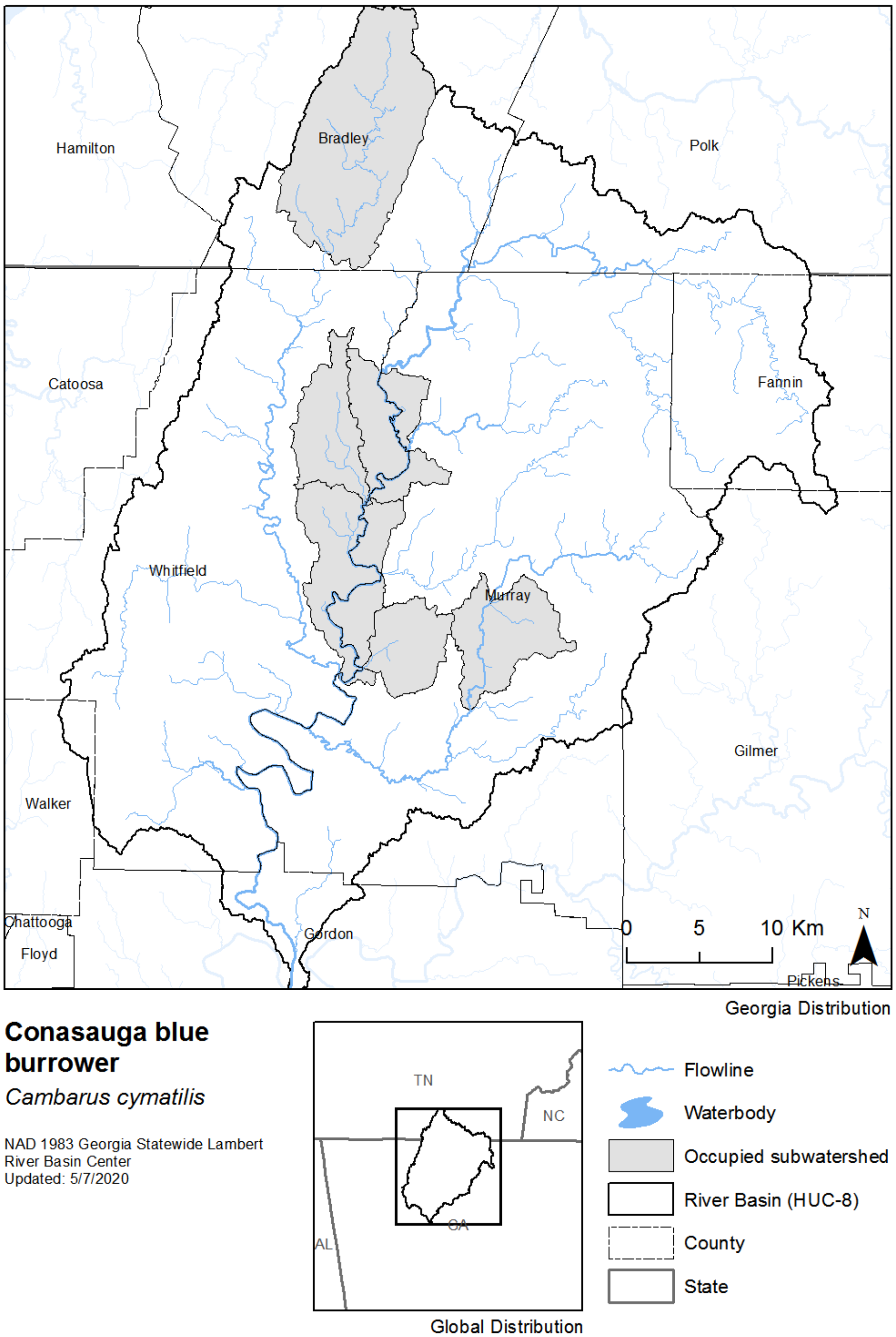
Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the Conasauga blue burrower is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Conasauga blue burrower were found. Because the Conasauga blue burrower is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants, relative to open water species, through both direct contact and its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the Conasauga blue burrower is categorized as somewhat intolerant (3).

Figure 11. Map. Range map of the Conasauga blue burrower.



COOSAWATTEE CRAYFISH

Species

Coosawattee Crayfish, *Cambarus coosawattae*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008a): The Coosawattee crayfish reaches a maximum total body length of about 75 mm (3 inches) and has a brownish to olive color. The posterior portion of the carapace and the posterior edge of each abdominal segment is reddish or burgundy in coloration. The Coosawattee crayfish has orange to reddish coloration on the margins of the rostrum and postorbital ridges. Relative to the body, the claws are quite large and the rostrum tapers anteriorly.

Life History

The Coosawattee crayfish is primarily found under rocks in fast-moving water (Hobbs 1981), although it may also be found in slower-flowing water near leaf packs or woody debris (Skelton 2008a). No diet studies are known for Coosawattee crayfish; however, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008a).

Male Coosawattee crayfish in reproductive condition have been observed in April, June, September, and October. Female Coosawattee crayfish were observed carrying eggs in April and June. Of eight female Coosawattee crayfish, brood sizes ranged from 27-101 and egg diameters ranged from 2.4-2.6 mm (0.09-0.1 in) (Skelton 2008).

Numbers, Reproduction, Distribution

The distribution of the Coosawattee crayfish is limited to Georgia (Simon 2011). More specifically, this species inhabits the Coosawattee River system upstream of Carter's Lake in Gilmer County, Georgia within the Blue Ridge physiographic province (Skelton 2008a). Schuster (2001) described the distribution of the Coosawattee crayfish as limited to the Ellijay and Cartecay Rivers and their tributaries. Several populations of the Coosawattee crayfish occur within the Chattahoochee National Forest (NatureServe 2020). Based on surveys conducted in 2001 (Schuster 2001) and 2013 (Skelton 2016), populations of Coosawattee crayfish are considered stable.

Conservation

The global conservation ranking status of the Coosawattee crayfish is G2, and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia, and it is not under any federal protections.

The Coosawattee crayfish is vulnerable to extirpation due to its small range, habitat degradation and loss due to urbanization, sedimentation from poor land management and development practices, and competition with invasive crayfishes (Skelton 2008a).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Coosawattee crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

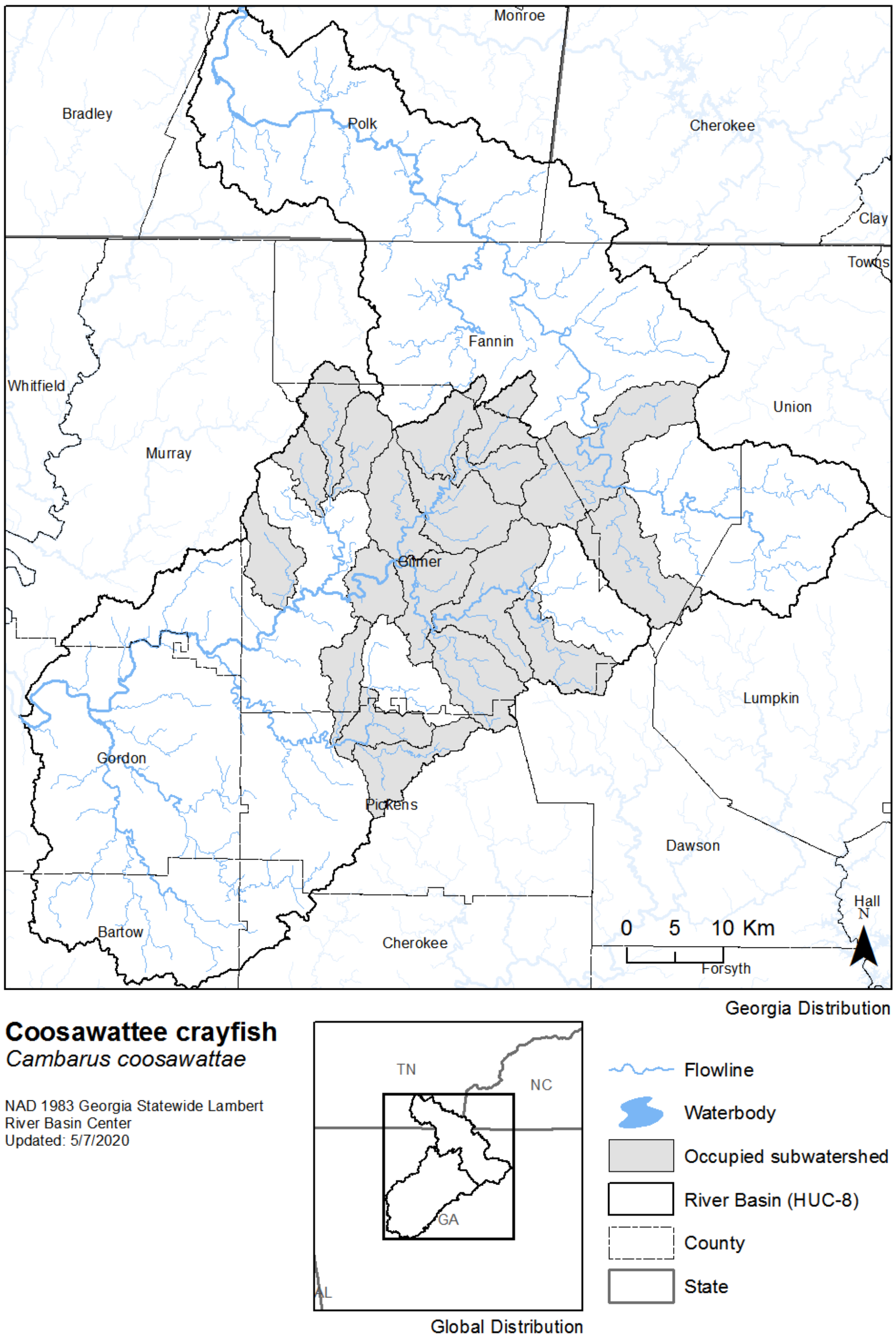
Due to limited information, the sediment sensitivity of the Coosawattee crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Coosawattee crayfish were found. Open water, especially riffle-dwellers, crayfishes are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Coosawattee crayfish is categorized as moderate (4).

Figure 12. Map. Range map of the Coosawattee crayfish.



DOUGHERTY BURROWING CRAYFISH

Species

Dougherty Burrowing Crayfish, *Cambarus doughertyensis*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008c): The body of the Dougherty Burrowing Crayfish is a brownish-orange and the claws somewhat brighter orange. The areola is obliterated and the abdomen is obviously narrower than the cephalothorax. Claws of adults can be robust and there are two rows of tubercles along the mesial margin of the palm. This species reaches a maximum total body length of about 75 mm (3 in).

Life History

The type locality of the Dougherty burrowing crayfish is a wooded wetland that is flooded seasonally. The Dougherty burrowing crayfish is an obligate burrower. Burrows are complex with multiple chambers, passages, and openings to the surface marked by chimneys. Burrows may be found among the roots of trees (Cooper and Skelton 2003).

No diet studies of the Dougherty burrowing crayfish were found. The diet of burrowing crayfishes is not well understood; however, crayfish are generally considered to be opportunistic omnivores. Therefore, burrowing crayfish likely consume animal, plant, detrital material within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008c).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008c).

Primary burrowing crayfish are generally restricted to their burrows for most of their lives. Male crayfish, however, leave their burrows to seek mates during the reproductive season. Male Dougherty burrowing crayfish in reproductive condition have been observed in March, May, and July. No female Dougherty burrowing crayfish have been observed (Skelton 2008).Unlike stream crayfish, multiple juvenile cohorts of burrowing crayfish may be observed together burrow (Skelton 2008c).

Numbers, Reproduction, Distribution

The distribution of the Dougherty burrowing crayfish includes Georgia (Simon 2011). More specifically, this species is likely restricted to the Flint River watershed (Skelton 2008c).

Conservation

The global conservation ranking status of the Dougherty burrowing crayfish is G1 and the Georgia state conservation ranking status is S1. This species is listed as endangered by the state of Georgia and is not under any federal protections. At least one population is considered protected because it persists on state owned property (Skelton 2008c).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Dougherty burrowing crayfish were found. As a primary burrower, the habitat of the Dougherty burrowing crayfish is isolated from sediment conveyed by surface waters. In the absence of an exposure route, the Dougherty burrowing crayfish is unlikely to be adversely affected by elevated sedimentation.

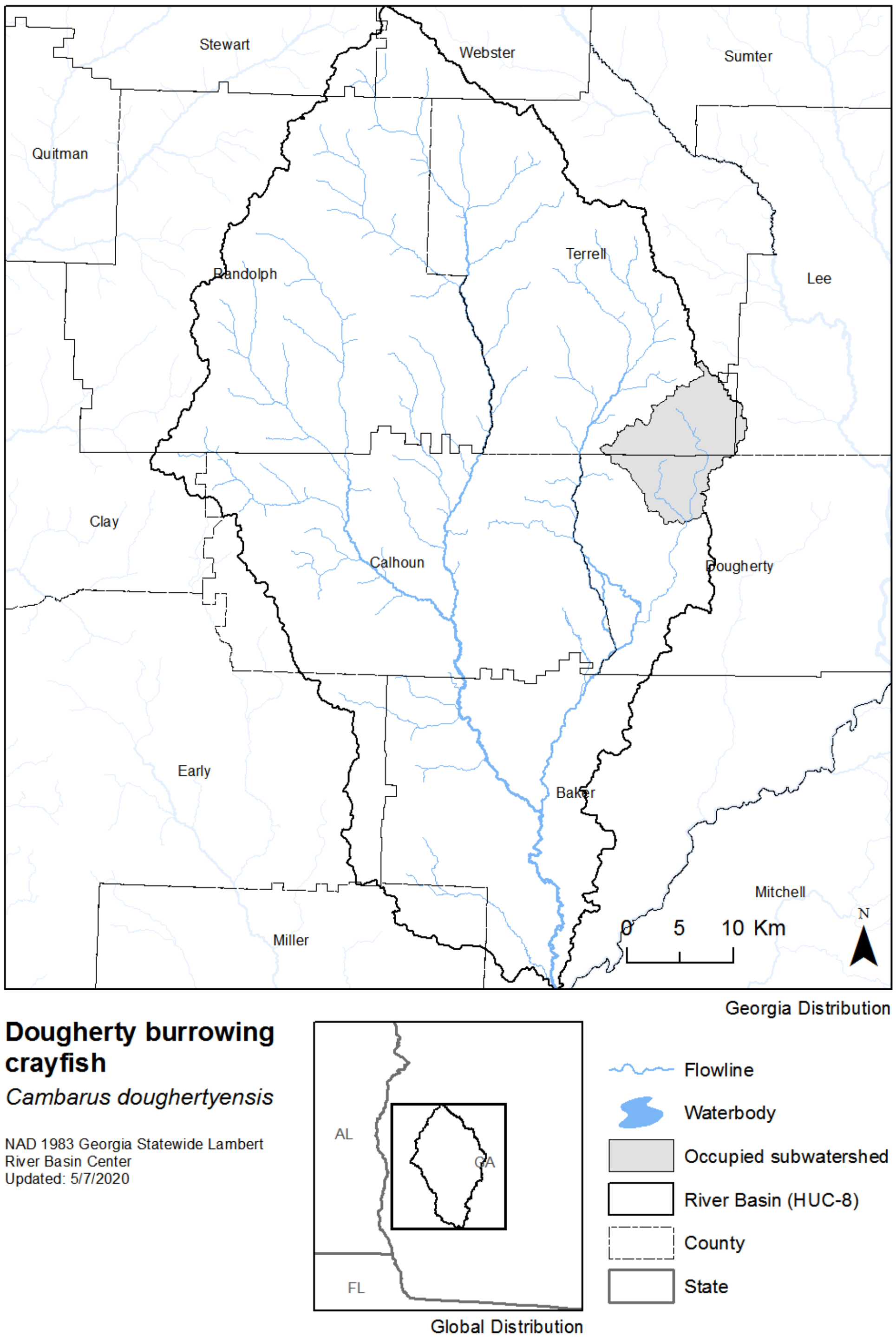
Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the Dougherty burrowing crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Dougherty burrowing crayfish were found. Because the Dougherty burrowing crayfish is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants (relative to open water species) through direct contact and through its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the Dougherty burrowing crayfish is categorized as somewhat intolerant (3).

Figure 13. Map. Range map of the Dougherty burrowing crayfish.



ETOWAH CRAYFISH

Species

Etowah crayfish*, Cambarus fasciatus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008f): The carapace and claw color of the Etowah Crayfish are brownish while the segments of the abdomen have pale centers and the rear edge of each segment is red. The tail may be bluish. The areola is wide and well-developed cervical spines are present. The rostrum narrows anteriorly, appears slightly pinched in the middle, and has marginal spines or tubercles. The claws of this species may get quite large compared to the body size and there is a gap between the fingers of the claws when the fingers are closed. This species reaches a maximum total body length of over 75 mm.

Life History

The Etowah crayfish is usually found beneath rocks in moderate to swift flowing areas of streams and occasionally in leaf packs and woody debris (Skelton 2008f). The type locality of this species is the Etowah River where the river is clear to cloudy and flows moderately swiftly over sand with rocks and woody debris (Hobbs 1981).

No diet studies on the Etowah crayfish were found. However, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008f).

Male Etowah crayfish have been observed in reproductive condition in March, April, and May. Female Etowah crayfish have been observed in May and June. Females with juveniles have been observed in May. Of eight female Etowah crayfish observed, clutch sizes ranged from 27-101. The smallest breeding male observed was 42 mm (1.7 in), and the smallest observed female with eggs was 53 mm (2.8 in) (Skelton 2008f).

Numbers, Reproduction, Distribution

The distribution of the Etowah crayfish includes Georgia and Tennessee (Simon 2011). Specifically, the Etowah Crayfish is found only in the Etowah River system, primarily above Allatoona Dam, but it has been collected at three locations downstream of the Dam. All of the records of this species are from the Piedmont physiographic province (Skelton 2008f).

Conservation

The global conservation ranking status of the Etowah crayfish is G3 and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia and it is not under any federal protections.

The Etowah crayfish is vulnerable to extirpation because of its small range, habitat loss and alteration due to urbanization, sedimentation related to poor land management and development practices, and introductions of non-native crayfishes (Skelton 2008f).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Etowah crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

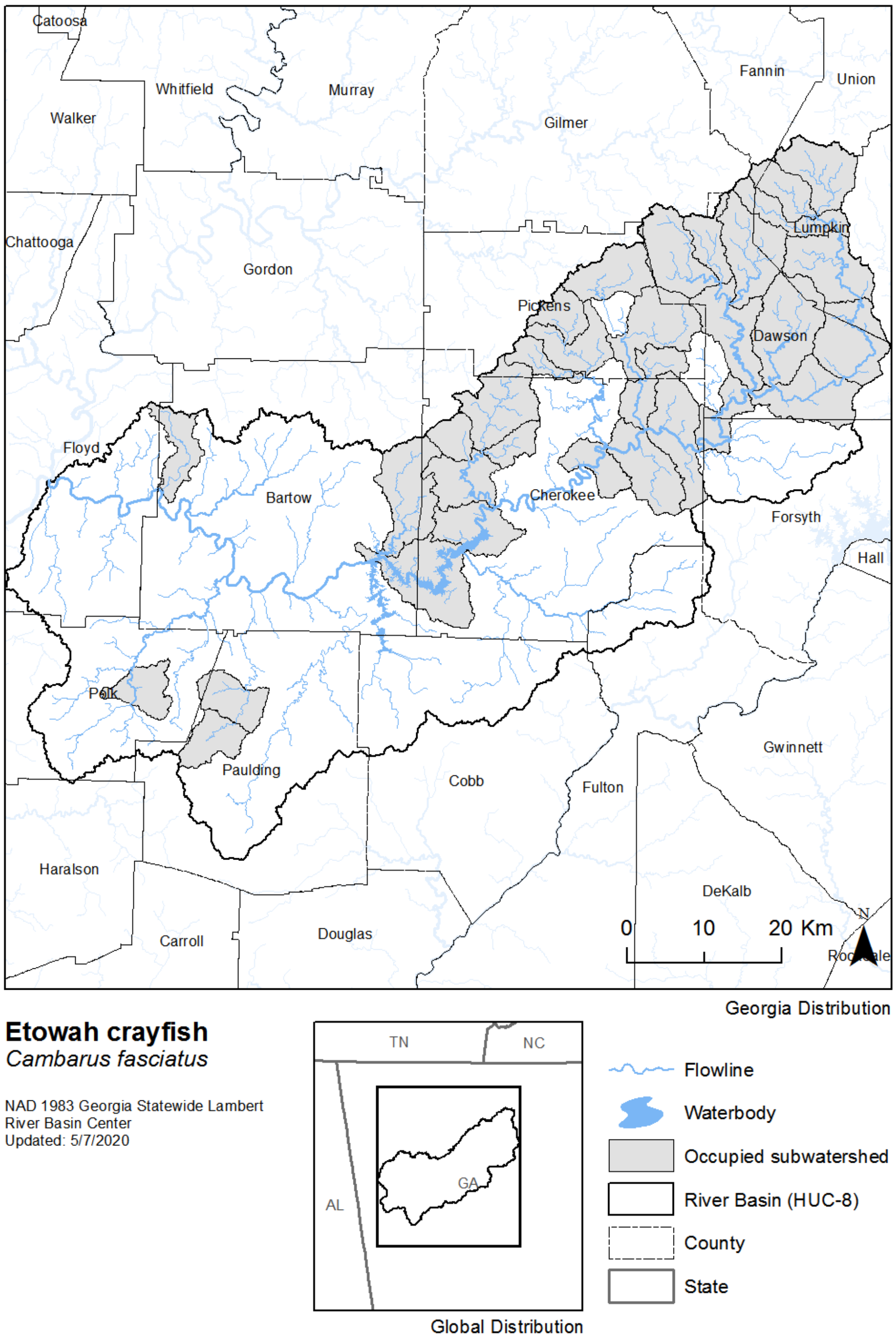
Due to limited information, the sediment sensitivity of the Etowah crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Etowah crayfish were found. Open water crayfishes, especially riffle-dwellers, are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Etowah crayfish is categorized as moderate (4).

Figure 14. Map. Range map of the Etowah crayfish.



GRAINY CRAYFISH

Species

Grainy Crayfish, *Procambarus verrucosus*

Description

Reproduced from the Georgia Department of Natural Resources (Stanton 2008):

The dorsal surface of the grainy crayfish has an overall olive coloration with darker mottling. The sides are tan and orange. The carapace is often speckled with light colored spots that appear as though they had been etched into the surface. A broad, dorsal stripe down the center of the abdomen may range from brown to black. This stripe is bordered by alternating pairs of light and dark stripes, the last of which may contain the etched spots described above. Claws brown with dark markings on top and lighter brown to orange underneath. The claws appear rather delicate and weak, but male claws are larger and longer than female claws. The areola is moderately narrow. This species reaches a maximum total body length of over 75 mm (3.5 in).

Life History

The type locality of the grainy crayfish is Calebea Creek near Tuskegee, Alabama. Calebea Creek is a clear creek approximately 10 feet wide and three feet deep with sandy substrate that flows through an open pasture (Hobbs Jr 1952). Since this first account, the grainy crayfish has been collected from lentic habitat including backwaters, woodland seeps, wetlands, marshes, beaver impoundments, and roadside ditches (Stanton 2003). This species is often observed in close association with macrophytes or inundated vegetation (Stanton 2008). The occurrence of the grainy crayfish is negatively correlated with pH (Stanton 2008). During dry periods in the summer, the grainy crayfish may seek refuge by burrowing (Stanton 2008).

No diet studies of the grainy crayfish were found. However, open water crayfish are generally considered to hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Stanton 2008).

Female grainy crayfish with eggs have not been observed in the field. Reproduction of this species has been observed in laboratory conditions in May, June, July, and August (Stanton 2003, 2008). A sperm plug was observed in a female during early spring (Hobbs Jr 1952). Juveniles hatch in the spring.

Numbers, Reproduction, Distribution

The distribution of the grainy crayfish is limited to Georgia and Alabama (Simon 2011). More specifically, the grainy crayfish has been collected from Upatoi and Ochillee Creeks and their tributaries within the Chattahoochee River system (Stanton 2008).

Conservation

The global conservation ranking status of the Grainy crayfish is G4 and the Georgia state conservation ranking status is S2. This species is listed as rare by the state of Georgia and is not under any federal protections.

The grainy crayfish is vulnerable to extirpation due to its small range, as well as disturbance/loss of wetland habitat. Although a large portion of grainy crayfish habitat has historically been protected by Fort Benning Military Reservation, increased development and military activity at Fort Benning could reduce suitable habitat (Stanton 2008).

Effects of Construction Activities

Sediment

Because the grainy crayfish has been reported from habitats with naturally higher turbidity and fine substrate, it is likely less sensitive to sedimentation events.

No lab or field studies investigating the effects of sediment on the grainy crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

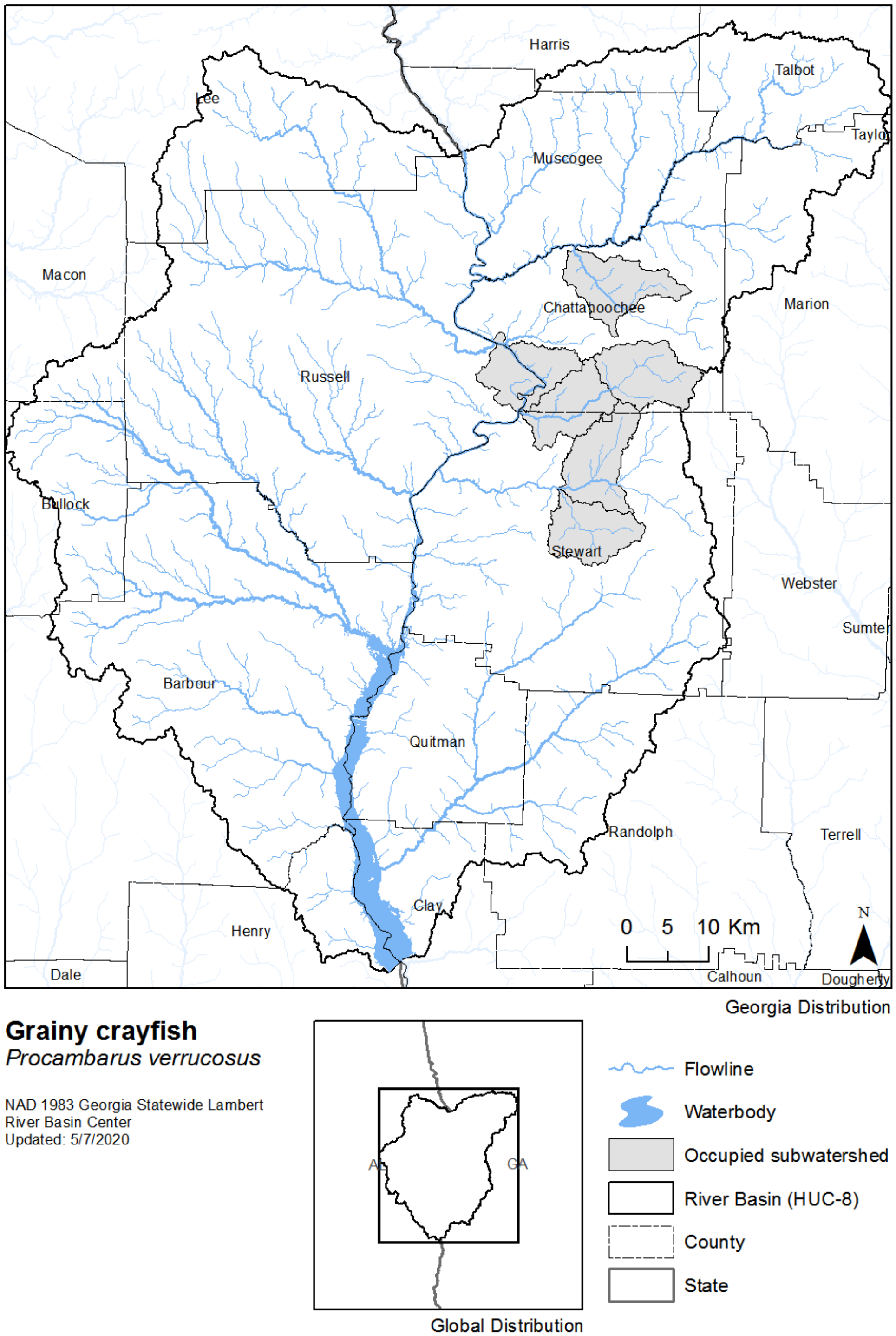
Because its habitat associations suggest a degree of tolerance, the sediment sensitivity of the grainy crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the grainy crayfish were found. Open water crayfishes are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. Because this species also burrows seasonally, it is likely exposed to higher concentrations of pollutants (accumulated in hydric riparian soils) through both direct contact and its diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the grainy crayfish is categorized as somewhat intolerant (3).

Figure 15. Map. Range map of the grainy crayfish.



HIWASSEE HEADWATER CRAYFISH

Species

Hiwassee Headwater Crayfish, *Cambarus parrishi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008): The overall color of the Hiwassee headwater crayfish is a brownish-green with dark mottling. The areola is wide and the rostrum gradually narrows anteriorly and has two very small marginal tubercles. This species reaches a maximum total body length of about 75 mm (3 in).

Life History

The Hiwassee headwater crayfish is usually found in swift, clear stream riffles under rocks or occasionally in leaf packs (Skelton 2008). This species is considered to be a generalist within its range (Russ and Fraley 2014).

No diet studies for the Hiwassee headwater crayfish were found. However, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008).

Male Hiwassee headwater crayfish have been observed in reproductive condition in January, April, May, August, October, and November. The smallest observed breeding condition (first form) male was 50 mm (2 in). Female Hiwassee headwater crayfish have been observed carrying eggs in April and June. Clutch sizes range from 38-112, and egg diameters range from 2.2-2.6 mm (0.08-0.10 in). The smallest observed female carrying eggs was about 53 mm (2.1 in) (Hobbs 1981, Skelton 2008).

Numbers, Reproduction, Distribution

This species is considered abundant at sites it occupies (Russ and Fraley 2014). The distribution of the Hiwassee headwater crayfish is limited to Georgia and North Carolina (Simon 2011). More specifically, the Hiwassee headwater crayfish has only been reported from the headwaters of the Hiwassee River system in the Blue Ridge physiographic province of the two states (Skelton 2008).

Conservation

The global conservation ranking status of the Hiwassee headwater crayfish is G2 and the Georgia state conservation ranking status is S1. This species is listed as endangered by the state of Georgia and is not under any federal protections.

The Hiwassee headwater crayfish is vulnerable to extirpation because of its small range, habitat loss and alteration due to urbanization, sedimentation due to poor land management and development practices, and competition with invasive crayfishes (Skelton 2008).

Some populations of this species inhabit locations within United States Forest Service land and therefore are somewhat protected from the threats discussed above (NatureServe 2020, Skelton 2008).

Effects of Construction Activities

Sediment

Russ and Fraley (2014) identify sedimentation as the primary threat to this species. Hiwassee headwater crayfish density was positively correlated with substrate roughness, percent cobble, and percent small boulder (Davis et al. 2015).

Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

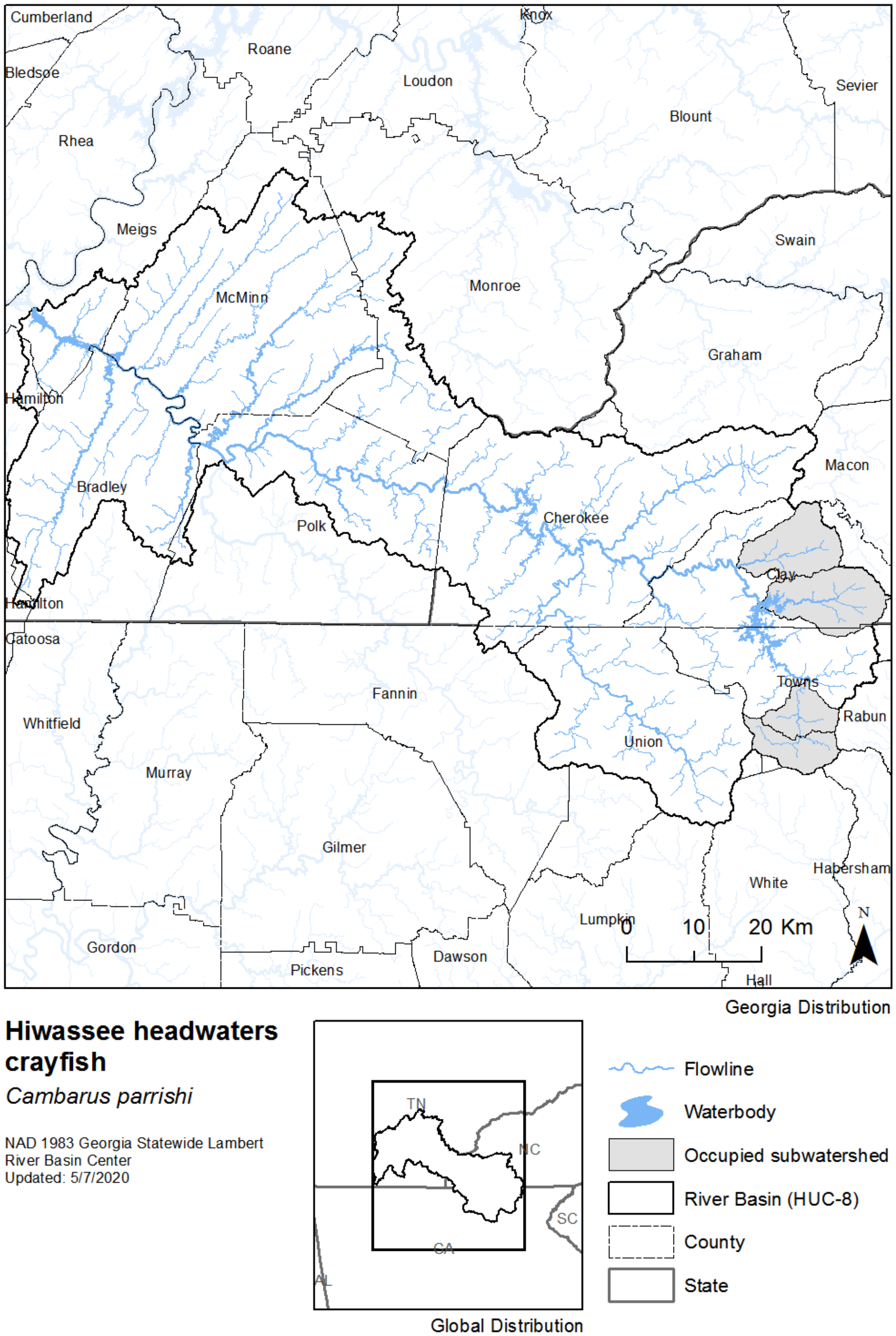
Based on the work by Davis et al., the sediment sensitivity of the Hiwassee headwater crayfish is categorized as intolerant (1).

Pollutants

No lab or field studies investigating the effects of pollutants on the Hiwassee headwater crayfish were found. Open water crayfishes, especially riffle-dwellers, are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Hiwassee headwater crayfish is categorized as moderate (4).

Figure 16. Map. Range map of the Hiwassee headwaters crayfish.



LEAN CRAYFISH

Species

Lean Crayfish, *Cambarus strigosus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008m): The overall color of the lean crayfish is orangish-olive to bluish-olive with the margins of the rostrum orange to creamy orange. There are two rows of orangish tubercles on the mesial margin of the palm. The areola is very narrow to non-existent and the abdomen appears much narrower than the cephalothorax. The claws may be robust. This species reaches a maximum total body length of about 75 mm (3 in).

Life History

The lean crayfish is an obligate burrower. The burrows of primary burrowers are often complex with multiple chambers, passages, and openings to the surface marked by chimneys. Burrows may be found among the roots of trees (Skelton 2008m).

No diet studies on the lean crayfish were found. The diet of burrowing crayfishes is not well understood; however, crayfish are generally considered to be opportunistic omnivores.

Therefore, burrowing crayfish likely consume animal and plant material within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008m).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008m).

Primary burrowing crayfish are generally restricted to their burrows for most of their lives. Male crayfish, however, leave their burrows to seek mates during the reproductive season. Male lean crayfish in reproductive condition have been observed in May and October. Female lean crayfish have been observed with eggs in April. Observed clutch sizes range from 21-39 eggs and egg diameters ranged from 2.0-2.1 mm. The smallest male observed in reproductive condition (first form) is 60 mm (2.4 in) and the smallest ovigerous female is about 54 mm (2.1 in) long (Skelton 2008m).

Unlike stream crayfish, multiple juvenile cohorts of burrowing crayfish may be observed together burrow (Skelton 2008m).

Numbers, Reproduction, Distribution

The distribution of the lean crayfish is limited to Georgia (Simon 2011). More specifically, this species has only been collected from the Broad River and Little River watersheds in northeastern Georgia within the Piedmont physiographic province (Skelton 2008m).

Conservation

The global conservation ranking status of the lean crayfish is G2 and the state of Georgia conservation ranking status is S2. This species is listed as threatened by the state of Georgia and it is not under any federal protections.

Populations of the lean crayfish are considered to be stable. However, this species is vulnerable to extirpation due to its small range, as well as urbanization and associated land disturbing activities that could destroy burrows and alter hydrology (Skelton 2008m).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the lean crayfish were found. As a primary burrower, the habitat of the lean crayfish is isolated from sediment conveyed by surface waters. In the absence of an exposure route, the lean crayfish is unlikely to be adversely affected by elevated sedimentation.

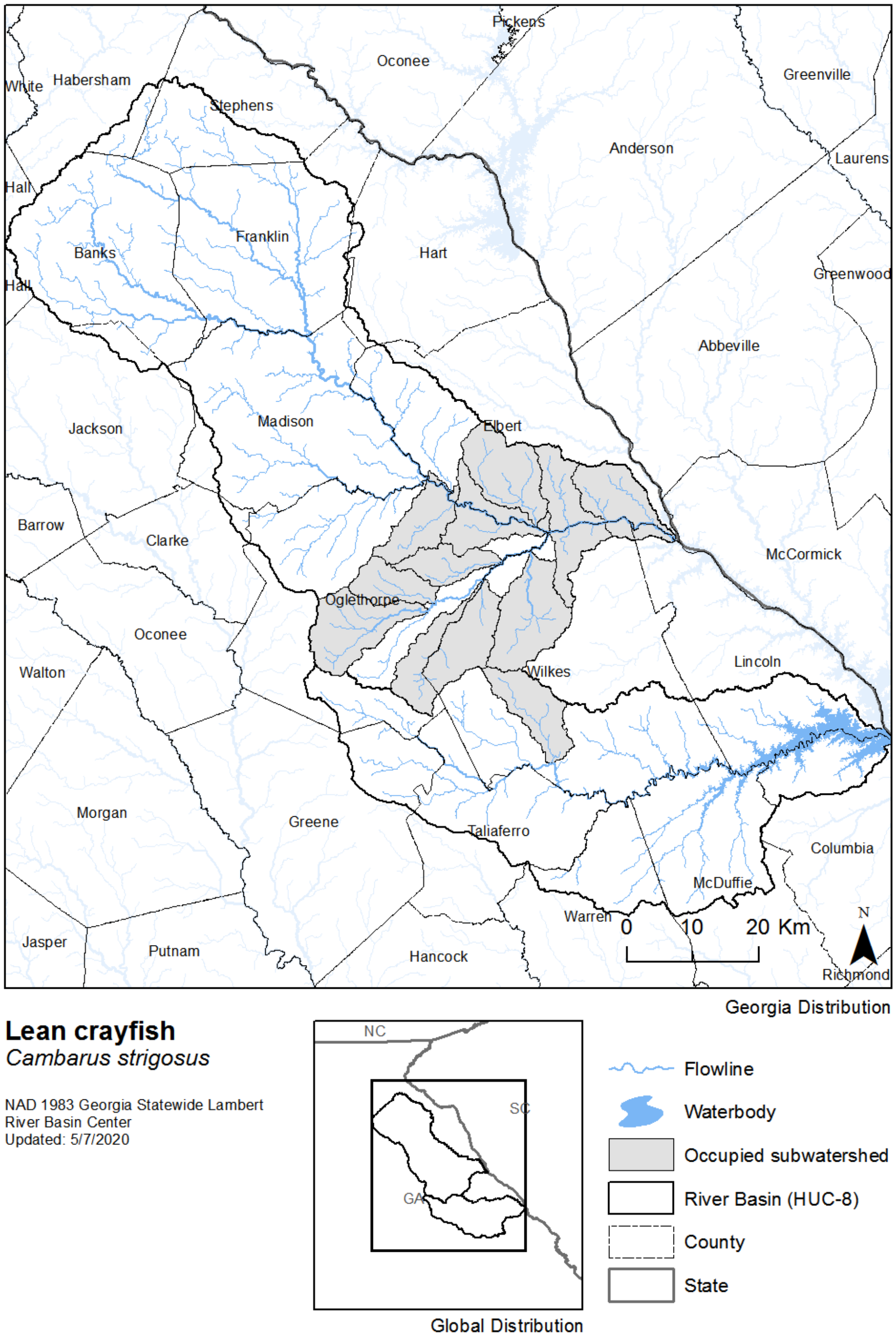
Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the lean crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the lean crayfish were found. Because the lean crayfish is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants, relative to open water species, through both direct contact and its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the lean crayfish is categorized as somewhat intolerant (3).

Figure 17. Map. Range map of the lean crayfish.



LITTLE TENNESSEE CRAYFISH

Species

Little Tennessee Crayfish, *Cambarus georgiae*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008g): The background color of the Little Tennessee crayfish is greenish-gray and the animal appears somewhat mottled. The abdomen has paired, slanted dark marks down each side of center. The rostrum is fairly long, narrow, and pointed with marginal spines. The areola is wide and nearly parallel-sided and cervical spines are present. This species reaches a maximum total body length of about 63 mm (2.5 in).

Life History

The Little Tennessee crayfish can be found in small streams of medium to low gradient in woody debris or leaf packs, and occasionally under rocks (Skelton 2008, Russ and Fraley 2014). This species been observed in diverse habitat, from rocky riffles to heavily sedimented areas (McLarney 1993). The type locality is the Little Tennessee River where it is 3 to 7 meters wide and up to one meter deep with a sand-clay bottomed runs and stony riffles (Hobbs 1981).

In streams where the Appalachian brook crayfish (*Cambarus bartonii*) is present, the Little Tennessee crayfish is collected more commonly from the stream margins. However, when the Appalachian brook crayfish is absent, the Little Tennessee crayfish is more common in riffles (Hobbs 1981). Although this may suggest the Appalachian brook crayfish may outcompete the Little Tennessee crayfish, McLarney (1993) posited that habitat partitioning between these two species interacts with stream size: Appalachian brook crayfish dominate in larger volume streams while the Little Tennessee crayfish is more common in smaller streams.

No diet studies of the Little Tennessee crayfish were found. However, stream crayfish generally hide during the day and come out at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008g).

Male Little Tennessee crayfish were observed in reproductive condition in March, April, and May. Female Little Tennessee crayfish in reproductive condition were observed in April (Skelton 2008) and June (McLarney 1993). McLarney (1993) also reported that females were more commonly observed throughout the year compared to males except for May-June, and young-of-the-year of both species began to appear in sizes large enough to be retained by the nets during the first week of July.

Numbers, Reproduction, Distribution

The distribution of the Little Tennessee crayfish includes Georgia and North Carolina (Simon 2011) within the Little Tennessee River and Betty’s Creek drainages (Skelton 2008). Upstream of Lake Emory, the Little Tennessee crayfish is considered common and populations are stable, but outside of this area the Little Tennessee crayfish is uncommon (Skelton 2008, Russ and Fraley 2014). This species has never been collected downstream of Franklin Dam nor in the mainstem Tuckasegee River (Russ and Fraley 2014). The Georgia range includes the Little Tennessee River watershed within the Blue Ridge physiographic province (Skelton 2008g).

Conservation

The global conservation status ranking of the Little Tennessee crayfish is G2G3 and the Georgia state conservation ranking status is S1. This species is listed as endangered by the state of Georgia and it is not under any federal protections.

The Little Tennessee crayfish is vulnerable to extirpation because of its small range, habitat loss and alteration due to urbanization, eutrophication likely due to nutrient runoff from agriculture, sedimentation due to poor land management and development practices, and introduction of non-native crayfishes (Skelton 2008g, Simmons and Fraley 2010). Betty's Creek, a major tributary to the Little Tennessee River, is considered high quality habitat and has protected headwaters (Skelton 2008g).

Effects of Construction Activities

Sediment

Because the Little Tennessee crayfish was observed occupying sedimented habitat, McLarney (1993) concluded this species is tolerant of sedimentation. However, he acknowledged that in some cases, the populations he observed may persist in sedimented habitat due to close proximity to a source population in less sedimented habitat. In a field study, observations of the Little Tennessee crayfish were correlated with less suspended and deposited sediment (Schofield et al. 2008). The Appalachian brook crayfish was observed at all sites, which suggests the Little Tennessee crayfish is more sensitive to sediment than the Appalachian brook crayfish (Schofield et al. 2008).

Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

Based on the available field studies, the sediment sensitivity of the Little Tennessee crayfish is categorized as moderate (3).

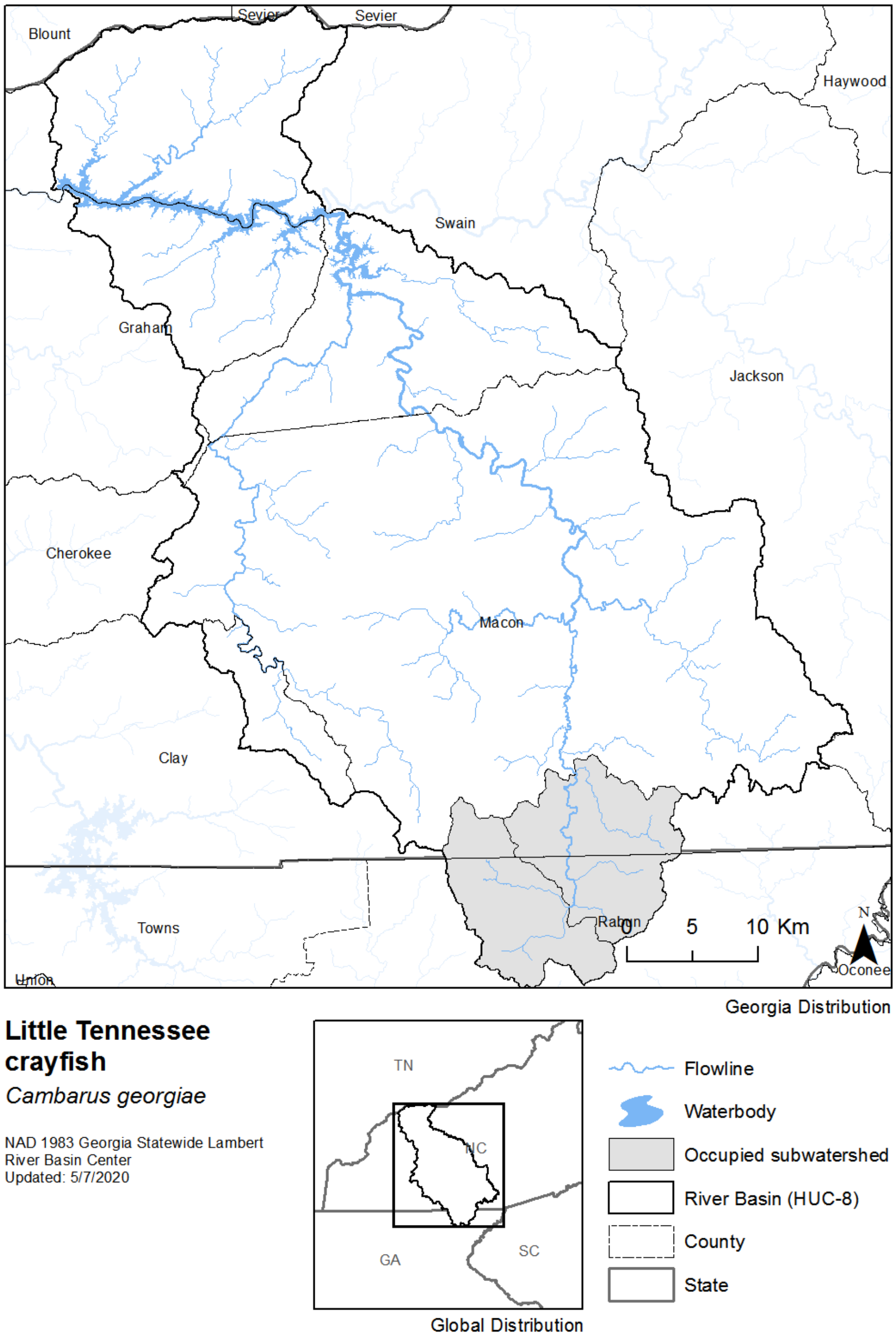
Pollutants

In a survey of sites throughout its known range, the Little Tennessee Crayfish was not observed at one site below an industrial outflow. However, this species was observed during the same survey immediately upstream and 2.3 miles downstream of the outfall (McLarney 1993). McLarney (1993) concluded that pollution may be a threat to this species.

Open water crayfishes, especially riffle-dwellers, are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Based on the limited information, the pollutant sensitivity of the Little Tennessee crayfish is categorized as moderate (4).

Figure 18. Map. Range map of the little Tennessee crayfish.



MUCKALEE CRAYFISH

Species

Muckalee Crayfish, *Procambarus gibbus*

Description

Reproduced from Georgia Department of Natural Resources (Skelton 2008p):

The carapace of the Muckalee crayfish ranges from pale to dark brown. A dark saddle crosses the top of the carapace just before the abdomen and extends forward along the sides of the carapace. The rostrum is long and sharply pointed. There are two distinctive cervical spines on either side of the carapace. The dorsal surface of the abdomen is tan with a dark margin along the posterior edge of each segment. The abdominal segments have green or black U-shaped stripes on the sides, the first four of which are bordered above by a scarlet to orange spot. These scarlet to orange markings are located more dorsally on the last abdominal segment and have irregular outlines. The telson alternates between tan and brown, has black spots, and its margins have an orange tinge. The claws are dark with a prominent row of light tubercles on the mesial margin of the palm. The tips of the fingers are red or orange. The areola is 2.8-3.5 times as long as broad and comprises 24-28% of carapace length. Adult Muckalee crayfish may reach a maximum total body length of over 100 mm (4 in).

Life History

Muckalee crayfish are often found in macrophytes or plant litter in riffles of clear, sandy-bottom creeks. Muckalee crayfish habitat generally is characterized by higher gravel and coarse sand content than the habitat of the sly crayfish (*Procambarus versutus*) and the white tubercled crayfish (*Procambarus spiculifer*) (Chadwick and Stanton 2011). Muckalee crayfish have been observed under rocks that are added to streams near road crossings (Skelton 2008). Muckalee crayfish have been historically reported from small streams and may be associated with a low abundance of fish predators and flow characteristics associated with small stream sites (Reisinger et al. 2011).

No diet studies for the Muckalee crayfish were found. However, stream crayfish generally hide during the day and emerge at night to feed opportunistically on plant, animal, and detrital material (Skelton 2008p).

Male Muckalee crayfish have been observed in reproductive condition in April and August. Juveniles hatch during the spring and summer (Hobbs 1981, Skelton 2008p). During a year of crayfish sampling in Marion County, Georgia, 124 Muckalee crayfish individuals were collected, and female captures were uncommon during the summer. Overall, Muckalee crayfish were most often captured during June and December. The mean carapace length of collected males was significantly longer than that of females (Chadwick and Stanton 2011).

Numbers, Reproduction, Distribution

The distribution of Muckalee crayfish is limited to Georgia (Simon 2011). More specifically, Muckalee crayfish have been collected primarily from the Muckalee Creek system within the Flint River drainage, located in the Fall Line Hills and Dougherty Plain physiographic provinces (Skelton 2008). Muckalee crayfish are considered rare and have only been reported from small tributaries to the Flint River (Reisinger et al. 2011). Based on sampling by Stanton (2006), Muckalee crayfish were absent from streams in the eastern part of Muckalee Creek watershed and the type locality from which this species was originally described (Chadwick and Stanton 2011). None of the reported occurrences of Muckalee crayfish are on publicly owned lands in Georgia (Skelton 2008).

Conservation

The global conservation of the Muckalee crayfish is G3Q and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia, and it is not under any federal protections. Chadwick and Stanton (2011) argued that because the Muckalee crayfish has a limited geographic range in Georgia (i.e. restricted to one stream system), this species merits conservation status.

The Mucklaee crayfish is vulnerable to extirpation due to its small range (Chadwick and Stanton 2011), habitat loss/alteration by urbanization, sedimentation resulting from poor land management and development practices, and competition with invasive crayfishes (Skelton

2008). The Muckalee Creek watershed in the Flint River system is primarily agricultural and additional threats to Muckalee crayfish populations include nutrient and pesticide runoff, inadequate riparian buffers, and stream impoundment (Skelton 2008).

Effects of Construction Activities

Sediment

The absence of Muckalee crayfish from historical collection sites was associated with anthropogenic land use changes that resulted in increased siltation and lower water velocities (Chadwick & Stanton 2011).

No lab or field studies investigating the effects of sediment on the Coosawattee crayfish were found. Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

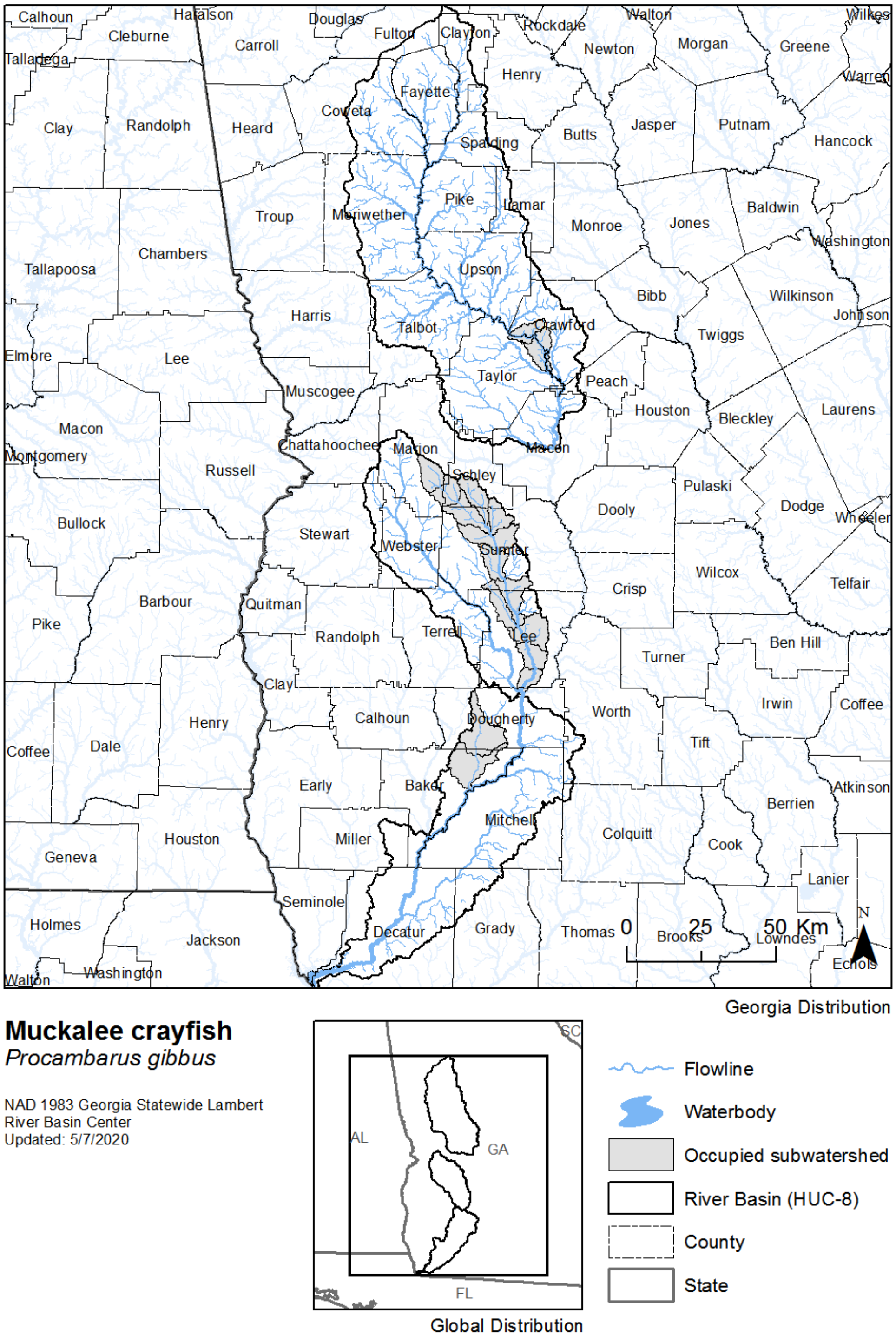
Due to limited information, the sediment sensitivity of the Muckalee crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the Muckalee crayfish were found. Open water crayfishes, especially riffle-dwellers, are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly, through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Muckalee crayfish is categorized as moderate (4).

Figure 19. Map. Range map of the Muckalee crayfish.



OCONEE BURROWING CRAYFISH

Species

Oconee Burrowing Crayfish, *Cambarus truncatus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008n): The overall color of the Oconee burrowing crayfish is pale to bright orange. The areola is virtually non-existent and the rostrum is short and broad. The abdomen is obviously narrower than the cephalothorax and the claws may be robust. There are two rows of tubercles along the mesial margin of the palm. This species reaches a maximum total body length of about 68 mm (2.7 in).

Life History

The Oconee burrowing crayfish is an obligate burrower that constructs burrows near surface water or in areas where the water table is near the surface. The burrows of primary burrowers are often complex with multiple chambers, passages, and openings to the surface marked by chimneys (Skelton 2008n).

No diet studies of the Oconee burrowing crayfish are known. The diet of burrowing crayfishes is not well understood; however, crayfish are generally considered to be opportunistic omnivores. Therefore, burrowing crayfish likely consume plant, animal, and detrital material within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008n).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008n).

Primary burrowing crayfish are generally restricted to their burrows for most of their lives. Male crayfish, however, leave their burrows to seek mates during the reproductive season. Male Oconee burrowing crayfish in reproductive condition have been observed in February, March, April, May, October, and November. Females with eggs have been observed in March and May and clutch sizes range from 10-31 eggs (mean = 28). The smallest male observed in reproductive condition (first-form) is 51 mm (2 in) long (Skelton 2008n). Unlike stream crayfish, multiple juvenile cohorts of burrowing crayfish may be observed together (Skelton 2008n, Roberson 2015). Breeding likely occurs in the early Spring and late Fall (Roberson 2015). Based on limited field and lab observations, the life history of the Oconee burrowing crayfish is most similar to a K-selected life history strategy (Roberson 2015).

Numbers, Reproduction, Distribution

The distribution of the Oconee burrowing crayfish is limited to Georgia (Simon 2011). More specifically, this species has only been collected from the Oconee River watershed at sites within the Coastal Plain physiographic province (Skelton 2008n).

Conservation

The global conservation ranking status of the Oconee burrowing crayfish is G2 and the Georgia state conservation ranking status is S2. This species is listed as threatened by the state of Georgia and is not under any federal protections.

Populations of the Oconee burrowing crayfish are considered to be stable (Skelton 2008n). However, this species is vulnerable to extirpation due to its small range, as well as urbanization and associated land disturbing activities that could destroy burrows and alter hydrology (Skelton 2008n).

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the Oconee burrowing crayfish were found. As a primary burrower, the habitat of the Oconee burrowing crayfish is isolated

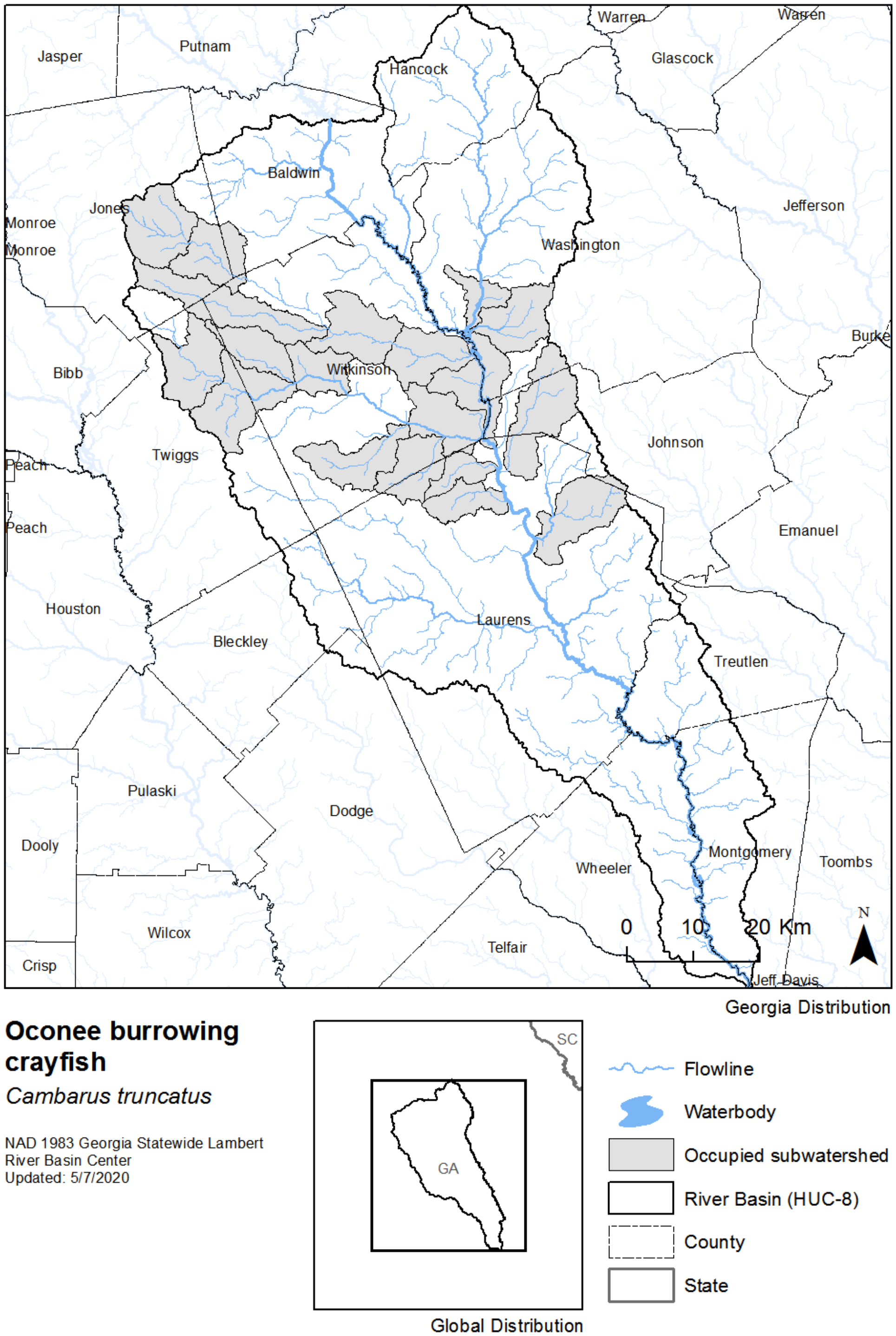
from sediment conveyed by surface waters. In the absence of an exposure route, the Oconee burrowing crayfish is unlikely to be adversely affected by elevated sedimentation.
Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the Oconee burrowing crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Oconee burrowing crayfish. Because the Oconee burrowing crayfish is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants, relative to open water species, through both direct contact and its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the Oconee burrowing crayfish is categorized as somewhat intolerant (3).

Figure 20. Map. Range map of the Oconee burrowing crayfish.



PIEDMONT BLUE BURROWER

Species

Piedmont Blue Burrower, *Cambarus harti*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008h):

As its name implies, the Piedmont blue burrower is deep blue in color, particularly on the claws. The areola is virtually non-existent, and the abdomen appears much narrower than the cephalothorax. The claws of this species may be robust. The Piedmont blue burrower reaches a maximum total body length of about 75 mm (3 inches).

Life History

The Piedmont blue burrower is an obligate, type 2 (burrows below water table) primary burrowing crayfish that constructs burrows in wooded areas with sandy, high humus soil near surface water, seepages, or in areas where the water table is near the surface. The burrow structure of primary burrowers are often complex with multiple chambers, passages, and openings to the surface marked by chimneys (Skelton 2008h, Helms et al. 2013, Gilmer 2014).

No diet studies of the Piedmont blue burrower were found. The diet of burrowing crayfishes is not well understood; however, crayfish are generally considered to be opportunistic omnivores. Therefore, burrowing crayfish likely consume plant, animal, and detrital material within their burrow. Burrowing crayfish have also been observed foraging outside of their burrow (Skelton 2008h).

Primary burrowing crayfish are considered to be long-lived, potentially up to ten years (Skelton 2008h).

Primary burrowing crayfish are generally restricted to their burrows for most of their lives. Male crayfish, however, leave their burrows to seek mates during the reproductive season. Male Piedmont Burrower in reproductive condition have been observed in April, May, and November. Female Piedmont blue burrowers in reproductive condition or with eggs were observed in May and June (Hobbs 1981, Skelton 2008h, Keller 2011, Helms et al. 2013). Two surveys of this species reported a female dominated sex-ratio, which may be related to contrasting capture efficiencies between males and females (Keller 2011, Helms et al. 2013). However, a high female to male sex ratio is common in other crustaceans (Helms et al. 2013). The smallest male observed in reproductive condition (first-form) is 48 mm (1.9 in) long (Skelton 2008h). Like other burrowing species, the most burrows in the field were occupied by a single crayfish, except in cases where juveniles and a female crayfish shared the burrow. However, in laboratory experiments with artificial burrows, adults were observed sharing burrows. Juvenile Piedmont blue burrowers were observed in June (Helms et al. 2013). Unlike stream crayfish, multiple juvenile cohorts of burrowing crayfish may be observed together (Skelton 2008h).

In a laboratory observation of one female Piedmont Burrowing Crayfish, eggs were extruded about 11 weeks after mating; eggs developed for four weeks; juveniles remained attached for one week; and juveniles occupied the burrow with the female an additional 11+ weeks (Helms et al. 2013).

Numbers, Reproduction, Distribution

The distribution of the Piedmont blue burrower is limited to Georgia (Simon 2011). More specifically, this species has been collected from the Flint, Chattahoochee, and Ocmulgee Rivers watersheds at sites within the Piedmont physiographic province (Skelton 2008h). Burrow density at three sites was 6.4, 9.0, and 12.3 burrows per square meter (Keller 2011).
One study predicted habitat suitability for this species using a spatial additive model. Keller (2011) hypothesized that elevation, soil type, geology, ecoregion, landcover, and hydrography may be important predictors of habitat suitability.

Conservation

The global conservation ranking status of the Piedmont blue burrower is G1 and the Georgia state conservation ranking status is S1. This species is listed as endangered by the state of Georgia and it is not under any federal protections.

The Piedmont blue burrower is vulnerable to extirpation due to its small range and urbanization and associated land disturbing activates that could destroy burrows and alter hydrology (Skelton 2008h).

Effects of Construction Activities

Sediment

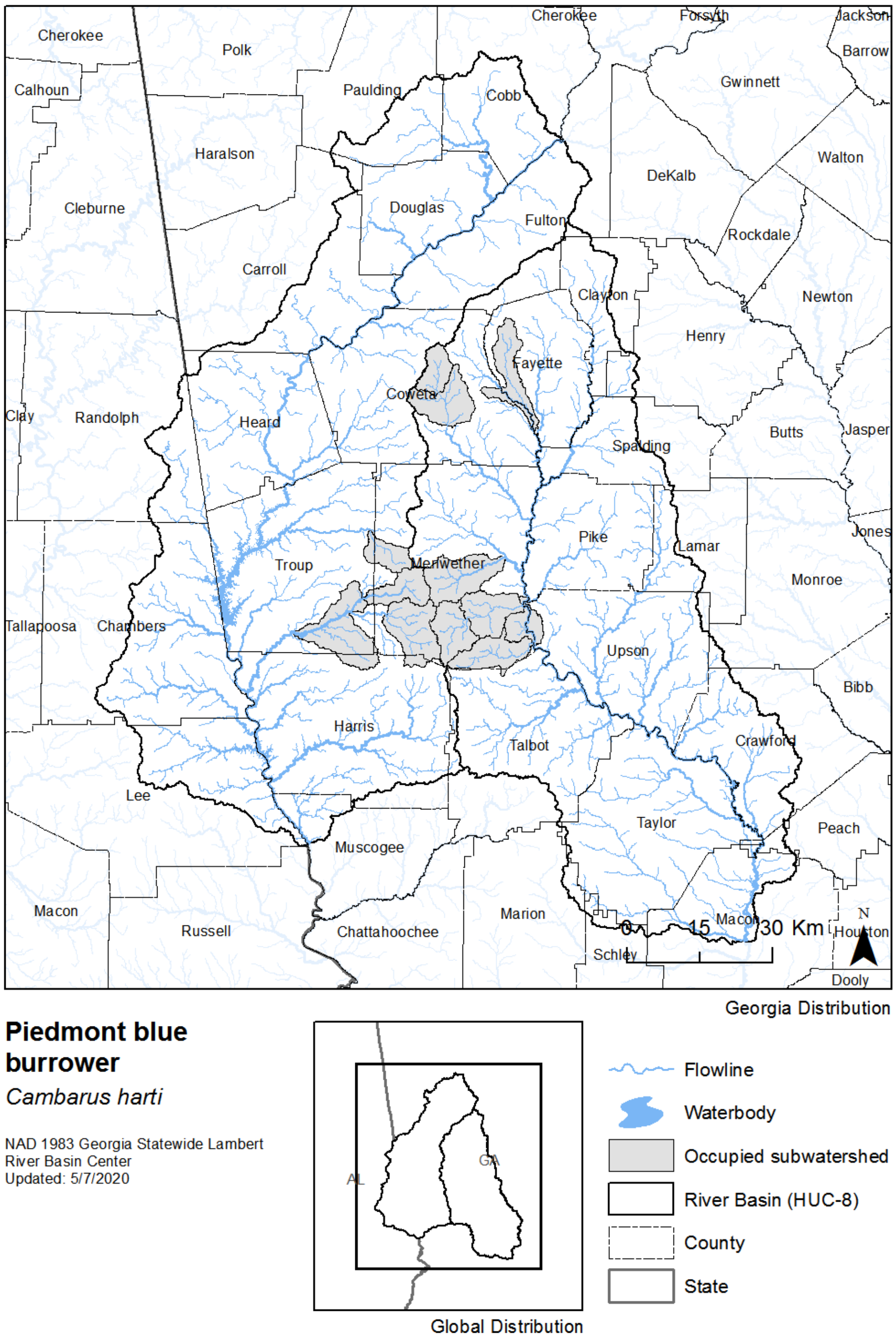
No lab or field studies investigating the effects of sediment on the Piedmont blue burrower were found. As a primary burrower, the habitat of the Piedmont blue burrower is isolated from sediment conveyed by surface waters. In the absence of an exposure route, the Piedmont blue burrower is unlikely to be adversely affected by elevated sedimentation.
Because its burrow habitat is isolated from sediment inputs, the sediment sensitivity of the Piedmont blue burrower is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Piedmont blue burrower were found. Because the Piedmont blue burrower is most likely found in type 2 burrow habitat (burrows in contact with the water table), it is indirectly exposed to roadway pollutants. As pollutants accumulate in riparian soils, this species is likely exposed to higher concentrations of pollutants relative to open water species through direct contact and its diet. However, in addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Because of its greater exposure to pollutants in riparian sediments, the pollutant sensitivity of the Piedmont blue burrower is categorized as somewhat intolerant (4).

Figure 21. Map. Range map of the Piedmont blue burrower.



SLY CRAYFISH

Species

Sly Crayfish, *Procambarus versutus*

Description

Reproduced from Georgia Department of Natural Resources (Skelton 2008q):

The sly crayfish is dorsally tan or brown with cream and black markings. Striking cream-colored stripes run horizontally along the sides of the carapace and abdomen. The rostrum bears spines lateral to the tip and a central ridge (carina). There are two distinctive cervical spines on either side of the carapace. The claws are dark, but the tubercles on the claws are even darker. The abdomen is brown and is covered with black blotches; these black markings form a horizontal band with irregular edges along the sides of the abdomen. The areola is 2-3 times as long as broad and comprises 24-28 percent of the total length of the carapace. Males of this species may reach a maximum total body length of over 90 mm (3.5 in). Mature females are about the same size, but males have notably larger claws.

Life History

The sly crayfish has been collected from clear, free-flowing streams with low pH and are often found in association with debris and aquatic plants located along the banks of sandy-bottomed streams (Skelton 2008). At night, the sly crayfish often forages over sand (Skelton 2008q). Because this species is most likely to be found in stream habitat, the research team classified this species as an open water crayfish for the purposes of this report; however, the sly crayfish may be found in simple burrows (Mitchell 2009).

Stewart et al. (2010) surveyed crayfish, including the sly crayfish, in 50 sites in southeastern Alabama. The sly crayfish was found in the following stream habitats for different percentages of time: riffle (21%), run (51%), and pool (28%) and selected woody debris (58%), leaf packs (31%), rootmats (30%), and logs (15%) of the time. The sly crayfish was primarily found on sand substrates (96% of the time) Stewart et al. (2010). This observation corroborates an early account of the sly crayfish: the highest abundance of the sly crayfish have been reported from sandy bottom and spring-fed streams (Hobbs and Hart 1959). Based on surveys of 39 tributaries of the Tallapoosa River drainage in Alabama, sly crayfish occurrences were not correlated with substrates in riffle and pool habitats (Ratcliffe and DeVries 2004). In contrast to the white-tubercled crayfish (*Procambarus spiculifer*), the sly crayfish is considered a habitat specialist (Ratcliffe and DeVries 2004). During a survey, the sly crayfish was the only crayfish species that was collected from two Coastal Plain streams (Ratcliffe and DeVries 2004).

Mitchell (2009) investigated production and trophic position of the sly crayfish using stable nitrogen and carbon isotope ratios and gut content analyses. Amorphous detritus was the main food type found crayfish diets, though animal matter and detritus were also found.
Male sly crayfish in reproductive condition were observed in all months of the year. Female sly crayfish were observed with eggs in May and June (Skelton 2008q).

Numbers, Reproduction, Distribution

The distribution of the sly crayfish lies within Georgia, Florida, and Alabama (Simon 2011). Within Georgia, the sly crayfish is known only from the Upatoi Creek system and some small creeks directly connected to the Chattahoochee River in Chattahoochee and Marion counties (Skelton 2008).

Conservation

The global conservation ranking status of the sly crayfish is G5 and the Georgia state conservation ranking status is S1. This species is listed as rare by the state of Georgia and it is not under any federal protections.

The sly crayfish is vulnerable to extirpation due to its small range as well as changes in land use that may alter its habitat and water quality. In Georgia, the sly crayfish has a small geographic range that overlaps within the Fort Benning Military Reservation, a federal property with habitat that had been well-protected in the past, but increased military training and activities could threaten crayfish habitats (Skelton 2008q). Efforts to protect populations of the sly crayfish should be implemented in Pine Knot, Black, and Juniper Creeks as well as Fort Benning (Skelton 2008q).

Effects of Construction Activities

Sediment

Mulholland et al. (2009) report that road construction is suspected to have adversely affected two of the best Marion County localities where the sly crayfish is found. Construction activities led to elevated stormflow turbidity and soil loss from stream banks. Effects on stream biota, however, were not detected. The authors suggest this is likely due to limitations of their monitoring protocol, including the study's short duration, and because these streams were already moderately disturbed prior to construction Mulholland et al. (2009).

Catchment disturbance (defined as percent of bare ground in the catchment) was negatively correlated with coarse woody debris, benthic organic material, and sly crayfish presence and density, especially in run habitats (Mulholland et al. 2007, Mitchell 2009).

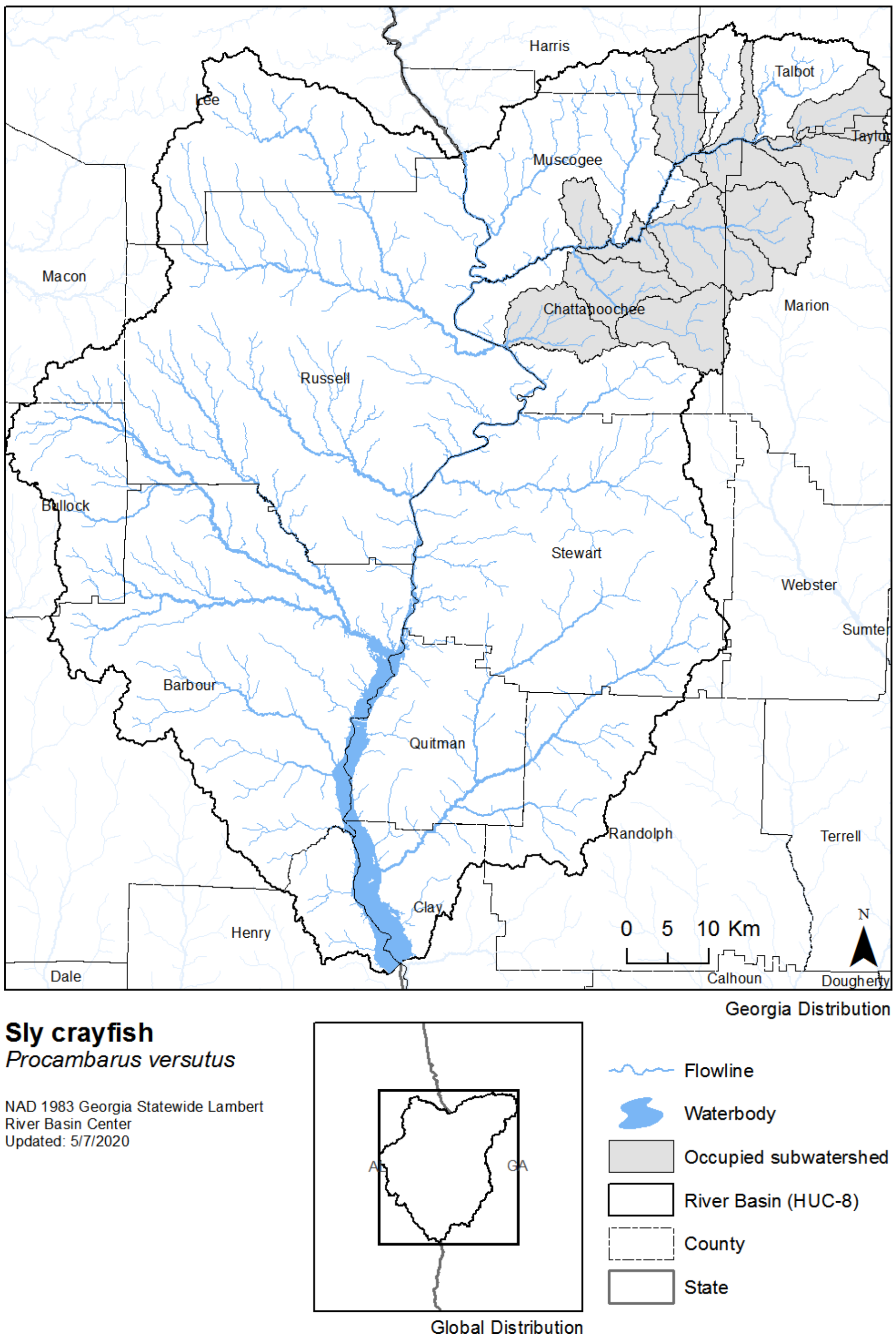
Based on the limited and mixed evidence, the sediment sensitivity of the sly crayfish is categorized as moderate (2).

Pollutants

No lab or field studies investigating the effects of pollutants on the sly crayfish were found. Open water crayfishes are primarily exposed to pollutants in the water column directly (e.g. via respiration) and indirectly through their diet. Because this species is also found in burrows, it is likely exposed to higher concentrations of pollutants (accumulated in hydric riparian soils) through both direct contact and its diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the sly crayfish is categorized as somewhat intolerant (3).

Figure 22. Map. Range map of the sly crayfish.



TALLAPOOSA CRAYFISH

Species

Tallapoosa Crayfish, *Cambarus englishi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton 2008d): The overall body color of the Tallapoosa crayfish is brownish to olive and the abdomen is almost black. The rostrum tapers toward the tip and appears slightly pinched in the middle. There are well-developed cervical spines. The claws of this species may be robust and have two rows of tubercles along the mesial margin of the palm. The antennae are whitish in live individuals. This species reaches a maximum total body length of about 90 mm (3.1 in).

Life History

This stream crayfish (i.e. "open water crayfish") is most commonly found in swiftly flowing riffles among large rocks (Ratcliffe and DeVries 2004, Helms et al. 2015). No diet studies for the Tallapoosa crayfish were found. However, stream crayfish generally hide during the day and come out at night to feed opportunistically on plant and animal material (Skelton 2008d).

Male Tallapoosa crayfish have been observed in reproductive condition in March, September, and October. Because of this, Hobbs (1981) concluded the breeding season likely extends from the spring through the summer. The smallest and largest breeding males are about 64 mm (2.5 in) and 75 mm (3 in), respectively. No ovigerous females have been observed. The largest female Tallapoosa crayfish observed is about 90 mm (3.5 in).

A closely related species, the slackwater crayfish (*C. halli*) is considered r-selected due to early age to reproduction (age-0 reach 19 mm and are reproductively active by end of first summer), rapid growth rate, and large numbers of offspring. Even so, relative to invasive species, the slackwater crayfish is considered less fecund, producing an average of 217 eggs per brood. The slackwater crayfish extrudes eggs in late March-early April; eggs hatch in April; and juveniles are independent in summer (Dennard et al. 2009).

Numbers, Reproduction, Distribution

The Tallapoosa crayfish is endemic to the Tallapoosa River basin (Freeman et al. 2003, Skelton 2008d) and exhibits significant genetic differentiation between populations at the scale of nearly every major tributary (Helms et al. 2015). Helms et al. (2015) suggests that evolutionarily significant units may be delimited by the Little, Upper, and Middle Tallapoosa.

Conservation

The global conservation ranking status of the Tallapoosa crayfish is G3 and the state of Georgia conservation ranking status is S2. This species is considered rare by the state of Georgia and it is not under any federal protections. In Georgia, no populations are known to persist in state or federally protected areas.

The Tallapoosa crayfish is vulnerable to extirpation due to its small range, habitat loss/alteration due to urbanization, sedimentation (due to poor land management and development practices), and the introduction of non-native crayfishes (Skelton 2008d).

Effects of Construction Activities

Sediment

In a study of Tallapoosa crayfish and habitat correlates, occurrence of this species was unrelated to substrate composition (Ratcliffe and DeVries 2004).

Open water crayfishes are much more exposed to sedimentation than their burrowing counterparts. Elevated levels of suspended and bedded sediment may cause an array of adverse effects on open water crayfishes. These effects include direct damage to tissues and reduced quality/quantity of habitat and food resources.

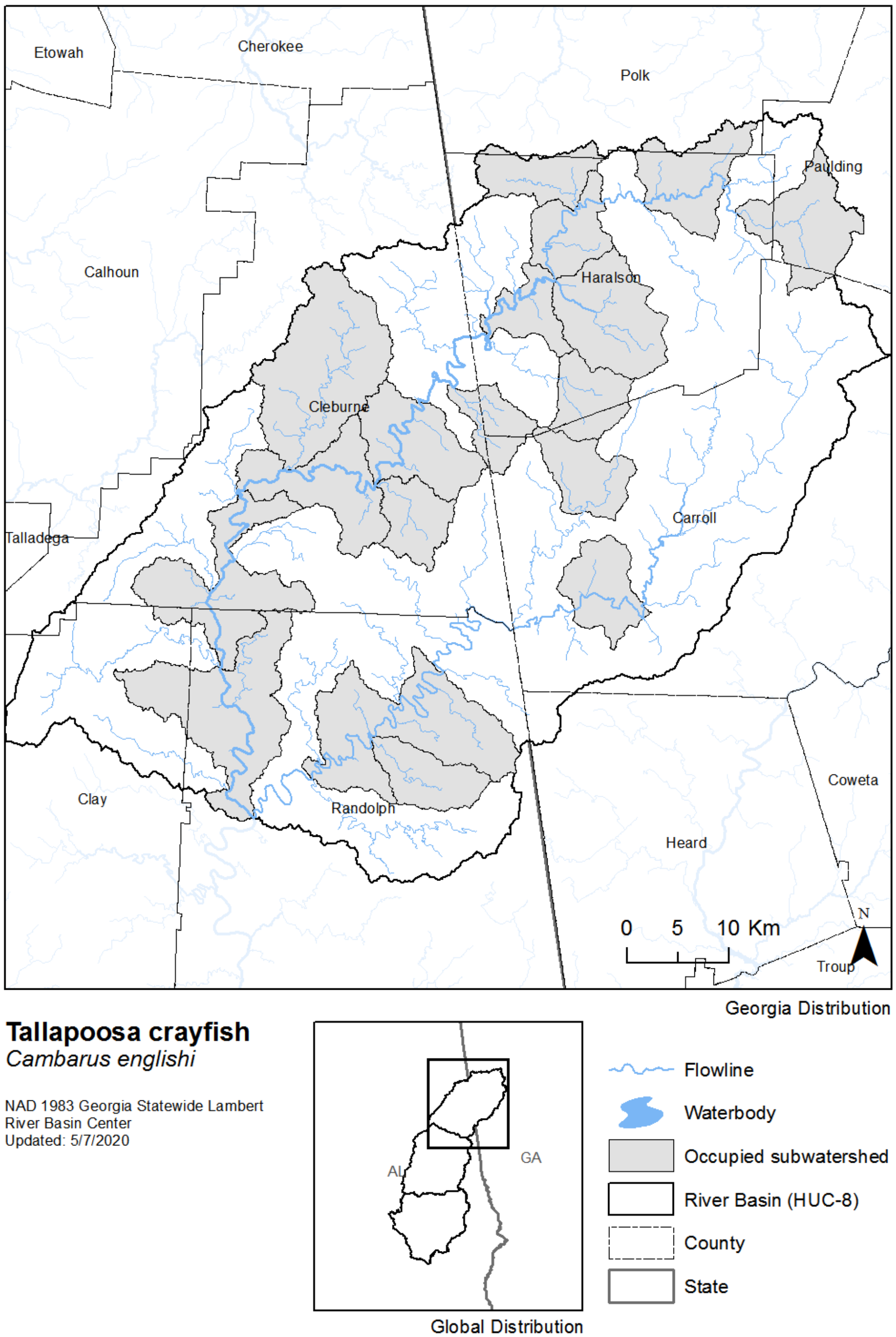
Based on the field study by Ratcliffe and DeVries, the sediment sensitivity of the Tallapoosa crayfish is categorized as tolerant (3).

Pollutants

No lab or field studies investigating the effects of pollutants on the Tallapoosa crayfish were found. Open water crayfishes, especially riffle-dwellers, are exposed to pollutants in the water column directly (e.g. via respiration) and indirectly through their diet. In addition to the more common mechanisms of pollutant inactivation/elimination, crayfishes sequester some pollutants in their exoskeleton followed by elimination via molting.

Due to limited information, the pollutant sensitivity of the Tallapoosa crayfish is categorized as moderate (4).

Figure 23. Map. Range map of the Tallapoosa crayfish.



DRAGONFLIES

CHEROKEE CLUBTAIL

Species

Cherokee Clubtail, *Stenogomphurus consanguis*

(formerly *Gomphus consanguis*)

Description

Cherokee clubtail larvae are 26.5-28.5 mm (1.04-1.12 in) long and are generally light brown with infrequent darker brown spots. Their surface is uniquely granulose, while this species' antennae, legs, and lateral abdomens are hairy. Larva have a lateral spine on their 9th abdominal segment, though it is shorter than that on segment 10, their labial palpal lobe terminates with an end hook, and the species has no noticeable dorsal abdominal spines (Westfall and Trogdon 1962). The Cherokee clubtail is closely related to other species in the former genus *Gomphus* (now divided into *Stenogomphurus, Phanogomphus, Gomphurus* and *Hylogomphus*), namely the sable clubtail.

Molecular phylogenetic analysis based upon nuclear, mitochondrial, and ribosomal sequences has resulted in a restructuring of the family Gomphidae and the addition of a number of new genera. Under this arrangement, *Gomphus* spp. do not occur in North America, but are now only found in Eurasia (Ware et al. 2017).

Life History

Cherokee clubtail larvae are most commonly found in small, high- to moderate-gradient spring-fed, slow-moving stream pools (often first- and second-order), especially below the outlets of small ponds. The pool bottoms are usually lined with silt, sand, gravel, and fine detrital substrate in partially shaded to open canopy areas (Beaton 2008a). Larvae overwinter, eat a variety of aquatic invertebrates, may have a two-year larval stage, and emerge as adults for a late May to late June flight season (Carle 1991; Beaton 2008a). During emergence, these dragonflies will crawl out of the stream onto vegetation and subsequently move into adjacent open habitats. Adults have been documented on the wing in Georgia from the 23rd of May thru the 23rd of June, however flight dates across the species' entire range are from the 23rd of May thru the 18th of July. After being fertilized, females return to the stream and oviposit by successively dipping the end of their abdomens into the water surface (Beaton 2008a).

Numbers, Reproduction, Distribution

This species is only found in the Ridge and Valley physiographic province of the southern Appalachians. Populations have been identified in Virginia, North Carolina, Tennessee, Georgia, and Alabama (Roble et al. 1997, Carle 1991, Beaton 2008a). In Georgia, Cherokee clubtail larvae are known to occur in ten streams of the Coosa and Tennessee River basins within six counties (Catoosa, Chattooga, Floyd, Gordon, Walker, and Whitfield; Beaton 2008, Beaton 2014, Mauffray and Beaton 2005). There are no protected populations of Cherokee clubtails, but healthy populations occur within several of the aforementioned streams in northwest Georgia (Beaton 2008a).

Conservation

The Cherokee clubtail has a global conservation ranking of G3 and a Georgia state ranking of S2. It is listed as Threatened in Georgia, but it is not federally listed. Threats to this species include loss of riparian buffers, impoundments, sedimentation and nutrients associated with agriculture, and pollutants associated with development practices (Beaton 2008a).

Effects of Construction Activities

Sediment

No field or lab studies investigating the effects of sediment on the Cherokee clubtail were found. Because the Cherokee clubtail larva is found in areas with substrates including silt and sand, it may be less sensitive to elevated inputs of fines sediments. However, because it inhabits spring-fed low-order streams, the duration of any adverse effects of a sedimentation event will be greatly prolonged by the lack of sediment flushing. Because its diet is primarily composed of macroinvertebrates, the Cherokee clubtail would likely be adversely affected by any reduction of abundance of their prey base following a sedimentation event.

Relying on the limited traits-based information, the sediment sensitivity of the Cherokee clubtail is categorized as moderate (2).

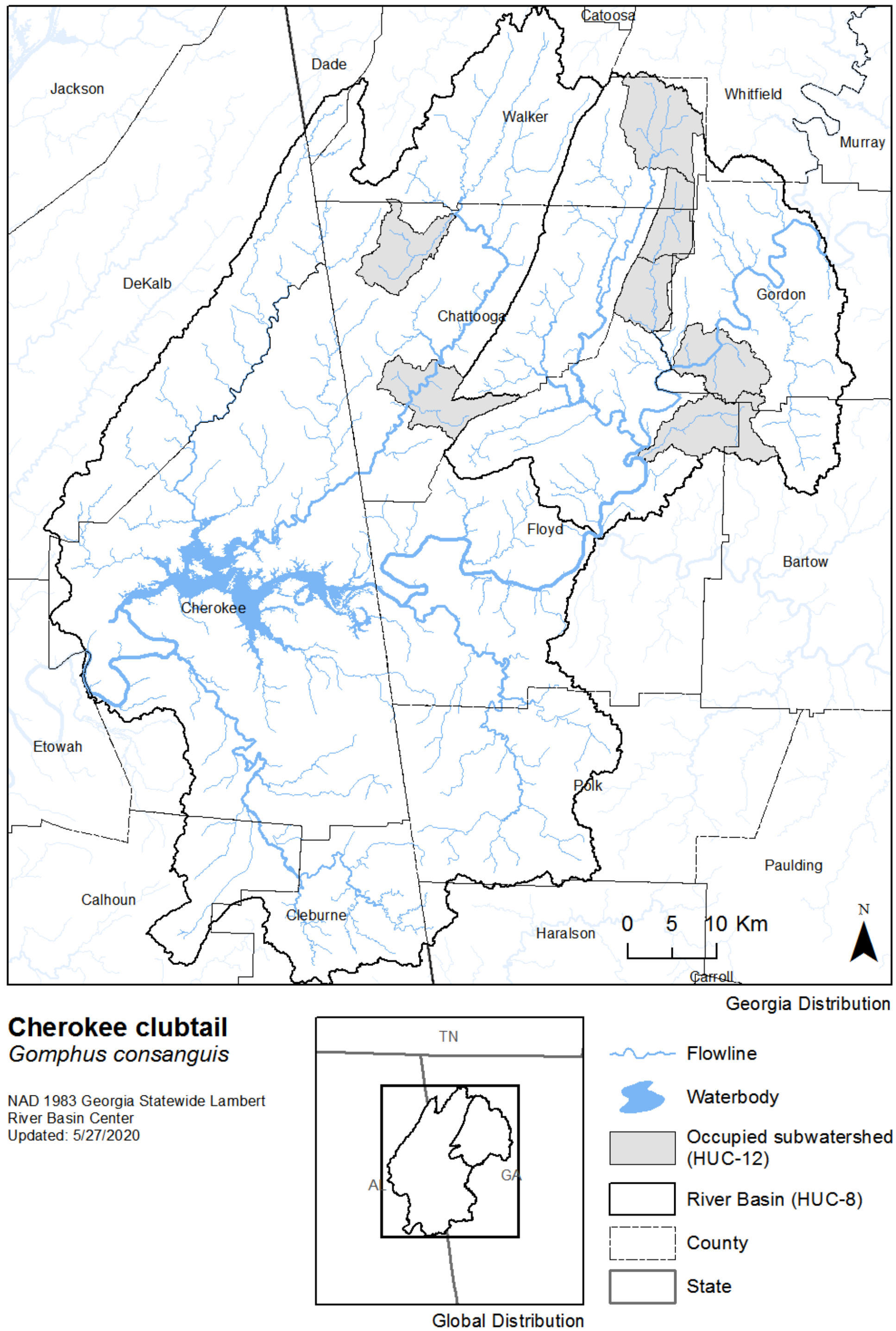
Pollutants

No field or lab studies investigating the effects of pollutants on the Cherokee clubtail were found.

Moreno et al. (2009) found that dragonflies in the Family *Gomphidae* occurred only in the least urbanized sites in a study of diversity across a developing basin. Diversity of larval dragonflies within *Gomphidae* has been shown to decline in basins subject to long-term land development and urbanization (Ferreras-Romero et al. 2009). Mahato and Kennedy (2008) found that *Gomphidae* larvae in urban stream enclosures had higher mortality rates than those in reference conditions, though they could not specify whether this pattern was a result of water quality or hydrologic differences among the urban and reference sites.

Based on the available information on members of the Family *Gomphidae*, the pollutant sensitivity of the Cherokee clubtail is categorized as somewhat intolerant (3).

Figure 24. Map. Range map of the Cherokee clubtail.



EDMUND'S SNAKETAIL

Species

Edmund's Snaketail, *Ophiogomphus edmundo*

Description

Species descriptions have been exclusively of adult specimens (e.g. Needham 1951), and as such the larval morphology of the Edmund's snaketail has not yet been described (Dunkle 2004).

Reproduced from Georgia Department of Natural Resources species profile (Beaton 2008b): Adults are typically 44 - 48 mm (1¾ -1⅞ inches) in total length. The thorax is bright green, with split mid-dorsal, two shoulder, and two lateral brown stripes. The anterior lateral stripe is very thin, and sometimes broken; the posterior stripe is much thicker. The eyes are blue-green to green, and the face is green. The legs are mostly black, but often have a very small yellow or pale area near the base of the thigh. The abdomen is very dark brown, with yellow dorsal markings on all segments that shorten posteriorly and are usually only represented as a spot on segments 8 - 9. Lateral yellow markings of male are present on segments 1 - 3, absent on segments 4 - 6, small on segment 7, becoming large spots on the edge of segments 8 - 9, and most of segment 10. Female is similar but the abdomen is thicker, with yellow lateral markings on every segment, but smaller on segments 7 - 9 than on male. Club is virtually absent in female.

Life History

Larvae can be found in clear, medium- to large-sized streams with moderately fast currents and eat a variety of aquatic invertebrates (Beaton 2008b). Though they are considered very rare in the Blue Ridge region, larvae likely occupy fast, clean forested streams with exposed rock (Mauffray and Beaton 2005).

Adults emerge and subsequently move away from the larval stream habitat into nearby open fields (Beaton 2008b). They then mature for one to two weeks and return to streamside habitat to set up mating territories. Fertilized females return to the stream channel and oviposit by dipping the end of their abdomen into the water several times (Beaton 2008b). Emergence dates vary, as adults have been seen on wing from the 24th of April thru the 25th of May, while the known flight dates for the Edmund's snaketail across the entirety of its range are the 24th of April thru the 29th of June (Beaton 2007, Beaton 2008b).

Numbers, Reproduction, Distribution

The Edmund's snaketail has historically been documented in two counties each of Georgia, North Carolina, and Tennessee (Bick 2003; Paulson and Dunkle 2012). More recently, individual populations have been found in South Carolina and the species is now known in a total of eight counties (USFWS 2017a). These eight counties contain portions of the southern Blue Ridge Mountains in North Carolina, Tennessee, South Carolina, and Georgia. Two of these county pairs are adjacent (Murray, Georgia and Polk, Tennessee; and Rabun, Georgia and Oconee, South Carolina) and effectually only represent single populations. This species has been known to occur in four streams and rivers in the southern Appalachian Mountains, and surveys from 2006-2008 documented healthy adult populations within long stretches of the upper Conasauga and upper Chattooga Rivers (Beaton 2008b, Dunkle 2004). However, during this same survey, the Edmund's snaketail was not found at a site within the Chattahoochee River Basin where it was previously known to occur, namely Smith Creek in White County, Georgia. Larvae are difficult to find in the large rivers in which this species is commonly found, though research continues to try to locate other watersheds with larval and/or adult populations (Beaton 2008b).

Conservation

The Edmund's snaketail has a global conservation status of G2 and a Georgia state status of S1. It is listed as endangered in Georgia, but it has no federal protections. The Georgia populations are incidentally afforded some protection, as much of the Chattooga and Conasauga River populations are known to fall within U.S. Forest Service lands. Additionally, the Chattooga population is found along the "Wild and Scenic" length of the river, but this species is also known to occupy stream reaches along private property (Beaton 2008b). Though recent surveys have increased the total number of recorded populations, this species is still vulnerable to a number of stressors resulting from agricultural activities (e.g. sedimentation, pesticide and fertilizer runoff) and development of commercial and residential areas (Beaton 2008b).

Effects of Construction Activities:

Sediment

No field or lab studies investigating the effects of sediment on the Edmund's snaketail were found.

Because larvae of the Edmund's snaketail are found in clear streams with exposed rock substrate, the species' habitat is likely to be substantially degraded by elevated inputs of fines sediments. Because its diet is primarily composed of macroinvertebrates, the Edmund's snaketail would likely be adversely affected by any reduction of abundance of their prey base following a sedimentation event.

Relying on the limited traits-based information, the sediment sensitivity of the Edmund's snaketail is categorized as intolerant (3).

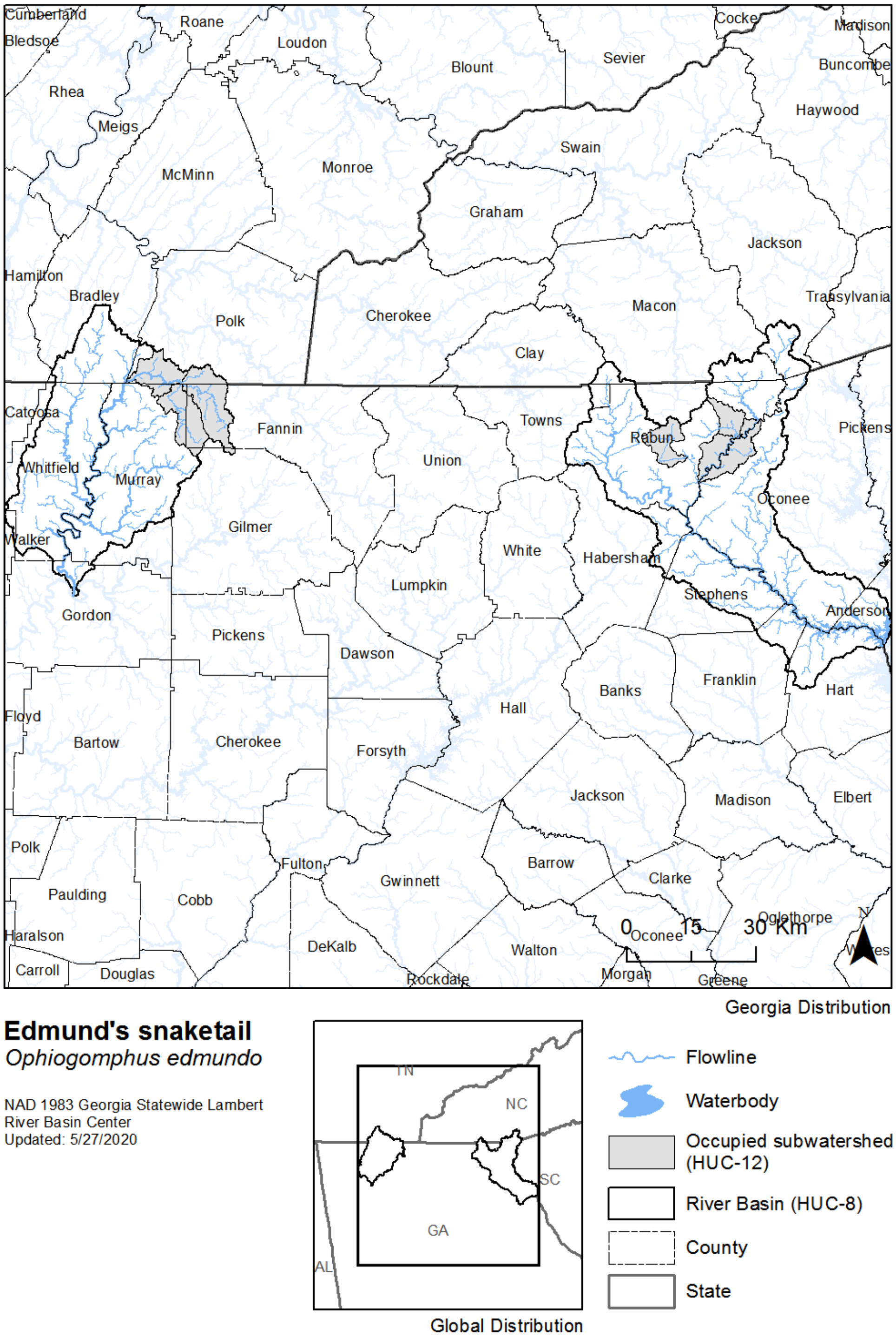
Pollutants

No field or lab studies investigating the effects of pollutants on the Edmund's snaketail were found.

Moreno et al. (2009) found that dragonflies in the Family *Gomphidae* occurred only in the least urbanized sites in a study of diversity across a developing basin. Diversity of larval dragonflies within *Gomphidae* has been shown to decline in basins subject to long-term land development and urbanization (Ferreras-Romero et al. 2009). Mahato and Kennedy (2008) found that *Gomphidae* larvae in urban stream enclosures had higher mortality rates than those in reference conditions, though they could not specify whether this pattern was a result of water quality or hydrologic differences among the urban and reference sites.

Based on the available information on members of the Family *Gomphidae*, the pollutant sensitivity of the Edmund's snaketail is categorized as somewhat intolerant (3).

Figure 25. Map. Range map of the Edmund's snaketail.



SAY'S SPIKETAIL

Species

Say's Spiketail, *Cordulegaster sayi*

(Synonym: *Zoraena sayi*)

Description

Say's spiketail is one of ten species of *Cordulegastridae* in North America (Tennessen 2019). It is typically classified under the genus *Cordulegaster*, however it can also be classified under the genus *Zoraena* (Tennessen 2019), which at one point was a subgenus of *Cordulegaster* (Pilgrim et al. 2002).

The larval stage of Say's spiketail ranges from 32.5-41.0 mm in length, it may be light to dark brown, and it is elongate with many setae (Tennessen 2019). The adults range from 60-69 mm in total length and has a dark brown thorax with "one shoulder and two pale-colored, lateral stripes." It also has two pale markings on segments three through eight (Beaton and Stevenson 2008).

Life History

Say's spiketail larvae are found in seep-fed streams in Georgia and Florida, inhabiting silt-bottom streams in hardwood forests and long-leaf pine ecosystems (Beaton and Stevenson 2008; Hipes et al. 2001). Within Georgia, Stevenson et al. (2009) reported finding them in "1st–2nd order mucky, perennial seepages (i.e., ground water springs originating from small, nearby sand aquifers issue water continuously year-round) surrounded by forest." The larvae can be difficult to locate but can be found by sifting through the silty habitat. The Say's spiketail is thought to have a two- or three-year larval stage before emerging and crawling out of the stream habitat (Beaton and Stevenson 2008). Dragonflies are primarily engulfing predators, and *Cordulegaster* species mainly await their prey, i.e. they do not stalk prey (Tennessen 2008). *Cordulegaster* species have been shown to consume a wide variety of aquatic invertebrates (Burcher and Smock 2002).

Adults forage in "scrub oak sandhills, brushy fields, or grasslands" near their larval stream (Beaton and Stevenson 2008). Known dates for adult flight range from February 27-April 23rd, and in Georgia starting from March 8th. The adult stage ranges from one to two weeks and females oviposit eggs directly into the substrate, with females "thrusting the tip of the abdomen vertically into the substrate" (Beaton and Stevenson 2008).

Numbers, Reproduction, Distribution

The species' range is "restricted to the eastern Coastal Plain sandhills of Georgia and Florida" (Beaton and Stevenson 2008). Eight populations in Florida have been identified in five different counties, including sites in Blackwater River State Forest, Toreya State Park, and Goldhead Branch State Park (Hipes 2001, Gregory 2004).

Reproduced from Georgia Department of Natural Resources species profile (Beaton and Stevenson 2008):

"In Georgia, *C. sayi* has been found at a total of 28 sites (in 17 counties). Recent surveys (2013-2018) have documented the species at 23 (82%) of the known sites. About 25% of the sites for this species in Georgia are on public land. This includes populations at Fort Stewart (Evans County), at Alapaha River WMA and Gordonia-Alatamaha State Park (Tattnall County) and Penholoway Swamp Wildlife Management Area (Wayne County). Other protected populations are on lands managed by The Nature Conservancy. No other populations in Georgia are protected, although at least two populations are on private land owned by conservation-minded property owners."

Conservation

The Say's spiketail has a global conservation ranking of G3 and a Georgia state ranking of S2S3. It is listed as Threatened in Georgia, but it is not federally listed.

Concerns about populations in Georgia and Florida primarily surround the limited habitat for this species as well as the small range and population. The primary threat facing this species is loss or degradation of habitat from residential or commercial development (Gregory 2004, Beaton and Stevenson 2008). Drought has also been identified as a potential threat to the habitat for Say's spiketail (Beaton and Stevenson 2008). Protecting seep-fed streams and surrounding habitat will likely be important for conserving this species (Gregory 2004, Hipes et al. 2001).

Effects of Construction Activities:

Sediment

No field or lab studies investigating the effects of sediment on the Say's spiketail were found. Because the Say's spiketail larva is most often found burrowed in silt-bottomed streams, it may be less sensitive to elevated inputs of fines sediments. However, because it inhabits seep-fed low-order streams, the duration of any adverse effects of a sedimentation event will be greatly prolonged by the lack of sediment flushing. Because its diet is primarily composed of macroinvertebrates, Say's Spiketail would likely be adversely affected by any reduction of abundance of their prey base following a sedimentation event.

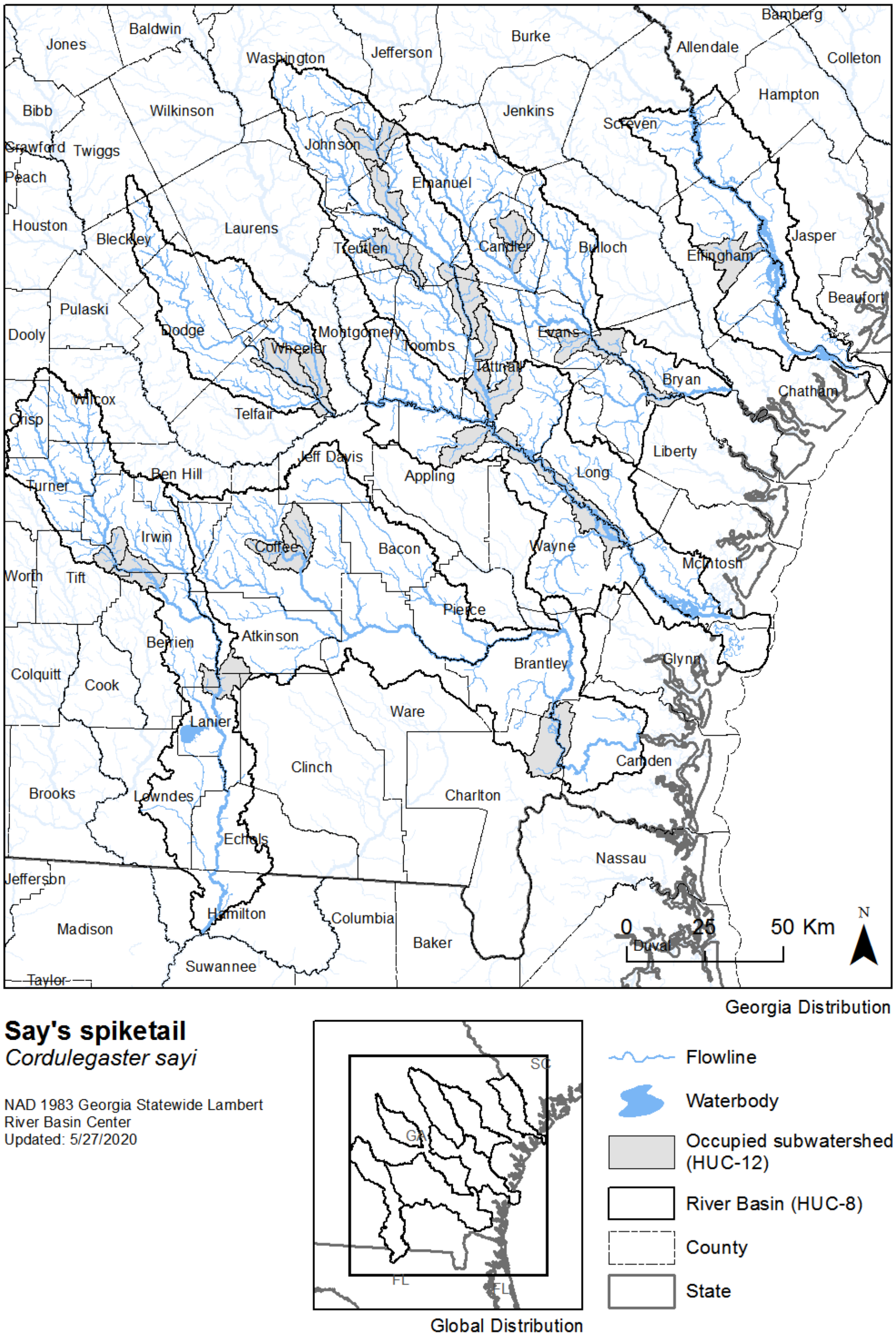
Relying on the limited traits-based information, the sediment sensitivity of the Say's spiketail is categorized as moderate (2).

Pollutants

No field or lab studies investigating the effects of pollutants on the Say's spiketail were found. Because dragonflies are predators on aquatic macroinvertebrates, they likely experience greater dietary exposure to pollutants that biomagnify. As a species that inhabits silty substrate, the Say's spiketail is likely has greater exposure to sediment-bound pollutants.

Relying on the limited traits-based information, the pollutant sensitivity of the Say's spiketail is categorized as moderate (4).

Figure 26. Map. Range map of the Say's spiketail.



FISHES

ALABAMA SHAD

Species

Alabama shad, *Alosa alabamae*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The Alabama shad has an elongated, laterally compressed body with a forked tail. Adult females are larger than males and may grow to 500 mm total length (ca. 20 in). This species has a large terminal mouth with a lower jaw projecting only slightly beyond the upper jaw. The tongue has a median row of small teeth; teeth are also present on the jaw in juveniles. There is a sharply angled notch in the center of the upper jaw. The number of gill rakers on the lower limb of the first gill arch usually exceeds 30 for all ages and typically numbers 42-48 for adults. The overall body coloration is silvery with a blue-green back; a darker shoulder spot may be evident in some individuals.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Alabama shad are a schooling, pelagic species that requires access to both saline and freshwater environments throughout its life span. Estuarine and marine habitat use by Alabama shad is generally unknown. During the spawning run, adult Alabama shad inhabit large rivers or streams and are generally found in areas with moderate currents and sand and gravel substrates. When inhabiting rivers and streams, adults and juvenile shad are rarely found in backwaters or areas with sluggish current. Alabama shad movement patterns may be similar to those of American shad, which move to deeper, quieter areas of the river channel at night.

Adult Alabama shad apparently feed little or not at all while in fresh water, as evidenced by the lack of food in their stomachs when captured. However, adult shad in fresh water will strike at fishing lures, and fishery biologists have angled for shad using tiny jigs as their primary collecting method. Although its significance is unknown, researchers have observed an unidentifiable slimy, green substance in the stomachs of several adult Alabama shad collected from the Apalachicola and Choctawhatchee rivers. Juvenile Alabama shad in the Apalachicola and other river drainages feed largely on aquatic dipterans and small fishes. In a diet study, fish collected from the Jim Woodruff Lock and Dam (JWLD) area contained a greater volume and variety of food per stomach, including fishes, than those collected further downstream, which likely contributed to the faster growth of juveniles from the JWLD region. The feeding habits of Alabama shad at sea are unknown.

The Alabama shad is an anadromous species, entering freshwater rivers to spawn and then returning to the sea to mature. Adults ascend open waters of medium to large Gulf Coast rivers from January to July; spawning usually occurs in April in Georgia. Alabama shad spawn over sand and gravel substrates in reaches with moderate current velocities. Eggs and larvae have been collected within a 6.5 km reach downstream of JWLD, from coarse sand and gravel habitats having moderate to swift current velocities (0.5 to 1.0 m/s). Spawning habitats occurred in areas with limestone outcroppings in the Choctawhatchee River, which may be an indicator of other potential spawning sites for the species. Juveniles are found in stream margin habitats over sand and gravel and then apparently move into salt water habitats at the end of their first summer. Adults may live to 6 years of age, and are usually 2 years old at time of spawning. Adults may spawn more than one time, although the proportion that repeat spawn is probably low.

More recent work by Kern et al. (2017) found that Alabama shad preferentially spawned in areas with limestone boulder substrate and avoided areas with coarse substrate, but showed no trends over areas with fine substrate. Spawning behavior of the Alabama shad has not been directly observed; however, it is likely a broadcast spawner like its sister species, the American shad (Jenkins and Burkhead 1994). The diet of early freshwater life stages of Alabama shad includes algae, insects from both aquatic and terrestrial sources, and a variety of unidentified organic materials likely foraged by filter feeding (Mickle et al. 2013).

Numbers, Reproduction, Distribution

Alabama shad inhabit Gulf coastal waters from Florida to Mississippi, using rivers as spawning grounds (Freeman et al. 1999). Once sufficiently abundant to supply commercial fisheries, they have been extirpated or greatly reduced in number throughout much of their historic range (Smith et al. 2011). Though already low, their current population is thought to be declining, as of 2005 (Smith et al. 2011). Within Georgia, the Alabama shad has been reported from the Apalachicola-Chattahoochee-Flint (ACF) system, which is also thought to be the largest spawning population (Ely et al. 2008). Based on data from 2005 to 2011, the adult spawning population of the Apalachicola River was estimated to be between 5,211 and 127,251 with a mean of ~24,800 (Ely et al. 2008, Young et al. 2012, Smith et al. 2011). The high variance in strength of year-class in this species and related species suggests that it is capable of recovery to much higher levels in the event that major anthropogenic stressors are eliminated (Ely et al. 2008).

Conservation

The Alabama shad has a current global conservation ranking of G2G3 and a Georgia state ranking of S1. The Alabama shad was petitioned for federal listing under the ESA, but after review by NMFS it was not found to warrant listing. This species is protected as Threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The construction of dams has long been considered the primary reason for the dramatic decline of Alabama shad and similar anadromous fishes across their ranges. Noting that large numbers of Alabama shad congregated below Keokuk Dam, IA, but none were ever captured above it, Coker (1930) reasoned that the dam likely limited the upstream passage of the species in the Mississippi River. Despite a lack of species-specific data, the proliferation of impassible structures constructed on rivers within its range is widely believed to have restricted returning adults from reaching their historic spawning grounds, and thus severely reducing or eliminating their ability to reproduce.

Any additional impoundments, particularly on the lower Flint River, threaten the survival of Alabama shad in Georgia. Dredging, sedimentation, water quantity, and habitat and water quality degradation are considered contributing factors to the decline of Alabama shad populations throughout its range. Hydropeaking operations may also result in intermittent reduction in discharge levels required for egg survival (PGEC 2005). Alteration of flows that decrease the stream margin habitat utilized by juveniles or shoal spawning habitat also pose problems. Poor water quality in the Flint or Suwannee river systems, especially downstream from major urban centers, is an additional threat.

Directed research and management is necessary to conserve and restore declining Alabama shad populations throughout their range. This focus is especially crucial considering the dearth of information available on what was once a wide-ranging species in North America.

Because it contains what is likely the largest remaining of the few known populations of Alabama shad, the Apalachicola River population has been a focus for research and conservation efforts. Information attained from future studies on this population is necessary, at the minimum, to provide information to state and federal conservation agencies on the ecology and status of this species. Conserving populations of Alabama shad depends upon maintaining and improving habitat quality in large rivers in the Apalachicola and Suwannee river drainages. The elimination of sediment runoff from land-disturbing activities and contaminants from urban and agricultural uses is critical to ensuring adequate resources and habitat for young shad. The impact from impoundments might be reduced somewhat in the Flint and Chattahoochee rivers by providing appropriate passage through Jim Woodruff Dam during spring spawning runs.

Effects of Construction Activities on Alabama shad

Sediment

Sedimentation of habitat has been cited as a potential stressor to Alabama shad (Smith et al. 2011, NMFS 2017), but no lab or field studies investigating its effects were found. In a four year telemetry study of Alabama shad migrations and spawning habitat, Kern et al. (2017) reported an overwhelming preference for the Flint River over the highly altered Chattahoochee River; however, it is unclear if sedimentation of habitat and/or degraded water quality were the primary drivers of this response.

In an investigation of the effects of acute exposure to suspended sediment on early life stages, Auld and Schubel (1978) found no effect on egg mortality of the sister species *A. sapidissima*, but did report mortality of larvae at concentrations of 100 mg/L and above, making the species more sensitive than *Morone saxatilis* and *Perca flavescens*. Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of *A. sapidissima* as moderate.

Given the lack of foraging by migrating Alabama shad in freshwaters, sediment is unlikely to adversely affect adults via their prey base. While juvenile Alabama shad rely primarily on aquatic and terrestrial insects, they are feeding generalists, making them relatively less sensitive to indirect effects of sediment on their prey base. Alabama shad showed a preference for boulder as spawning substrate, suggesting sensitivity to the presence of fine sediments, but they did not avoid sand/fine particles for spawning areas. However, with demersal eggs, Alabama shad reproduction may be harmed by smothering of eggs following spawning.

Given the mixed traits-based evidence, the sediment sensitivity of the Alabama shad is categorized as moderate (2).

Pollutants

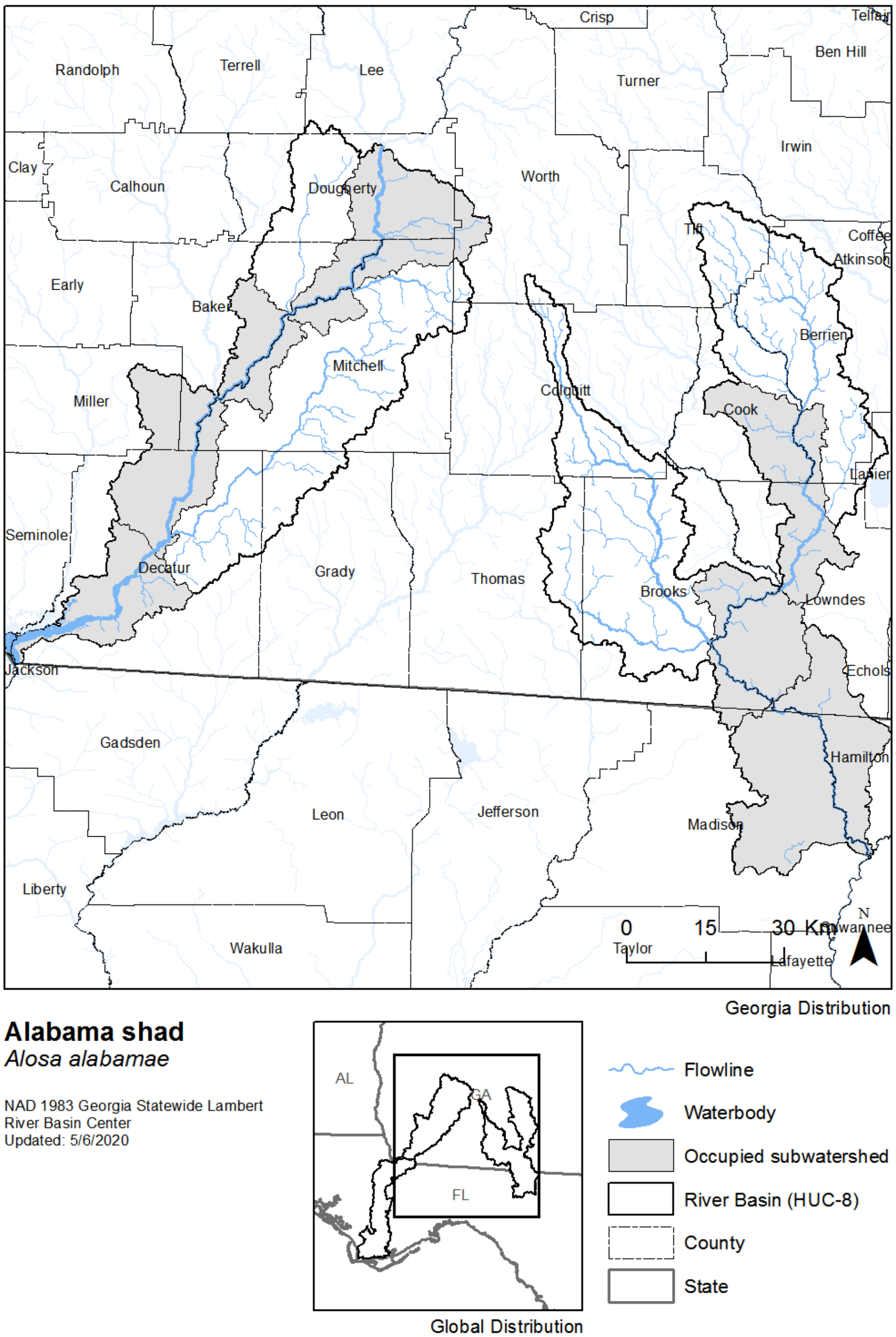
In an assessment of early life stage contaminant sensitivity, Dwyer et al. (2000) found that *A. sapidissima* was slightly more sensitive to acute exposures to five tested compounds (i.e. fungicide, detergent, molluscicide, and insecticides) than two standard test species, *Oncorhynchus mykiss* and *Pimephales promelas*, but sensitivity to a standard effluent mix was comparable to *P. promelas.*

Meador and Carlisle (2007; Meador unpublished data 2020) classified the specific conductivity tolerance of *A. sapidissima* as moderate.

Because adult shad are present in freshwater systems only temporarily, where they feed little or not at all, both their direct and dietary exposure to roadway-associated pollutants is extremely low. Juveniles experience some dietary exposure via aquatic insects, but are unlikely to be exposed via other major components of their diet (i.e. algae and terrestrial insects). Eggs/embryos of Alabama shad may be exposed to sediment-bound pollutants, but this is likely reduced by their preference for limestone boulder spawning substrate.

The limited toxicological data on the closely related *A. sapidissima* suggests moderate sensitivity, therefore the pollutant sensitivity of the Alabama shad is categorized as moderate (4).

Figure 27. Map. Range map of the Alabama shad.



ALTAMAHA SHINER

Species

Altamaha Shiner, *Cyprinella xaenura*

(formerly *Notropis xaenurus*)

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999h): A robust minnow, the Altamaha shiner can reach a maximum total length of 11 cm (4.3 in). This fish has a pointed snout and a terminal mouth. It has dusky olive coloration dorsally, a dark dorsal stripe, and a lateral black stripe on the posterior half of the body that can expand to form a spot at the base of the caudal fin. Breeding males are recognizable by a blue coloration on the sides and yellow to orange dorsal, caudal, and anal fins.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999h): Little is known concerning the life history of the Altamaha shiner, but based on the similarities between most members of the genus Cyprinella, spawning probably occurs over crevices in rocks or submerged logs where eggs are attached and then fertilized. Breeding males will develop prominent tubercles or bumps on the head and scales. Spawning probably occurs from mid-spring through mid-summer.

Altamaha shiners inhabit small tributaries and rivers. They are most often found in small pools with rocky to sandy substrates.

Its diet probably consists of aquatic insects or terrestrial insects captured from stream drift.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999h): Altamaha shiners are endemic to the Piedmont portion of the upper Altamaha River drainage of north central Georgia, from both the Ocmulgee and Oconee River systems. Historically, this species has been recorded from 25 different HUC 10 watersheds within its range. Between 1998 and 2009, this species has been documented within 18 of these watersheds.

Its recent population trend is unknown, but it may be stable or slowly declining slowly (Natureserve 2020).

Conservation

The Altamaha shiner has a global conservation status of G2/G3, no national status, and a Georgia state status of S2/S3. It was petitioned for listing under the ESA by the Center for Biological Diversity on 20 April 2010; USFWS issued a partial 90-day finding on the petition on 27 September 2011. It was subsequently withdrawn from the petition on 17 Dec. 2015 (Center for

Biological Diversity 2010, FWS 2011, Natureserve 2020). This species is protected as Threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999h): Threats to the Altamaha shiner are principally degradation and impoundment of tributary streams in the upper Altamaha drainage. 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 that depend upon small crevices to lay their eggs in are especially vulnerable to impacts of excessive sedimentation. The range of the Altamaha shiner includes the rapidly developing Piedmont physiographic province where many streams have become damaged by urban development to the point that they support only a very few hardy, tolerant fishes. The invasive red shiner, if it spreads throughout the Altamaha system, could be a very significant threat to the Altamaha shiner through hybridization and competitive displacement effects.

Conserving populations of the Altamaha shiner depends on maintaining and restoring habitat and water quality in tributaries of the upper Altamaha River drainage. 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), and maintain 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, containing and slowly releasing 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

No lab or field studies investigating the effects of sediment on the Altamaha shiner were found, but some work has examined the effects on its congeners. Research into the effects of sediment on *C. galactura* found that elevated suspended sediment resulted in reduced spawning effort, reduced spawning output, and delayed spawning (Sutherland 2007). Other research found that suspended sediment caused gill damage, stress, and reduced growth of *C. galactura* (Sutherland 2003; Sutherland and Meyer 2007; Sutherland et al. 2008). Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species, including *C. trichroistia*, decreased with increasing turbidity and bedded sediments. Burkhead and Jelks (2001) observed that exposure of *C. trichroistia* to suspended and bedded sediments resulted in delayed spawning, reduced the number of spawns, and reduced the number of eggs laid per clutch.

As a likely crevice-spawner, the reproduction of the Altamaha shiner is sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. While its feeding habits have not been documented, the Altamaha shiner is likely to be a drift-feeding insectivore and may therefore be indirectly and adversely affected by sediment effects on its prey base. Additionally, sexually dimorphic species, like the blue stripe shiner, rely on visual cues to induce spawning, which may be impaired by elevated turbidity.

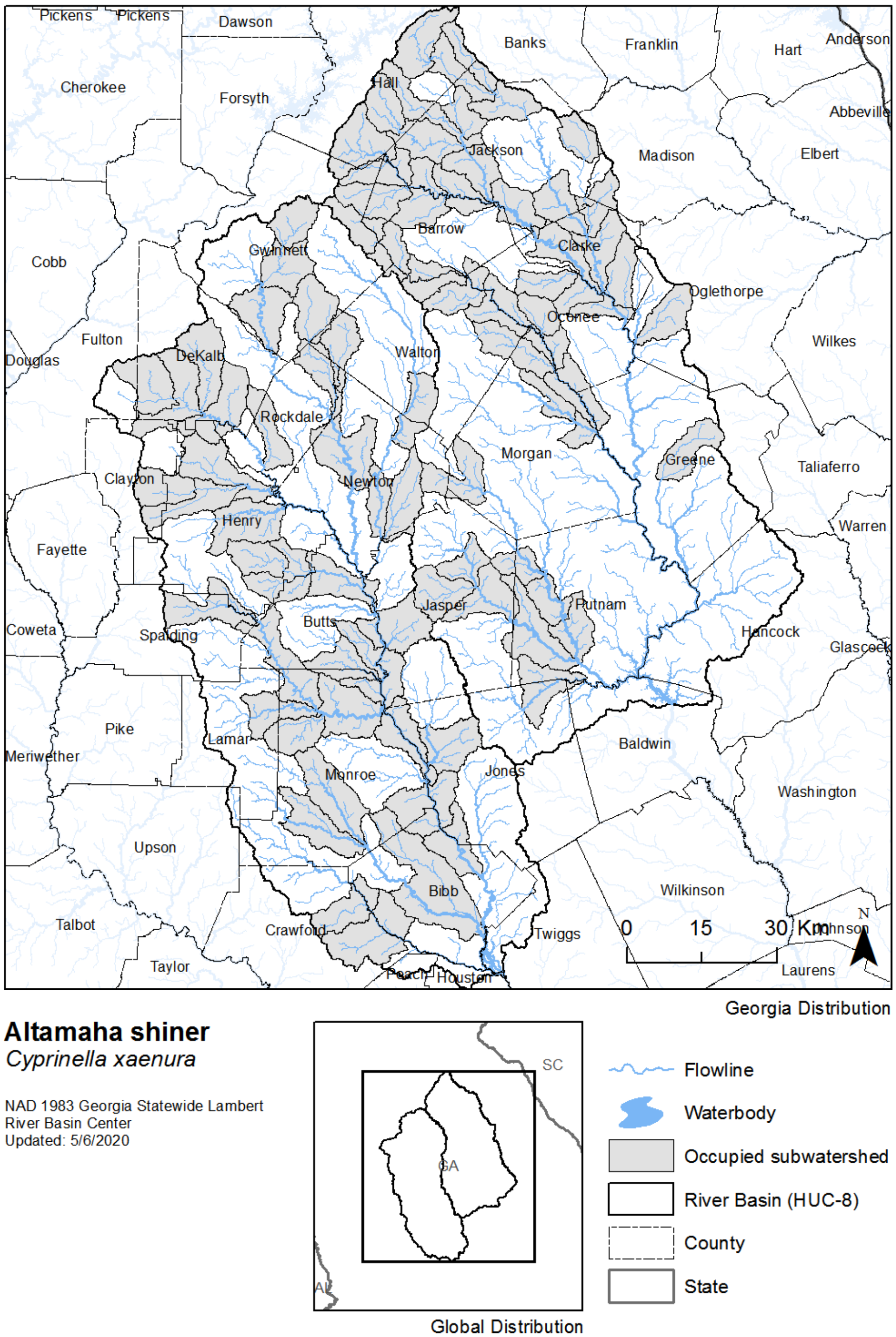
Based on the sensitivity of its spawning habitat, the sediment sensitivity of the Altamaha shiner is categorized as intolerant (1).

Pollutants

No lab or field studies investigating the effects of pollutants on the Altamaha shiner were found, but some work has examined the effects on its congeners. By quantifying changes in relative abundance over time, Oronato et al. (2000) categorized the congeners *C. callistia* and *C. trichroistia* as sensitive to the effects of urbanization, but also categorized the similar sympatric *C. venusta* as tolerant.

As a probable crevice-spawner, the eggs/embryos of the Altamaha shiner are not likely to come into direct contact with sediment-bound pollutants. If the Altamaha shiner is shown to be a drift-feeding insectivore, it likely carries a lower body burden of pollutants since its prey are at a lower trophic level and generally do not come in direct contact with sediment-bound pollutants. Based on the mixed and limited evidence on its congeners, the pollutant sensitivity of the Altamaha shiner is categorized as somewhat intolerant (3).

Figure 28. Map. Range map of the Altamaha shiner.



AMBER DARTER

Species

Amber Darter, *Percina antesella*

Description

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

The amber darter is distinct from other all other darters in the upper Coosa River System in having four dark saddles that contrast with a golden brown dorsum. The saddles may be narrowly haloed by a light greenish margin. The sides are marked with indistinct, small brown blotches. The belly and underside of the head are generally light in color, but often a faint blue coloration is present on the underside of the head. The snout is pointed, and a wide, dark teardrop extends below the eyes. The fins are mostly clear with faint banding on the dorsal, pectoral and caudal fins. Breeding males develop tubercles on the anal, caudal and paired fins, belly and caudal peduncle. In adults, males have an elongate anal fin that may be used to distinguish them from females. This slender darter reaches a maximum standard length of 63 mm (2.5 inches).

Life History

Amber darters are most often found in riffles and runs of moderate depth over clean gravel (Freeman and Freeman 1994, USFWS 2019j). They have been observed burrowing into substrate for cover (USFWS 2019j). They also tend to be found in association with riverweed (Podostemum ceratophyllum) (USFWS 2019j). Their diet consists primarily of aquatic insects and other macroinvertebrates (e.g. snails and limpets) (USFWS 2019j). Lifespan is likely four years and sexual maturity is reached after one or two years (Etnier and Starnes 1993). The spawning window of the amber darter extends from late fall to early spring (Mettee et al. 1996). Females bury their eggs in clean gravel substrate and post-hatch larvae use similar substrate as habitat (USFWS 2019j).

Number, Reproduction, Distribution

The amber darter is endemic to the upper Coosa River system in northwest Georgian and southeast Tennessee (USFWS 2019). It was first discovered in the Etowah system in 1948, and was subsequently discovered in the Conasauga River and formally described (1977). The species was only sporadically observed in the Etowah River until the 1990's, when populations were found in several shoal locations. It was recently also reported from the Coosawattee River, downstream of Carters Dam and reregulation structure (Stowe et al. 2020). The range of the amber darter is now disjunct, split between the Conasauga River, northeast of Dalton, and the Etowah River, upstream of Lake Allatoona. Its historic range likely also included the Oostanaula River. Since the 2000s, occupancy and abundance in the Conasauga have declined substantially, and the species has not been detected since 2017 (Freeman et al. 2017, Stowe et al. 2020). Amber darter populations in the Etowah are also declining, but at a slower rate (Stowe et al. 2020).

The declining abundance of the amber darter in the Etowah River system coincides with increasing urbanization of the surrounding watershed (USFWS 2019j). In contrast, the same research found that the estimated number of Conasauga River sites occupied by the amber darter decreased from 12.0 to 6.4 over the same time period (Freeman et al. 2017). A number of factors contributing to the decline in the Conasauga were proposed by the authors, especially agricultural pollutants, but the causes remain unclear.

Conservation

The global conservation ranking status of the amber darter is G1/G2 and the Georgia state conservation ranking status is S1. The amber darter is listed under the ESA as endangered (listed in 1985). This species is protected as Endangered in the state of Georgia.

Across its range, the amber darter is threatened by a number of anthropogenic impacts. These include: erosion of soil and stream banks caused by agricultural and construction activities; herbicides/pesticides and excess nutrients from agriculture (especially in the Conasauga watershed); lack of or inconsistent riparian buffer; geographic and genetic fragmentation of small populations by impoundments and altered habitat (e.g. Lake Allatoona); reduced base-flows caused by excessive water withdrawals; increasing urbanization of surrounding watersheds and associated runoff from impervious areas (especially in the Etowah watershed); loss of habitat diversity by reductions in associated Podostemum; and likely climate change as well (USFWS 2019j, Freeman et al. 2017).

Actions designed for conservation of the amber 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. 1999t).

Effects of Construction Activities

Sediment

Wenger and Freeman (2007) and the most recent species status assessment by the U.S. Fish and Wildlife Service (USFWS 2019j) identified sedimentation of habitat as a primary stressor to the amber darter. Occurrence of the closely related snail darter (*P. tanasi*) has been negatively correlated with fine sediments (Ashton and Layzer 2008, Shollenberger 2019). Walters et al. (2003) found that relative richness and relative abundance of ‘endemic highland species’ of the Etowah River, including P. palmaris (that has served as a surrogate for the amber darter), decreased with increasing turbidity and bedded sediments. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the tolerance of two closely related species (*P. shumardi* and *P. tanasi*) to suspended sediment as tolerant and moderate, respectively.

As a benthic invertivore, the amber darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that buries its eggs in clean gravel, amber 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.

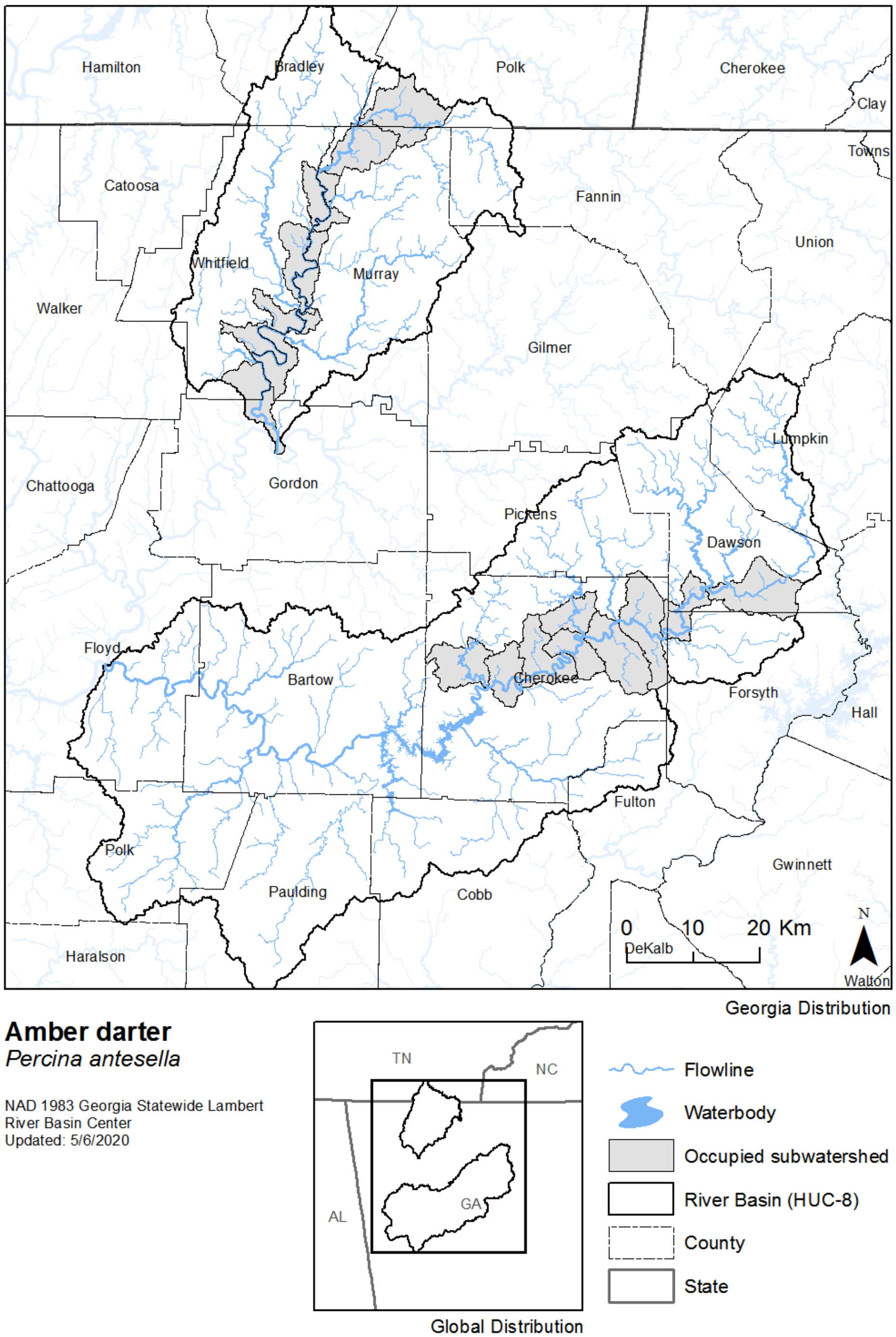
Based on the identification of sediment as a primary stressor and the sensitivity of its spawning habitat, the sediment sensitivity of the amber darter is categorized as intolerant (11).

Pollutants

Wenger and Freeman (2007) and the most recent species status assessment by the U.S. Fish and Wildlife Service (USFWS 2019j) identified stormwater pollutants and urbanization-related imperviousness as primary stressors to the amber darter. Wenger et al. (2008) and Wenger (2008) evaluated the relationship of fish occurrence with effective impervious area (EIA) for five Etowah mainstem river species, including the amber darter and the bronze darter (*P. palmaris*). The bronze darter was selected as a surrogate to supplement limited occurrence data for the amber darter. Response curves indicated that species occurrence probability in a given shoal approached zero at about 5% EIA in the upstream watershed for the bronze darter and 10% EIA for the amber darter. Building on these data, Wenger et al. (2010) described the amber darter as "intermediate" in sensitivity to imperviousness, relative to *E. etowahae* and *E. scotti.*

Based on the work by Wenger et al., the pollutant sensitivity of the amber darter is categorized as somewhat intolerant (3).

Figure 29. Map. Range map of the amber darter



BLACKBANDED SUNFISH

Species

Blackbanded Sunfish, *Enneacanthus chaetodon*

Description

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

The blackbanded sunfish is a small, laterally compressed and deep-bodied species reaching a maximum total length of 100 mm (4 inches). There is a prominent notch separating the spinous and soft-rayed portions of the dorsal fin. It is distinctively marked with 5-6 black bars along the sides that extend from the dorsum to the venter. The first of these bars passes through the eye, and the third extends through the first three membranes of the spinous dorsal fin to the upper edge of the fin. This barring pattern is unique to this species. The blackbanded sunfish is also very colorful with black vertical bars, olive-brown to variegated-brown on the dorsum and upper sides, and orange-copper marking the leading edge of the pelvic fins and the irises.

Life History

Blackbanded sunfish are found only in slow-moving, clear (but tea-colored) water in both river/stream and pond/lake habitats (Freeman et al. 1999). They are found in strong association with dense aquatic macrophytes, which presumably serves as cover for them and habitat for their prey. Their diet is composed of small invertebrates found among the aquatic macrophytes (Freeman et al. 1999).

Spawning has been reported from March (North Carolina) to late June (Delaware) in water temperatures from 20 to 28 °C (Freeman et al. 1999). Spawning adults create shallow depressions in sand/gravel, under the cover of macrophytes, but also may lay eggs in plant roots or plant masses. Adult males then guard the nests during development. Beaver ponds have been reported as important for early life stages. Estimates of life span range from 3 to >8 years (Freeman et al. 1999).

Numbers, Reproduction, Distribution

The species range of blackbanded sunfish extends along the Atlantic coast from Florida to New Jersey, in locations below the fall line (Freeman et al. 1999). Within Georgia, they are known from Savannah, St. Marys, Suwanee, Alapaha, and Aucilla Rivers as well as the Okefenokee Swamp; though their distribution within this range is very sparse. They are generally rare or uncommon within Georgia rivers, which may be due to competition with other centrarchids. There are no estimates of abundance or population trends in Georgia, but it is estimated that the single largest population in Georgia is found within the Okefenokee Swamp (Freeman et al. 1999).

Conservation

The blackbanded sunfish has a global conservation ranking of G3/G4 and a Georgia state conservation ranking of S1, but it is currently under no federal protections (Freeman et al. 1999). This species is protected as Endangered in the state of Georgia. Threats to the blackbanded sunfish include: small and localized populations, an invasive snail species that may reduce macrophytes used as habitat, and land use changes such as agriculture that may increase nutrients or decrease overall flows. Extensive sampling efforts have been made to document blackbanded sunfish to improve knowledge of their range, occurrence, and abundance. Methods included trapping, seining, boat electrofishing, and eDNA sampling. These sampling efforts have resulted in the above description of their occurrence as very sparse (Freeman et al. 1999, Darden et al. 2019).

Recommended actions for the conservation of blackbanded sunfish populations focus on habitat quality and include: avoidance of anthropogenic activities that may introduce pollutants or reduce water inputs, avoidance of exotic species introductions that may directly or indirectly degrade habitat, and refrain from stocking of competitive game fishes (Freeman et al. 1999).

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the blackbanded sunfish tolerance to suspended sediment as intolerant; they also evaluated the suspended sediment tolerance of two closely related species (*E. gloriosus, E. obesus)* as moderate and tolerant, respectively.

Because blackbanded sunfish occupy habitats below the fall line, dominated by sandy substrates, this species may be less sensitive to inputs of sediment. However, because their habitat is generally low-velocity, any adverse effects resulting from an elevation of fine sediment would be prolonged by a lack of sediment flushing by the current. As invertivores, the blackbanded sunfish may be indirectly affected by sediment via a reduction of macroinvertebrate abundance. Because spawning adults build nests in sand/gravel or among plant roots, blackbanded sunfish reproduction is likely not affected by the initial presence of fine sediment. Additionally, adult males are known to guard nests and, while it has not been reported for this species, they may maintain nests free of subsequent sedimentation inputs by fanning of the eggs like other centrarchids.

Based on this and on the classification by Meador and Carlisle, the overall sediment sensitivity of the blackbanded sunfish is categorized as intolerant (11), although further research may cause this to be revised to moderate.

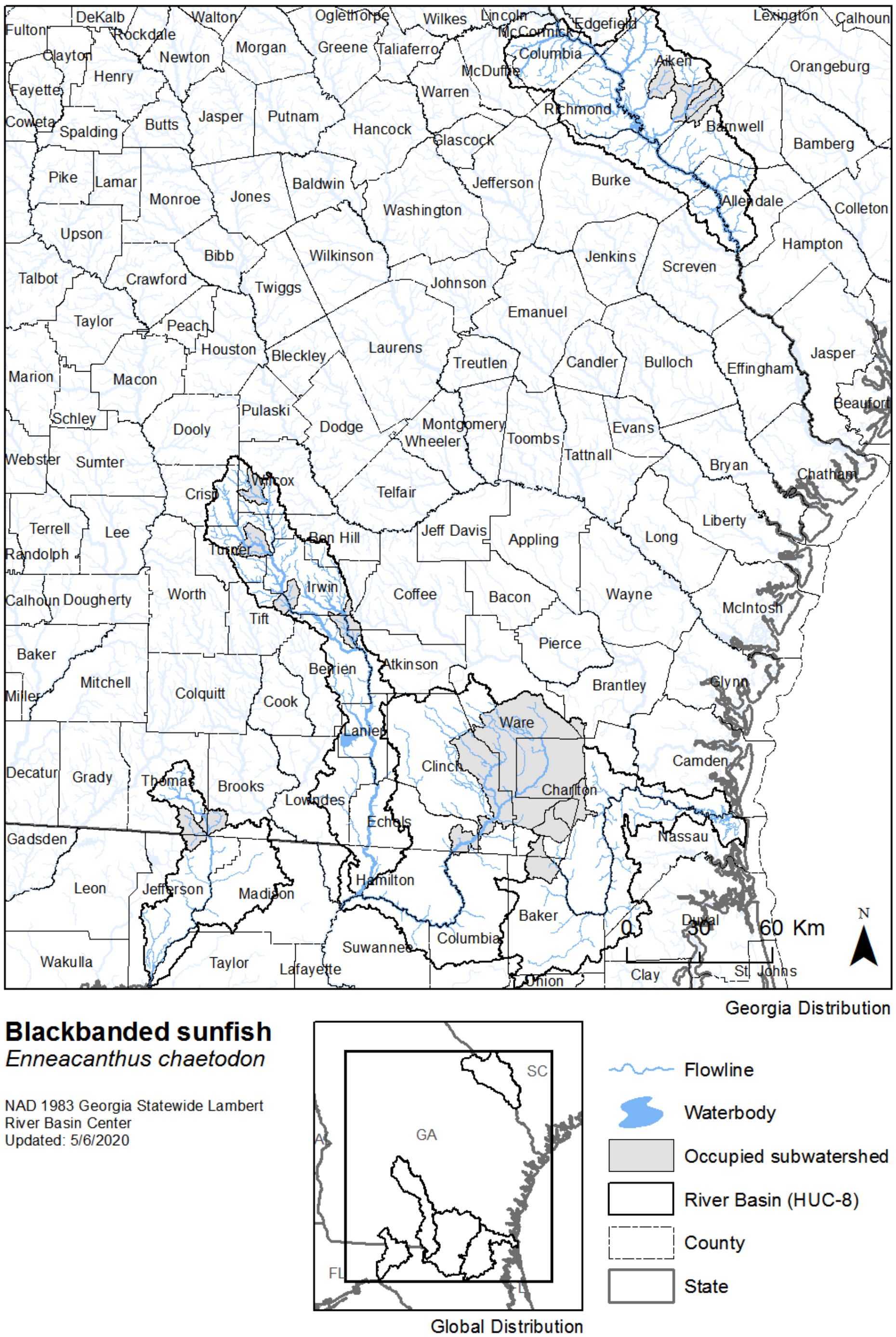
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the blackbanded sunfish tolerance to conductivity as intolerant; they also evaluated the conductivity tolerance of two closely related species (*E. gloriosus, E. obesus)* as moderate and intolerant, respectively.

While some eggs of blackbanded sunfish are laid on root masses, others are laid on sand/gravel and may come into direct contact with sediment-bound pollutants. Blackbanded sunfish may be exposed to pollutants through their diet on macroinvertebrates, although their prey are less likely to have direct contact with sediment-bound compounds because of their use of macrophytes as habitat.

The overall pollutant sensitivity of the blackbanded sunfish is categorized as somewhat intolerant (3).

Figure 30. Map. Range map of the blackbanded sunfish.



BLACKSIDE SNUBNOSE DARTER

Species

Blackside Snubnose Darter, *Etheostoma duryi*

(a.k.a. Black Darter)

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The blackside snubnose darter grows to a maximum length of 70 mm (2.8 in), with a blunt snout typical of the "snubnose darter" group. Eight to nine dark saddles cross the tan dorsum and about 9 dark blotches form a midlateral stripe; the fourth dorsal saddle is often the darkest and may extend ventrally to the midlateral stripe. The venter is pale yellow. A small orange spot occurs at the front of the first dorsal fin, and a black teardrop descends below the eye. Males are slightly larger than females. Breeding males have a green throat and chin, an orange breast and belly, and brick red pigmentation in the dorsal fins.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Spawning occurs from March to early May. The aggressive males may chase one another and follow females as they search for a site to attach their eggs. The accompanying male embraces the female in an S-shaped position to fertilize the eggs as the female lays them one by one on the surfaces of rocks. Sexual maturity is reached at age one and the maximum life span is likely three years.

The blackside snubnose darter inhabits small creeks and rivers, living in pools and slowly moving riffles with gravel, cobble, boulder or bedrock substrata.

Their diet consists of benthic aquatic insects.

Numbers, Reproduction, Distribution

This species' range extends across four states, Georgia, Tennessee, Mississippi, and Alabama, but it is only found in the Tennessee River system (Freeman et al. 1999). Within Georgia, it is only found in the Chickamauga Creek and Lookout Creek systems, having been collected there in the early 2000s (Freeman et al. 1999). The short-term population trend over the past ten years or three generations is unknown but thought to be relatively stable (NatureServe 2019).

Conservation

The blackside snubnose darter has a global conservation ranking status of G4, a Georgia state conservation ranking status of S1, 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. 1999): Conserving populations of the blackside snubnose darter depends on maintaining and improving habitat quality in small streams 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.

Effects of Construction Activities on the Blackside Snubnose Darter

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of the blackside snubnose darter as moderate. They also evaluated the tolerance of three closely related species, categorizing two as moderate (*E. flavum, E. ramseyi*) and one as intolerant (*E. coosae*). Sedimentation is considered a primary stressor to several closely related species (*E. brevirostrum, E. chermocki, E. tallapoosae*) in the subgenus (Hartup 2005; FWS 2019; Hubbell and Banford 2019). 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 *E. scotti*, decreased with increasing turbidity and bedded sediments.

As a benthic invertivore, the blackside snubnose darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that spawns on coarse substrate, blackside snubnose 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).
Primarily because of the sensitivity of its spawning habitat, the overall sediment sensitivity of the blackside snubnose darter is categorized as intolerant (11).

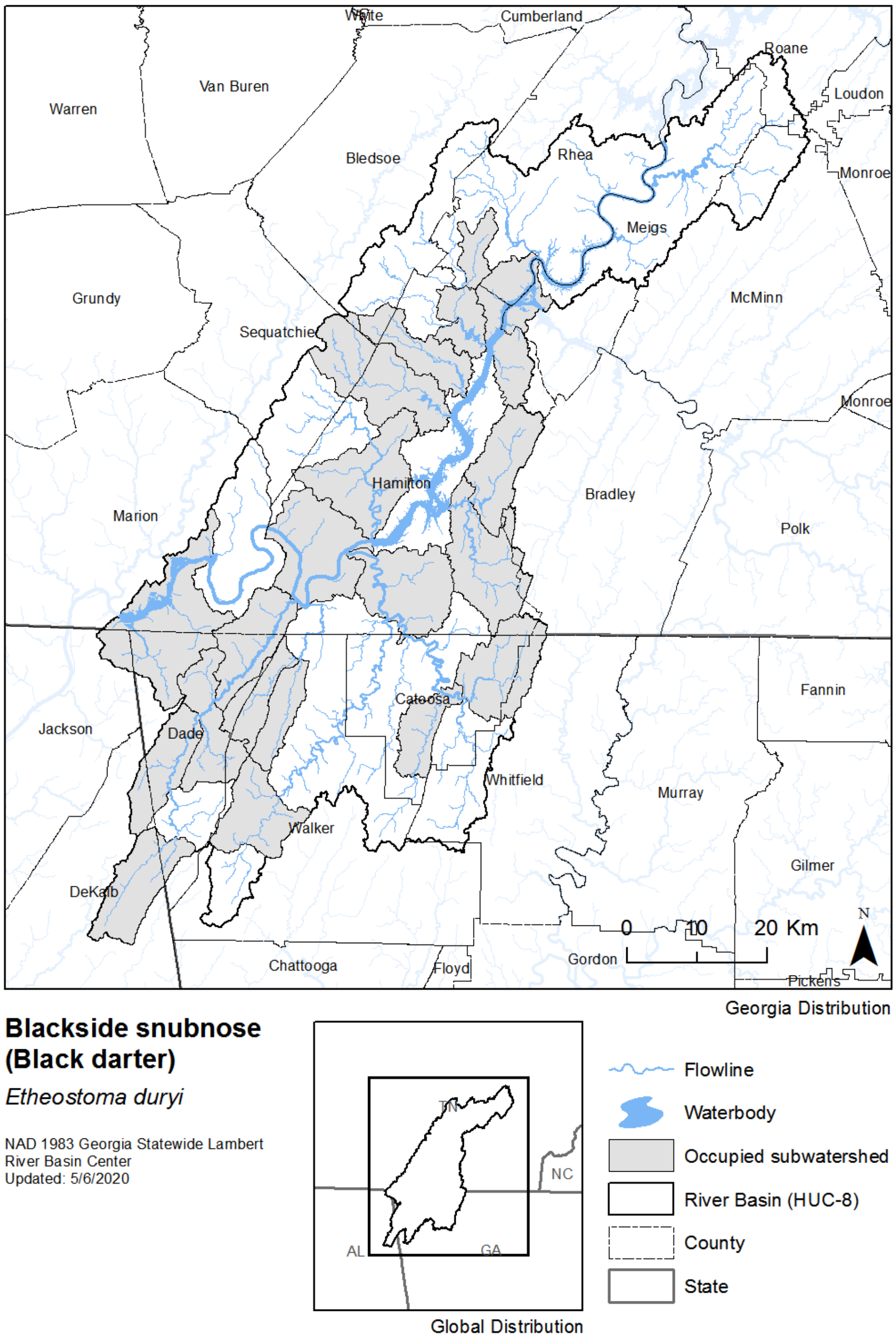
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of the blackside snubnose darter as moderate. They also evaluated the tolerance of several closely related species, categorizing all three as moderate (*E. coosae, E. flavum, E. ramseyi*). Stormwater pollutants are considered a primary stressor to several species (*E. brevirostrum, E. chermocki, E. scotti)* closely related to the blackside snubnose darter (Hartup 2005; Wenger and Freeman 2007; FWS 2019). Wenger and Freeman (2008) found that abundance of the closely related *E. scotti* decreased with increasing imperviousness; however, Wenger et al. (2008) found no relationship between imperviousness and *E. scotti* occurrence.

The blackside snubnose 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 lays its eggs on rocky substrate, those eggs are less likely to come into direct contact with sediment-bound pollutants during development.

Based on the classification by Meador and Carlisle as well as the mix of traits-based evidence, the overall pollutant sensitivity of the blackside snubnose darter is categorized as somewhat intolerant (3).

Figure 31. Map. Range map of the blackside snubnose darter.



BLOTCHED CHUB

Species

Blotched Chub, *Erimystax insignis*

Description

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

The blotched chub is a small silvery chub with a large upward-directed eye, a blunt nose overhanging an inferior mouth, and single large barbels located at each corner of the mouth. Blotched chubs are very distinctive in having 6-9 large rectangular-shaped blotches along the mid-side of the body. The maximum total length is 10 cm (4 in). The species epithet *insignis* means remarkable and is in reference to the prominent blotches.

Life History

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

The blotched chub lives in moderate-sized creeks and small upland rivers, usually in riffles and runs with coarse, rocky substrates (e.g., gravel, cobble, bedrock).

Their diet consists of large amounts of periphyton and aquatic insect larvae, especially fly larvae and mayfly larvae.

Most blotched chub reach sexual maturity at age 1. Spawning occurs when the water temperature approaches 15 °C (59 °F), usually in mid-April to May, sometimes lasting into early June when temperatures may reach 25 °C (77F). Spawning has been observed in relatively deep water (50-80 cm) over rocky substrates and involves rapid vibrations of the spawning pair. Young utilize slow-current shallow areas before moving into riffle and run habitats used by all other sizes. Males display nuptial tubercles. The life span is about 2.5 years.

For spawning, blotched chubs need open, benthic areas and clean coarse substrates like gravel (Harris 1986, McCormick et al. 2001).

Numbers, Reproduction, Distribution

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

The blotched chub occurs throughout the Tennessee and Cumberland river drainages in several southeastern states, but most of its range is in Tennessee. In Georgia, this species is known from the Toccoa, Nottely, and Hiwassee river systems in Fannin, Union, and Towns counties: most records are from the mainstem Toccoa and Nottely rivers and from Brasstown Creek. All of these streams are within the Blue Ridge physiographic province.

Within Georgia, 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 blotched chub was observed at 12 of these sites (41%), all of which were located upstream of Lake Blue Ridge. Since there is no historic data for comparison, this occupancy rate may serve as a baseline from which to evaluate future changes in population status. Despite extensive sampling, the last records of the blotched chub in the Nottely River system and Brasstown Creek were documented in the 1990s.

Subpopulations of blotched chub are common within Tennessee and Virginia. An estimate of the total adult population size of the blotched chub is not available, but is believed to exhibit relatively stable short-term trends in population (NatureServe 2020).

Conservation

The blotched chub currently has a global conservation ranking status of G4 and a Georgia state conservation ranking status of S2. They are 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 and Albanese 1999a):

The blotched chub depends on good water quality and fast-water habitats in upland streams. Impoundments have reduced available habitat for the blotched chub 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 blotched chub in the Toccoa, Nottley, and Hiwassee river systems. Finally, hemlock wooly adelgid is an additional threat to aquatic habitats in this region.

Conserving populations of the blotched chub will require maintaining and improving habitat quality in the Toccoa River and the other streams within the Hiwassee River system 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.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of the blotched chub as moderate. Brown et al. (1998) found the closely related *Erimystax dissimilis* to be almost expirpated (relative to reference sites) from two rivers affected by gravel mining where turbidity and sedimentation rates were significantly higher. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described *E. dissimilis* as "highly sensitive" to sedimentation.

As a species that requires clean coarse substrate for spawning, the blotched chub is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. Omnivorous species like the blotched chub are likely not sensitive because of their ability to adjust foraging habits in response to sedimentation presence or events.

Based on the limited information from Meador and Carlisle, the sediment sensitivity of the blotched chub is categorized as moderate (2).

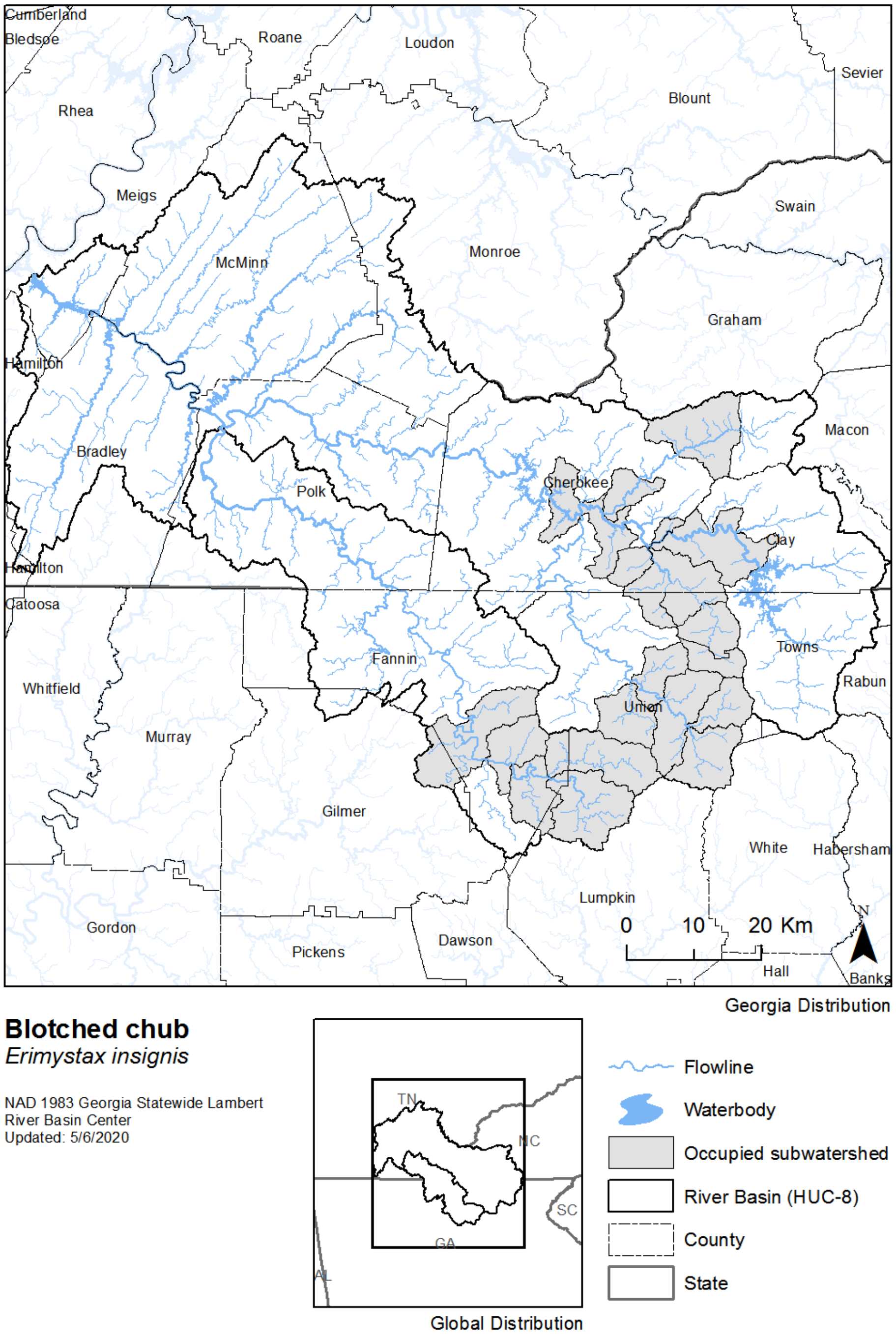
Pollutants

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 the genus *Erimystax*. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described *E. dissimilis* as “highly sensitive” to pollutants.

Because they spawn in coarse substrate, incubating embryos are unlikely to come into direct contact with pollutants associated with fine sediments. The periphyton portion of the blotched chub’s diet is unlikely to serve as a source of dietary exposure to pollutants; however, as an omnivore they are still susceptible to pollutants which biomagnify through their prey items such as aquatic insects and larvae.

Based on the limited evidence from Griffith et al., the pollutant sensitivity of the blotched chub is categorized as moderate (4).

Figure 32. Map. Range map of the blotched chub.



BLUEFIN KILLIFISH

Species

Bluefin Killifish, *Lucania goodei*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 2009): Bluefin killifish are small, reaching up to 50 mm total length (2 in), with a slender, compressed body and a terminal, upturned mouth. This species has a dusky brown to olive back marked with darkly edged scales. A wide black stripe extends from the tip of the nose to the black spot at the base of the caudal fin. Adult males have brightly colored dorsal, caudal, anal and pelvic fins. Several color patterns (i.e., morphs) have been described and the pattern exhibited depends upon genetics and lighting environment. The dorsal fin has basal and marginal bands of black pigment and at least some blue in between these bands. The remainder of the dorsal fin may be blue, red, or yellow. The anal fin also has basal and marginal bands of black pigment, but the remainder of the fin may be red, yellow, blue, orange, or a combination of colors. The pelvic fins and the base of the caudal fin may be red or yellow. Nuptial males may also develop golden yellow coloration on the abdomen. In contrast to males, females have clear fins and do not exhibit bright breeding coloration.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 2009):

The bluefin killifish may reach sexual maturity at an age of 2 months and at a size less than 20 mm standard length. Males aggressively defend territories associated with dense aquatic vegetation on which spawning occurs. Male courtship behavior includes circling the female, head flicking and fin spreading. Eggs may be deposited singly, with up to 20 being released in a day. Spawning is protracted and occurs over a period of weeks. There is no evidence of post-hatching parental care. The bluefin killifish has been reported to breed throughout the spring to summer in South Carolina, and possibly throughout the year in Florida. Life span is approximately 2 years. The bluefin killifish is strongly associated with aquatic vegetation in slowly flowing to non-flowing waters. They can occur in drainage ditches, ponds, sloughs, lakes, pools and backwaters of streams, springs, and spring runs. The bluefin killifish is also tolerant of brackish water. Their diet consists of plants and small invertebrates.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 2009): The bluefin killifish ranges from the Choctawhatchee River drainage in Florida (except panhandle) to north-central South Carolina and eastern North Carolina. A small population has been reported from extreme southeastern Alabama from the Chipola River system. Populations in South and North Carolina may be introduced, as they are close to large human population centers. The bluefin killifish has also been introduced into other areas clearly outside of its native range (e.g., Texas and California). In Georgia, this fish has been found in the lower Flint River system near Lake Seminole, ponds on Sapelo and Blackbeard Islands, and within a spring-run tributary to the Ogeechee River.

To the best of our knowledge, the Sapelo Island population is currently restricted to a small pond, which was sampled annually between 2006 and 2009. The bluefin killifish was detected every year, but qualitative abundance rankings have varied between rare and common. Other sites from Sapelo Island and Blackbeard Island are from the 1950s and the status of these populations is unknown. The Ogeechee River tributary population was discovered in Spring 2009. At the time of discovery, the bluefin killifish was extremely abundant and extended for several hundred meters along the spring run. The bluefin killifish is apparently very abundant in the lower Flint River system near Lake Seminole.

The total population size of the bluefin killifish is unknown but relatively large. The trend over the past ten years is uncertain but likely relatively stable or slowly declining (NatureServe 2019).

Conservation

The global conservation ranking status of the bluefin killifish is G5, a Georgia state conservation ranking status of S1, 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 (Freeman et al. 2009):

Threats to the bluefin killifish are habitat loss resulting from reduced water levels in small marshes and wetlands; flow reduction in tributaries and seasonally wetted channels (e.g., because of water withdrawal for irrigation); and vegetation removal from marshes, wetlands and stream margins. The bluefin killifish appears to be a hardy species. The two populations in the Carolinas are presumed to be introduced and have become well established. Additional surveys need to be conducted in extreme southern Georgia and Atlantic Coastal Plain streams to determine if other populations exist. Known populations should be routinely monitored. The development of habitat management plans that include maintenance of water level, water quality, and aquatic vegetation will ensure longevity for currently known populations of the bluefin killifish.

Effects of Construction Activities

Sediment

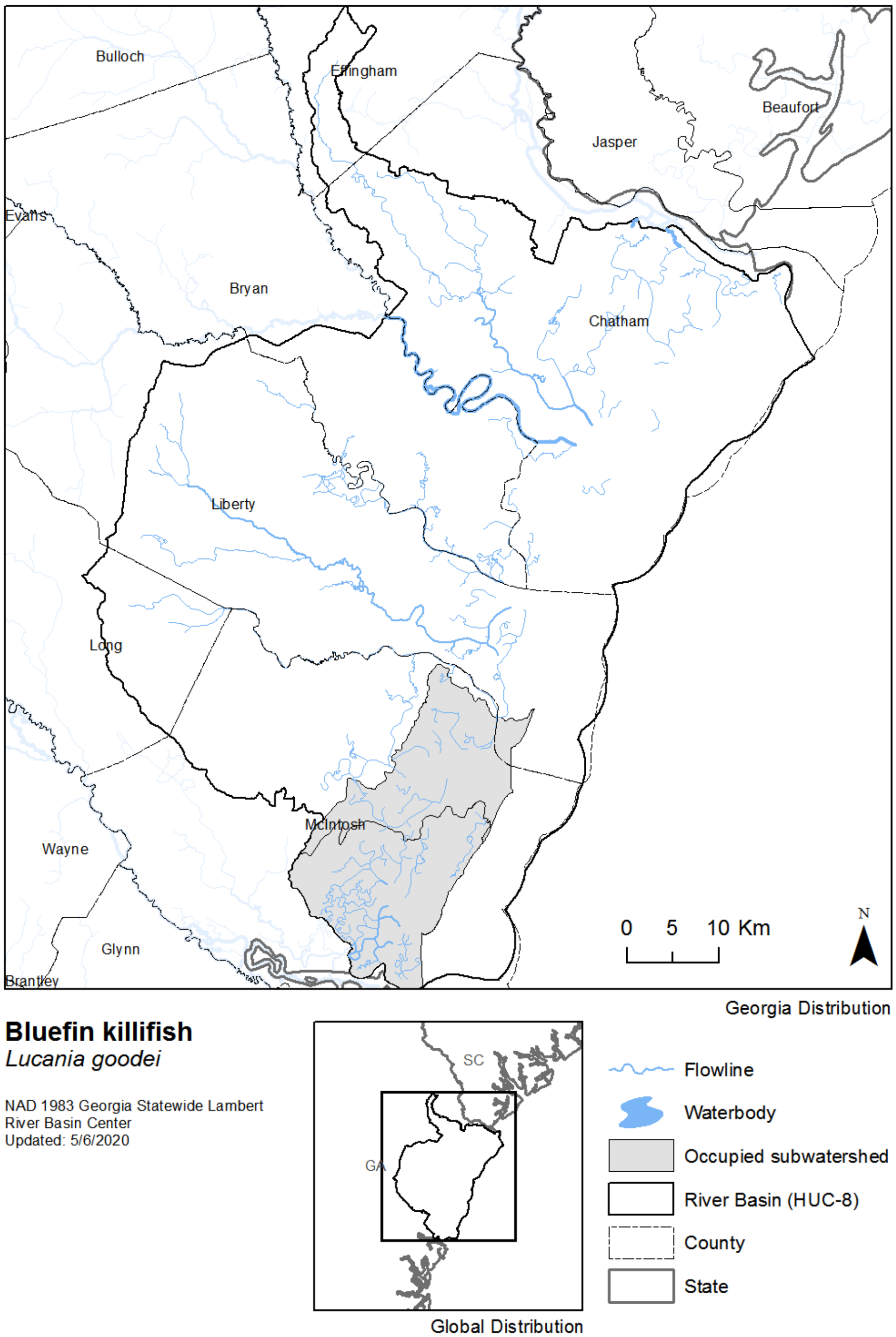
There are no studies directly investigating the effects of sediment on the bluefin killifish.
Since the bluefin killifish attach their eggs to macrophytes, they are likely less sensitive to sediment because eggs/embryos are elevated above where suspended sediments settle out. As an omnivorous species, it is likely not sensitive to sediments because of its ability to adjust foraging habits in response to sedimentation presence or events. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration

(Seehausen et al. 1997; Burkhead and Jelks 2001). With a prolonged spawning period, bluefin killifish reproduction may be more resilient to adverse effects from a single sedimentation event. Because of its overall "hardiness" (Freeman et al. 2009), its flexible habitat requirements, and lack of any species-level studies suggesting sediment sensitivity, the bluefin killifish sediment sensitivity is categorized as tolerant (3).

Pollutants

Three are no studies investigating the effects of construction- or roadway-derived pollutants on the bluefin killifish. Since the early life stages of the bluefin killifish are not associated with sediments, they are less sensitive to pollutants attached to sediments. The bluefin killifish is likely less sensitive to pollutants which bio-magnify through lower trophic levels since it is mostly feeds on plants and small invertebrates. However, because bluefin killifish are often found in areas with slow or no water current, the duration of any adverse effects of a pollution event may be prolonged by the lack of flushing. The pollutant sensitivity of the bluefin killifish is categorized as moderate (4).

Figure 33. Map. Range map of the bluefin killifish.



BLUE SHINER

Species

Blue Shiner, *Cyprinella caerulea*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Blue shiners grow to 10 cm (4 in) in length. Coloration is olive dorsally with silvery sides. A distinctive metallic blue-black lateral stripe runs from the gill covering to the caudal fin where it widens to form a spot at the base of the caudal fin. Scale edges above and below the lateral stripe are edged with melanophores to form a distinctive diamond shape. Mouth opens just below the snout tip and is slanted in profile. Breeding males develop intense yellow on all fins except the dorsal.

Life History

The substrate of occupied habitat often consists of mixtures of silt, sand, and gravel (USFWS 2014). Blue shiners feed at all levels of the water column, including the surface, and generally prefer shallow and slow waters (USFWS 2014). The diet of the blue shiner consists primarily of terrestrial insects but also includes aquatic insects, indicating that they are likely a visually oriented drift feeder (Etnier and Starnes 1993).

Like other members of the genus, blue shiners are sexually dimorphic, with breeding males developing tubercles and a blue body coloration with yellow fins (Etnier and Starnes 1993). The blue shiner is a crevice-spawning fish, which deposits its eggs in silt-free crevices in rocks or woody debris and engages in no parental care (Johnston Shute 1997). The extended spawning season of a blue shiner lasts from May to August (GADNR 2013).

Numbers, Reproduction, Distribution

The blue shiner is endemic to the Mobile River drainage in Alabama, Georgia, and southeastern Tennessee. Within Georgia, the blue shiner has been reported in the Conasauga River, the Jacks River, and several creeks: Holly, Rock, Jobs, and Minnewauga (USFWS 2014). It is considered extirpated in the Oostanaula and Coosawatee River systems (USFWS 2014).

An estimate of the total adult population size is unavailable. The species was reported to be in decline during the 1990's (Etnier and Starnes 1993), but Freeman et al. (2007) found little evidence of decline in surveys conducted in the Conasauga mainstem from 1996 to 2006. The trend over the past ten years is uncertain, but is thought to be in decline (NatureServe 2020).

Conservation

Blue shiners have a global conservation ranking status of G2, a Georgia state conservation ranking status of S2, and a national conservation ranking status of N2. They are federally listed as threatened under the ESA. This species is protected as Endangered in the state of Georgia.

Throughout its range, the blue shiner is subject to an array of anthropogenic stressors. Range-wide threats include: geographic and genetic fragmentation by impoundments and obstacles, generally small populations, natural hydrology impaired by water withdrawals and shifting flow regimes, altered channel morphology, acute pollution events, chronic pollution inputs from agriculture (nutrients, herbicides, pesticides) and urbanization (metals, hydrocarbons), and degradation of habitat by elevated sedimentation and turbidity (USFWS 2014). Within Georgia, specific threats include increasing urbanization of areas around Dalton and nearby cities, sediments eroded from agricultural and timber lands, and pollutants released by industrial/commercial activities (e.g. perfluorocarbons and chlorine). An additional biological threat in Georgia is potential hybridization with the introduced red shiner, which has been documented in laboratory studies (Walters et al. 2008, USFWS 2014). Actions aimed at conserving blue shiner include: expanded population surveys/monitoring, continued partnering with stakeholders and government agencies to develop management plans and employ best management practices, and protection/restoration of habitat.

Effects of construction activities

Sediment

Elevated sedimentation and/or turbidity is cited as a cause of loss/degradation of habitat for the blue shiner, *C. caerulea*, in the most recent 5-year review by the U.S. Fish and Wildlife Service (USFWS 2014). Specifically, the absence or low abundance of some Georgia populations in Holly Creek and Rock Creek were linked to sedimentation/turbidity (USFWS 2014).

Research into the effects of sediment on the related *C. galactura* found that elevated suspended sediment resulted in reduced spawning effort, reduced spawning output, and delayed spawning (Sutherland 2007). Other research found that suspended sediment caused gill damage, stress, and reduced growth of *C. galactura* (Sutherland 2003; Sutherland and Meyer 2007; Sutherland et al. 2008). Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species, including the related *C. trichroistia*, decreased with increasing turbidity and bedded sediments. Burkhead and Jelks (2001) observed that exposure of *C. trichroistia* to suspended and bedded sediments resulted in delayed spawning, reduced the number of spawns, and reduced the number of eggs laid per clutch.

As a crevice-spawner, the reproduction of the blue shiner is sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. As a drift-feeding insectivore, the blue shiner is likely to be indirectly and adversely affected by sediment effects on its prey base; however, this may be somewhat mediated by the lesser proportion of its diet consisting of aquatic insects. Additionally, sexually dimorphic species, like the blue shiner, rely on visual cues to induce spawning, which may be impaired by elevated turbidity.

Because of the sensitivity of its spawning habitat and sensitivity of related species, the sediment sensitivity of the blue shiner is categorized as intolerant (11).

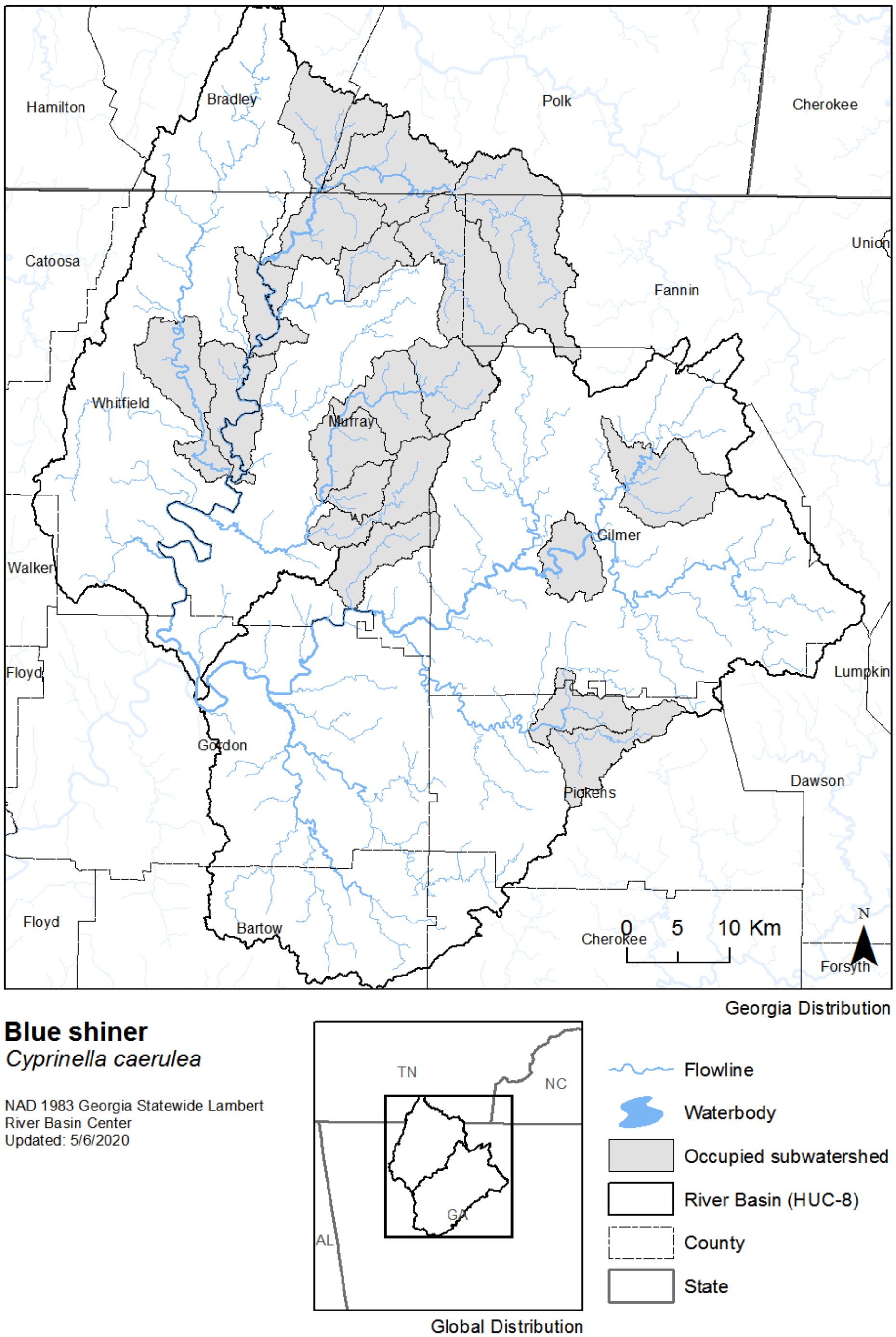
Pollutants

Stormwater pollutants were cited as a cause of degradation of habitat for the blue shiner in the most recent 5-year review by the U.S. Fish and Wildlife Service (USFWS 2014). One unpublished finding, documented an acute sensitivity of blue shiner to chlorine and copper (USFWS 2014). By quantifying changes in relative abundance over time, Onorato et al. (2000) categorized the related *C. trichroistia* as sensitive to the effects of urbanization, but also categorized the similar sympatric *C. venusta* as tolerant. The blue shiner itself has been extirpated from the upper Cahaba over a time period associated with urbanization of the watershed (Onorato et al. 2000).

As a probable crevice-spawner, the eggs/embryos of the blue shiner are not likely to come into direct contact with sediment-bound pollutants. Because the blue shiner is a drift-feeding insectivore, it likely carries a lower body burden of pollutants since its prey are at a lower trophic level and generally do not come in direct contact with sediment-bound pollutants.

Based on the sensitivity characterization and the reported extirpation reported by Onorato et al., the pollutant sensitivity of the blue shiner is categorized as very intolerant (2).

Figure 34. Map. Range map of the blue shiner.



BLUEBARRED PYGMY SUNFISH

Species

Bluebarred Pygmy Sunfish, *Elassoma okatie*

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese and Owers 2008): Like other pygmy sunfishes, the bluebarred pygmy sunfish is a small, laterally compressed species with a rounded caudal fin and single broad dorsal fin containing both spines and rays. It does not does exceed 30 mm standard length (1¼ inches). It has a small, surface-directed mouth and the top of its head is not scaled. It sides are typically marked with 8-14 (usually 10-12) dark vertical bars that are about 3 times wider than the lighter spaces between each bar. Breeding males are brilliantly colored with blue-green fins and blue-green flecks of pigment scattered over their dark black bodies. Females are light brown in color, but may be sparsely marked with yellow, green, or blue flecks of pigment on their bodies and fins.

Life History

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

Very little is known about the biology of this species, but generalized information is available for other pygmy sunfishes. Pygmy sunfishes are spring spawners. Males guard breeding territories around submerged aquatic plants and defend them from competing males and non-receptive females using threat displays. Males also display a “wiggle-waggle” dance toward receptive females that includes repeated lowering, erection and undulation of fins, swimming up and down in the water-column, and darkening of body coloration. Adhesive eggs are deposited on plant stems and a single female can spawn several times with one or several males. Males of some species guard the eggs and larvae for several days after hatching. Growth is rapid and both sexes typically reach sexual maturity within their first year. Lifespan is short and most fish do not reach age 2.

Bluebarred pygmy sunfishes are known from slow-moving to stagnant, heavily vegetated areas within ditches, impoundments, creeks, and rivers. They are strongly associated with aquatic plants, including alligator weed, bladderwort, duckweed, grasses, pondweed, rushes, and spatterdock. Waters are typically tea-stained and acidic.

No diet studies have been completed for the bluebarred pygmy sunfish. However, the Carolina pygmy sunfish (*Elassoma boehlkei*), a closely related species, is an opportunistic carnivore that feeds on a variety of small crustaceans (such as copepods and cladocerns) and aquatic insects (such as dipterans).

Numbers, Reproduction, Distribution

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

The bluebarred pygmy sunfish is known from several distinct subpopulations. It is known from the Edisto, New, and Savannah River drainages of South Carolina and Georgia. Within Georgia, it is only known from a few streams on the Fort Gordon military installation (Savannah River drainage). All Georgia records are within the upper Coastal Plain. Additional sampling in the upper Coastal Plain of the Savannah drainage is needed to better define the range of this species in Georgia.

Conservation

The bluebarred pygmy sunfish has a global conservation ranking status of G2/G3, a Georgia state conservation ranking of S1, and 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 (Albanese and Owers 2008):

Small range size is the most severe threat to the continued existence of the bluebarred pygmy sunfish in Georgia. For example, a severe drought or a chemical spill could quickly wipe out one or more of the few populations in the state. Nutrient runoff associated with fertilizer application or livestock waste may lead to algal blooms that negatively impact the fine-leaved aquatic plants utilized by this species. Efforts to remove aquatic plants using herbicides or manual removal should be avoided when this species is present.

Fort Gordon has developed a management plan for the bluebarred pygmy sunfish and two other rare fishes that occur on base. The plan recommends the protection of existing populations by minimizing military traffic near streams and wetlands and managing for natural forest cover in occupied watersheds. Additional survey efforts are needed outside of the boundary of Fort Gordon in effort to identify and protect additional populations in Georgia.

Effects of Construction Activities

Sediment

There are no studies directly investigating the effects of sediment on the bluebarred pygmy sunfish, but data on related species will inform these sensitivity estimates. Meador and Carlisle (2007; Meador unpublished data 2020) classified the sediment tolerance of congeners *E. evergladei* and *E. zonatum* as intolerant and moderate, respectively. Using expert opinion, Jester (1992) classified the congener *E. zonatum* as intolerant to degradation of habitat (as opposed to water quality).

As a sight-feeding invertivore, the bluebarred pygmy sunfish may be adversely affected by sediment-associated turbidity and a reduction in visual acuity that may reduce its foraging efficiency. However, because the bluebarred pygmy sunfish is often found in acidic tea-stained waters, it may be adapted to an environment with lower visibility and therefore less sensitive to elevation of turbidity. As a species that attaches its eggs to aquatic plants, the bluebarred pygmy sunfish is likely less sensitive to sediments because its eggs/embryos are elevated above where suspended and bedded sediments settle out. Because the bluebarred pygmy sunfish is most often found in areas with slow or no water current, the duration of any adverse effects of a sedimentation event may be prolonged by the lack of sediment flushing.

Based on the mix of traits-based evidence, the bluebarred pygmy sunfish sediment sensitivity is categorized as moderate (2).

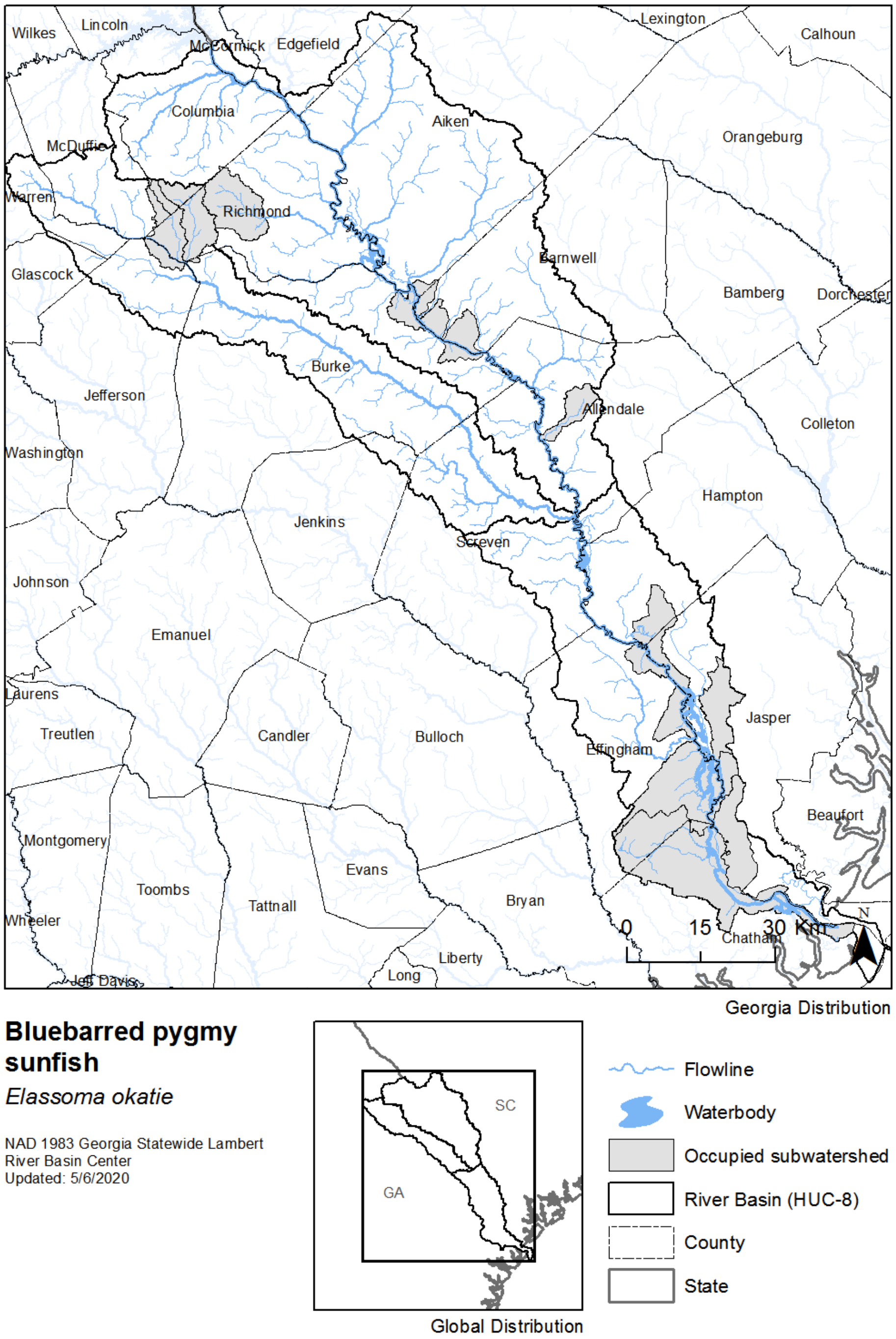
Pollutants

There are no studies investigating the effects of construction- or roadway-derived pollutants on the bluebarred pygmy sunfish, but some evidence are available relating to its few congeners. Using expert opinion, Jester (1992) classified the congener *E. zonatum* as intolerant to degradation of water quality (as opposed to habitat). Three congeners (*E. okefenokee, E. zonatum, E. evergladei*) did not show significant differences in their relative abundance in a study investigating the effects of kraft mill effluents on a fish assemblage (Greenfield and Bart 2005).

Because the bluebarred pygmy sunfish spawns by attaching its eggs to submerged vegetation, its early life stages are unlikely to come into direct contact with sediment-associated pollutants. Being an opportunistic invertivore, it may be exposed to pollutants which biomagnify through lower trophic levels.

Based on the mix of limited information on related species, the bluebarred pygmy sunfish pollutant sensitivity is categorized as moderate (4).

Figure 35. Map. Range map of the bluebarred pygmy sunfish.



BLUENOSE SHINER

Species

Bluenose Shiner, *Pteronotropis welaka*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The bluenose shiner is a slender minnow with a compressed body, a pointed snout and a terminal to subterminal mouth. Adults reach 53 mm (2.1 in) standard length. The first ray of the dorsal fin (i.e., the origin) is distinctly posterior to the first ray of the pelvic fin. There are 3-13 pored scales on the lateral line, 8-9 anal fin rays, and a typical pharyngeal tooth count formula of 1-4-4-1 (occasionally 0-4-4-0). A wide, dark lateral stripe runs along the length of the body between the snout and the caudal spot and is often flecked with silvery scales in both males and females. A thin, light-yellow stripe runs just above the black lateral stripe. The oblong caudal spot extends onto the median rays of the caudal fin and is bordered above and below by de-pigmented areas. The dorsum is dusky olive-brown and the venter is pale. This species exhibits striking sexual dimorphism, which includes a bright blue snout and greatly enlarged dorsal, pelvic, and anal fins on breeding males. The dorsal fin becomes black with a pale band near its base and the anal and pelvic fins turn white to golden yellow with contrasting black pigment within the middle of each fin. These characteristics develop gradually with age and many males will exhibit only partial development of nuptial male morphology and color patterns (e.g., a blue snout, but not greatly enlarged fins). Some sources report that females also develop some blue on their snout, but other studies have reported that they do not.

Life History

Based on sampling and gonadal analyses in Mississippi, bluenose shiners have protracted spawning periods from May to August that can feature multiple spawning bouts (Johnston and Knight 1999). This species is a sunfish nest associate, aggregating over and laying eggs within the nests, where larval fish have also been observed (Johnston and Knight 1999). The species was thought to have a relatively short lifespan (1-2 years) based on length-frequency data from this same Mississippi study, but data from other populations indicate that the species may live up to 3 years (Freeman et al. 1999). Diet is not well known: one study documented the presence of large amounts of filamentous algae in the gut contents of several individual, but this was not a comprehensive analysis (Freeman et al. 1999).

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

Bluenose shiners are primarily found in small to medium-size streams, inhabiting pools with slow current and moderate to deep water. They are strongly associated with aquatic vegetation, including bur-reed (*Sparganium*), arrowhead (*Sagittaria*), and bladderwort (*Utricularia*). A 2004-2005 survey in Georgia captured bluenose shiners in sites with relatively high conductivity and in sites that were within or near the largest stream in the watershed. Their occurrence in relatively large streams in Georgia contrasts with their distribution in Mississippi, where the species is usually collected in small, headwater streams.

Number, Reproduction, Distribution

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

The bluenose shiner occurs below the Fall Line in the Apalachicola River drainage and westward to the Pearl River drainage in Mississippi and Louisiana. A disjunct population is also known from the St. Johns River drainage in Florida. In Georgia, the bluenose shiner is known from tributaries to the Flint River system in southwest Georgia.

A targeted survey for the bluenose shiner was carried out in the Flint River system during 2004-2005. Thirty-nine sites were sampled, including all five historical sites and additional randomly-selected sites throughout historical watersheds. The bluenose shiner was detected at 5 of 39 sites (13%). Additional non-random sampling downstream of occupied sites and examination of museum specimens resulted in additional occurrences in the mainstem of Spring Creek and an Ichawaynochaway Creek tributary. Overall, the species was documented from nine-sites in the early to mid-2000s. These sites are clustered in the Spring Creek, Ichawaynochaway Creek, and Pennahatchee Creek systems.

An estimate of the total adult population size of the bluenose shiner is unavailable. The probability of detecting this species during surveys is low, so there may be undocumented populations within its range. The population trend over the past ten years is uncertain but distribution and abundance are probably slowly declining (NatureServe 2020).

Conservation

The global conservation ranking status of the bluenose shiner is G3/G4 and the Georgia state conservation ranking status is S1. It is currently under no federal protections (Freeman et al. 1999). This species is protected as Threatened in the state of Georgia.

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

Small range size and the isolated nature of each population make the bluenose shiner vulnerable to extirpation from Georgia. Specific threats include sedimentation and nutrient run-off from agricultural areas. Excessive water withdrawal is also a significant threat to stream habitat quality in southwest Georgia, particularly during extreme drought periods.

Conserving populations of the bluenose shiner depends on protecting habitat quality in Coastal Plain streams that may frequently be overlooked as important habitats for rare aquatic species. Special care must be taken to protect streams from unnecessary runoff, contamination by pesticides or fertilizers, and streambank disturbance. These streams must also be protected from excessive water withdrawals (for irrigation, for example) that diminish streamflow, especially during dry periods.

Effects of Construction Activities

Sediment

No lab or field studies investigating the sediment sensitivity of the bluenose shiner were found, but some work has been done on closely related species. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of *Notropis cummingsae* and *N. harperi* (now recognized as part of the *Pteronotropis* clade) (Schönhuth et al. 2018), finding them to be intolerant and moderate, respectively.

Because bluenose shiners occupy habitats below the fall line, dominated by sandy substrates, this species may be less sensitive to inputs of sediment. However, because their habitat is generally low-velocity, any adverse effects resulting from an elevation of fine sediment would be prolonged by a lack of sediment flushing by the current. While the diet of bluenose shiners is not well studied, some evidence suggests that it is herbivorous, relying on filamentous algae (Boschung and Mayden, 2004). However, the diets of other Pteronotropis shiners are diverse and several taxa appear to be fairly omnivorous (e.g. *P. hubbsi, Notropis harperi*; Fletcher and Burr 1992, Davis 2017). Omnivory in the diet of the bluenose shiner might mitigate against risks to any specific food resources posed by excess sediment. Because the bluenose shiner is a nest associate of sunfishes which construct and then maintain their nests free of fine sediment by fanning, its developing embryos are likely not sensitive to either the presence or subsequent input of sediment. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking coloration (Seehausen et al. 1997; Burkhead and Jelks 2001).

Based on the low sensitivity of its spawning mode and habitat, the overall sediment sensitivity of the bluenose shiner is categorized as tolerant (3).

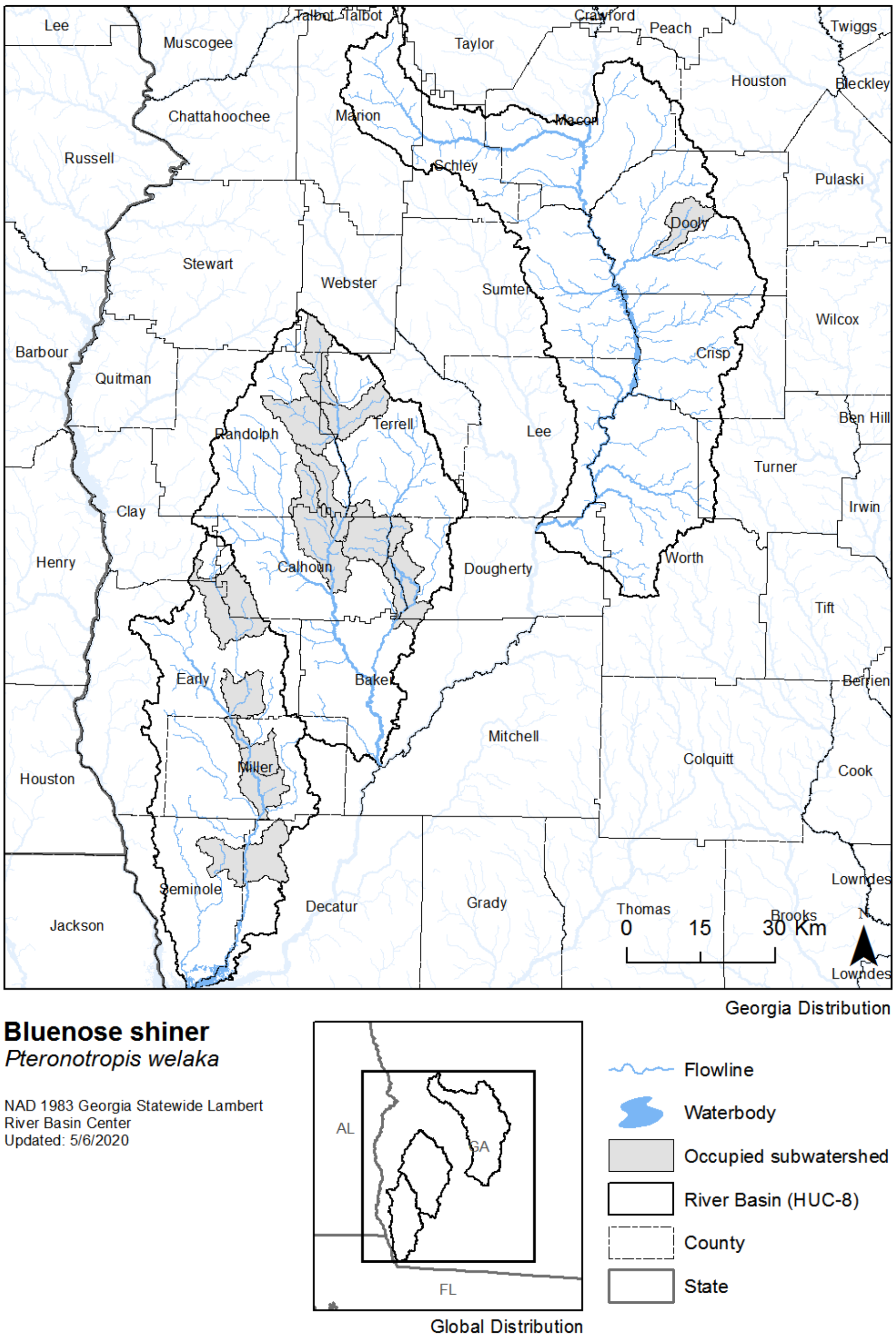
Pollutants

No lab or field studies investigating the pollutant sensitivity of the bluenose shiner were found, but some work has been done on closely related species. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of *Notropis cummingsae* and *N. harperi* (now recognized as part of the Pteronotropis clade), finding them to be intolerant and moderate, respectively.

Because the bluenose shiner likely feeds at a low trophic level (filamentous algae), its dietary exposure to pollutants is likely relatively low. As a species that lays its eggs directly on sandy substrate, early life stages of bluenose shiner are exposed to sediment-bound pollutants.

Based on the mixed and limited information, the overall pollutant sensitivity of the bluenose shiner is categorized as somewhat intolerant (3).

Figure 36. Map. Range map of the bluenose shiner.



BLUESTRIPE SHINER

Species

Bluestripe Shiner, *Cyprinella callitaenia*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The average adult bluestripe shiner has a total body length up to 90 mm (3.5 in). The head is long and rounded, and the snout projects slightly over its subterminal mouth. There are 7-8 anal fin rays and a pharyngeal tooth count formula of 1-4-4-1. Coloration consists of a dusky olive shading on the back and silvery sides with diamond-shaped scale outlines. A blue-black lateral stripe runs from the gill covering to the base of the caudal fin, where it widens to form a dark spot. There is also a crescent-shaped black line that runs from the eye to the mouth. Breeding males develop white on the paired fins, anal fins and on the tips of the caudal fin, and an intense salmon color immediately above the lateral stripe.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Bluestripe shiners inhabit mainstem reaches of rivers and large streams in riffles and runs with rubble or sand substrate and are most often collected in areas with swift current velocities. It has also been found in the lower reaches of several small impounded tributaries to the Chattahoochee River, where the backwaters of the reservoir apparently mimic large stream habitat.

Its diet probably consists of aquatic insects or terrestrial insects captured from stream drift. The bluestripe shiner has an extended reproductive period, and spawns over rock crevices, as is typical of the genus, from April until August. A study of a population in a tributary to the Chattahoochee River documented spawning pairs depositing gametes into crevices in bedrock or between the edges of large rocks and underlying bedrock, in areas with moderate to swift current. Females have the ability to propel eggs a considerable distance relative to their body length, thus making it possible to place eggs in predation-resistant sites.

Numbers, Reproduction, Distribution

An estimate of the total adult population size of bluestripe shiners is unavailable. Their recent population trend in Georgia is unknown but probably slowly declining (Natureserve 2020).

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Bluestripe shiners are endemic to the Apalachicola River drainage, occurring in the mainstem Apalachicola, Chattahoochee and Flint rivers, and major tributaries. In the middle section of the Chattahoochee River (Georgia/Alabama border), it can be found in several small, western tributaries whose lower reaches have been inundated by mainstem reservoirs. In

Georgia, this species has been collected from the Chattahoochee and Flint river systems, from the Coastal Plain to the upland districts of the Piedmont physiographic province.

Much of its historic habitat in the Chattahoochee River has been lost due to impoundments, which have inundated long reaches of the main channel and the lower reaches of numerous tributaries. Still, the species has been able to persist in the Chattahoochee River in some reservoirs (e.g., Walter F. George), and in the lower reaches of some inundated tributaries. There are also a few recent records in the Chattahoochee and Chestatee Rivers, upstream of Atlanta. The species is still relatively common in much of the main channel Flint River, where it often is the numerically dominant species.

Conservation

Bluestripe shiners have a global conservations status ranking of G2/G3 and a Georgia state conservation ranking of S2. Bluestripe shiners were petitioned for federal listing in 2010 and withdrawn from consideration in August 2016. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Potential threats to the bluestripe shiner are degradation and impoundment of streams in the main channel of the Chattahoochee and Flint river systems. The range in Georgia is spotty, with most known populations occurring in the Flint as opposed to the Chattahoochee system. Recent fish collection efforts in the Chattahoochee River system in the Atlanta area documented the absence of the bluestripe shiner from these streams. 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 threaten the bluestripe shiner where populations still exist. Fishes like the bluestripe shiner depend upon small crevices within which to lay their eggs and are therefore especially vulnerable to impacts associated with excessive sedimentation. The filling of these spawning sites with silt and sediment prevents successful spawning.

Conserving populations of the bluestripe shiner depends on maintaining and restoring habitat and water quality in streams of the Chattahoochee and Flint River systems. It is essential to eliminate sediment runoff from land disturbance activities such as road and house construction; maintain forested buffers along stream banks; eliminate the input 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 stormwater runoff, which scours stream channels and lowers baseflow. For these reasons, containing and slowly releasing stormwater runoff from developed areas is an important element in protecting stream habitats for not only the bluestripe shiner but other aquatic organisms. Impounding streams should be a last resort for developing water supplies.

Effects of Construction Activities

Sediment

No lab or field studies investigating the effects of sediment on the bluestripe shiner were found, but some work has examined the effects on its congeners. The absence or low abundance of some Georgia populations of the closely related blue shiner, *C. caerulea*, were linked to sedimentation/turbidity in Holly Creek and Rock Creek (USFWS 2014). Research into the effects of sediment on *C. galactura* found that elevated suspended sediment resulted in reduced spawning effort, reduced spawning output, and delayed spawning (Sutherland 2007). Other research found that suspended sediment caused gill damage, stress, and reduced growth of *C. galactura* (Sutherland 2003; Sutherland and Meyer 2007; Sutherland et al. 2008). Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species, including *C. trichroistia*, decreased with increasing turbidity and bedded sediments. Burkhead and Jelks (2001) observed that exposure of *C. trichroistia* to suspended and bedded sediments resulted in delayed spawning, reduced the number of spawns, and reduced the number of eggs laid per clutch.

As a probable crevice-spawner, the reproduction of the bluestripe shiner is sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. While its feeding habits have not been documented, the bluestripe shiner is likely to be a drift-feeding insectivore and may therefore be indirectly and adversely affected by sediment effects on its prey base. Additionally, sexually dimorphic species, like the blue stripe shiner, rely on visual cues to induce spawning, which may be impaired by elevated turbidity.

Based on the sensitivity of its spawning habitat, the sediment sensitivity of the bluestripe shiner is categorized as intolerant (11).

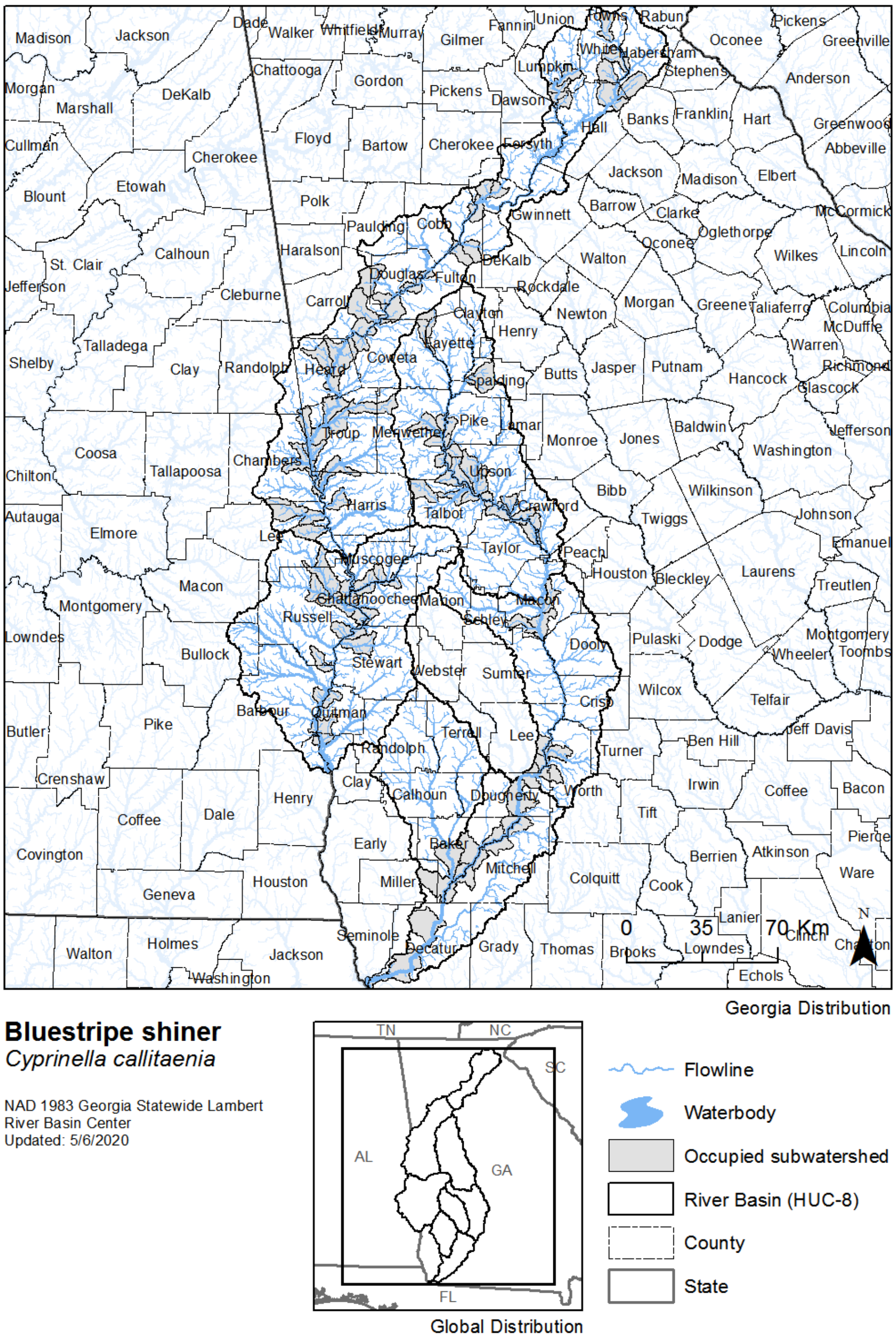
Pollutants

There are no studies describing the effects of construction- or roadway-derived pollutants on the bluestripe shiner, but some work has investigated its congeners. In an analysis of fish assemblages from urban and reference sites, Kemp (2014) found *C. analostana* to be primarily associated with urban sites. In contrast, *C. caerulea* was extirpated from the upper Cahaba River over a time period associated with urbanization of the watershed (Oronato et al. 2000). By quantifying changes in relative abundance over time, Oronato et al. (2000) categorized *C. callistia* and *C. trichroistia* as sensitive to the effects of urbanization, but also categorized the similar sympatric *C. venusta* as tolerant.

As a crevice-spawner, the eggs/embryos of the bluestripe shiner are not likely to come into direct contact with sediment-bound pollutants. If the bluestripe shiner is shown to be a drift-feeding insectivore, it likely carries a lower body burden of pollutants since its prey are at a lower trophic level and generally do not come in direct contact with sediment-bound pollutants.

Based on the mixed and limited evidence on its congeners, the pollutant sensitivity of the bluestripe shiner is categorized as somewhat intolerant (3).

Figure 37. Map. Range map of the bluestripe shiner.



BRIDLED DARTER

Species

Bridled Darter, *Percina kusha*

Description

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

The bridled darter is a small, slender darter that reaches about 75 mm total length (3 inches). The sides are marked with 8-11 oval blotches that are fused into a continuous dark-brown to black lateral stripe. The stripe has undulating margins and terminates as a square-shaped spot that extends onto the base of the caudal fin rays. The dorsum is light brown and the belly is white or cream-colored. The sub-orbital bar is absent or weakly developed. Nuptial males have a dark basal band, an unpigmented medial band and a thin, dark marginal band in the first dorsal fin.

Life History

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

The bridled darter inhabits small, clear rivers and the lower reaches of tributary streams. It is mostly found in flowing pools or runs and has been observed in association with a variety of substrates and cover types, including sand, gravel, cobble, bedrock, woody debris, aquatic plants, and detritus. Occupied streams generally have very good water quality. Annual, seasonal, and diurnal shifts in habitat use have been documented for the population in the Conasauga River population.

Specimens from the Conasauga River have been observed picking immature aquatic insects from the drift and the stream bottom; gut content studies from the same population indicate consumption of blackfly larvae and mayfly nymphs. The closely related muscadine darter (*P. smithvanizi*) is also known to feed on immature aquatic insects, such as blackflies, mayflies, and caddisflies.

Spawning has been observed in the Conasauga River during May and June in water temperatures ranging from 16-22 ºC (61-72 ºF). A male pairs with a single female during courtship and will attempt to chase away other males trying to intrude during the spawning act. Courtship behavior has been observed in sandy areas, where the eggs are probably buried. The collection of gravid females from the Conasauga River system suggests relatively low fecundity (mean = 75 ova). Length frequency data suggest a lifespan of about 3 years.

Number, Reproduction, Distribution

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

The bridled darter is endemic to the Coosa River system in Georgia and Tennessee, but nearly all of its range occurs within Georgia. Populations occur in three main areas: the upper Conasauga River and tributaries; Talking Rock Creek (Coosawattee River system) and the upper Etowah River and tributaries (e.g., Amicalola Creek, Cochran Creek, Long Swamp Creek, Shoal Creek).

This species has very small populations and very limited range within each of the three areas (Etowah River, Conasauga River, and Talking Rock Creek). In their description of this species, Williams et al. (2007) considered the bridled darter to be an endangered species. Public lands in the headwaters of the Etowah and Conasauga river systems provide partial but not complete protection for these two populations.

Williams et al. (2007) concluded that the species appears to naturally occur in low abundances. They are considered to be relatively stable based on both short- and long-term trends (NatureServe 2020).

Conservation

The global conservation ranking status of the bridled darter is G2, a Georgia state conservation ranking status of S1, and they are 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 (Albanese 2008d): Limited geographic range and the species' restriction to clear flowing pools in medium-sized rivers make the bridled darter vulnerable to habitat degradation. Land disturbance associated with residential and urban development in the north Georgia mountains could threaten populations, especially in the upper reaches of the Etowah River and Long Swamp Creek where development is imminent. Failure to follow agricultural best-management practices is a threat to the Conasauga River population.

Conserving populations of the bridled darter will require general watershed-level conservation and restoration practices. Implementation of the Etowah Habitat Conservation Plan should decrease the risk of extirpation associated with the high development pressures in this system. Continued incentives to help farmers implement best-management practices could improve instream habitat in the Conasauga River system by decreasing sediment, nutrient, and chemical runoff and increasing riparian forest cover.

Effects of Construction Activities

Sediment

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified sedimentation as a primary stressor to the bridled darter and other imperiled species of the Etowah River. Walters et al. (2003) found that relative richness and relative abundance of the bridled darter and the closely related *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 (*P. nigrofasciata, P. sciera*), categorizing both as moderate.

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

Therefore, the overall sediment sensitivity of the bridled darter is categorized as intolerant (1).

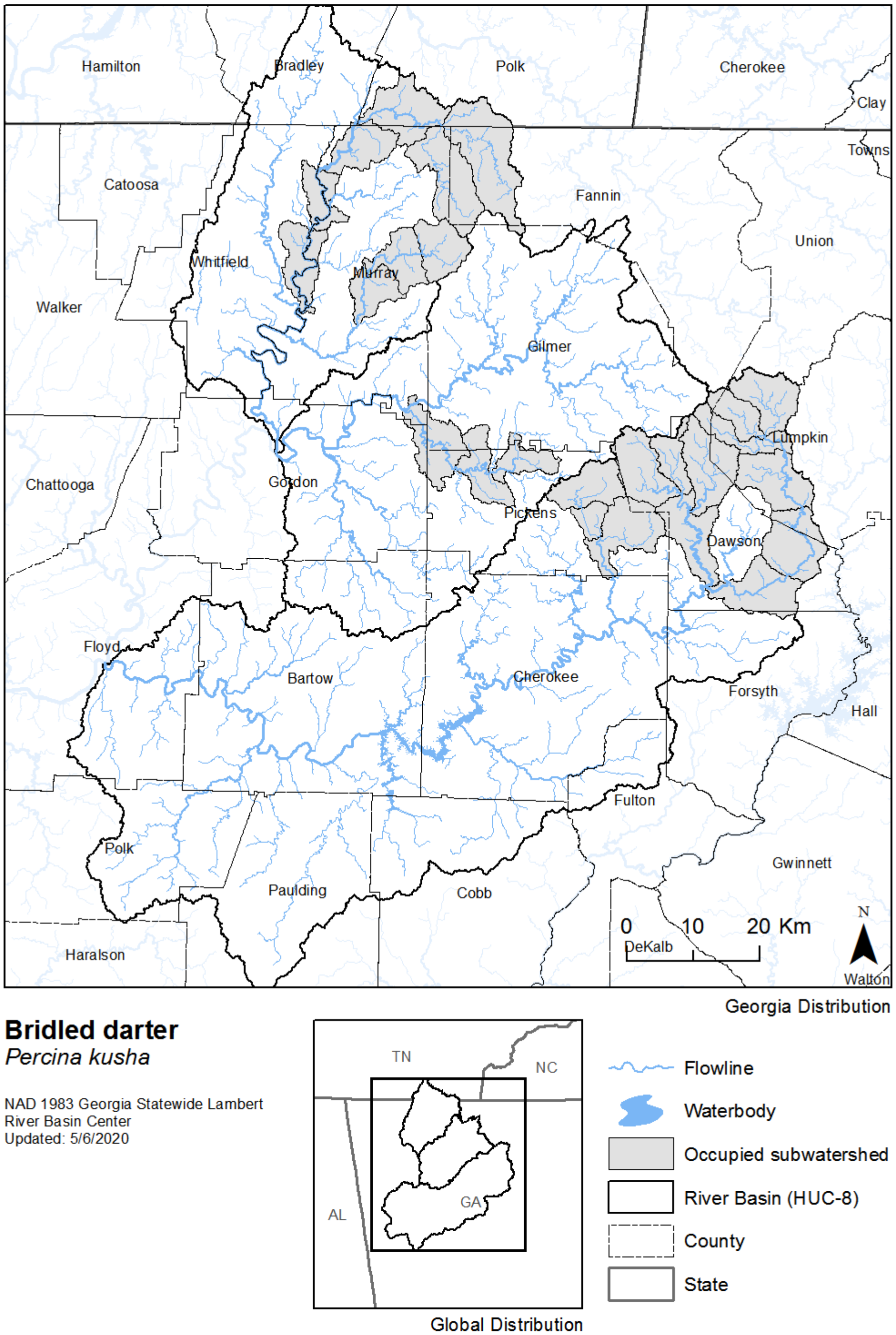
Pollutants

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified stormwater pollutants as a primary stressor to the bridled darter and other imperiled species of the Etowah River. 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*). Kollaus et al. (2015) found a significant decrease in abundance of the closely related *P. apristis* 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 *E. nigrofasciata* increased as urbanization of the Little Uchee creek increased from 8-13%.

Because the bridled 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, bridled darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Based on traits that suggest a degree of sensitivity, the pollutant sensitivity of the bridled darter is categorized as somewhat intolerant (3).

Figure 38. Map. Range map of the bridled darter.



BROADSTRIPE SHINER

Species

Broadstripe Shiner, *Pteronotropis euryzonus*

Description

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

The broadstripe shiner is a colorful minnow attaining a maximum total length of about 7 cm (2.8 in). Broadstripe shiners have a deep, compressed body that tapers toward the caudal fin. The bluish gray lateral stripe covers over half the area of the side, extends from the tip of the snout to the base of the caudal fin, and is bordered above by a narrow orange band. The small, wedge-shaped caudal spot is not continuous with the lateral stripe and is bordered above and below by small red spots. The central caudal rays immediately beyond the caudal spot are not pigmented, creating a clear window in the center of the fin. This species has a complete lateral line, 9-11 anal fin rays, and a modal pharyngeal tooth count formula of 2-4-4-2. There are large tubercles present on the ventral surface of the lower jaw (i.e., mandibular tubercles) of males and females. The dorsal and anal fins of males have much longer rays than those of females and the anterior dorsal fin rays of nuptial males extend past the posterior fin rays when the fin is depressed. Breeding males also develop a bright orange caudal fin and a dull orange anal fin. The interradial membranes of the dorsal fin of nuptial males are primarily dark except for orange pigment along the base of the fin and yellow-green pigment on the tips of the fin rays.

Life History

The biology of the broadstripe shiner is not well studied, and the timing and duration of spawning are not known for this species. Boschung and Mayden (2004) state that female broadstripe shiners begin to lay eggs at ages of six months, which might suggest short female lifespans. In an aquarium setting, broadstripe shiners are broadcast spawners that lay a limited number of eggs on “spawning mops” (Katula 1993, Boschung and Mayden 2004, Johnston pers. comm. 2020). Broadstripe shiners are primarily drift-feeding insectivores and may also eat detritus (Freeman et al. 1999i).

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

The broadstripe shiner occurs in small and medium-sized streams. Preferred habitats include pools and runs in moderate current velocities over sand, silt, and bedrock, often near logs, snags and aquatic vegetation. The broadstripe shiner is tolerant of moderately low pH waters that are often stained with organic acids. These stained water streams, or blackwater systems, have naturally low pH values ranging down to pH 4 or even less.

Number, Reproduction, Distribution

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

The broadstripe shiner is endemic to the middle Chattahoochee River system of Georgia and Alabama near and below the Fall Line. Georgia records are currently bounded by Talbot County (Upatoi Creek System) to the north and Clay County (Kolomoki Creek System) to the south, but the species could also occur in poorly sampled tributaries beyond this range. The status of this species has not been rigorously assessed, but the broadstripe shiner appears to be currently stable in Georgia. About 30 locations are represented in the Wildlife Conservation Section's Database as of 2009, the majority of which have been documented within the last 10 years. The broadstripe shiner is very abundant within some of these locations.

An estimate of the total adult population size of the broadstripe shiner is unavailable. These shiners may be locally abundant or locally common in their preferred habitat. The short-term population trend of the broadstripe shiner is thought to be relatively stable (NatureServe 2020).

Conservation

The global conservation ranking status of the broadstripe shiner is G3 and the Georgia state conservation ranking status is S3. It is not currently under any federal protections. This species is protected as Rare in the state of Georgia.This species is evidently stable and moderately threatened mainly due to siltation that affects aquatic vegetation (NatureServe 2020).

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999i): The major threat to the survival of broadstripe shiners is water quality and habitat degradation in tributary streams to the Chattahoochee River. A recent study showed that their abundance was negatively associated with catchment disturbance on a military base. Restricted range and localized distributions further contribute to the vulnerability of this species. Conservation of the broadstripe shiner depends upon identifying and protecting specific habitats within its range. This includes protecting streams that have abundant aquatic vegetation and coarse woody debris (i.e., logs). Watershed clearing and increasing urban development can modify habitats by altering hydrology and increasing nutrients in stream systems that may be naturally nutrient poor. Additional research on the life history, habitat requirements, and current range of this species is also needed.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the broadstripe shiner's suspended sediment tolerance as moderate; they also categorized the closely related sailfin shiner (*P. hypselopterus*) as intolerant.

An investigation of the effects of disturbance in headwater stream watersheds found that as the percentage of bare ground and unpaved roads increased, the relative abundance and mean body size of broadstripe shiners decreased (Maloney et al. 2006). Maloney et al. (2006) found that when catchment-scale disturbance in headwater stream drainages at Fort Benning, GA, exceeded 5–8.1%, the proportion of broadstripe shiners declined. The authors attributed these declines to the broadstripe shiner's need for stable spawning bed material associated with vegetation (but sources cited did not confirm vegetation as preferred spawning substrate).

As a broadcast spawner, the reproduction of the broadstripe shiner is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. As insectivorous drift feeders, broadstripe shiners could potentially suffer sublethal effects of sedimentation on their foraging ability as a result of impaired visual acuity and reduced abundance of prey. Additionally, sexually dimorphic species, like the broadstripe shiner, rely on visual cues to induce spawning, which may be impaired by elevated turbidity.

Based on its reduced relative abundance reported by Maloney et al., the sediment sensitivity of the broadstripe shiner is categorized as intolerant (1).

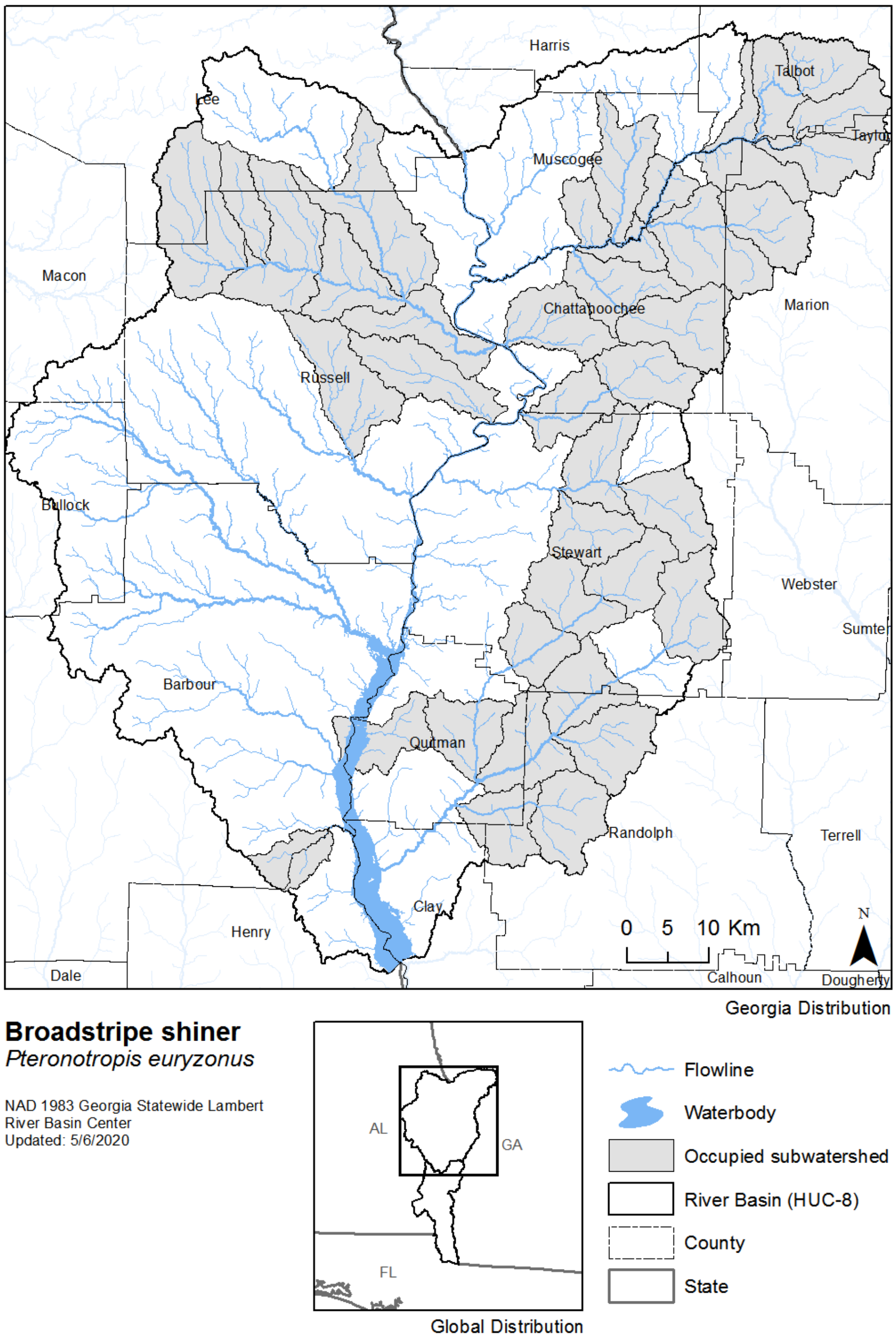
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of the broadstripe shiner as intolerant. Meador and Carlisle also categorized two closely related species, *P. hypselopterus* and *P. signipinnis*, as moderate and intolerant, respectively.

As drift-feeding insectivores, the broadstripe shiner feeds at a low trophic level and its dietary exposure to roadway-associated pollutants is likely to be relatively low. As a broadcast spawner, the early life stages of this species may be more closely associated with pollutant-bound sediments.

On balance of its life history traits and the previous classification by Meador and Carlisle, the pollutant sensitivity of the broadstripe shiner is categorized as somewhat intolerant (3).

Figure 39. Map. Range map of the broadstripe shiner.



BURRHEAD SHINER

Species

Burrhead Shiner, *Notropis asperifrons*

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008c): The burrhead shiner is a slender minnow with a snout that slightly overhangs the mouth. Adults reach about 75 mm (3 inches) in total length. The anterior lateral line scales are elevated (taller than wide) and there are usually 7 anal fin rays. It has a dark, narrow lateral stripe that encircles the snout and terminates as a spot at the base of the caudal fin. There is a pale stripe directly above the dark lateral stripe. The stripe running down the midline of the back (the mid-dorsal stripe) is limited to short streaks at the beginning and rear margin of the dorsal fin. The burrhead shiner does not develop bright breeding coloration, but nuptial males may develop a pale orange coloration on their body and fins.

Life History

Little has been published on the life history of the burrhead shiner. According to Stallsmith et al. (2007), peak reproduction within a tributary of the Sipsey Fork of the Warrior River is likely in April, with female GSI values suggesting that spawning occurred through late July. The length of the spawning period is suggestive of multiple spawnings over the reproductive season. Specimens examined by Etnier and Starnes (1993) indicate an April through June spawning season. Though exact spawning mode is unknown, in an aquarium setting, individual burrhead shiners were often buried in the aquarium substrate, and spawned eggs were retrieved from the bottom of the substrate, suggesting a close spawning association with the benthos (Stallsmith et al. 2007). Little is known on the diet of the burrhead shiner, but it is thought to feed on aquatic insects as most minnows do (Albanese 2008c). The burrhead shiner prefers pools and runs over rocky or sandy substrate in medium creeks to small rivers and is often associated with the benthos (Albanese 2008c, Etnier and Starnes 1993).

Number, Reproduction, Distribution

The burrhead shiner occurs in the Mobile Basin and is found primarily above the fall line in Alabama and Georgia, with its range barely extending into Tennessee. In Georgia, burrhead shiners are found in the Conasauga and Oostanaula river drainages, primarily within the Ridge and Valley physiographic province (Albanese 2008c).

The IUCN lists the burrhead shiner population as stable but extremely fragmented with a continued decline of mature individuals. The population trend over the last 10 years is uncertain but likely to be relatively stable or slowly declining (IUCN Red List 2019).

Conservation

Burrhead shiners have a global conservation status ranking of G4, a Georgia state conservation ranking of S2, and are currently under no federal protections. This species is protected as Threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008c): The small number of populations makes this species vulnerable to extirpation from Georgia. It is also threatened by development along the I-75 corridor and the failure to follow agricultural best-management practices.

Conserving populations of the burrhead shiner 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

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the burrhead shiner's tolerance to suspended sediment as intolerant. They also evaluated the suspended sediment tolerance of six closely related Notropis minnows species within the Alburnops clade, categorizing two as intolerant (*N. baileyi*, and *N. xaenocephalus*), three as moderate (*N. chalybaeus*, *N. petersoni*, and *N. texanus*) and one as tolerant (*N. blennius*). Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species decreased with increasing turbidity and bedded sediments, including the closely related *N. xaenocephalus*. The extirpation and decline of the closely related *N. texanus* within streams in Illinois has been attributed to excessive sedimentation and the loss of extensive gravel- and sand-substrate habitats to silt (Smith 1971).

Because it is likely a substrate spawner, the burrhead shiner's reproduction may be sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. As a likely insectivore, the burrhead shiner may be indirectly affected by sediment via a reduction of macroinvertebrate abundance; however, this effect may be reduced if its diet includes both aquatic and terrestrial insects, as does the diet of many *Notropis* species.

Following Meador and Carlisle's conclusions, the overall sediment sensitivity of the burrhead shiner is categorized as intolerant (1).

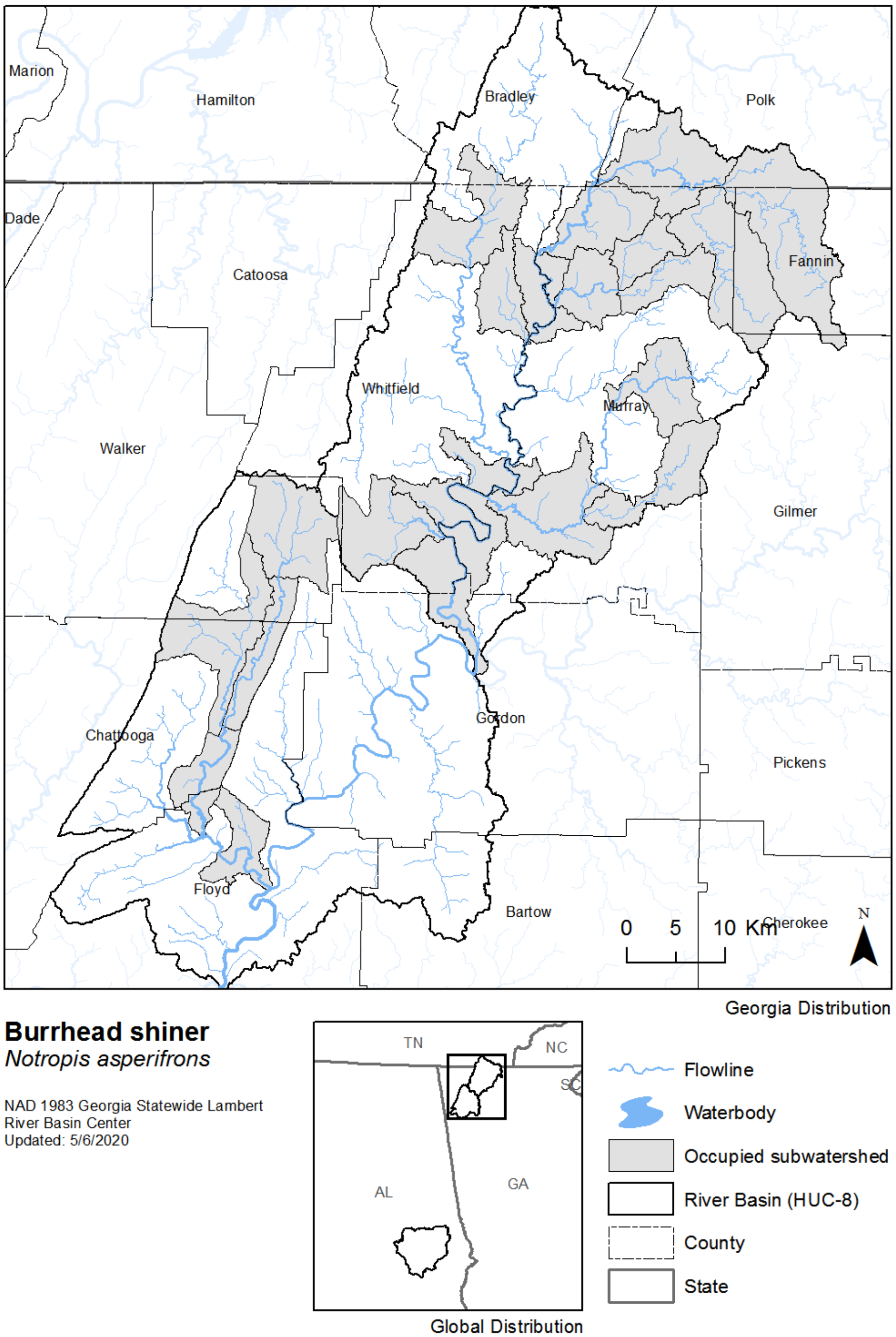
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the burrhead shiner tolerance to specific conductivity as moderate. They also evaluated the conductivity tolerance of six closely related Notropis minnows species within the Alburnops clade, categorizing five as moderate (*N. baileyi, N. chalybaeus, N. petersoni, N. texanus,* and *N. xaenocephalus*) and one as tolerant (*N. blennius*).

As a likely substrate spawner, the egg/larval life stages of the burrhead shiner may come into direct contact with sediment-associated pollutants, but as a likely drift-feeding insectivore, the burrhead shiner feeds at a low trophic level and its dietary exposure to roadway-associated pollutants is likely to be low.

Based on expert opinion and the work by Meador and Carlisle, the overall pollutant sensitivity of the burrhead shiner is categorized as somewhat intolerant (3).

Figure 40. Map. Range map of the burrhead shiner.



CHEROKEE DARTER

Species

Cherokee darter, *Etheostoma scotti*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999v): The Cherokee darter has a rounded snout, a distinct dark bar beneath the eye, and 7-8 dorsal blotches that may fuse with the 7-8 lateral blotches. The lateral blotches elongate into slightly oblique greenish-olive bars in breeding males. The anterior lateral line pores are usually outlined in black. Breeding males have an anterior red window and a single broad reddish band in the first dorsal fin, red in the second dorsal fin, and a green-edged anal fin. The caudal fin may also be edged in green dorsally and ventrally. Adult size of the Cherokee darter is 40-65 mm (1.6-2.6 in) total length.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999v): Cherokee darters spawn from mid-March to late June at water temperatures of 11.5-18C (52.7-64.4F). Spawning typically occurs in runs and pools adjacent to riffles at depths less than 0.5 m (1.64 ft) with moderate velocities (often 0.1-0.4 m/sec (0.33-1.3 ft/sec)). Cherokee darters display spawning behaviors typical of other Ulocentra. The female searches for a suitable spawning substrate while the male pursues her, chasing away other males. The female typically selects large gravel or cobble-sized substrate, though bedrock or large wood may be used. She pecks at the surface with her mouth, possibly to further clean the site before the egg is attached. She then positions her ovipositor over the cleaned area, the male mounts her and they quiver. A single egg is attached to the substrate during a spawn, and it is not further acknowledged by the pair, although the substrate may be used for more than one spawn. In some cases, females have been observed to select a site, peck repeatedly at the substrate, and then disregard it to search for another location. This behavior may indicate that the substrate had too much sediment or algae to be a suitable spawning site, which would emphasize the need for clean spawning substrate. Life span of the Cherokee darter is unlikely to exceed 3-4 years.

The Cherokee darter is most often found in small to medium creeks, in areas of moderate current, and shallow depth (0.1 to 0.5m; Bauer et al. 1995). It prefers the reduced currents found in runs above and below riffles, as well as the transition areas between riffles and backwaters (Bauer et al. 1995). Its preferred substrate is large gravel, cobble, and small boulder (Bauer et al. 1995). Higher abundances are found in reaches with low turbidity and substrate free of fine sediments (Bauer et al. 1995). Its diet is unknown, but likely consists of midge and black fly larvae, as well as other small invertebrates (USFWS 2014).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999v): The Cherokee darter is endemic to the Etowah River watershed within the upper Coosa

River system in Georgia. Currently, this species is known from only about 20 small tributaries to the Etowah River. Populations of Cherokee darters exhibit a fragmented pattern of disjunct populations upstream and downstream of Allatoona Reservoir. The three ESUs are geographically isolated and can be divided into upper, middle and lower regions of the Etowah system. The upper ESU is found in the Camp, Proctor, Palmer, Russell and Shoal Creek tributary systems, as well as in other unnamed tributaries to the Etowah River, primarily in Lumpkin and Dawson Counties. The downstream limit of the upper ESU is near the mouth of Shoal Creek (Dawson County). The middle ESU can be found between Yellow Creek (likely upstream limit) and two tributaries to Allatoona Reservoir: Kellog Creek (southern) and Sweetwater Creek (northern). Major tributary systems within the middle ESU include Long Swamp, Sharp Mountain, Canton, and Shoal (Cherokee County) Creeks. To date, the upstream-most collections of the lower ESUs have been in the Stamp Creek system and Allatoona Creek system, both now tributaries to Allatoona reservoir. The downstream ESU is also found in the Pettit, Pumpkinvine and Raccoon Creek systems. Raccoon Creek is the downstream-most limit of the lower ESU and of Cherokee darters more generally.

The total adult population size of Cherokee darters is likely below the estimate of 536,000 individuals forecast under the development conditions recommended by the Etowah HCP (Wenger et al. 2010).

Conservation

The Cherokee darter has a global conservation status ranking of G2 and a Georgia state conservation status ranking of S2. It is federally listed under the ESA as threatened (listed in 1994). This species is protected as Threatened in the state of Georgia.

Current threats to the Cherokee darter include: limited connectivity within and among populations; altered flow and thermal regimes by hydroelectric facilities and urbanization; sedimentation of habitat by erosion from agricultural/commercial activities; extensive loss and degradation of riparian buffers; loss of habitat by alteration of stream/river morphology (channelization and piping); and contaminants from roadway runoff, accidental spills, and agricultural/commercial activities (USFWS 2014).

Actions designed for conservation of the Cherokee 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, commercial, and construction activities; protection/restoration of riparian buffers; improved management of stormwater runoff from roadways and urbanizing areas; maintenance of natural flow regimes by limiting water withdrawals; and continued efforts to evaluate population size and trends as well as their drivers (Freeman et al. 1999v, USFWS 2014).

Effects of Construction Activities

Sediment

Elevated sedimentation is cited as a primary cause of loss/degradation of Cherokee darter habitat in both the original listing rule and the most recent 5-year review by the U.S. Fish and Wildlife Service (FWS 2014). Sedimentation was also identified as a primary stressor to the Cherokee darter (as well as other species), in an analysis conducted in support of the Etowah HCP (Wenger and Freeman 2007). Bauer et al. (1995) described the Cherokee darter as “relatively intolerant of moderate to heavy silt deposition” and found its abundance to be highest in areas with clean coarse substrate and low turbidity. In a study of the spawning behavior and habitat of the Cherokee darter, Storey et al. (2006) identified fine sediment inputs as a substantial source of spawning habitat degradation that would likely lead to reduced spawning success. Roy (2004) found that reduced abundance of Cherokee darters was associated with higher levels bed mobility and fine sediments. Walters et al. (2003) found that relative richness and relative abundance of ‘endemic highland species,’ including the Cherokee darter and two congeners (greenbreast darter, *E. jordani*; Etowah darter, *E. etowahae*), decreased with increasing turbidity and bedded sediments.

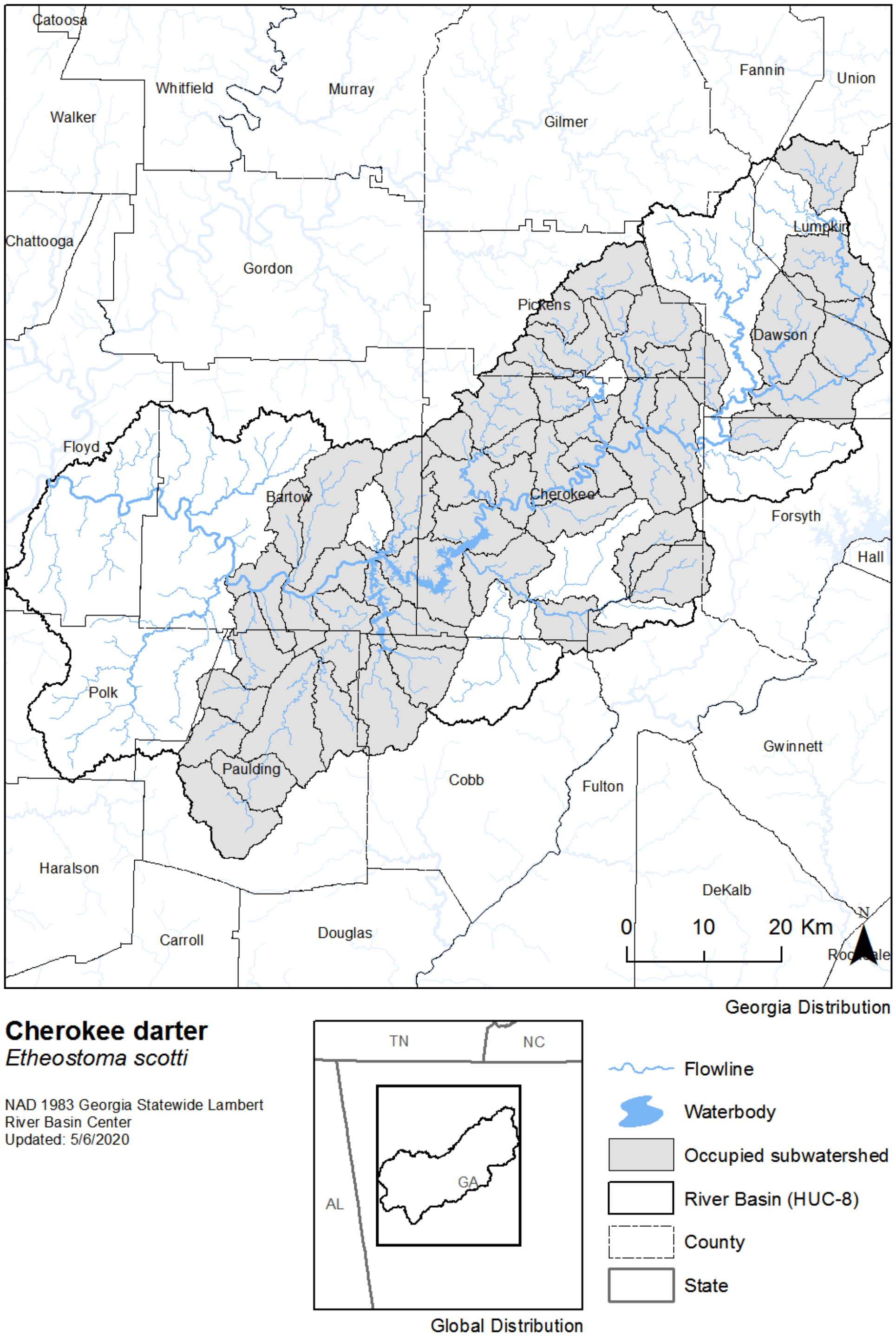
Because richness and abundance of Cherokee darters were found to decrease with increasing turbidity and bedded sediments, the sediment sensitivity of the Cherokee darter is categorized as intolerant (1).

Pollutants

Several studies relating imperviousness to Cherokee darter occupancy and abundance were conducted as part of the preparation of the Etowah Aquatic Habitat Conservation Plan. One study identified roadway-associated pollutants as the primary stressor to imperiled fishes, including the Cherokee darter, in the Etowah River (Wenger and Freeman 2007). Another study found that abundance of Cherokee darters decreased with increasing imperviousness; however, it found no relationship between imperviousness and occurrence of Cherokee darters (Wenger and Freeman 2008, Wenger et al. 2010). The most comprehensive study modeled occurrence of five benthic fishes in the Etowah river and found that while probability of occurrence decreased with increasing imperviousness for four species, there was no relationship between imperviousness and occurrence of Cherokee darters (Wenger et al. 2008). These findings led Wenger et al. (2010) to describe the Cherokee darter as being less sensitive to effective impervious area, relative to the Etowah darter (*E. etowahae*, sensitive) and the amber darter (*Percina antesella*, intermediate sensitivity; Wenger 2008).

Because research found that abundance of Cherokee darters was negatively related but occurrence was not related to imperviousness, (Wenger et al. 2008, Wenger and Freeman 2008), the pollutant sensitivity of the Cherokee darter is categorized as moderate (4).

Figure 41. Map. Range map of the Cherokee darter.



COLDWATER DARTER

Species

Coldwater Darter, *Etheostoma ditrema*

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese et al. 1999): The coldwater darter is small, reaching only 65 mm (2.6 in) maximum total length. It has an incomplete lateral line that forms a pale stripe on the anterior half of the body; this stripe arches slightly upward under the first dorsal fin. Body coloration is typically mottled brown, with brown banding on the median fins, a distinct vertical stripe below each eye, and three dark spots vertically aligned at the base of the caudal fin. Breeding males have a blue marginal and a red submarginal band on the first dorsal fin, and profuse orange ventral coloration from the belly to the caudal peduncle.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Albanese et al. 1999): The primary habitat of the coldwater darter consists of limestone springs and spring runs in the Ridge and Valley physiographic province. They are found in association with aquatic plants and organic debris in areas with slow or no water current. Aquatic plant species utilized include watercress, milfoil, eelgrass, and aquatic mosses. Many springs within the range of this species are unoccupied, probably because they are too small or lack adequate aquatic plant coverage. Occasional coldwater darter specimens have been collected in the Conasauga River near the Georgia-Tennessee boundary. It is unknown whether these individuals represent river-dwelling populations or strays from springs connected to the river. They feed on crustaceans, mainly amphipods, as well as insect larvae. Coldwater darters may normally live only two years; thus, successful spawning every year is essential to population persistence. Spawning may occur over a prolonged period, from March through September, in the relatively constant water temperatures provided by spring habitats. Females attach adhesive eggs to vegetation and there is apparently no-post spawning parental care.

Numbers, Reproduction, Distribution

The coldwater darter range includes a small area in southeastern Tennessee and larger areas above the fall line in northeastern Alabama and northwestern Georgia (Albanese et al. 1999). In Georgia, collections of this species have been reported from Conasauga, Coosa, Etowah, and Oostanaula River systems (Albanese et al. 1999). However, the original reports of the species' occurrence in the Etowah River are in doubt (pers. comm. M. Freeman 2020). The adult population size of this species is unknown. This species is locally abundant in spring habitat (Etnier and Starnes 1993), but overall is not common. Page and Burr (2011) regarded it as rare and highly localized. The coldwater darter complex likely includes three distinct species (Albanese et al. 1999).

Conservation

The coldwater darter currently has a global conservation ranking status of G2 and a Georgia state conservation ranking of S1. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Albanese et al. Freeman 1999): The small number of extant populations is the greatest threat to the persistence of this species in Georgia. Almost all populations are isolated from each other by long distances, which limits opportunities for recolonization after local population loss. This species requires vegetated springs, which are extremely vulnerable to water supply development, recreational use and abuse, vegetation control practices (e.g., herbicides), and development. For example, conversion to a concrete-bottom swimming pool has probably eliminated the coldwater darter from one of the historic sites in Whitfield County (Conasauga River system). Another site has received extensive sedimentation from land clearing and cattle grazing around the spring and spring run. Without specific protection, the coldwater darter is clearly vulnerable to extirpation as a result of the loss of spring habitats.

As of 2009, the coldwater darter has only been documented from thirteen locations in the state of Georgia. Almost all of these sites, along with other springs with potentially suitable habitat for the coldwater darter, were surveyed by Bernie Kuhajda and Rick Mayden in the early 2000s. Their data, along with 2 recent collections from the Oostanaula system, documents persistence at seven of the thirteen collection locations since 2000. The species is either extirpated or extremely rare within the remaining sites. Based on the small number of extant populations and evidence of population loss, the state of Georgia changed the status of this species from Threatened to Endangered in 2006.

A conservation strategy for the coldwater darter should focus on protecting and monitoring remaining populations. Springs are vulnerable to contamination from runoff of sediment and pollutants, excessive water withdrawal, and destruction. However, the localized nature of springs also makes them relatively easy to protect. Large buffers of native vegetation should be left around occupied springs and downstream spring runs. Any land-disturbing activities occurring in the upstream watershed area should utilize best-management practices to reduce sedimentation, chemical and nutrient runoff, and hydrologic alteration. Occupied springs should not be stocked with predatory fishes. Although the range of this species has been well-surveyed, the small size of springs and their occurrence on private lands suggest the possibility of additional, undiscovered populations. The Georgia DNR Nongame Conservation Section maintains a database of known coldwater darter sites and can provide guidance on when additional surveys should be carried out.

Effects of construction activities

Sediment

There are no studies investigating the effects of sediment on the coldwater darter, but some data exist on its closely related species in subgenus *Astatichthys*. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of some species closely related to the coldwater darter, categorizing four as moderate *(E. caeruleum, E. swaini, E. lepidum, E. exile)* and one as tolerant (*E. asprigene).*

As a benthic invertivore, the coldwater darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that attaches its eggs to vegetation, coldwater darter reproduction is likely less sensitive to sedimentation by either degradation of habitat or direct smothering of eggs/larvae. Coldwater darters may have a prolonged spawning period, making their reproduction more resilient to adverse effects from a single sedimentation event. However, because coldwater darters are most often found in areas with slow or no water current (i.e. springs), the duration of any adverse effects of a sedimentation event will be greatly prolonged by the lack of sediment flushing.
Based on the sensitivity of its habitat, the coldwater darter sediment sensitivity is categorized as intolerant (1).

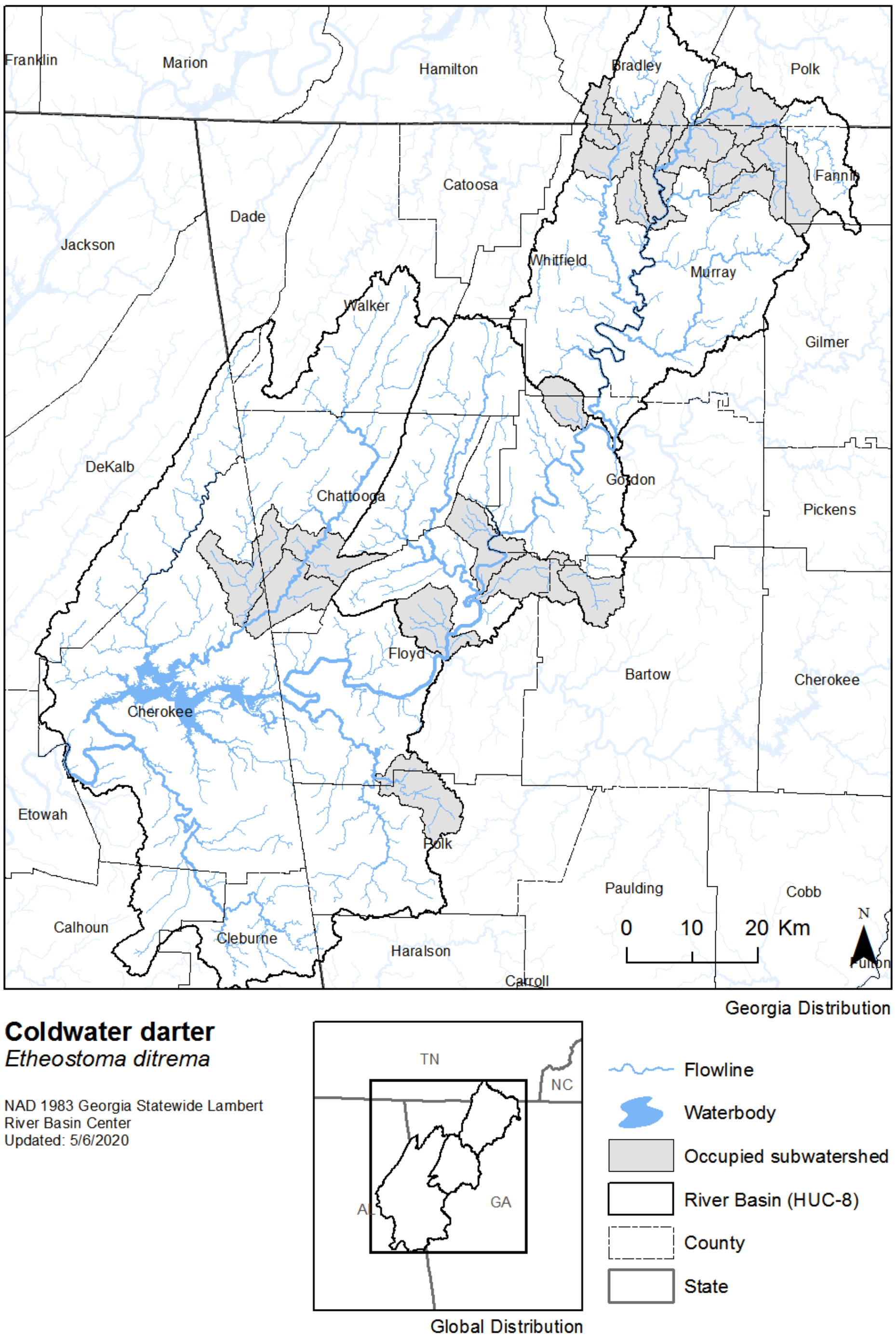
Pollutants

There are no studies investigating the effects of construction- or roadway-derived pollutants on the coldwater darter, but some research has examined closely related species. The abundance of *E. swaini* decreased following inputs of byproduct water (elevating salinity and metals) from nearby coalbed natural gas mining activities (Davis et al. 2006). Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the conductivity tolerance of some species closely related to the coldwater darter, categorizing four as moderate *(E. asprigene, E. caeruleum, E. swaini, E. lepidum)* and one as tolerant (*E. exile).* 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 *E. caeruleum*.

The coldwater 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, coldwater darter eggs are less likely to come into direct contact with sediment-bound pollutants during development. Because coldwater darters are most often found in areas with slow or no water current (i.e. springs), the degree of any adverse effects of pollutants will likely be greater due to the lack of flushing.

Based on the sensitivity of its habitat, the coldwater darter pollutant sensitivity is categorized as somewhat intolerant (3).

Figure 42. Map. Range map of the coldwater darter.



CONASAUGA LOGPERCH

Species

Conasauga Logperch, *Percina jenkinsi*

Description

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

A large darter reaching a maximum of 140 mm (5.5 in) in total length, the Conasauga logperch has a conical snout and narrow vertical bars on the sides. Eight dark bars extend ventrally below the lateral line, and narrower half- and quarter-length bars separate these primary bars. The width of these primary bars is always much less than the lighter colored space between the primary bars and the half-length bar. There is a dark bar extending below the eye, a large spot at the base of the caudal fin, and light banding on the dorsal and caudal fins.

Life History

The Conasauga logperch is most often found in riffles and runs with swift currents over gravel/cobble substrate (Etnier and Starnes 1993, USFWS 2019b). It is generally rare in areas where it does occur. Like other logperches, it feeds on aquatic larval insects by flipping pebbles/gravel to expose prey. Lifespan is thought to be at least five years. Age at maturity for the Conasauga logperch is unknown, but may be two years, based on other species. Spawning likely begins in March, with water temperature above 13°C. Spawning mode and substrate are not known, but some captive breeding work suggests a preference for sandy substrate. Juveniles are rarely collected with adults, suggesting they use different habitat (USFWS 2019b).

Number, Reproduction, Distribution

The Conasauga logperch is endemic to the Conasauga River and has only been reported in the river from the confluence with the Jacks River near the GA/TN (river mile 76.1) border downstream to Mitchell Bridge in Murray Co., GA (river mile 40.6) (USFWS 2019b). Survey data from 2008 and analysis of records from the late 1980's show reduced occurrence of the Conasauga logperch in the upper and lower portions of its range, suggesting that it is likely declining overall (Hagler et al. 2011). Analysis of long-term data by the U.S. Fish and Wildlife Service indicates that numbers of individuals in the upper and lower portions of its range have dropped since 2008. This trend occurred in spite of the release of hundreds of a captive propagation effort that released 300 individuals in 2012. These declines are attributed to stochastic events, the inherent risks associate with small population size and limited range, degradation of habitat by poor agricultural practices, increasing urbanization, and climate change. These declines are attributed to stochastic events, the inherent risks associate with small population size and limited range, degradation of habitat by poor agricultural practices, increasing urbanization, and climate change (USFWS 2019b).

Conservation

The Conasauga logperch is an endangered species currently under federal and state protections. It has a global conservation status ranking of G1 and a Georgia state conservation status ranking of S1. It is federally listed as endangered under the ESA (listed in 1985). This species is protected as Endangered in the state of Georgia.

The land use within the range of the Conasauga logperch is dominated by agriculture and forestry, with increasing levels of urbanization (USFWS 2019b). Threats to the species include degradation of habitat by sediment delivered as a result of agricultural and forestry practices as well as construction of stream-crossing structures. Agricultural areas likely also alter temperature and deliver herbicides/pesticides and elevated nutrients to the Conasauga River. Urban areas contribute roadway associated contaminants delivered by stormwater runoff. Conservation actions aimed at protecting and restoring water quality and habitat of the Conasauga logperch include: restoration of riparian buffers, development of nutrient management plans, employment of agricultural BMPs, improved treatment of stormwater runoff from urban areas (USFWS 2019b).

Effects of Construction Activities

Sediment

In their most recent 5-year review, the U.S. Fish and Wildlife Service (USFWS 2019) identifies sedimentation as a primary threat to the Conasauga logperch and its habitat. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of several species closely related to the Conasauga logperch, categorizing four as moderate (*P. burtoni, P. caprodes, P. kathae, P. macrolepida*) and one as tolerant (*P. carbonaria*).

As a benthic invertivore, the Conasauga logperch is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that likely spawns in sand/gravel, Conasauga logperch 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.

Based on its likely use of sand/gravel as spawning substrate, the sediment sensitivity of the Conasauga logperch is categorized as intolerant (1).

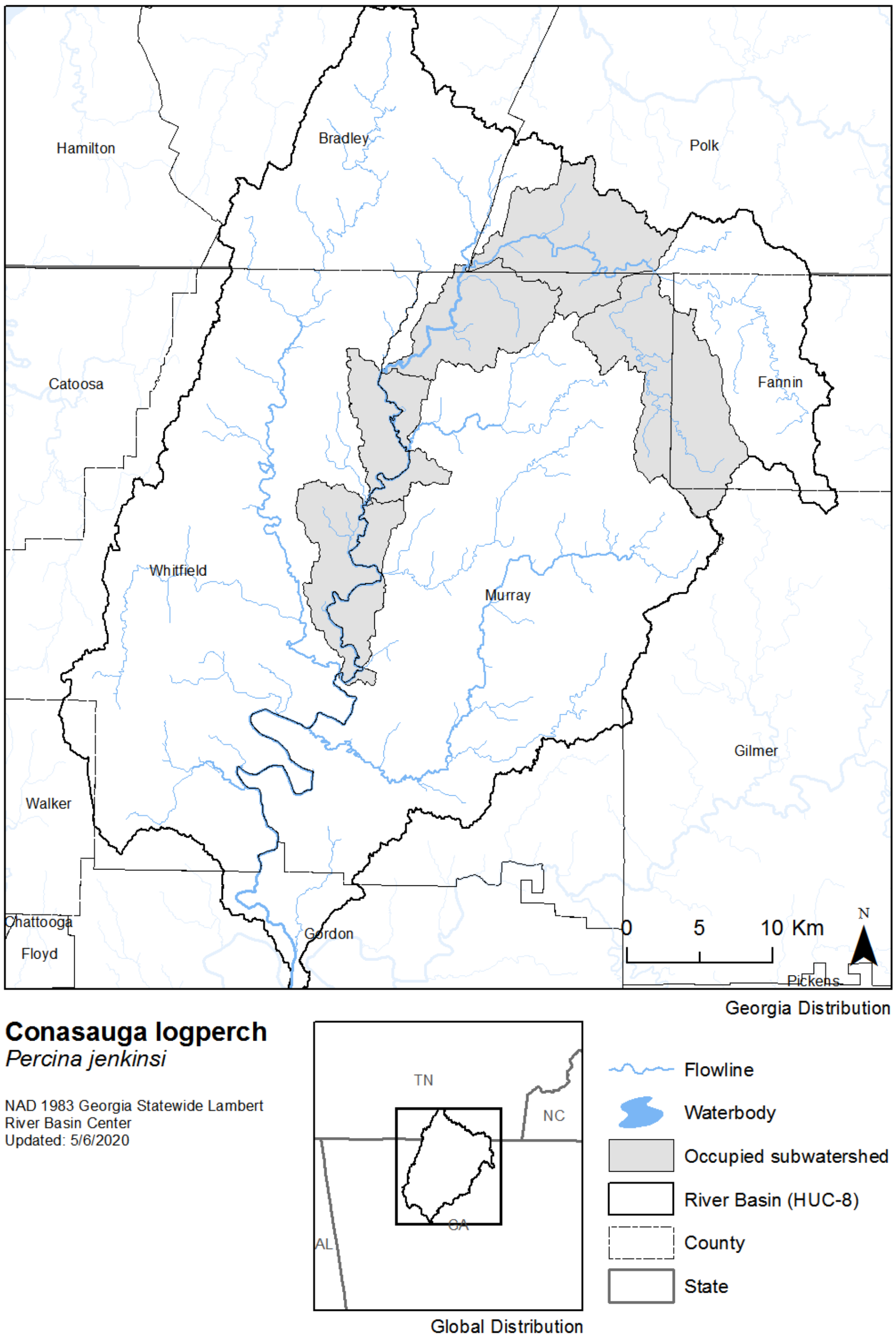
Pollutants

In their most recent 5-year review, the U.S. Fish and Wildlife Service (USFWS 2019b) identifies urbanization as a primary threat to the Conasauga logperch and its habitat. More specifically, the observed decline in abundance and/or occurrence since the mid-2000's may be explained, in part, by the increasing urbanization of the Mill Creek watershed (USFWS 2019b). Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the conductivity tolerance of several species closely related to the Conasauga logperch, categorizing four as moderate *(P. burtoni*, *P. caprodes, P. kathae, P. macrolepida*) and one as tolerant (*P. carbonaria*). 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. caprodes*.

Because the Conasauga logperch 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 sand/gravel, Conasauga logperch eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Because the above-mentioned decline is associated with increasing urbanization in the Mill Creek watershed, the pollutant sensitivity of the Conasauga logperch is categorized as somewhat intolerant (3).

Figure 43. Map. Range map of the Conasauga logperch.



COOSA CHUB

Species

Coosa Chub, *Macrhybopsis etnieri*

Description

Reproduced from Georgia Department of Natural Resources species profile (Hagler 2008):
The Coosa chub is a slender minnow with large eyes, a blunt, rounded snout, subterminal mouth, and a relatively long maxillary barbel at each corner of the jaw. Standard length can reach 62 mm (2⅜ inches). Along the sides, the body is silver with a pink or purplish hue and black speckles that form a weakly defined lateral stripe. The dorsum is tan and the belly is silver. The dorsal, anal, and caudal fins and the snout are often tinted red or orange. Males are not readily distinguished from females. The dorsal fin insertion is slightly posterior to or directly above the pelvic fin insertion. This species typically has 34 - 41 lateral line scales, 8 anal fin rays, and a pharyngeal tooth count formula of 1, 4 - 4, 1.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Hagler 2008):
The life history of the Coosa chub is largely unknown. Coosa chubs reach a maximum age of two or three, and are likely to spawn multiple times during the summer. Platania and Altenbach

spawned *Macrhybopsis aestivalis* (speckled chub) in aquaria and determined that they are broadcast spawners, producing transparent, nonadhesive semi-buoyant eggs about 1mm in size upon expulsion. In rivers, the eggs are kept afloat by stream current. The distance traveled during the drift-stage of development may be substantial depending on abiotic factors (e.g., water temperature, channel shape, and stream flow). The presence of multiple dams along rivers has likely contributed to the imperilment of some western *Macrhybopsis* species, since still water conditions are unsuitable for larval development. Most studies of *Macrhybopsis* species have focused on western species that occur in larger, more turbid rivers, and rivers that have greater fluctuations in stream flow, including some that experience significant drying during summer months. While Coosa chub life history patterns may be similar, studies of their behavior in southeastern systems are needed.

Coosa chubs are found in large streams and rivers and generally occur in swift water over gravel or cobble, often in association with riverweed (*Podostemum ceratophyllum*). At ten shoals on the Etowah River sampled annually from 1998-2004, adults were more than twice as likely to occur in areas where microhabitat conditions included the presence of riverweed.

Although no studies have looked at the diet of the Coosa chub, other species in this genus are known to be benthic invertivores. A diet analysis of *Macrhybopsis tetranema* (peppered chub) occurring in New Mexico and Texas showed a high proportion of dipterans, along with considerable amounts of plant material, detritus, sand, and silt. Many western *Macrhybopsis* species are highly adapted for life in turbid streams, having barbels, reduced eye size, advanced olfactory senses, and cutaneous or compound taste buds that make them efficient foragers in highly turbid waters. Coosa chubs probably rely more on visual senses than the western species, since they have relatively large eyes and occur in systems with much lower turbidity.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Hagler 2008): Coosa chubs are endemic to the Mobile Basin and only occur above the Fall Line in the Coosa, Tallapoosa, and Cahaba river systems within Georgia, Tennessee, and Alabama. In Georgia, Coosa chubs occur in the Ridge and Valley and Piedmont physiographic provinces in the Conasauga, Coosawattee and Etowah river systems. They are primarily known from the mainstem of the Etowah River from Lumpkin County downstream to Allatoona Reservoir, but they also occur in the downstream portions of some major tributaries to the Etowah River. The Conasauga population is nearly restricted to the mainstem from Ball Play Creek (Polk County, Tennessee) downstream to Holly Creek. In the Coosawattee system, Coosa chubs are only known from a few, small collections in the Coosawattee, Ellijay and Cartecay rivers.

Warren et al. (2000) listed the Coosa chub as vulnerable. At that time, both the Conasauga and Etowah populations were fairly strong. In the Etowah River, the Coosa chub population continues to appear stable based on annual surveys over the last decade at ten Etowah River shoals. In the Conasauga River, however, there has been a rapid decline in the rate of occurrence and abundance of Coosa chubs at seven shoals sampled annually since 1996 (excluding 2004). The number of shoals occupied by Coosa chubs dropped from 54% in 1998 and 1999 to 0% (none collected) since 2003. Population status in the Coosawattee is currently unknown and more surveys should be conducted to determine if that small population is persisting. Thus, the only strong population remaining in Georgia is in the Etowah River in Cherokee, Dawson and lower Lumpkin counties.

In a review of previous surveys and collections, Gilbert et al. (2017) described the Coosa chub as generally uncommon and patchily distributed. They also stated that the species "does not appear to be under any immediate threat;" however, this did not take into account the later work by Freeman et al. (2017). By analyzing long-term datasets (1995-2014) from the Conasauga and Etowah Rivers, Freeman et al. (2017) found that the estimated number of Conasauga sites occupied by the Coosa chub decreased from 11.9 to 0.3, but found no change in occupancy in the Etowah River. A number of factors contributing to the decline in the Conasauga were proposed by the authors, especially agricultural pollutants, but the causes remain unclear.

Conservation

The Coosa chub has a global conservation ranking status of G3G4, a Georgia state conservation ranking status of S1, and 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 (Hagler 2008):
Major threats to the Coosa chub come from changes associated with increased urbanization and poor agricultural practices. The Coosa chub population in the Etowah system appears stable at present. The Etowah watershed is experiencing rapid urban and suburban growth which may

continue to pose a threat to Coosa chubs. In the Conasauga River, scientists at the University of Georgia have documented a dramatic decline in the abundance of Coosa chubs, especially in the lower portion of their historically known range. Coincident with the decline of Coosa chubs, they have also documented a large decrease in riverweed cover at shoals sampled since the late 1980s. Coosa chubs are more likely to occur with riverweed in shoals in the Etowah River, where riverweed cover appears to be stable. Riverweed may not be required for their persistence; however, the dramatic decline of both riverweed and Coosa chubs in the Conasauga, indicates that changes in land use are negatively affecting stream biota. The Coosa chub occurs in a portion of the Conasauga River that is largely upstream of major urban influences. It appears that runoff from agricultural lands, potentially including pesticide runoff and runoff of excess nutrients (leading to eutrophication, algal blooms and other trophic effects) may be exacerbating the decline of the Coosa chub in the Conasauga River.

Conservation of Coosa chub populations depends on protecting and improving water quality in the Conasauga, Etowah, and Coosawattee Rivers. This includes controlling upland erosion and sedimentation, maintaining riparian buffers, eliminating leaking septic systems, and improving stormwater management to prevent flashy stream hydrology, warming of stream waters, and to allow for filtration of upland pollutants. Additional research is needed to determine if changes in agricultural land-use practices in the Conasauga watershed are causing the recent decline in Coosa chubs and other biota.

Effects of Construction Activities

Sediment

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified sedimentation as a primary stressor to the Coosa chub and other imperiled species of the Etowah River.

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of three closely related species, (*M. aestivalis, M. gelida, M. storeriana*) and classified all three as tolerant. In contrast, Miltner et al. (2004) described *M. aestivalis* as “highly sensitive” to sediment, based on previous work (Trautman 1981, Ohio EPA 1987). As noted above by Hagler (2008), the degree to which information on western congeners can be used to inform the discussion of the Coosa chub may be limited due to their adaptations to more turbid environments (Meador and Layher 1998; Bonner and Wilde 2000, 2002; Quist et al. 2004).

As a likely benthic invertivore, the Coosa chub is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. If the Coosa chub is shown to be a broadcast spawner with semi-buoyant eggs, like *M. aestivalis*, its reproduction is not likely adversely affected by elevated sediment inputs.

Although the evidence is mixed, the recent decline of the species in the Conasauga suggests sensitivity to either sediment, contaminants or both, so the overall sediment sensitivity of the Coosa chub is categorized as sensitive (1).

Pollutants

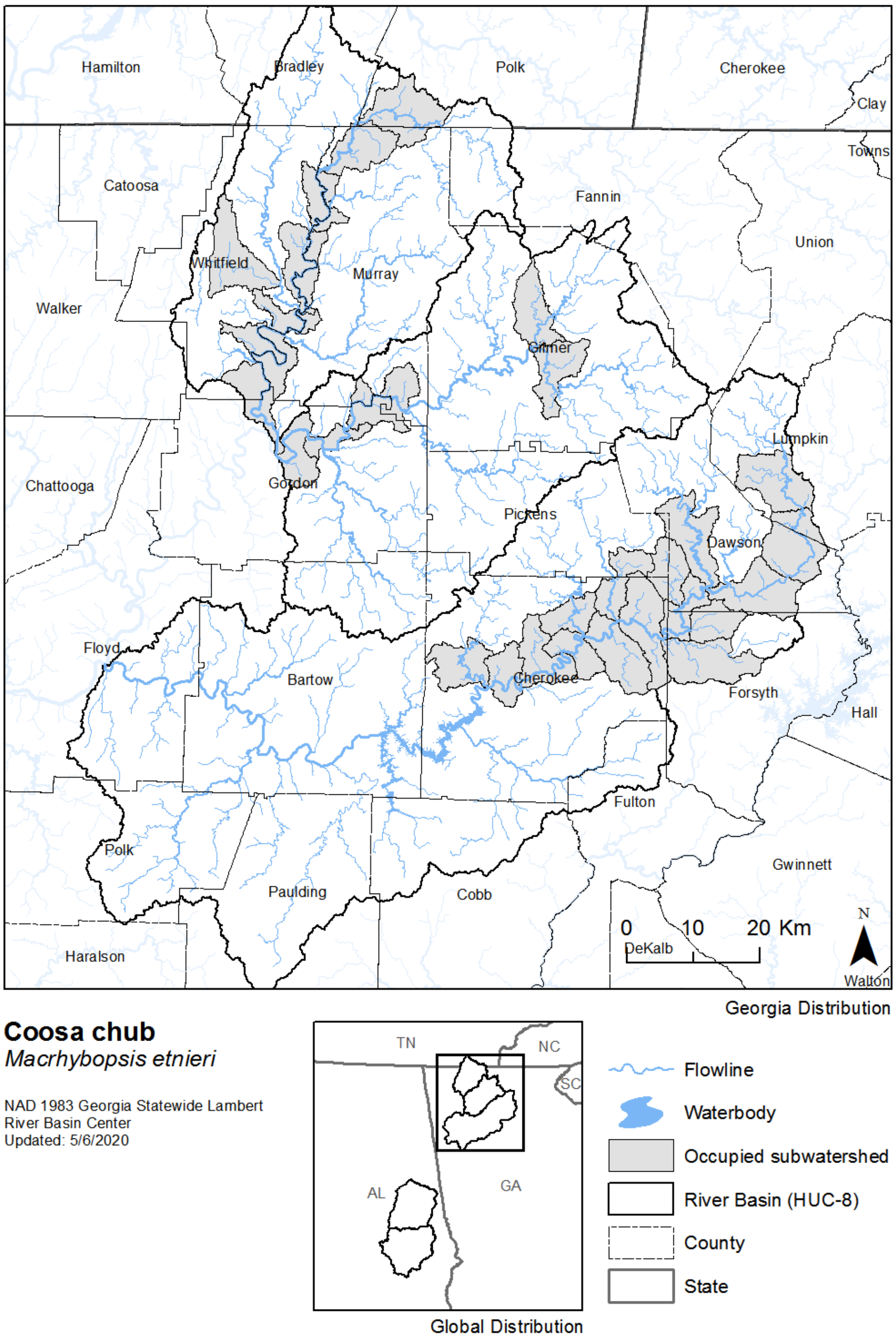
In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified pollutants from impervious surfaces as a primary stressor to the Coosa chub and other imperiled species of the Etowah River.

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of three closely related species, (*M. aestivalis, M. gelida, M. storeriana*) and classified all three as tolerant. In contrast, Miltner et al. (2004) described *M. aestivalis* as "highly sensitive" to pollutants, basing his description on previous work (Trautman 1981, Ohio EPA 1987). Using expert opinion, Jester (1992) classified two congeners, *M. aestivalis* and *M. storeriana*, as moderately intolerant and moderately tolerant, respectively, of degradation of water quality (as opposed to habitat).

As a benthic invertivore, the Coosa chub 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. The developing embryos of the Coosa chub are not likely associated with fine sediments and therefore are less likely exposed to sediment-bound pollutants.

Although the evidence is mixed, the decline of the species in the Conasauga argues for sensitivity to sediment, pollutants or both, so the pollutant sensitivity of the Coosa chub is categorized as very intolerant (2).

Figure 44. Map. Range map of the Coosa chub.



COOSA MADTOM

Species

Coosa Madtom, *Noturus sp cf. N. munitus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The Coosa madtom is an undescribed species in the subgenus Rabida, closely related to the frecklebelly madtom (*Noturus munitus*). This small catfish, which grows to 99 mm (3.9 in) total length, displays striking yellow and brown coloration. Four dark saddles cross the yellow dorsum. Black pigment speckles the sides, belly and barbels. The fins are yellow with dark bands; the rounded caudal fin has two distinct dark bands. As in all madtom catfishes (genus *Noturus*), the entire length of the adipose fin is joined to the dorsum. The Coosa madtom has spines at the front of the dorsal and pectoral fins that can deliver painful jabs to a careless handler, similar to most other catfishes. The large pectoral spines of the Coosa madtom have 6-10 well-developed serrations (teeth or barbs).

While not yet described, the Coosa madtom was recognized as a separate taxon (formerly within *N. munitus*) by Warren et al. (2000) and has since been treated as such in the scientific literature (Freeman et al. 2003, Boschung and Mayden 2004, Bennett et al. 2005, Hagler 2006, Freeman et al. 2017).

Life History

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

Little is known about this small catfish, which may live about 4 years. Spawning may occur in late spring and summer. Females deposit eggs in protected cavities, sometimes including discarded soda cans or bottles. Males typically guard the nests and eggs until the fry hatch and disperse. This species likely feeds primarily at night and hides beneath cobbles or among gravel during the day. Captive Coosa madtoms have been observed burying in sandy sediments when disturbed, a behavior they may also exhibit in the wild. Recruitment of young-of-year may be impacted by stream flow pattern, as more young-of-year have been collected in fall samples in years with relatively higher variability of spring flows and low variability of summer flows. However, more data is needed to understand the relationship between stream flow and juvenile recruitment.

No dietary studies have been conducted for the Coosa madtom, but the diet of the closely related frecklebelly madtom consists primarily of caddisfly and mayfly larvae and to a lesser extent, midge and blackfly larvae.

The Coosa madtom occurs in swift flowing riffles or shallow runs at depths of typically 20-50 cm, often with the submerged aquatic macrophyte, riverweed (*Podostemum ceratophyllum*), and with moveable coarse gravel to cobble bed sediments.

Number, Reproduction, Distribution

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

The Coosa madtom is endemic to the upper Coosa River basin in northwest Georgia southeastern Tennessee (just barely). Coosa madtoms are almost completely restricted to the mainstems of the Etowah and Conasauga Rivers; they have been collected near the mouth of Amicalola Creek, a major Etowah River tributary. Coosa madtoms occur in an 85 km reach of the Etowah River that extends from upstream of Allatoona Reservoir (Cherokee County) to just upstream of GA Hwy 136 (Dawson County). In the Conasauga River, Coosa madtoms are known from a 40 km reach between the mouth of Coahulla Creek and TN Hwy 74/GA Hwy 225.

Annual surveys over the last decade suggest a small but stable population of Coosa madtoms in the Etowah River, while the population in the Conasauga River may be lost or restricted and too small to be easily detected. This madtom was last documented in the Conasauga River in 2000 when a single individual was collected near Tibbs Bridge (Murray-Whitfield County, Georgia). The decline of Coosa madtoms in the Conasauga River has coincided with loss or decline of several other fish species (e.g., *Macrhybopsis etnieri*, *Cyprinella trichroistia*, and *Percina antesella*), decline in riverweed, and an apparent increase in algal production. The status of the Coosa madtom population in the Conasauga River is a major concern for the survival of the species.

By analyzing long-term datasets (1995-2014) from the Conasauga and Etowah Rivers, Freeman et al. (2017) found that the estimated number of Conasauga sites occupied by the Coosa madtom decreased from 5.3 to 0.2, but found no change in occupancy in the Etowah River. A number of factors contributing to this decline were proposed by the authors, especially agricultural pollutants, but the causes remain unclear.

Conservation

The Coosa madtom is not yet recognized as a separate species by the U.S. Fish and Wildlife Service. It is still considered part of the N. munitus complex, which is currently under review in consideration for listing under the ESA. This is why it is referred to in the range map below by the common name frecklebelly madtom. N. munitus currently has a global conservation ranking status of G3 and a Georgia state conservation ranking status of S1. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):
Coosa madtoms are vulnerable to loss of quality habitat resulting from suburban and urban development in the Etowah watershed and parts of the Conasauga watershed, as the human population is rapidly increasing. Suburban development remains fairly restricted in the upper Conasauga system, where non-point source pollution from agricultural lands may be significant. Stream degradation results from failure to employ Best Management Practices (BMPs) or

otherwise inhibit upland runoff in forestry and agriculture, failure to control soil erosion from upland housing, commercial and road construction, and increased stormwater runoff from impervious areas. Water-supply reservoirs constructed on tributaries and off-stream that discharge to the mainstems of the Etowah or Conasauga could significantly alter water flow and thermal regimes in main channel riffles that provide habitat for Coosa madtoms. Potential point sources of contaminants include landfills adjacent to the Etowah River in Forsyth and Cherokee Counties.

Conserving the Coosa madtom and other unique aquatic resources of the upper Coosa River system depends on maintaining habitat quality in the upper Etowah River (upstream from Allatoona Reservoir) and upper Conasauga River (upstream of Dalton, GA), and ultimately improving habitat and water quality in the lower portions of those systems. Coosa madtoms and other species that depend on rivers are particularly vulnerable because there is no suitable refuge should conditions in the river deteriorate. Conditions in the tributaries directly and strongly influence conditions in the rivers, thus long-term viability of Coosa madtom populations will require watershed-scale land-use management that protects the entire system. Eliminating runoff of upland sediment from land-disturbing activities, such as roadway and housing construction, and runoff of contaminants, such as fertilizers and other nutrients, pesticides, heavy metals, and surfactants is critical to protecting aquatic resources. Forested buffers should be maintained and enhanced along stream banks to aid in protecting water quality. Stream buffers are essential, but offer inadequate water quality protection where surface runoff is directed to bypass buffered areas, (e.g., where stormwater or other surface drains are in place to accelerate upland runoff to streams). Protecting riverine habitat quality will require the maintenance of natural patterns of stream flow by minimizing water withdrawals, new impoundments, and impervious cover. The Coosa madtom and other fishes that depend on riffle habitats are especially vulnerable to stream flow depletion because habitats with swift currents are diminished at low flows.

Effects of Construction Activities

Sediment

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified sedimentation as a primary stressor to the Coosa madtom and other imperiled species of the Etowah River. Freeman et al. (2003) modeled occupancy of the Coosa madtom and found a significant positive relationship with the proportion of forested land cover. Additionally, the species was found only in watersheds with a minimum of 40% forested land cover. Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of the closely related N. eleutherus and N. miuris as moderate. By analyzing long-term (1950-1999) survey data and museum records from the Pearl River drainage (Louisiana and Mississippi), Piller et al. (2004) found that N. munitus have undergone major declines in occupancy and abundance, attributing the decline to transformation of extensive patches of firm gravel to loose, shifting sands by impoundments, channel and flow modification.

As a benthic invertivore, the Coosa madtom is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. The reproductive behavior of depositing eggs in cavities may make the Coosa madtom sensitive to the initial presence of sediment as well as infilling and smothering by a subsequent sedimentation event. However, the male is known to guard the developing embryos and, while it has not been reported, may maintain the nest free of sediment.

Based on the absence of the Coosa madtom from watersheds without a majority of forested land cover, the overall sediment sensitivity of the Coosa madtom is categorized as intolerant (1).

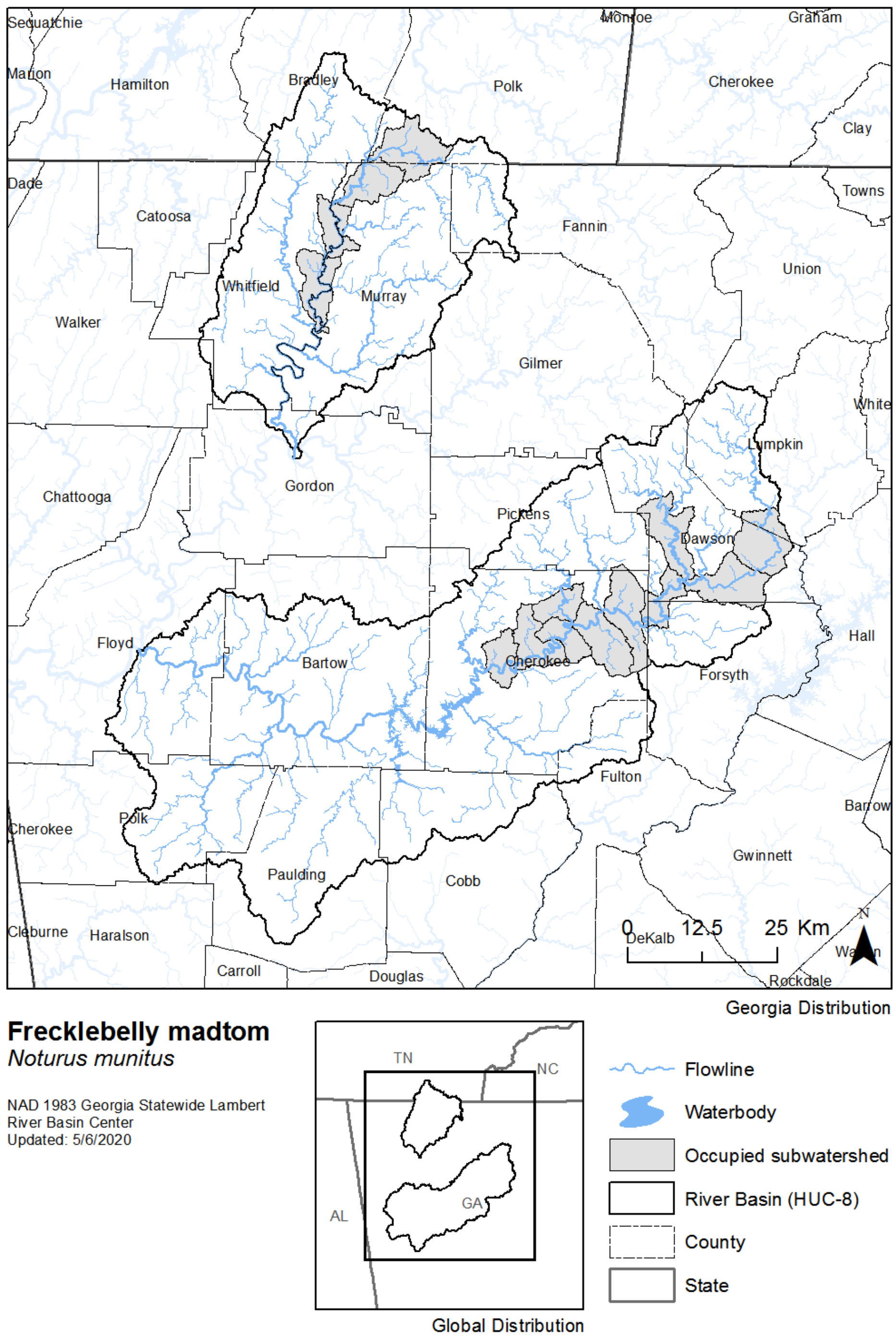
Pollutants

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified pollutants from impervious surfaces as a primary stressor to the Coosa madtom and other imperiled species of the Etowah River. Freeman et al. (2003) modeled occupancy of the Coosa madtom and found no relationship with the proportion of urban/commercial land use. However, it was only found in watersheds with less than one percent urban land cover. 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 *N. miurus*. 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 of Pb, Cd, and Zn (Wildhaber et al. 2000).

The early life stages of frecklebelly madtom are not associated with fine sediments and therefore are less likely exposed to sediment-bound pollutants. As a benthic invertivore, the Coosa 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.

Based on the mixed evidence reported by Freeman et al. (2003), the pollutant sensitivity of the Coosa madtom is categorized as somewhat intolerant (3).

Figure 45. Map. Range map of the frecklebelly madtom.



DUSKY DARTER

Species

Dusky Darter, *Percina sciera*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999kk): The dusky darter is a slender darter growing to a maximum total length of about 130 mm (5.1 in). It is typically tan or gray in color, with 8-12 dark oval blotches along the sides, dorsolateral reticulations above the lateral blotches, and 7-9 vague to dark saddles on the dorsum. A fleshy bridge of tissue (i.e., a frenum) connects the snout to the upper lip. The gill membranes are moderately connected. A suborbital bar is sometimes present. The fins are speckled (or darkened in breeding males) and three spots form a vertical row at the base of the caudal fin, although the lower two spots often blend together. The dusky darter lacks bright breeding coloration.

Life History

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

This widespread species occurs in moderate to low gradient streams and rivers. In Georgia, it is usually collected from larger streams, such as Tiger Creek, Lookout Creek, and Little Chickamauga Creek. It is typically associated with moderate current velocities in habitats ranging from rocky riffles to sand-bottomed areas with abundant woody debris.

Their diet includes aquatic insect larvae, including caddisflies, black flies, midges, and mayflies.

The breeding season occurs from late spring to early summer. Dusky darters probably broadcast spawn their adhesive eggs over gravel and sand substrata. Both sexes reach sexual maturity at age 1. Females have between 80 and 196 mature eggs during a breeding season. Maximum life span is about 3 years for females and 4 years for males.

Number, Reproduction, Distribution

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

The dusky darter is found in Gulf Coast drainages from Texas to west Alabama, including the Mississippi River basin northward to Indiana and Ohio. In Georgia, the dusky darter has been found in the Chickamauga Creek, Lookout Creek and Toccoa River systems. Toccoa specimens are only known from Star Creek and from the Ocoee River within Tennessee.

Although its overall range in the state is small, the dusky darter is widely distributed within the Chickamauga Creek system in northwest Georgia. Recent (i.e. early to mid 2000s) records indicate persistence within several creek systems. The dusky darter is only known from one tributary stream in the Georgia portion of the Toccoa River system, where its current status is unknown.

Conservation

The dusky darter currently has a global conservation ranking status of G5, a Georgia state conservation ranking status of S3, and 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. 1999k):

The dusky darter, although abundant in parts of its range, has a limited distribution in Georgia. The Georgia localities for this small, versatile darter represent populations along the Tennessee River system that have been isolated from other populations by impoundments. The principal threat to the dusky darter in Georgia is 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.

Conserving aquatic species restricted to Tennessee River tributaries, including the dusky darter, depends on protecting stream habitat quality in these streams 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 streamflow patterns. Special efforts must be taken to minimize contaminant, sediment, and stormwater runoff from urban and residential developments if stream habitat and sensitive aquatic species are to be protected.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of the dusky darter, categorizing it as moderate. They also categorized the tolerance of the closely related *P. nigrofasciata* (subgenus *Hadropterus*) as moderate. Walters et al. (2003) found that relative richness and relative abundance of two closely related species (*P. kusha, P. palmaris*) decreased as turbidity and bedded sediments increased.

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

TIn following Meador and Carlisle, the overall sediment sensitivity of the dusky darter is categorized as moderate (2).

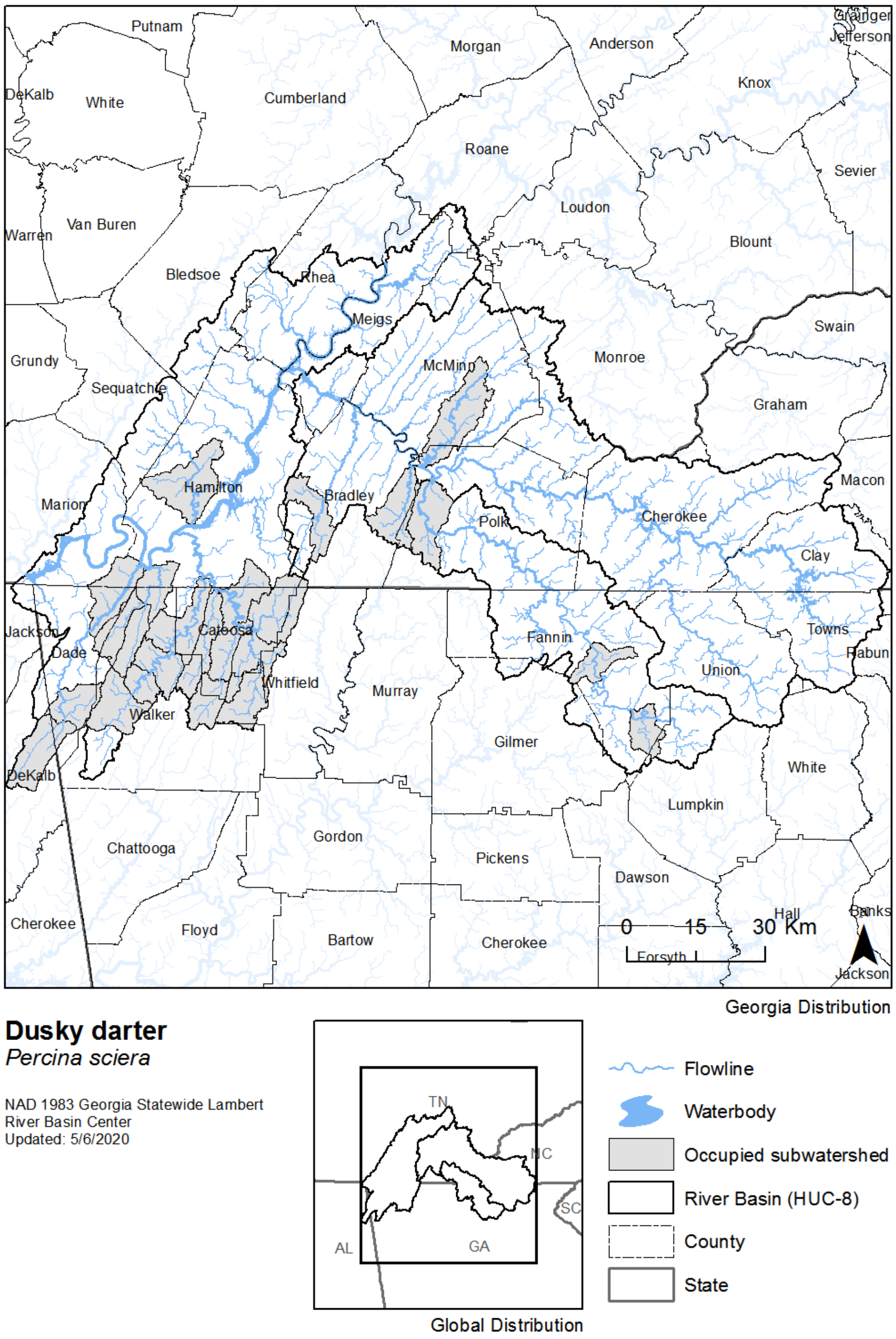
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of the dusky darter, categorizing it as moderate. They also categorized the tolerance of the closely related *P. nigrofasciata* (subgenus *Hadropterus*) as moderate. 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 *E. nigrofasciata* increased as urbanization of the Little Uchee creek increased from 8-13%.

Because the dusky darter feeds on benthic invertebrates, it likely 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 likely spawns over sand and gravel, dusky darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Following Meador and Carlisle, and also considering its broad distribution and apparently flexible habitat requirements, the overall pollutant sensitivity of the dusky darter is categorized as moderate (4).

Figure 46. Map. Range map of the dusky darter.



ETOWAH DARTER

Species

Etowah darter, *Etheostoma etowahae*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999s): Reaching a maximum total length of approximately 70 mm (2.8 in), the Etowah darter has a compressed body with eight broad blotches marking the dorsum and up to 11 indistinct dark bars along the sides. Males have brilliant red bands in the dorsal and caudal fins, and bluish coloration on the lower sides of the head and on the pectoral, pelvic and anal fins.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999s): Etowah darters spawn from May to mid-August within the upper Etowah River at water temperatures between 16-23℃. Etowah darters spawn in moderate to swiftly flowing areas of coarse sand or fine gravel interspersed with or protected by larger gravel and cobble. Females appear to choose a suitable spawning site while a male may follow or chase her. There are numerous acts of aggression during the courtship towards other females or males that may attempt to cut in. If a second female comes along that is ready to spawn, she may be chased away by the first female, or the male may choose to leave the first female to couple with the second. In addition to the commonly observed male-on-male aggressive chasing behavior, male Etowah darters have been observed biting the tail of another rival male; at times two males may be locked together, each with the other's tail in his own mouth. When the female is ready to spawn she dives rostrum-first into the sand, partially burying herself. The male mounts the female, quivering as they push into sand stirring up the sediment. The female may remain in place partially buried for several minutes after the male leaves. The courtship and spawning behavior may continue, with multiple spawns occurring in the same general area.

Etowah darters generally reach maturity after the first year and their life span is usually about three years (USFWS 2014). The species is most often found in riffle habitat with gravel/cobble substrate with swift currents (Freeman et al. 1999s). While little direct evidence on its diet, the closely related greenbreast darter, and likely the Etowah darter, eats a variety of benthic invertebrates: mayflies, water mites, caddisflies, midge larvae, and sometimes mollusks (Mettee et al. 1996).

Numbers, reproduction, distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999s): The Etowah darter occurs only in the Etowah River system in Georgia. Once thought to be restricted to the upper Etowah (upstream from Allatoona Reservoir), recent work has shown that Etowah darters also occur in the lower portion of the basin (downstream of Allatoona dam), where they co-occur with the closely related greenbreast darter. Etowah darters have been collected in the lower Etowah mainstem and in Raccoon Creek, a tributary to the lower Etowah River. In the upper Etowah, Etowah darters occur in the mainstem and some of its larger tributaries, including Long Swamp Creek, Amicalola Creek, and Shoal Creek (Dawson County). Etowah darters also occur in Stamp Creek, a tributary to Allatoona Reservoir.

More recent work has shown that while the Etowah darter does occur in Raccoon Creek, it does not occur in the lower Etowah mainstem; nor does it co-occur with the greenbreast darter (pers. comm. M. Freeman 2020).

The lower portion of the Etowah River (below Lake Allatoona) may not support all life stages of fluvial specialist fishes like the Etowah darter due to the effects of operation of several hydroelectric facilities (USFWS 2014). Survey data from 2001 to 2014 along one portion of the mainstem Etowah River (shoals between Amicalola Creek and Sharp Mountain Creek) showed an increase in the presence of Etowah darters, from 6.5 to 8.5 mean sites occupied (Freeman et al. 2017). The species is generally found in low numbers and is abundant in only a few areas: the Etowah River headwaters, Amicalola Creek, Long Swamp Creek, Shoal Creek, and Raccoon Creek (USFWS 2014). The most recent five-year review by the U.S. Fish and Wildlife Service considers the species' populations to be stable, but is likely to change with increasing urbanization and greater imperviousness of the watershed (USFWS 2014).

Conservation

The Etowah darter has a global conservations status ranking of G1 and a Georgia state conservation ranking of S1. It is federally listed as endangered under the ESA (listed in 1994). This species is protected as Endangered in the state of Georgia. Current threats to the Etowah darter include: reduced connectivity of already small populations by movement barriers; altered flow and thermal regimes by hydroelectric facilities and urbanization; sedimentation of habitat by erosion from agricultural/commercial activities; extensive loss and degradation of riparian buffers; loss of habitat by alteration of stream/river morphology (channelization and piping); and contaminants from roadway runoff, accidental spills, and agricultural/commercial activities (USFWS 2014).

Actions designed for conservation of the Etowah 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 roadways and urbanizing areas, and maintenance of natural flow regimes by limiting water withdrawals (Freeman et al. 1999s).

Effects of construction activities

Sediment

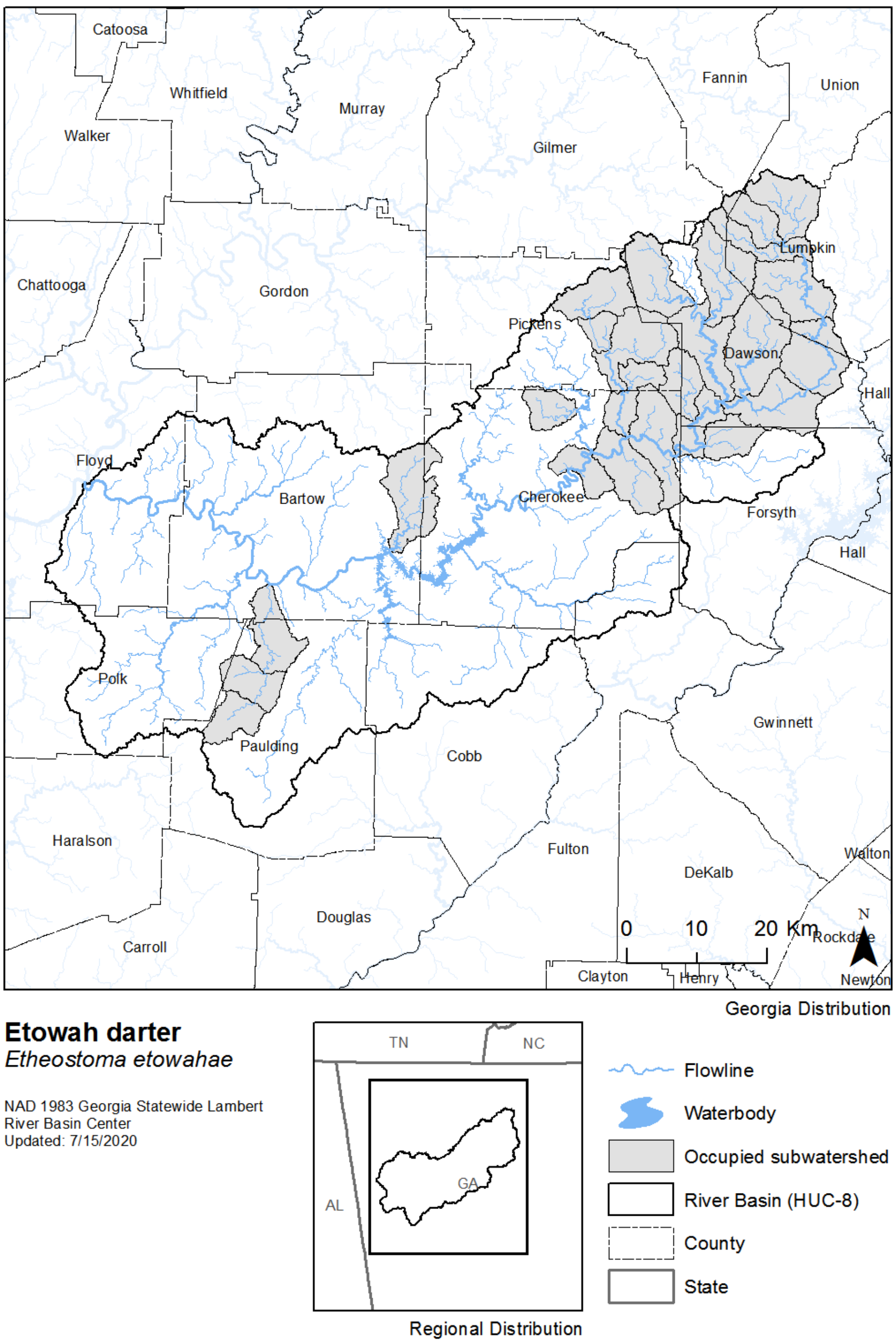
Elevated sedimentation is cited as a primary cause of loss/degradation of Etowah darter (and Cherokee darter) habitat in both the original listing rule and the most recent 5-year review by the U.S. Fish and Wildlife Service (FWS 2014). In an analysis conducted in support of the Etowah HCP, Wenger and Freeman (2007) identified sedimentation as a primary stressor to the Etowah darter and other imperiled species of the Etowah River. Walters et al. (2003) found that relative richness and relative abundance of 'endemic highland species,' including the Etowah darter and the closely related *E. jordani* decreased with increasing turbidity and bedded sediments. Because richness and abundance of the Etowah darter were negatively related to increasing turbidity and bedded sediments, the sediment sensitivity of the Etowah darter is categorized as intolerant (1).

Pollutants

Several studies relating imperviousness to Etowah darter occupancy and abundance were conducted as part of the preparation of the Etowah Aquatic Habitat Conservation Plan. Wenger and Freeman (2007) identified stormwater pollutants as a primary stressor to the Etowah darter and other imperiled species of the Etowah River. Another study modeled occurrence of five benthic fishes in the Etowah River and found that probability of occurrence of the Etowah darter was strongly and negatively related to imperviousness (Wenger et al. 2008). Their results indicated that probability of occurrence approached zero at only 4% effective impervious area, leading a related study (Wenger et al. 2010) to describe the Etowah darter as more sensitive to imperviousness, relative to two other darters in the Etowah (Cherokee darter, *E. scotti*; amber darter, *Percina antesella*).

Because Wenger et al. (2008) found a strong negative relationship between Etowah darter occurrence and imperviousness, the pollutant sensitivity of the Etowah darter is categorized as extremely intolerant (1).

Figure 47. Map. Range map of the Etowah darter.



FATLIPS MINNOW

Species

Fatlips Minnow, *Phenacobius crassilabrum*

Description

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

The fatlips minnow is slender and elongated with a sucker-like mouth and small scales. Hard pads (i.e., jaw plates) occur right behind the lips and bear strong ridges or tooth-like projections. There are 7 anal fin rays, more than 52 lateral-line scales, and 17-21 scales around the caudal peduncle. The body is olive to brown dorsally with an iridescent gold mid-dorsal stripe and a wide lateral band that may be darkly pigmented or yellow to gold in appearance. Breeding males develop rusty tints in the middorsal and lateral stripes as well as in the fins and on the sides of the head. The body below the lateral stripe is white as are the pelvic and anal fins. The pectoral, dorsal, and caudal fins are pale olive and there are pale areas above and below the caudal spot. The maximum reported total length for the fatlips minnow is 112 mm (4.4 in). The combination of thick fleshy lips and hard jaw pads make it difficult to confuse the fatlips minnow with any other fish species in its range.

Life History

Fatlips minnows in Tennessee and Virginia spawn from April through June based on tubercle development, and life history is compressed: large age-1 and all age-2 fish are sexually mature and fish rarely exceed lifespans of three years (Etnier and Starnes 1993, Jenkins and Burkhead 1994). Observations of fatlips minnows guarding territories on the nests of river chubs (*Nocomis micropogon*) have led to their categorization as nest associates (Freeman et al. 1999g). Fatlips minnows are insectivores and consume larval aquatic insects such as midges, craneflies, caddisflies, and beetles. (Etnier and Starnes 1993, Freeman et al. 1999g). They inhabit riffles in cold, upland streams, and are generally associated with clean gravel, cobbles and boulders (Etnier and Starnes 1993, Freeman et al. 1999g).

Number, Reproduction, Distribution

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

The fatlips minnow has a restricted range and is endemic to the upper Tennessee River drainage in Georgia, Tennessee, North Carolina, and Virginia. It is primarily found in the Blue Ridge physiographic province. In Georgia, the fatlips minnow has only been collected from a few sites in the Little Tennessee River system, including sites in Betty Creek and the mainstem Little Tennessee River.

The fatlips minnow has been recently (in 2009) collected from Betty Creek and the mainstem Little Tennessee River. Collections are typically represented by one or just a few individuals.

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

Conservation

The global conservation ranking status of the fatlips minnow is G3/G4 and the Georgia state conservation ranking status is 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. 1999g): Threats to the existence of the fatlips minnow in Georgia include road-building, increasing urbanization, and failure to implement Best Management Practices (BMPs) for forestry and agriculture. The preference of fatlips minnows for clean coolwater streams with gravel bottoms suggests that they may not fare well in urbanized settings. 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 change water temperatures and allow sediment and excess nutrients to reach the stream more quickly. Hydrologic alteration as a result of increased pavement and other impervious surfaces is also a threat.

Conservation of the fatlips minnow and other stream fishes in the Little Tennessee River system depends on maintaining and improving habitat quality. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction), maintain and restore forested buffers along stream banks, eliminate inputs of contaminants (such as fertilizers and pesticides), utilize the best technology available for treating industrial effluent and sewage, and maintain natural patterns of stream flow.

Effects of Construction Activities

Sediment

In a study assessing drivers of fish occupancy in the Little Tennessee River Basin, the amount of fine sediment at the channel-unit scale had a small but positive effect on the occupancy of fatlips minnows, whereas its effect was negative on many sensitive minnow species (Kirsch 2011). In an ordination analysis of the relationship between fish assemblages and landscape and environmental attributes, Rashleigh (2004) found that relative abundance of fatlips minnow was correlated to sites with less agriculture.

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the fatlips minnow's tolerance to suspended sediment as moderate. They also categorized three closely related species as moderate (*P. catostomas, P. mirabilis, P. uranops*) and one as intolerant *(P. teretulu*s). *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 likely river chub nest associate, fatlips minnow spawning is likely not sensitive to the presence of fine sediments, but still sensitive to the adverse effects of subsequent sedimentation events. As a tactile feeder, turbidity may not limit their feeding ability compared to visual feeders, but sedimentation that reduces or buries populations of invertebrate prey on rock surfaces may cause sublethal effects.

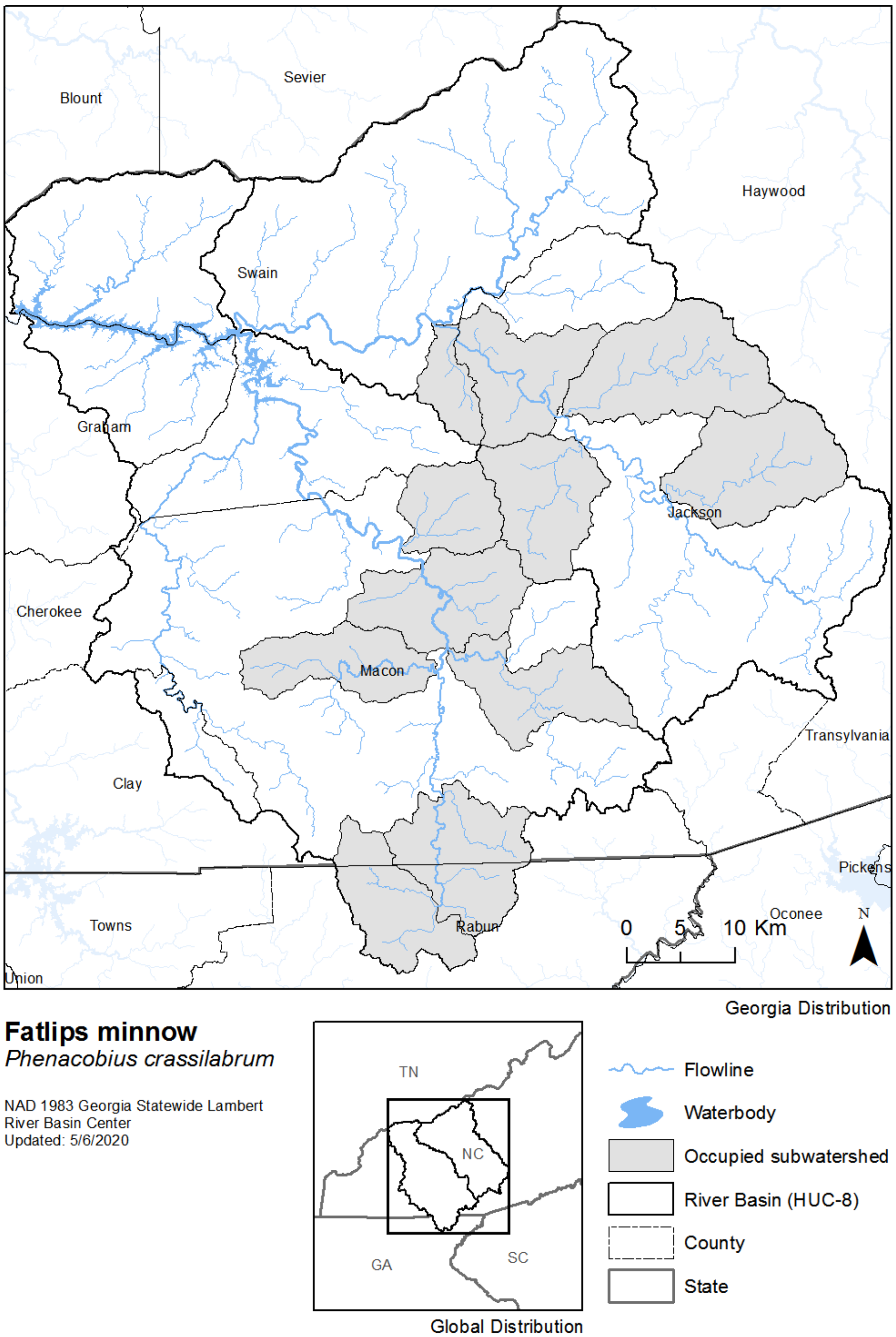
Based on the mix of direct evidence, the sediment sensitivity of the fatlips minnow is categorized as moderate (2).

Pollutants

In the same analysis mentioned above, Rashleigh (2004) found that relative abundance of fatlips minnow was correlated to sites in more urbanized locations. This mirrors findings by Onorato et al. (2000), which suggests that *P. catostomus* was among species tolerant to the effects of urbanization. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the fatlips minnow's tolerance to specific conductivity as moderate. They also categorized two closely related species as moderate (*P. catostomas, P. uranops*), 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.*

Because the direct evidence suggests a degree of tolerance, the pollutant sensitivity of the fatlips minnow is categorized as tolerant (5).

Figure 48. Map. Range map of the fatlips minnow.



FLAME CHUB

Species

Flame Chub, *Hemitremia flammea*

Description

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

This unusual minnow is small (up to 78 mm or 3 in total length) and heavy-bodied, with a deep caudal peduncle and a slightly compressed body shape. The head and snout are short and blunt. The lateral line is not completely pored and the pharyngeal tooth count formula is 2-5-4-2. Coloration of juveniles and small adults is olive green above and white below, with a pale band above the lateral stripe. The dark lateral stripe extends from the snout to a small caudal spot. Above the lateral line it has a gold stripe and the dorsal portion of the body is brown to olive green. During the breeding season, males develop bright red coloration on the lower body below the lateral stripe, at the front base of the dorsal fin, and above and below the caudal spot. Males will usually have some red coloration during the remainder of the year as well. Females often grow larger than males.

Life History

Flame chubs are known only from cold springs and spring-fed streams with high water clarity (Freeman et al. 1999). The size of such occupied streams varies widely (1-20m wide). Aquatic macrophytes (e.g. pondweed, watercress, and smartweed) are often associated with their occurrence. The diet of the flame chub is broad, including macroinvertebrates (e.g. snails, isopods, oligochaetes, hemipterans), insects (terrestrial and aquatic), and filamentous algae. The lifespan of the flame chub is thought to be about 2 years, but is possibly longer (Freeman et al. 1999).

The flame chub spawning season likely extends from January to May (water temp 11-17 º C), based on observations of egg sizes and nuptial coloration of males (Freeman et al. 1999). Spawning substrate consists of clean gravel, within moderate water velocities, at the upper portion of riffles. Males (1-4) induce the spawning act in females by nudging, until the female deposits eggs over an existing depression in the gravel substrate. Females are likely multiple-clutch spawners (Freeman et al. 1999).

Numbers, Reproduction, Distribution

The current species range is much smaller that the historical range, now extending along the Tennessee River from the confluence with the Duck River upstream to the Knoxville area. Within Georgia, the flame chub has been documented only in a few sites in the Chickamauga Creek system. However, the species has not been reported outside the Tiger Creek system, a tributary of South Chickamauga Creek, since the 1960s (Freeman et al. 1999). Abundance and trends for this population are not known, but the species as a whole is thought to be in decline (Stallsmith 2010).

Conservation

The flame chub currently has a conservation global ranking of G3 and a Georgia state conservation ranking of S1. It is currently under no federal protections. This species is protected as Endangered in the state of Georgia. The primary threat to the flame chub is degradation of its sensitive habitat, springs and spring-fed streams. Degradation may occur by removal of vegetation, inputs of sediment or pollutants, water withdrawals, or direct destruction. Conservation actions may include improved occurrence data by conducting additional surveys and development of habitat protection plans for known populations (Freeman et al. 1999).

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of the flame chub as intolerant; they also evaluated the suspended sediment tolerance of the closely related *Semotilus atromaculatus* as moderate. As part of an investigation into relative sediment sensitivity by feeding guild, Sullivan and Watzin (2010) described *S. atromaculatus* as intermediate between the more sensitive benthic invertivores (e.g. white sucker, *Catostomus commersoni*) and less sensitive omnivores (e.g. pumpkinseed, *Lepomis gibossus*).

As a species that spawns over clean gravel, flame chub 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. (Seehausen et al. 1997; Burkhead and Jelks 2001). Because flame chubs are most often found in areas with slow or no water current (i.e. springs), the duration of any adverse effects of a sedimentation event will be greatly prolonged by the lack of sediment flushing.

Based on the classification by Meador and Carlisle and the sensitivity of its habitat, the overall sediment sensitivity of the flame chub is categorized as intolerant (1).

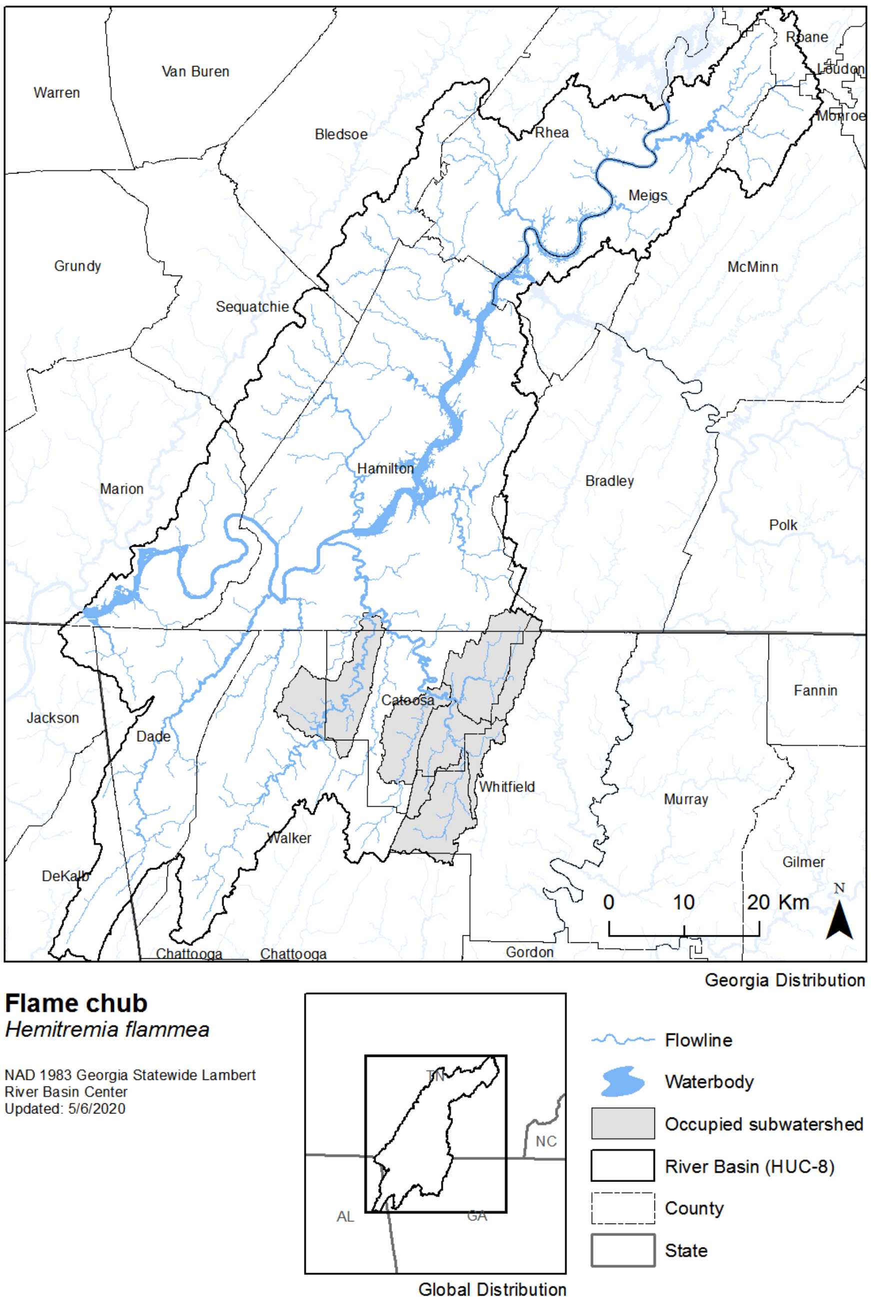
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the flame chub tolerance to specific conductivity as intolerant. 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 *S. atromaculatus*.

Because flame chubs are most often found in areas with slow or no water current (i.e. springs), the degree of any adverse effects of pollutants will likely be much greater due to the lack of flushing.

Based on the classification by Meador and Carlisle and the sensitivity of its habitat, the overall pollutant sensitivity of the flame chub is categorized as somewhat intolerant (3).

Figure 49. Map. Range map of the flame chub.



FRECKLED DARTER

Species

Freckled Darter, *Percina lenticula*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999o): The largest darter, reaching 200 mm (7.9 in) total length, this species is characteristically dusky in appearance with at least 77 lateral scales, about eight dark blotches and smaller spots along the sides, eight dorsal blotches and three dark spots at the base of the caudal fin. Males have 1-2 rows of enlarged, toothed scales on the belly. There may be a dark teardrop beneath each eye, and the fins are darkly banded. A basal black spot characteristically occurs at the front of the second dorsal fin. Neither males nor females develop bright coloration during the spawning season.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999o): Found in larger streams, this darter prefers riffles and runs with swift current over rocky substrates or around large woody debris. The freckled darter may occupy relatively deep (>50 cm, 20 in) portions of riffles and runs.

The diet of the freckled darter consists of aquatic invertebrates. A study in Mississippi found that freckled darters feed on relatively large insects, including net-spinning caddisflies, dragonflies, and hellgrammites.

Little is known of the life history of this relatively rare darter. Larval freckled darters have been collected in Alabama in March, suggesting an early spring spawning season. Eggs are probably buried beneath gravel or sand in riffle and run habitats. Adults have been observed foraging on woody debris in fast currents.

Number, Reproduction, Distribution

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

The freckled darter occurs in Gulf of Mexico tributaries from the Pearl River drainage east to the Mobile River drainage (Louisiana, Mississippi, Alabama and Georgia). In Georgia, this species is known from isolated localities in the Etowah River (Cherokee County) and Conasauga River main-stems in the upper Coosa River system. It was first collected in Georgia in 1950, from the Etowah River at the mouth of Town (Canton) Creek and the species was detected again at this site in 2007.

The freckled darter is a rare species and has been collected only 53 times since 1950, based on occurrence records in the Georgia Museum of Natural History. Annual surveys in the Conasauga and Etowah rivers over the past decade or more (through 2008) suggest a small spottily distributed population, with continued occurrences at the same collection sites.

The freckled darter is thought to occur rarely; however, their detection is difficult and actual abundances may be higher than reported (Boschung and Mayden 2004; NatureServe 2020). An estimate of the total adult population size is not available (NatureServe 2020).

Conservation

The freckled darter currently has a global conservation ranking status of G3, a Georgia state conservation ranking status of S2, and 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. 1999o): Extensive habitat loss due to impoundments threatens the survival of this fish. Water development and construction projects in the Etowah and Conasauga basins that reduce water quality and increase sediment input, or that may diminish flow in riffle and run habitats, especially threaten this species in Georgia.

The freckled darter requires swift-flowing habitats in medium to large streams with good water quality. Maintaining populations of this species in Georgia depends on maintaining in-stream habitat quality in the less-impacted upstream portions of the Conasauga and Etowah rivers. This can be accomplished by eliminating sediment runoff from land-disturbing activities (such as roadway and housing construction) and inputs of contaminants (such as fertilizers and pesticides), while maintaining both forested buffers along the banks of the rivers and their tributary streams and natural stream-flow patterns (by preventing excessive water withdrawal or unnaturally flashy runoff such as from urban storm water runoff). The freckled darter and other fishes that similarly depend on riffle and run habitats are especially vulnerable to stream-flow depletion, because habitats with swift currents are diminished at low flows.

Effects of Construction Activities

Sediment

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified sedimentation as a primary stressor to the freckled darter and other imperiled species of the Etowah River basin. Walters et al. (2003) found that relative richness and relative abundance of two closely related species, *P. kusha* and *P. palmaris* (subgenus Hadropterus), 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 (*P. nigrofasciata*, *P. sciera*), categorizing both as moderate.

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

Because the species' traits constitute multiple exposure routes to the effects of sediment, the overall sediment sensitivity of the freckled darter as intolerant (1).

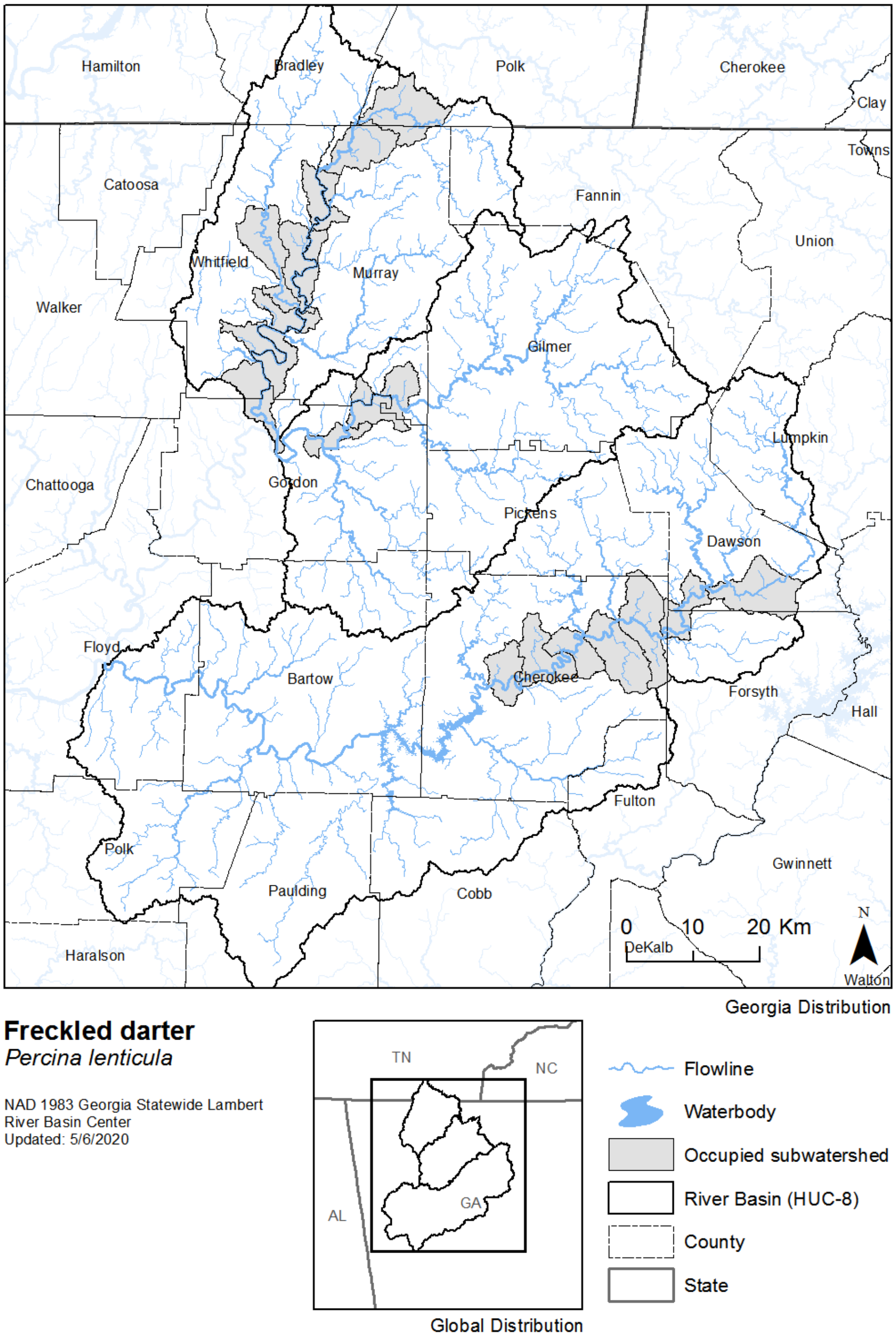
Pollutants

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) identified stormwater as a primary stressor to the freckled darter and other imperiled species of the basin. Freeman et al. (2003) modeled occupancy of the freckled darter and found a significant negative relationship with the proportion of urban/commercial land cover. Specifically, the species was 1.3 times less likely to occur at a given site as urban/commercial land cover increased by 0.5%. Related species have shown variable responses to urban runoff. 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 (*P. nigrofasciata, P. sciera*), categorizing both as moderate.

Because the freckled darter feeds on larger invertebrates (likely benthic, given its known habitat), it may 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 likely spawns in sand and gravel, freckled darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Because the occupancy modeling by Freeman et al. found a significant negative relationship with urban/commercial land cover, the overall pollutant sensitivity of the freckled darter is categorized as very intolerant (2).

Figure 50. Map. Range map of the freckled darter.



GOLDLINE DARTER

Species

Goldline Darter, *Percina aurolineata*

Description

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

The goldline darter is a slender-bodied fish that can reach 9 cm (3.5 in) total length. This darter has a brown or amber wavy stripe above 8-9 oval blotches along the sides. The fins are lightly banded, and three vertically-aligned spots are found at the base of the caudal fin. Juveniles have dorsal blotches that usually become indistinct in adults. Breeding males develop bright yellow coloration dorsally, including a yellow or orange submarginal band on the dorsal fins, and bluish coloration ventrally.

Life History

The goldline darter is most often found in riffle and run areas of larger streams in moderate to swift currents. Their preferred substrate is a mix of sand, gravel, cobble, and boulders, and they are often associated with woody debris, Podostemum, and sandy patches (USFWS 2015). Their diet consists of aquatic invertebrates (Freeman et al. 1999). Spawning in the wild was reported from April to July, but was also reported in captivity from late February to early June (Boschung and Mayden 2004, USFWS 2015). Adhesive eggs were deposited in a combination of sand and gravel in an eddy zone (Boschung and Mayden 2004). Larvae were reported to be strongly phototrophic (USFWS 2015).

Number, Reproduction, Distribution

The goldline darter is now only known from two disjunct areas: the Cahaba River in Alabama and the Coosawattee River drainage in northwestern Georgia (USFWS 2015). Specifically, within Georgia, it has been reported in the Cartecay River, Ellijay River, upper Coosawattee River, and Mountaintown Creek (USFWS 2015). It is presumed extirpated from Talking Rock Creek and the lower Coosawattee River (below Carters Dam) (Albanese et al. 2014).

Conservation

The goldline darter has a global conservation ranking status of G2 and a Georgia state conservation ranking status of S2. It is listed as threatened under the US ESA (1992). This species is protected as Endangered in the state of Georgia.

Across its range, the goldline darter is threatened by a number of anthropogenic impacts. These include: sedimentation of habitat by erosion from commercial, agricultural, and construction activities; lack of or inconsistent riparian buffer; flow reduction due to excessive water withdrawals; isolation and fragmentation of small populations; and increasing urbanization of watersheds with associated runoff from impervious areas (Freeman et al. 1999, USFWS 2015).

Actions designed for conservation of the goldline 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. 1999, USFWS 2015).

Effects of Construction Activities

Sediment

Sedimentation of habitat is considered a primary threat to the goldline darter in the most recent 5-year review by the USFWS (USFWS 2015). Walters et al. (2003) found that relative richness and relative abundance of two closely related species, *P. kusha, P. palmaris,* decreased as turbidity and bedded sediments increased. Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of two closely related species, *P. nigrofasciata* and *P. sciera,* as moderate.

As a benthic invertivore, the goldline darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that spawns in sand and gravel, goldline darter reproduction is sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. Additionally, because this species deposits its eggs in eddy zones, they may be more likely to be covered by sediments settling out of suspension following a sedimentation event. With a strongly phototrophic larval stage, goldline darter recruitment may be adversely affected by a sedimentation-associated increase in turbidity. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration, common among darters.

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

Pollutants

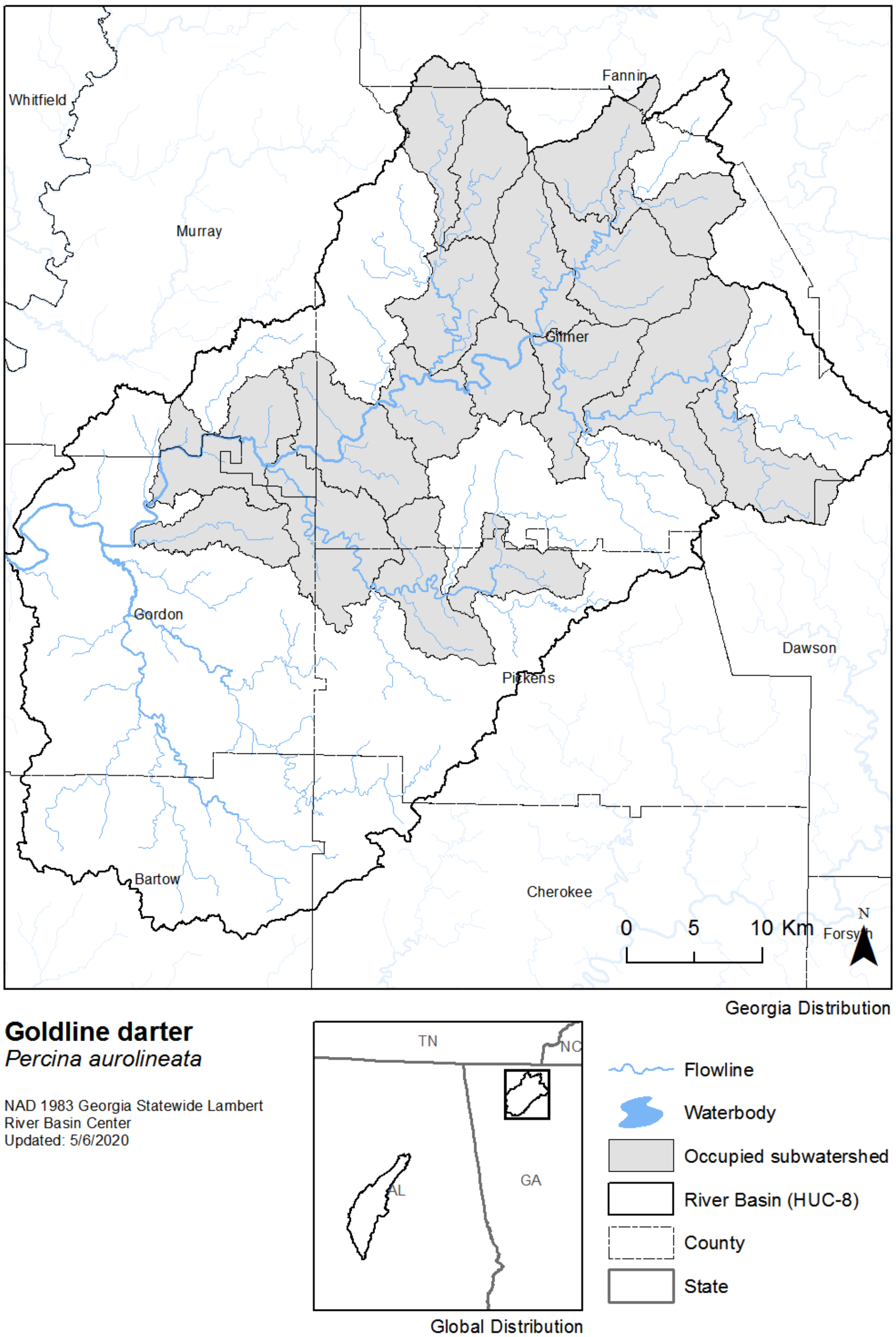
Degradation of water quality by increasing watershed urbanization is considered a primary threat to the goldline darter (Albanese et al. 2014; USFWS 2015). In contrast, using occupancy and distribution models, Albanese et al. (2014) found no relationship between goldline darter occupancy and the increasing urbanization of the watershed above Carters Lake from 1996 to 2011.

Meador and Carlisle (2007; Meador unpublished data 2020) classified the specific conductivity tolerance of two closely related species, *P. nigrofasciata* and *P. sciera,* as moderate. 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 *E. nigrofasciata* increased as urbanization of the Little Uchee Creek increased.

Because the goldline 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 spawns in sand and gravel, goldline darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

While urbanization is considered a primary stressor to the goldline darter, no relationship was found by Albanese et al. Therefore the pollutant sensitivity of the goldline darter is categorized as somewhat intolerant (3).

Figure 51. Map. Range map of the goldline darter.



GOLDSTRIPE DARTER

Species

Goldstripe Darter, *Etheostoma parvipinne*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The goldstripe darter is a generally small, robust fish reaching about 75 mm (3 in) maximum total length and has a short, rounded snout. The lateral line is straight and nearly complete, with just a few un-pored scales. The gill membranes are moderately connected and a frenum is present. This darter has a light-colored stripe along the lateral line, as well as a dark suborbital teardrop, 2-4 dark spots vertically aligned at the base of the caudal fin, and numerous small spots on the upper side of the body and fins. Larger individuals may have 10-12 brownish blotches along the sides. This species lacks the bright breeding coloration characteristic of many other darters. However, male pigmentation darkens during breeding and aggressive interactions and their eyes may turn red.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Goldstripe darters are generally found in small streams and spring seeps and runs associated with aquatic vegetation, organic debris (such as wood and leaves), or slow-moving riffle habitats. Their diet consists of variety of aquatic invertebrates common in small stream habitats. Goldstripe darters probably live 2-3 years. Spawning occurs during the spring months. Females attach their adhesive eggs one at a time to plants or rocks. The aggressive males may acquire darkened lateral bars and blackened fins as they compete with each other for spawning opportunities. Little else is known of this species' life history.

Numbers, Reproduction, Distribution

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

The goldstripe darter almost always occurs below the Fall Line, from the Brazos River (Texas) northeastward to tributaries of the Mississippi River in Missouri, Kentucky, and Tennessee, and southeast to the Altamaha River drainage in Georgia. In Georgia, the goldstripe darter is known from areas below the Fall Line in the Chattahoochee, Flint, Ocmulgee, and Oconee river systems.

The species has an extremely patchy distribution in Georgia and is only know from about a dozen sites in the state. Collections are distantly scattered in time and space. It may be more common in tiny headwater streams, which are sometimes overlooked during fish surveys. However, these habitats are also vulnerable to poor land management practices and development.

Conservation

The goldstripe darter has a global conservation status ranking of G4/G5, a Georgia state ranking of S2/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. 1999):

The goldstripe darter is vulnerable to habitat destruction and water flow depletion in small stream habitats and spring runs, which occur as a result of poor development practices and failure to employ Best Management Practices (BMPs) for forestry and agriculture. The small streams in which this species occurs are particularly vulnerable to habitat degradation. Furthermore, the isolated nature of each population makes population recolonization and recovery unlikely after man-caused or natural disturbances (e.g., droughts).

Conserving populations of goldstripe darters requires maintaining and improving habitat quality in small streams and spring runs 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 stream flow. There are many technical assistance and cost-sharing programs that can help farmers implement best management practices to protect small streams. Similarly, the Georgia Forestry Commission has also developed best management practices for minimizing the impacts of forestry operations on water quality. Small streams like those typically inhabited by the goldstripe darter may frequently be overlooked as important habitats for rare aquatic species and may be degraded by relatively small-scale construction activities. Special care must be taken to protect small streams from unnecessary runoff and stream bank disturbance.

Effects of Construction Activities

Sediment

While the research team knows of no laboratory or field investigations that directly tested the sediment sensitivity of the goldstripe darter, Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of two closely related species, *E. fusiforme* and *E. serrifer*, categorizing both as moderate.

As a benthic invertivore, the goldstripe darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. However, because goldstripe darters are often found in sand-bottomed runs, their preferred habitat is likely less vulnerable to degradation by erosion and sedimentation events. As a species that attaches its eggs to plants or rocks, goldstripe darter reproduction is likely less sensitive to sedimentation by either degradation of habitat or direct smothering of eggs/larvae.

Based on the mix of traits-based evidence, the overall sediment sensitivity of the goldstripe darter is categorized as moderate (2).

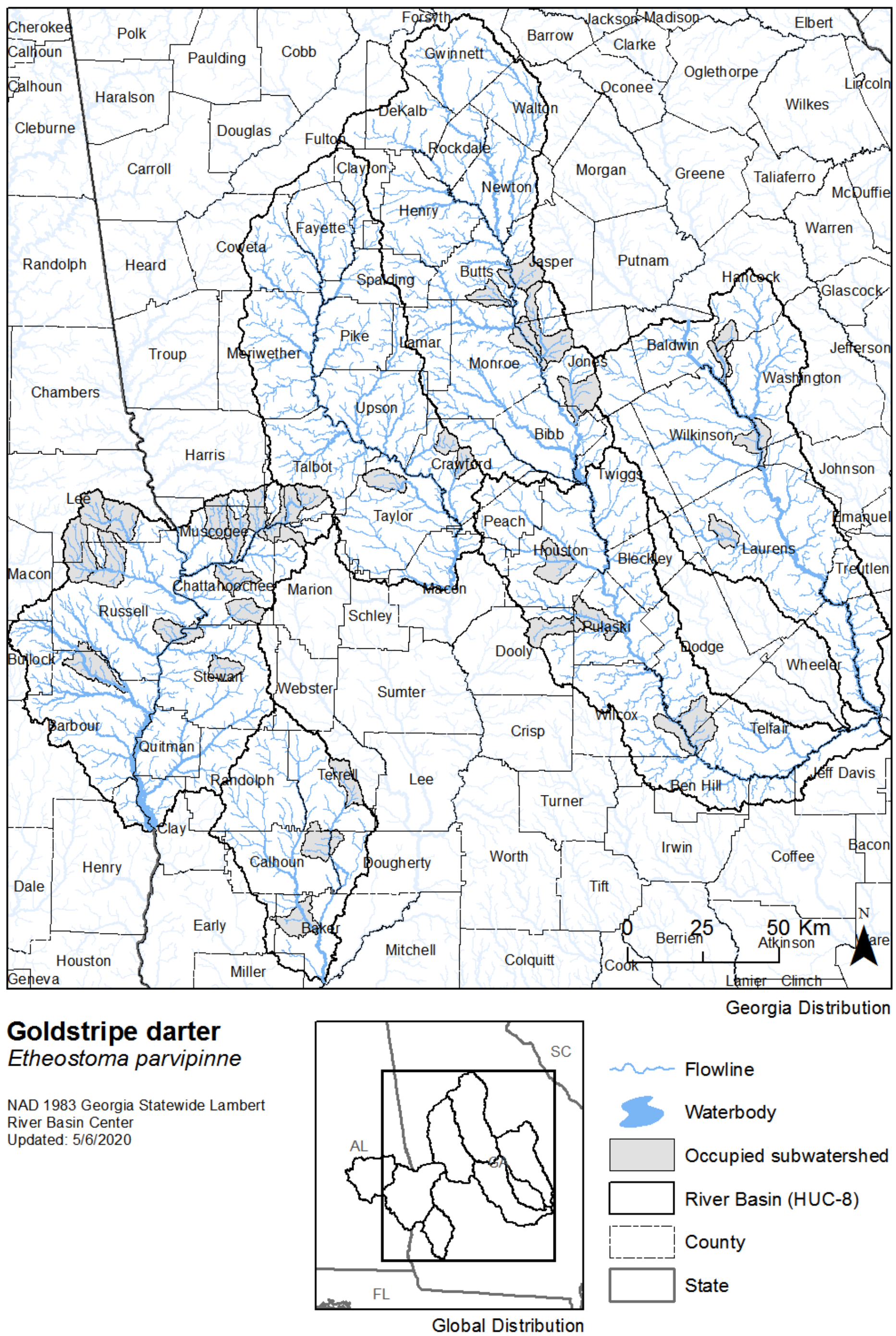
Pollutants

No laboratory or field investigations that directly tested the sediment sensitivity of the goldstripe darter were found, Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of two closely related species, *E. fusiforme* and *E. serrifer*, categorizing both as moderate.

The goldstripe 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 plants or rocks, goldstripe darter eggs are less likely to come into direct contact with sediment-bound pollutants during development.

Based on the mix of traits-based evidence, the overall pollutant sensitivity of the goldstripe darter is categorized as somewhat intolerant (3).

Figure 52. Map. Range map of the goldstripe darter.



GREENFIN DARTER

Species

Greenfin Darter, *Etheostoma chlorobranchium*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The greenfin darter is a relatively large, colorful darter reaching a maximum 110 mm (4.3 in) total length, with a compressed body form and a short, blunt snout. The dorsal, caudal, and anal fins are edged by a dark marginal band and a lighter sub-marginal band. A dark bar extends downward from each eye. The sides of the fish are marked by 10-12 dark vertical bars or blotches and 12-15 thin horizontal stripes. Adult males are deep green in color with green fins and brownish red spots along the sides.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Very little is known about the biology of the greenfin darter. Length-frequency data suggest a life span of about four years. Spawning probably occurs during late spring and summer in swift-flowing riffles. Spawning behavior is probably similar to the closely related bluebreast darter (*Etheostoma camurum*), which is known to be an egg-burying species. During egg deposition and fertilization, females may partially bury themselves in the sand or gravel.

The greenfin darter inhabits riffles with swift currents over bedrock, boulder, or cobble substrata in medium to large, high-elevation streams with cool to cold water temperatures.

Their diet consists of a wide variety benthic aquatic invertebrates.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): This darter occurs only in mountain streams of the upper Tennessee River drainage in Georgia, North Carolina, Tennessee, and Virginia. In Georgia, this fish is known from the Little Tennessee River system in Rabun County.

The greenfin darter is only known from the Little Tennessee River system in Georgia, with recent (2009) records known from the mainstem Little Tennessee River and Betty Creek. There is some evidence that greenfin darter populations are increasing in the Georgia portion of its range.

In areas outside of Georgia where present, this species is regarded as common (Page and Burr 2011). The trend over the past 10 years or three generations is uncertain but likely to be relatively stable (IUCN Redlist 2019).

Conservation

The greenfin 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 Threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The primary threat to the greenfin darter in Georgia is 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. Increasing commercial, residential and highway development utilizing poor construction and riparian management practices pose a significant threat to stream habitat quality in North Georgia.

Conserving populations of the greenfin darter in Georgia will require maintaining and improving habitat quality in the Little Tennessee River system 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 streamflow.

Effects of Construction Activities

Sediment

Scott (2006) found "highland endemic" species of the Little Tennessee, including the greenfin darter, to be sensitive to a combination of anthropogenic stressors that included reduced forest cover, suggesting it to be sensitive to sedimentation. Sutherland et al. (2002) found that relative abundance of gravel-spawners, including the greenfin darter, declined as turbidity and bedded sediments increased. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of the greenfin darter as moderate.

As a benthic invertivore, the greenfin darter is likely indirectly and adversely affected by sediment via a reduction of macroinvertebrate abundance. As a species that likely spawns in a combination of sand and gravel, greenfin 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 documented effects of sediment on its abundance, the overall sediment sensitivity of the greenfin darter is categorized as intolerant (1).

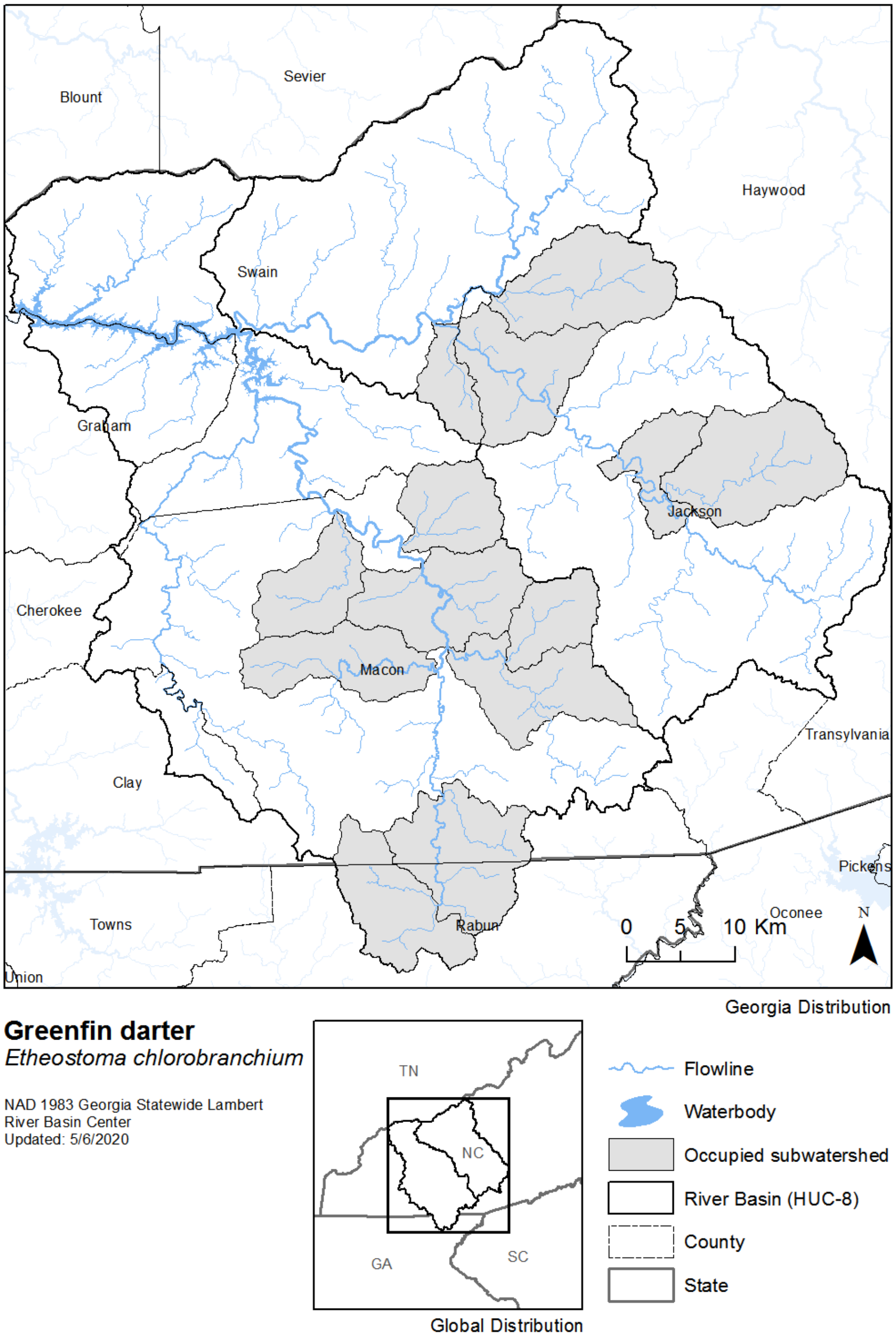
Pollutants

Scott (2006) found “highland endemic” species, including the greenfin darter, to be sensitive to a combination of anthropogenic stressors that included road- and building-density, suggesting it to be sensitive to roadway-associated pollutants. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of the greenfin darter as intolerant.

The greenfin 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 likely 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 the direct evidence suggest a degree of sensitivity, the overall pollutant sensitivity of the greenfin darter is categorized as somewhat intolerant (3).

Figure 53. Map. Range map of the greenfin darter.



HALLOWEEN DARTER

Species

Halloween Darter, *Percina crypta*

Description

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

The Halloween darter is a large darter marked with 7 -13 dark lateral bars, 7 closely spaced rectangular dorsal saddles, and a broad bar under the eye. Adults are 100 - 130 mm (4 - 5 inches) total length. The sides and dorsum are tinged amber or gold between the saddles and bars; the venter is dusky in males, suffused with pink, and females have small blotches or scrawl marks between the ventral extensions of the lateral bars. The first dorsal fin in males is edged in black with an orange submarginal band and dusky base. Females also have a submarginal orange band in the first dorsal fin. All other fins are banded, or dusky in nuptial males, and often washed in yellow.

Life History

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

The Halloween darter has been observed to spawn during April and May, based on gonad condition and occurrence of nuptial coloration, when mean monthly water temperatures are 18 to 20C. Clutch sizes may vary between about 23 and 335 ova, with larger females having larger clutches. Ripe ova average about 1.5 mm in diameter. Juveniles less than 25 - 38 mm (1 - 1½ inches) in length occur in shoal habitats with adults beginning in June, and typically grow to over 50% of the maximum adult size by October. Individuals usually reach sexual maturity at age one; maximum observed age has been estimated at three years based on otolith examination. Nothing is known about dispersal or migratory movements of the Halloween darter.

The Halloween darter inhabits riffles or shoals in the Flint and Chattahoochee River mainstems and larger tributaries to these rivers. This species almost exclusively occurs in shallow, swift-flowing habitats over cobble, gravel, and bedrock, and often in association with the aquatic plant, riverweed (*Podostemum ceratophyllum*). Adults and juveniles occupy similar habitats; nuptial individuals have also been observed in swiftly flowing riffle habitats, where spawning most likely occurs.

Aquatic insects, particularly mayfly (*Ephemeroptera*) nymphs, midge and blackfly (*Dipter*a) larvae, and caddisfly (*Trichoptera*) larvae, form the major part of the Halloween darter diet.

Number, Reproduction, Distribution

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

The halloween darter is endemic to the Apalachicola River drainage in Georgia and Alabama. Populations are known to occur in four widely separated portions of the drainage: the upper Chattahoochee River system, upstream of Lake Lanier; the upper Flint River system, upstream of Lake Blackshear; the lower Flint River system, between Lake Blackshear and Lake Seminole; and, in Alabama, the Uchee Creek system, which flows into the Chattahoochee River upstream of Lake Eufaula.

The halloween darter's range occurs almost entirely within Georgia and has been reduced by mainstem impoundments that inundate river shoal habitat. For example, river shoal habitat in the Chattahoochee River has been substantially reduced by 14 mainstem impoundments, and the halloween darter populations in Uchee Creek and the upper Chattahoochee system almost certainly represent remnants of a formerly broader and more continuous distribution. Currently, the halloween darter appears most abundant in shoals of the upper Flint River mainstem, where it is the most commonly encountered darter species. Collections in the Uchee Creek system in Alabama, in particular, have usually been restricted to few individuals, and the status of the Uchee Creek population is uncertain. The halloween darter also appears less common in shoals of the lower Flint River system than in the upper Flint. Some protection to the species is afforded by occurrence in the portion of Ichawaynochaway Creek that flows through the J.W. Jones Ecological Research Center.

The Halloween darter is both common and abundant in shoals of the Flint River above the fall line (Marcinek 2003, Freeman et al. 2008). The species most often outnumbers the co-occurring and related species *P. nigrofasciata*; however, *P. nigrofasciata* is generally found in greater abundances in the lower Flint and in the Chattahoochee River system (Marcinek 2003, Freeman et al. 2008). The Halloween darter is found almost exclusively in shoal habitat while *P. nigrofasciata* has broader range of habitat use (i.e. runs, riffles, and pools; Marcinek 2003, Freeman et al. 2008).

Conservation

The global conservation ranking status of the Halloween darter is G2, a Georgia state conservation ranking status of S2, and it is currently under no federal protections. This species is protected as Threatened in the state of Georgia.

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

The Halloween darter has a relatively broad geographic range within the Flint and Chattahoochee River systems; the four areas where the species occurs, however, are mutually isolated by reservoirs that would prevent natural population refounding in case of extirpation from any of these four portions of the drainage. In addition, within the upper Chattahoochee system, Lake Lanier separates populations in the Chestatee and Chattahoochee mainstems. In the lower Flint system, Albany dam and impoundment separates populations in the Ichawaynochaway Creek system and the Flint River below Lake Blackshear. Residential and urban development in the north Georgia mountains around Helen, Georgia, and in the rapidly growing area surrounding the headwaters of the Flint River, on the south side of the Atlanta metropolitan area, likely threaten the survival of the Halloween darter. The upper Flint and upper Chattahoochee River systems contain the apparently strongest populations of the species, and both of these areas are increasingly affected by urban and suburban growth. Point and nonpoint pollution, and stormwater runoff, are major causes of stream degradation and species loss in urbanizing areas. Increasing development is also increasing water supply demands. Because the species is nearly restricted to shallow, swiftly-flowing riffle or shoal habitats, withdrawals or reservoirs that decrease the level of base flows in the mainstem of the upper Flint River or in the upper Chattahoochee and Chestatee Rivers could decrease available habitat for the Halloween darter.

Protecting shoal habitats in the mainstems of the upper Flint River and upper Chattahoochee and Chestatee rivers are essential to conserving the Halloween darter. Water supply planning efforts should attempt to minimize impacts to the Halloween darter and other aquatic species by encouraging water conservation practices. New water withdrawals and reservoirs, when absolutely necessary, should be designed and located to minimize fragmentation of existing fish populations and impacts to downstream communities. General watershed conservation practices will also benefit the Halloween darter, especially in urbanizing portions of the upper Chattahoochee and Flint River systems. These practices include elimination of sediment runoff from land-disturbing activities, maintenance of forested buffers along stream banks, minimizing paved and other impervious surfaces, and efforts to reduce runoff of fertilizers, pesticides, and other contaminants.

Effects of Construction Activities

Sediment

There are no studies investigating the effects of sediment on the Halloween darter, but some data exist on other species in the subgenus Hadropterus. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of two related species, categorizing both as moderate (*P. nigrofasciata, P. sciera*). Walters et al. (2003) investigated the relative effects of urbanization-driven sedimentation on “endemic highland” species (described as narrowly distributed, often specialized, and sensitive to habitat alteration) and “cosmopolitan” species (described as widespread, generalist, and tolerant of human disturbance). Walters et al. found that as turbidity and bedded sediments increased, the relative richness and relative abundance of endemic highland species, including the closely related *P. kusha* and *P. palmaris*, decreased while the relative richness and abundance of cosmopolitan species, including the related *P. nigrofasciata*, increased.

The greater abundance of *P. nigrofasciata*, relative to the Halloween darter, in portions of their range with generally higher levels of fine substrate composition, suggests that the Halloween darter is more sensitive to sedimentation (Marcinek 2003, Freeman et al. 2008). This is supported by their almost exclusive occurrence in shoal habitat (Freeman et al. 2008).

As a benthic invertivore, the Halloween darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. If the Halloween darter is shown to be a sand- or gravel-spawner (like many darters), its 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.

Based on its reliance on shoal habitats and strong association with coarse substrates (Hill 1996, Marcinek 2003), the overall sediment sensitivity of the Halloween darter is categorized as intolerant (1).

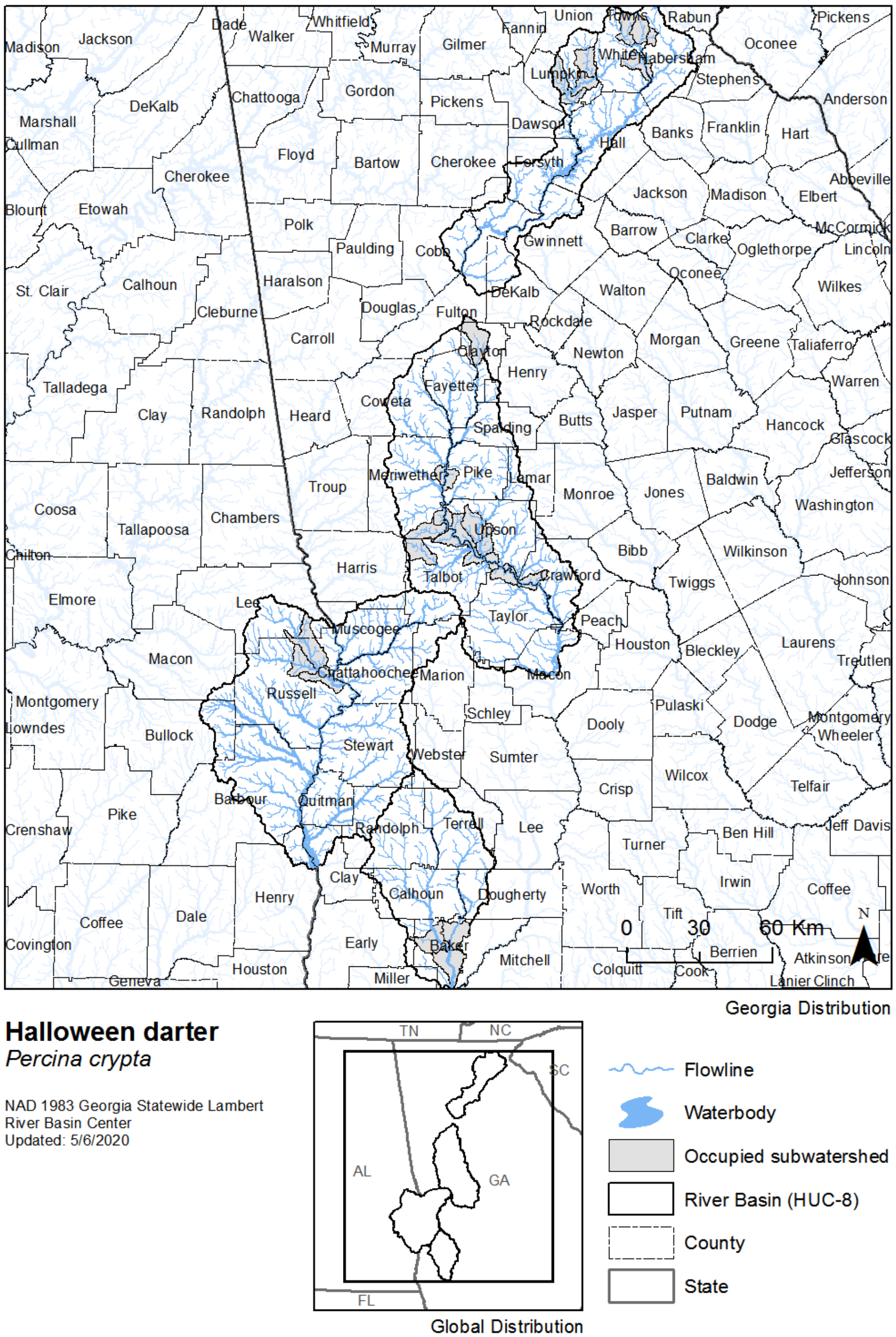
Pollutants

There are no studies investigating the effects of construction- or roadway-derived pollutants on the Halloween darter, but some data exist on other members of the subgenus *Hadropterus*. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of two related species, categorizing both as moderate (*P. nigrofasciata, P. sciera*). 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 *E. nigrofasciata* increased as urbanization of the Little Uchee creek increased from 8-13%.

Because the Halloween 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. If it is shown to be a sand- or gravel-spawner (like many darters), Halloween darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

While evidence on closely related species is mixed, its life history traits suggest a degree of sensitivity. Therefore the pollutant sensitivity of the Halloween darter is categorized as somewhat intolerant (3).

Figure 54. Map. Range map of the Halloween darter.



HIGHSCALE SHINER

Species

Highscale Shiner, *Notropis hypsilepis*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999e): The highscale shiner is a slender, compressed minnow reaching 64 mm (2.5 in) total length. It is characterized by large eyes set high on the head, a small subterminal mouth, and a blunt snout. The dorsum is pale yellow, with the uppermost scales darkly outlined. A broad, clear stripe lays over a narrower, dusky stripe along the sides. This dark lateral band continues onto the snout. At the base of the caudal fin is a wedge-shaped spot that is distinctly separated from the lateral stripe. The anterior lateral-line scales are elevated, meaning that the exposed portion of the scale is much higher than wide. Lateral line scales are also punctuated with black pigment. There are 7 anal fin rays and a pharyngeal tooth count formula of 2-4-4-2.

Life History

Little is known about the life history of the highscale shiner. Individuals likely spawn from March to June based on tuberculate specimens (Boschung and Mayden 2004). Highscale shiners are thought to be benthic fish (Lee et al. 1980) and are likely drift-feeding insectivores (Freeman et al. 1999). They are frequently found over sandy substrate near the confluence of small streams and larger rivers (Boschung and Mayden 2004), and more generally occur in runs and pools over bedrock or sand (Freeman et al. 1999). While its reproductive behavior has not been documented, the highscale shiner may be a broadcast spawner like the closely related *N. chalybaeus* (Marshall 1946).

Number, Reproduction, Distribution

The highscale shiner is found primarily above the fall line in the Chattahoochee and Flint river drainages of Georgia and Alabama (Freeman et al. 1999e). Most captures have been downstream from Lake Lanier in the Chattahoochee River basin. Detections of this species from a Tallulah River tributary within the Savannah River drainage in Georgia represent a likely introduction (Freeman et al. 1999e). Total adult population size of the highscale shiner is unknown. This species is generally uncommon. In Alabama, populations are generally small (Boschung and Mayden 2004).

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

Apart from some middle Chattahoochee tributaries in eastern Alabama, the entire range of the highscale shiner lies within Georgia. The status of this species has not been rigorously assessed, but the species is widely distributed in the Piedmont portions of the Flint and Chattahoochee River systems (below Lake Lanier). The species is more sparsely distributed upstream of Lake

Lanier and most records in this area pre-date the 1960s. The Tallulah River system record dates to 1955.

Conservation

Highscale shiners have a global conservation ranking status of G3, a Georgia state conservation ranking status of S3, and are 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. 1999e):

Conserving populations of the highscale shiner depends on maintaining and restoring habitat and water quality in tributaries and the main channels of the upper Chattahoochee and Flint river systems. It is essential to minimize sediment runoff from land-disturbing activities such as roadway and housing construction, maintain forested buffers along stream banks, minimize inputs of contaminants such as fertilizers and pesticides, and maintain natural patterns of stream flow.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the highscale shiner's tolerance to suspended sediment as moderate. Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species decreased with increasing turbidity and bedded sediments, including the closely related *N. xaenocephalus*.

Because the highscale shiner likely feeds on terrestrial and aquatic insects in drift, its foraging efficiency may be reduced and the abundance of the aquatic portion of its prey base may be reduced by the effects of sediment. If the highscale shiner is shown to be a broadcast spawner, its reproduction may be sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae.

Considering the limited direct- and traits-based information per Meador and Carlisle, the sediment sensitivity of the highscale shiner is categorized as moderate (2).

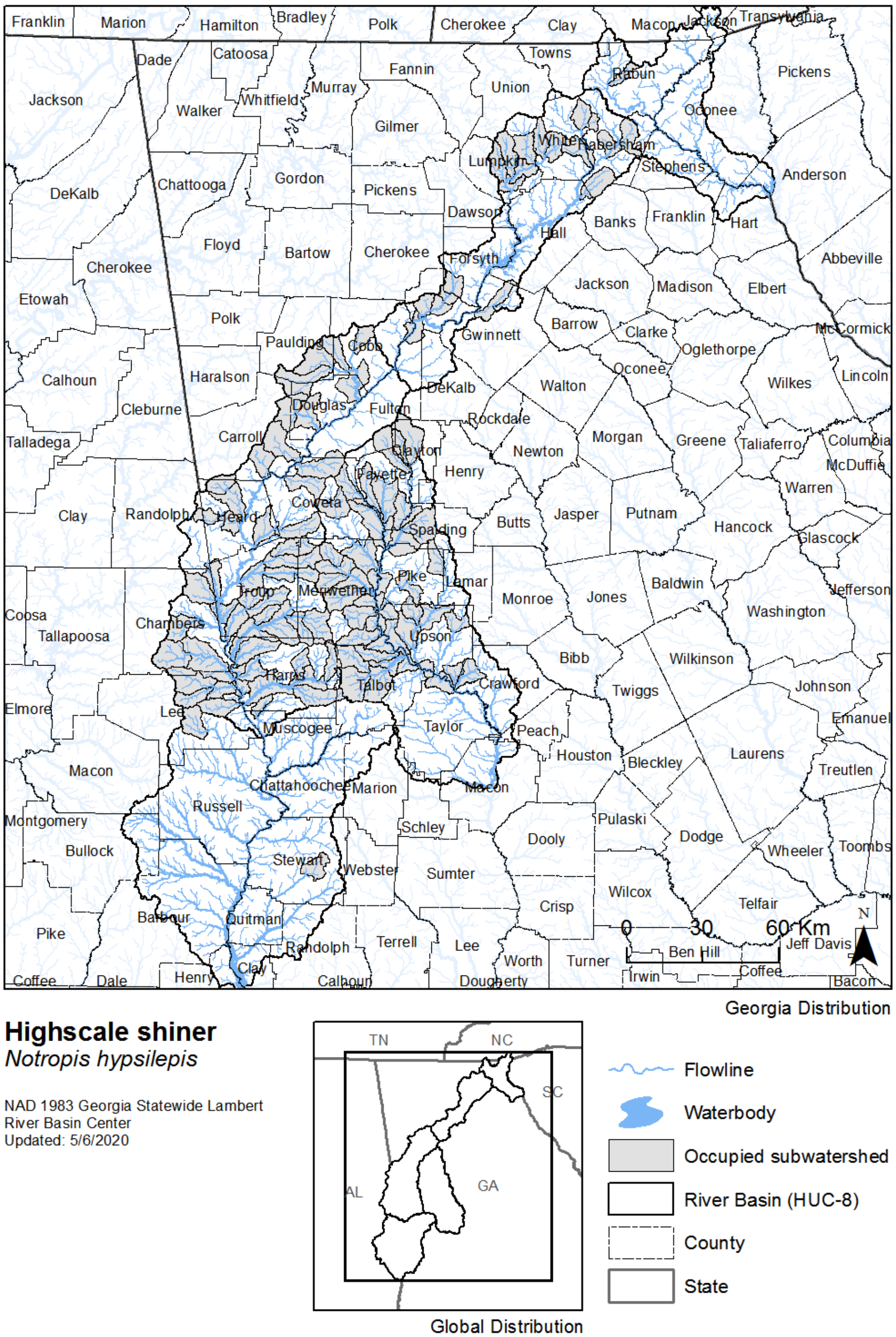
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the highscale shiner's tolerance to specific conductivity as intolerant.

As a potential broadcast spawner, the early life stages of this species are more likely to come into direct contact with sediment-bound pollutants. As a likely drift-feeding insectivore, it feeds at a low trophic level and its dietary exposure to roadway-associated pollutants is likely to be relatively low.

Based on the classification by Meador and Carlisle, the pollutant sensitivity of the highscale shiner is categorized as very intolerant (2).

Figure 55. Map. Range map of the highscale shiner.



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