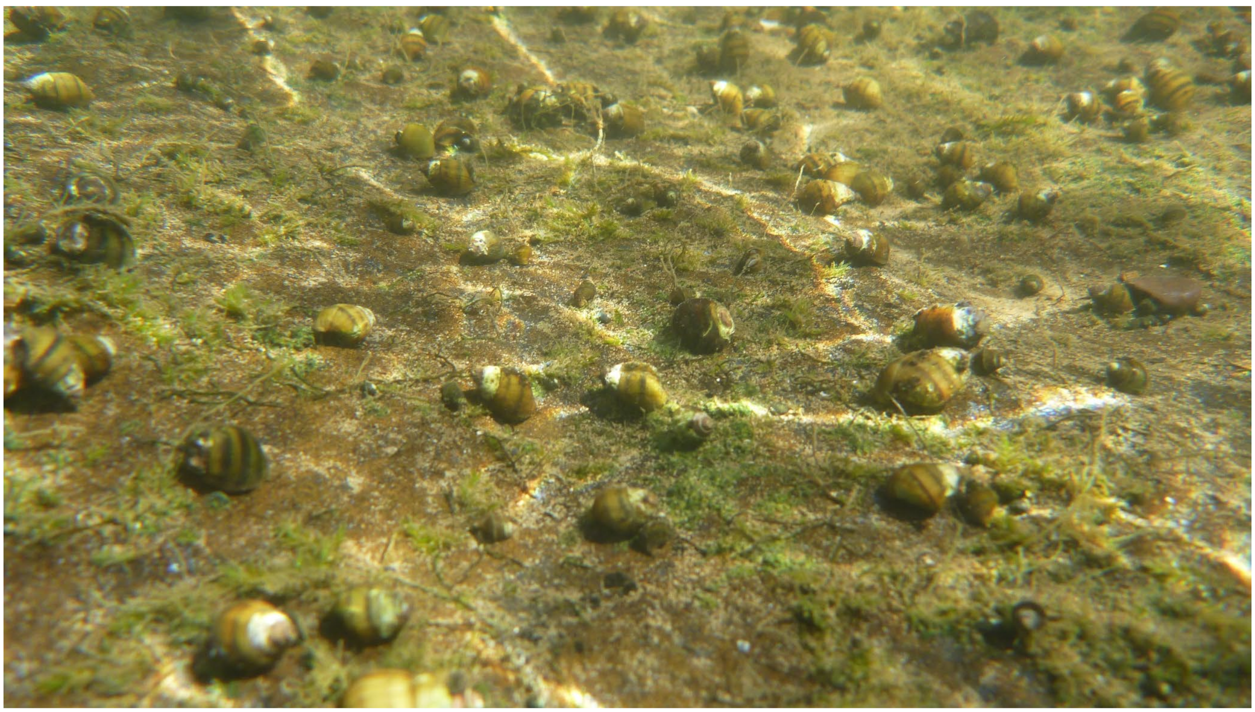
Species Status Assessment Report for the Oblong Rocksnail Version 1.0



Assorted freshwater snails (Pleuroceridae) from the Cahaba River, old Marvel Slab Site, Living River Property, Bibb County, AL October 19, 2016. Photo by Paul Johnson, Alabama Department of Conservation and Natural Resources.

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U.S. Fish and Wildlife Service
Atlanta, GA

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Species Status Assessment Report or the
Oblong Rocksnail (*Leptoxis compacta*)
Prepared by the
U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

The oblong rocksnail (*Leptoxis compacta* Anthony, 1854) is a freshwater snail native to the Cahaba River in Alabama (p. 122). After the species was not observed in a 1992 survey of the Cahaba River Basin (Bogan and Pierson 1993, p. 28), it was presumed extinct in 1997 by Neves et al. (p. 62) and then declared extinct in 2000 by the International Union for Conservation of Nature (IUCN) (Bogan 2000, p. 2). Upon its rediscovery in 2011, it appears to be abundant within a limited reach, and is located entirely in a 9.2 km reach of the Cahaba River in Alabama. Genetics work reveals recent evidence of a bottleneck; however, the oblong rocksnail still shows similar genetic diversity to round rocksnail (*Leptoxis ampla*), a species that is currently in the same genus as the oblong rocksnail (Wright *et al.* 2020, p. 7).

Future threats to the species are informed by the linear arrangement of the current range. The most likely threats relate to declining water quality -- either short-term and catastrophic, or long-term, resulting in conditions incompatible with survival or reproduction. Additionally, the combined effects of development and climate change are expected to cause flashier flood events and decreased flows in summer. The species also remains susceptible to a single pollution (e.g., fuel) or siltation event due to its highly restricted range (Whelan *et al*. 2012, p. 4) and single-channel linear arrangement; however, the probability of another fuel spill is small.

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ACRONYMS

ACRONYM OR ABBREVIATION	MEANING
Act	Endangered Species Act
ADCNR	Alabama Department of Conservation and Natural Resources
ADEM	Alabama Department of Environmental Management
BAU	Business as Usual
CRBCWP	Cahaba River Basin Clean Water Partnership
CRBPSC	Cahaba River Basin Project Steering Committee
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
FR	Federal Register
FSC	Friends of Shade Creek
HCA	High Consequence Area
IUCN	International Union for Conservation of Nature
LULC	Land Use/Land Cover
MS4	Municipal Separate Stormwater Sewer Systems
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination Syste
NRC	National Response Center
PHMSA	Pipeline and Hazardous Material Safety Administration
RCP	Representative Concentration Pathway
RPCGB	Regional Planning Commission of Greater Birmingham
SLEUTH	Slope, Land Use, Excluded Area, Urban Area, Transportation, Hillside Area Model
SSA	Species Status Assessment
SWAT	Soil and Water Assessment Tool
TMDL	Total Maximum Daily Load
WLA	Waste Load Allocation
WQC	Water Quality Criteria
WWTP	Wastewater Treatment Plant

CHAPTER 1. INTRODUCTION

The oblong rocksnail (*Leptoxis compacta* (Anthony 1854)) is a freshwater snail native to the Cahaba River in Alabama (p. 122). The oblong rocksnail was petitioned for listing under the Endangered Species Act of 1973, as amended (Act), in 2016 (82 FR 60362). A Species Status Assessment (SSA) for the oblong rocksnail has been completed to evaluate the species' current and future viability. The SSA framework (Service 2016, entire; Smith *et al.* 2018, entire) is intended to support an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA Report for the oblong rocksnail is intended to provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered. However, the SSA Report does not result in a decision by the Service on whether this species should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the oblong rocksnail. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the *Federal Register* (FR), with appropriate opportunities for public input.

We have determined what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios. In conducting this analysis, we took into consideration the likely changes that are happening in the environment – past, current, and future – to help us understand what factors drive the viability of the species. For this assessment, we generally define viability as the ability of the oblong rocksnail to sustain populations in natural river systems over time. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Smith *et al.* 2018, entire).

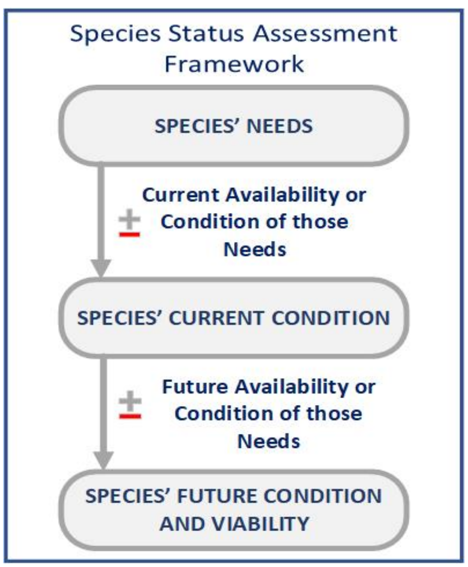

Figure 1. Species Status Assessment framework.

- **Resiliency** is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature or rainfall), periodic disturbances within the normal range of variation (floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of stochastic events.

- **Redundancy** is the ability of a species to withstand catastrophic events. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely. Redundancy is about spreading the risk and can be measured through the duplication and broad distribution of resilient populations which are connected across the range of the species. The larger the number of resilient populations the species has, distributed over a larger area, the better chances that the species can withstand catastrophic events. For aquatic species, populations in tributaries or other river systems may be important.

- **Representation** describes the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments-- referred to as adaptive capacity--is essential for viability, as species need to continually adapt to their continuously changing environments. Species adapt to novel changes in their environment by either moving to new, suitable environments, or by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change. The latter occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift.

To evaluate the biological status of the oblong rocksnail both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3Rs). This SSA Report provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species. This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future risk factors to the oblong rocksnail.

CHAPTER 2. LIFE HISTORY AND BIOLOGY

In this chapter we provide basic biological information about the oblong rocksnail, including its taxonomic history, genetics, morphological description, and known life history traits. Here we report those aspects of the life history of the oblong rocksnail that are important to our analysis.

2.1. Taxonomy

The oblong rocksnail (*Leptoxis compacta*) is a Pleurocerid snail, which are operculate snails that breath through a highly vascularized mantle (Lydeard *et al.* 1997, p. 117). Pleurocerids are the second most diverse group of North American freshwater snails, and 79 percent of known species are imperiled (Johnson *et al.* 2013, p. 253). The genus *Leptoxis* was once widespread in the southeastern United States. In the last 80 years, 10 of 23 *Leptoxis* species have gone extinct (Whelan *et al.* 2015, p. 86). The oblong rocksnail was described as *Melania compacta* Anthony 1854, from the Cahaba River in Alabama. It was later moved to *Lithasia* Haldeman 1840, corrected to Chenu 1840 (Morrison 1954, p. 362) by Tryon (1873, p. 36), followed by placement in *Anculos*a Say 1821, by Goodrich (1922, p. 49), and finally to *Leptoxis* Rafinesque 1819 by Morrison (1954, pp. 361-362), which was later reinforced by Burch and Tottenham (1980, p. 154) and subsequent authors.

The currently accepted classification is:

Phylum: Mollusca
Class: Gastropoda
Order: Neotaenioglossa
Family: Pleuroceridae
Species: *Leptoxis compacta*

2.2. Morphological Description

The oblong rocksnail is a freshwater snail with an ovate-conic, smooth, thick and yellowish-green shell (Anthony, 1854, p. 122). Oblong rocksnails grow to about 0.6 inches (15 millimeters (mm)) shell height. The external tissue is yellow, mottled with black, and includes prominent black bands in the middle of the proboscis, as well as on both eyes (Whelan *et al.* 2012, p. 1). The radula (a structure used for scraping or cutting food) is often used to distinguish snails in the family Pleuroceridae. The radula of the oblong rocksnail is distinct from other *Leptoxis* species in the Cahaba River, with a widely convex basal margin of the rachidian tooth, a blunt central cusp flanked by 4–5 denticles, and a lateral tooth with one larger rectangular central cusp flanked by 4–5 outer denticles and 3–4 inner denticles (Whelan *et al.* 2012, p. 3).

2.3. Life History

Snails in the family Pleuroceridae are dioecious (have separate sexes) and generally reach sexual maturity in the wild after one or two years (Aldridge 1982, p. 197; Whelan 2013, p. 73). The mechanism of reproduction is unknown; males lack a penis and sperm transfer has not been observed (Whelan *et al.* 2015, p. 85). Warming temperatures appear to serve as a cue to begin and end egg laying; oviposition in laboratory conditions ceased when the daily maximum water temperature reached 29 degrees Celsius (°C) (84 degrees Fahrenheit (°F)) (Whelan *et al*. 2012, p. 3). Females lay eggs either singly or in lines on the undersides or vertical sides of hard surfaces below the water line in early spring through May (Whelan *et al*. 2012, p. 3; Whelan *et al.* 2015, pp. 86, 88). Eggs of species in the genus *Leptoxis* take about 14 days to hatch, depending on water temperature (Whelan 2013, p. 80). Females mate with multiple males in a spawning season and are not known to store sperm long term (i.e., over the winter) (Whelan and Strong 2014, p. 993; Whelan 2022, personal communication). Pleurocerid snails live between two and six years, depending on the species, but the specific life span is not known for the oblong rocksnail (Whelan 2013, p. 73). Pleurocerids often do not lay eggs under lab conditions if snail density is low (Whelan *et al.* 2015, p. 87); however, it is not known if this also occurs with wild snail populations.

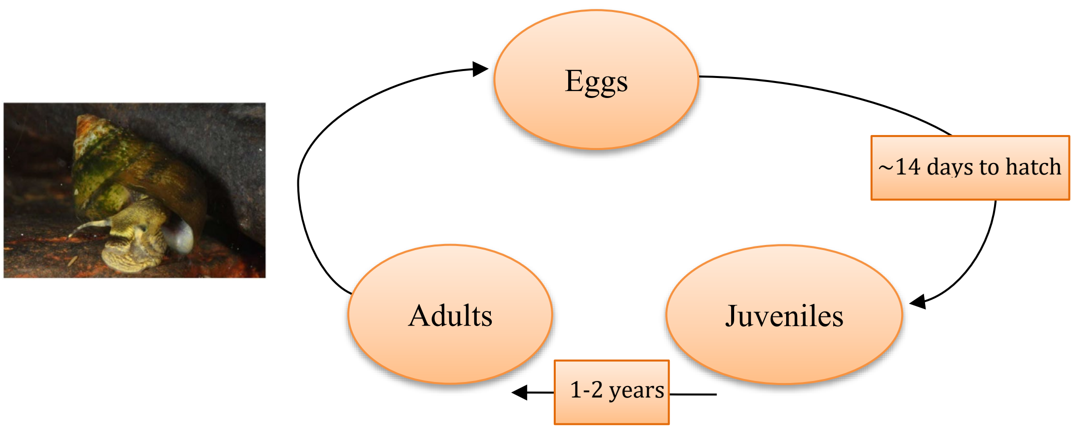

Figure 2. Life history of oblong rocksnail. Adult oblong rocksnail image (Whelan *et al.* 2012, p. 4).

2.4. Genetic Diversity

Oblong rocksnail genetic diversity has been compared to other species of *Leptoxis* at the population and species levels (Wright *et al.* 2020, Entire). At the population level, the oblong rocksnail exhibits relatively high genetic diversity, compared to other species of *Leptoxis.* However, because this species has only a single population, genetic diversity is low at the species level (Wright *et al.* 2020, p. 1), likely as a result of extreme range reduction. Genetic studies corroborate the evidence of population decline, indicating relatively recent genetic bottlenecks (Wright *et al.* 2020, p. 1). Despite this, the species retains a relatively high amount of genetic diversity with similar levels of heterozygosity as the round rocksnail (*L. ampla*), a pleurocerid with a wider range (Wright *et al.* 2020, p. 7). However, research shows that they should not be in the same genus (Whelan 2022, personal communication).

CHAPTER 3. HISTORICAL AND CURRENT DISTRIBUTION

3.1. Historical Range and Distribution

The Cahaba River, a tributary of the Alabama River, is the longest free-flowing river in Alabama (Dosdogru *et al*. 2020, p. 2). The river passes through two physiographic zones: the Ridge and Valley and the Coastal Plain, which are separated by the Fall Line (Onorato *et al.* 2000, p. 48). The geography changes from mountainous regions directly to coastal plain, which creates a unique habitat and significant biodiversity. This basin supports at least 16 pleurocerid species, eight of which are endemic (ADWFF 2017, pp. 9-13), including the oblong rocksnail. Historically, the species was most abundant in the central section of the Cahaba River at Lily Shoals in Bibb County, Alabama, extending from Centerville, Alabama, upstream to the confluence with Buck Creek, approximately 50 river miles (~80 km), and into lower Buck Creek (Whelan *et al.* 2012, p. 2) (Figure 3).

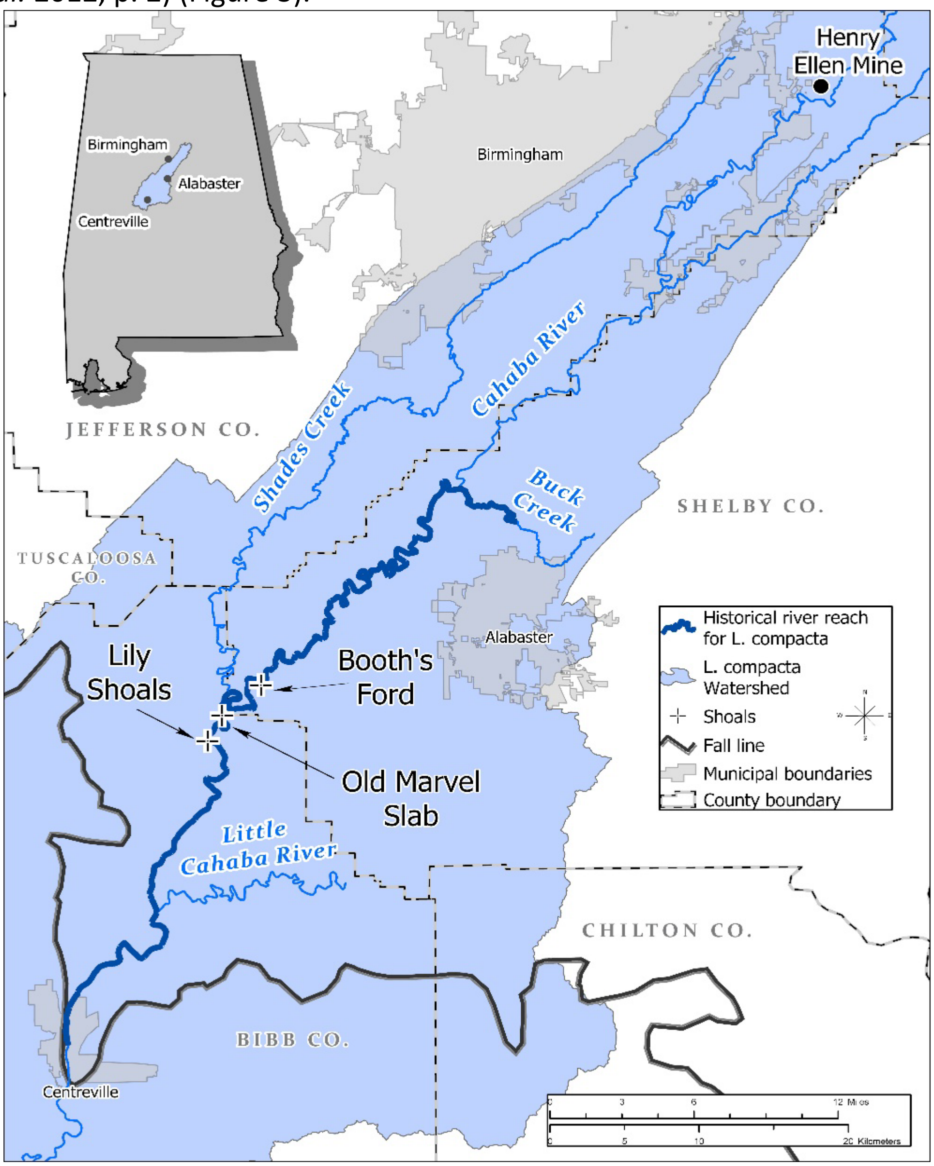

Figure 3. Historical range of oblong rocksnail (Source: FWS).

It is unlikely the species historically occurred downstream of Centerville, which is near the Fall Line. Many species are limited to either above or below the Fall Line due to a dramatic shift in the underlying geological structure, resulting in dramatic aboveground habitat changes (CRBPSC 2000, p. 11). Streams above the Fall Line are generally swift, due to higher gradients, whereas streams below the Fall Line are generally slower, have soft substrates, and have lower gradients (CRBCWP 2013, p. 11). The presence of fauna adapted to these distinct physiographic zones is a major reason for the high faunal diversity that has been historically present in this drainage system (Onorato *et al.* 2000, p. 48).

By 1935 the species' range was contracting, as historical reports describe the oblong rocksnail as occurring in "immense numbers" near Lily Shoals in the late 1800's, but only a few individuals were found in 1935 (Goodrich 1941, p. 25). The oblong rocksnail was declared extinct in 2000 (Neves *et al.* 1997, p. 62; Turgeon *et al.* 1998, p.65; Bogan 2000, entire), as it had not been seen in over 70 years despite repeated surveys (Whelan *et al.* 2012, p. 1), but was rediscovered in 2011 (Whelan *et al.* 2012, entire).

There is a historical report of the species from near Henry Ellen Mine (Goodrich 1941, p. 25), which is northeast of Birmingham. This location is quite a bit upstream, approximately 38 river miles (61.2 km) from the confluence with Buck Creek (Padgett 2021, personal communication), currently considered the most upstream extent of the species' distribution. Because the identification cannot be verified through museum specimens and the location is so disjunct from the known, verified range (Johnson and Whelan 2020, personal communication), we are not considering it to be part of the historical range of the oblong rocksnail.

3.2. Current Range and Distribution

Currently, the oblong rocksnail occurs in about 5.7 river miles (9.2 km) of the Cahaba River (see Figure 4 below) from Old Marvel Slab upstream to Booth's Ford (Wright *et al*. 2020, p. 6). More than 30 individuals were found at the site of rediscovery – an unnamed shoal upstream of the Cahaba River and Shades Creek confluence in Shelby County, Alabama, in 2011 (Whelan *et al.* 2012, p. 2). This site also contained all gastropods known to this section of the Cahaba River, including the round rocksnail, a related, federally threatened species. In 2019, the oblong rocksnail was found downstream 1.1 miles (1.8 km) and upstream 2.9 miles (4.8 km) at Booth's Ford (Wright *et al.* 2020, p. 13) relative to the site of rediscovery. It remains sparse and hard to detect at the upstream location, but at other locations it is considered locally abundant (Wright *et al.* 2020, p. 4).

Three putative oblong rocksnails were found at Belle Ellen Shoals, 5.5 miles (8.9 km) downstream of the known current range (Johnson 2019, p. 1), but because identification was uncertain and the species has not been found at this location since (Wright *et al.* 2020, pp. 8-9), we are not currently considering this site to be part of the known occupied range of the species.

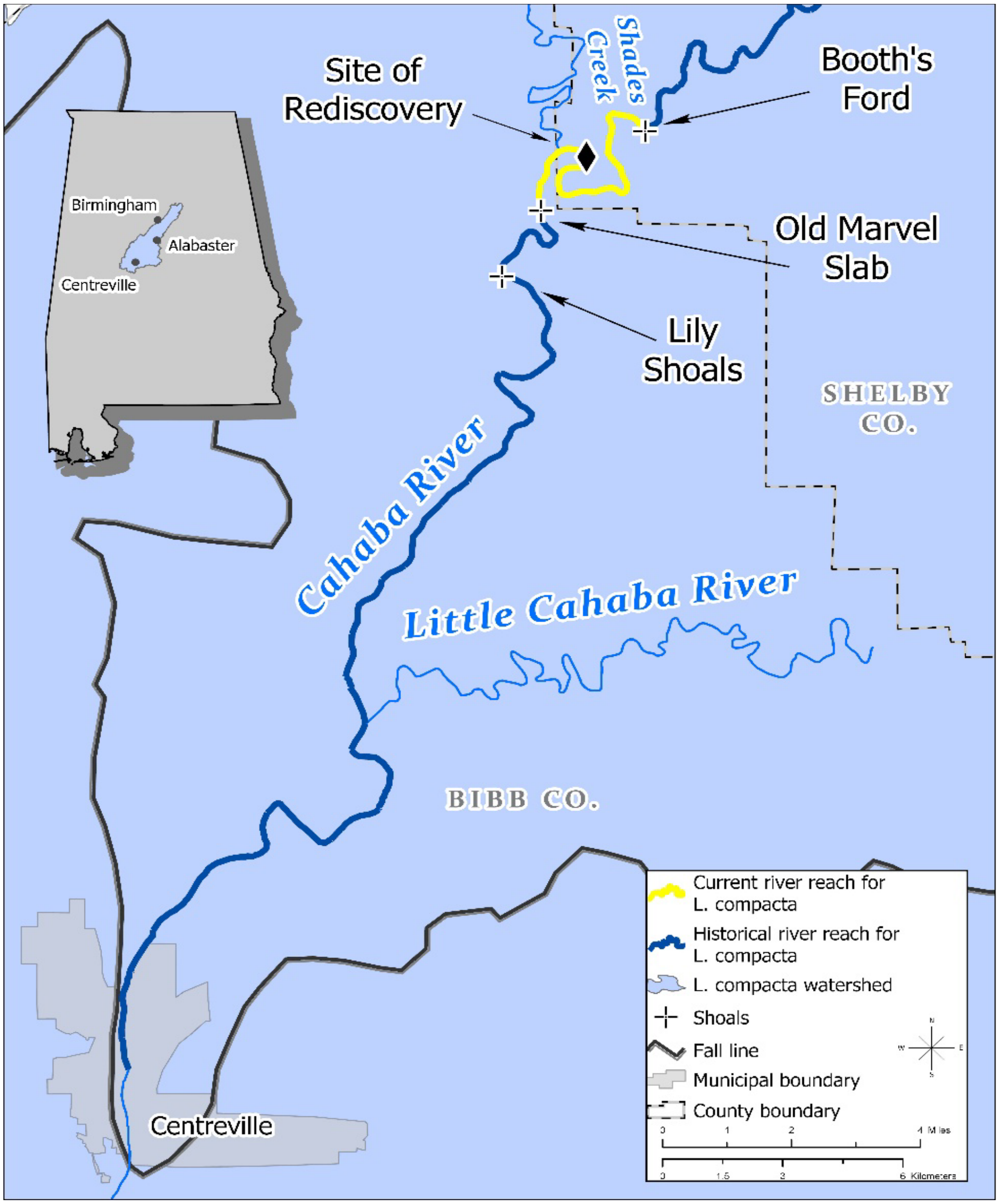

Figure 4. Current distribution of the oblong rocksnail (Source: FWS).

CHAPTER 4. OBLONG ROCKSNAIL NEEDS (INDIVIDUAL- AND SPECIES-LEVEL)

As discussed in Chapter 1, for the purpose of this assessment, we define **viability** as the ability of the species to sustain populations in the wild over time; in this case, 40 years, which is the extent of the SLEUTH model. Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its **resiliency**, **redundancy**, and **representation** (the 3Rs). Using the current and future condition of the 3Rs, we thereby describe the species' level of viability over time. Here we report the individual- and species-level needs of the oblong rocksnail that inform the current condition of the species.

4.1. Individual-Level Needs

Oblong rocksnails are grazers and occur on large boulders and bedrock, typically toward the middle of the river. These large flat rocks provide periphyton for food (Miller-Way and Way 1989, p. 193; Johnson *et al.* 2013, p. 248). In general, periphyton availability, substrate composition, and water velocity appear to be important components in determining habitat suitability of Pleurocerid snails (Stewart and Garcia 2002, p. 178). Scraping of periphyton is easier from a hard substrate and contains higher concentrations of limiting nutrients such as nitrogen than other food sources (White 1978, pp. 73-74; McMahon *et al.* 1974, p.392; Brown 2001, p. 305). Observations of wild *Leptoxis* snails indicate that eggs are often laid on vertical surfaces or undersides of rocks without siltation or much vegetation (Whelan *et al.* 2015, p. 88).

Additionally, gastropods have been shown to be some of the more sensitive species to contaminants compared to other macroinvertebrate taxa and fish (Gibson *et al.* 2018, p. 244). A species currently in the same genus, the round rocksnail, has demonstrated low tolerance of several contaminants, including nickel, potassium, zinc, chloride, and sodium dodecyl sulphate (Gibson *et al.* 2018, pp. 244-247; Gibson *et al.* 2016, p. 31).

Pleurocerid snails have slow and restricted dispersal capabilities (reviewed in Huryn and Denny 1997). Recent studies show pleurocerid snails have much greater downstream movement than upstream (Whelan *et al.* 2019, pp. 1593, 1603; Redak *et al.* 2021, p. 643), suggesting it would be difficult for the species to move to upstream sites (i.e., suitable shoals) or into any habitat that might occur in tributaries on their own, should additional suitable habitat become available.

Table 1. Resource needs of the oblong rocksnail by life stage.

Life Stage	Resource Needs (Habitat)	References
Eggs Spring and summer ~14 days to hatch 0.3 mm (0.01 inch)	• Eggs laid in lines on hard surfaces in fresh water • Required vernalizing period (cold period with subsequent warm up), egg-laying beginning on or about 22°C (71 °F) ceasing at 29 °C (84 °F)** • Cumulative degree-days (14) to hatch • Low levels of contaminants*	Whelan *et al.* 2012, p. 3 Whelan 2013, p. 73 Gibson *et al.* 2016, p. 233 Gibson *et al.* 2018, p. 244
Juveniles ~1- 2 years	• Fresh water, with low levels of contaminants* • Scrape periphyton attached to rocks	Miller-Way and Way 1989, p. 193 Gibson *et al.* 2016, p. 233 Gibson *et al.* 2018, p. 244
Adults 3-5 years	• Fresh water, low levels of contaminants* • Scrape periphyton attached to rocks	Miller-Way and Way 1989, p. 193 Gibson *et al.* 2016, p. 233 Gibson *et al.* 2018, p. 244

*Refer to section 6.2 on contaminants for specific levels tested in this and related species.
** Data for temperature range based on 13 *Leptoxis* species in Whelan 2013 (pp. 95-96). Oblong rocksnail does not have a listed start temperature, but approximate end temperature was 29 °C.

4.2. Species-Level Needs

For the species to maintain viability, the oblong rocksnail must be resilient to both stochastic events (resiliency) and catastrophic events (redundancy), as well as adapt to changing environmental conditions (representation). In this section, species needs are described in terms of the 3Rs. Stochastic events that have the potential to affect the oblong rocksnail population include water quality changes and changes to habitat. First described are population and habitat factors influencing the resiliency of populations and ability of the population to inhabit the reach, followed by requisites for maintaining representation and redundancy.

Population Factors

Abundance – The species persisted at low numbers in the Cahaba throughout the 20th century, as evidenced by the limited genetic diversity observed in the species, which indicates the species experienced a bottleneck (Wright *et al.* 2020, p. 12). Abundance must be sufficient for genetic diversity to be maintained and for the overall population in the stream reach to recover from any one stochastic event. Abundance should be stable or increasing for populations to be resilient. Surveys to date have not estimated abundance; however, the species appears to be abundant within the presently occupied reach, except at the northernmost site where it is said to be sparse.

Reproduction and Recruitment – A resilient population of oblong rocksnails must be reproducing and recruiting young individuals into the reproducing population. Population size and abundance reflects previous influences on the population and habitat, while reproduction and recruitment reflect population trends that may be stable, increasing or decreasing. We have no data on reproduction or recruitment of the population; therefore, maintenance of the population at locations where it has been detected in the recent past indicates recruitment is occurring within the population.

Occupied Stream Length/Dendritic networking – The oblong rocksnail needs to occupy sufficient stream length and in enough tributaries such that stochastic events that affect the population in the mainstem do not eliminate the entire population of the species. Occupying branches of a river network (dendritic networking) increases habitat diversity and allows the species to repopulate from those tributaries should a spill, flood, or drought create unsuitable habitat conditions in the Cahaba mainstem. Because the potentially habitable reach is relatively short and within the mainstem, increasing the complexity of the occupied reach may prevent the oblong rocksnail from being eliminated by a single stochastic event.

Habitat Factors

Substrate and Flowing Water **–** Oblong rocksnails need large, flat boulders and bedrock for feeding and reproduction. The channel should be relatively free of fine sediment and with flows sufficient to maintain clean-swept rock surfaces for attachment, egg-laying and periphyton growth.

Water Quality – Pleurocerid snails, as a group, are sensitive to changes in water quality parameters such as sodium chloride, potassium, nickel, zinc, and pollutants. Habitats with appropriate levels of these parameters are considered suitable, while those habitats with levels outside of the appropriate ranges are considered less suitable. Further, nutrient enrichment needs to remain low enough not to result in algal blooms (see Chapter 6 for more information).

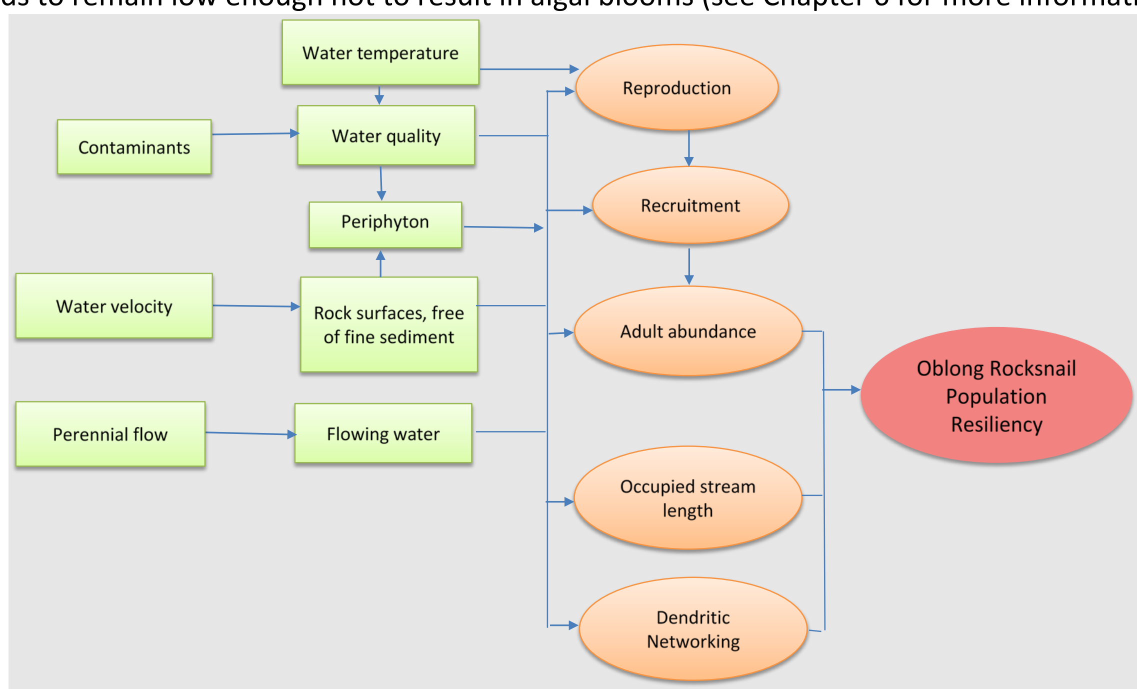

Figure 5. Oblong rocksnail population ecology factors that influence resiliency.

Representation
Maintaining representation in the form of genetic or ecological diversity is important to maintain the oblong rocksnail's capacity to adapt to future environmental changes. The species likely was genetically diverse historically, but severe range contraction and genetic drift resulted in reduced diversity at the species level. Further, recent studies show pleurocerid snails have much greater downstream movement than upstream (Whelan *et al.* 2019, pp. 1593, 1603; Redak *et al.* 2021, p. 643), indicating it would be highly difficult for the species to move great distances upstream on their own, should additional suitable habitat become available.

As an exercise to further explore the species adaptive capacity relative to climate change, we used the approach described in Thurman et al. (2020, entire) (see section 6.3 for more information). Collectively, 36 attributes were identified through their research as contributors to a species' ability to move through a landscape (shift in space) or accommodate changing climate in place, with twelve of those attributes referred to as "core attributes" to focus on for conservation decision-making if data are limited (Thurman et al. 2020, p. 522).

Redundancy
Ideally, the oblong rocksnail would have multiple resilient populations distributed throughout its range (including a tributary, e.g., Buck Creek) to provide for redundancy; this provides a safeguard against negatively affecting a large portion of the population by a catastrophic natural or anthropogenic event at a given point in time -- The more populations, and the wider the distribution of those populations, the more redundancy the species would exhibit. Species that are well-distributed across their historical range are considered less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll *et al.* 2010, entire; Redford *et al.* 2011, entire).

CHAPTER 5. CURRENT CONDITION OF THE OBLONG ROCKSNAIL

The available information indicates that the oblong rocksnail is currently restricted to approximately 11% of its historically known range in the Cahaba River. The species has been extirpated from 44.4 river miles (71.5 km) and is currently found in 5.7 river miles (9.2 km) from Old Marvel Slab upstream to Booth's Ford (Wright *et al*. 2020, p. 6). Additional survey efforts have failed to locate the species at other sites within the historical range.

Resiliency
Overall, the extant population occurs in the most intact reach of the Cahaba River, downstream of Birmingham and upstream of the Fall Line. The current condition of the factors influencing the resiliency of the oblong rocksnail population in the Cahaba River are described here.

Abundance – As discussed above, we have no abundance estimates for the oblong rocksnail. The population occurs at or above detectable limits in 5.7 miles (9.2 km) of the Cahaba River, and the species is considered locally abundant where it occurs.

Reproduction and Recruitment – As with abundance, we have no estimates of reproduction and recruitment in the oblong rocksnail population. However, the abundance of the species at occupied sites indicates recruitment is currently occurring at levels to sustain the population.

Occupied Stream Length/Stream Complexity – The oblong rocksnail occupies 5.7 miles (9.2 km) of the Cahaba River and is not known to occupy any tributaries. This limited occupied area and lack of stream complexity limits the resiliency of the population.

Substrate and Flowing Water – The oblong rocksnail occupies a reach of the Cahaba River that is downstream of the confluence of several large tributaries, including Buck Creek. The volume of water in this reach is sufficient to maintain clean-swept hard surfaces in the main channel of the Cahaba River and support periphyton such that oblong rocksnails can attach, feed, and lay eggs, resulting in an apparently stable, single population of oblong rocksnail.

Water Quality – The Cahaba River in the range of the oblong rocksnail has experienced improved water quality over the past 30 years. Improved water quality standards and reduced contaminants from urban runoff, chicken processing facilities, and municipal wastewater has resulted in higher water quality throughout the occupied reach than in the recent past. At present, levels appear sufficient to support known sites. See Chapter 6 for more information.

Representation
We consider the oblong rocksnail to have limited representation, as it is only found in one population with limited overall genetic diversity. The loss of genetic variation due to contraction may negatively impact its long-term survival (Wright *et al.* 2020, p. 10). Evidence suggests the oblong rocksnail has lost genetic diversity through both bottleneck and genetic drift (Wright *et al.* 2020, p. 12). Even in the unlikely event that additional individuals with

ancestral genes occur in unsampled populations, they would not be common; genetic bottleneck likely explains observed presence of ancestral genes, rather than recent migration, which would require populations of the species occurring elsewhere (Wright *et al.* 2020, p. 12).

Higher habitat suitability, and subsequently more rocksnails at some of the remaining sites provided for maintenance of genetic diversity despite the decline that occurred in the 20th century, and some retention of ancestral alleles (Wright *et al.* 2020, pp. 12-13). Its lowest values for genetic diversity were higher than the lowest genetic values among populations of round rocksnail, a more widespread Leptoxis species (Wright *et al.* 2020, p. 1). Genetic diversity is increased at downstream sites (Whelan *et al.* 2019, p. 1593), facilitated by much greater downstream movement than upstream movement (Redak *et al.* 2021, p. 643). This downstream-biased movement, coupled with a lack of suitable habitat upstream, results in a decline of representation at upstream sites despite recent discovery at multiple sites and a slightly expanded known distribution.

Redundancy
The oblong rocksnail has no redundancy; the species is found in one small river reach and currently has very limited ability to rebound from a catastrophic event.

CHAPTER 6. INFLUENCES ON VIABILITY

In this chapter, we evaluate the past, current, and future influences that are affecting what the oblong rocksnail needs for long term viability (refer to Chapter 4 for definition of viability). Risks including overutilization for commercial and scientific purposes, as well as disease, are typically discussed in an SSA; however, they are not known to have effects on the oblong rocksnail and are not discussed in this SSA report. Influences on water quality upstream (discussed below) in addition to a dramatic shift in habitat type downstream limit where the species likely occurred historically (CRBPSC 2000, p. 1) and continues to limit potential range expansion of the oblong rocksnail.

6.1. Water Quality Impairment

The Cahaba River has a long history of water quality issues and remediation activities (Thom *et al.* 2013, pp. 60-62). As early as 1949 issues such as high coliform counts and readings of 0.0 ppm for dissolved oxygen were recorded in Shades Creek, a tributary of the Cahaba River, related to discharges from water treatment activity (WIAC 1949, pp.79-84, 180).

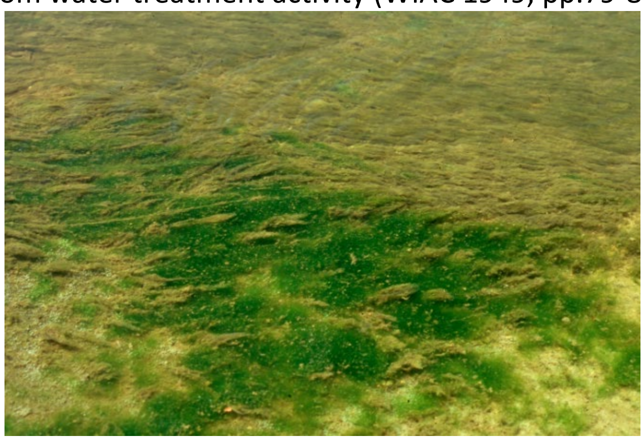

Figure 6. Algae growth at Booth's Ford in Montevallo, AL. Photo by Patrick O'Neil, 1993.

The upper portion of the watershed is largely shaded and urbanizing, while further downstream the canopy begins to open, and more sunlight reaches the river. Excess nutrients in the water provide the opportunity for excessive algae growth, which has impacted the Upper Cahaba as recently as the 1990s (seen above in Fig. 6). Excess nutrients create a toxic algae cycle (Fig. 7).

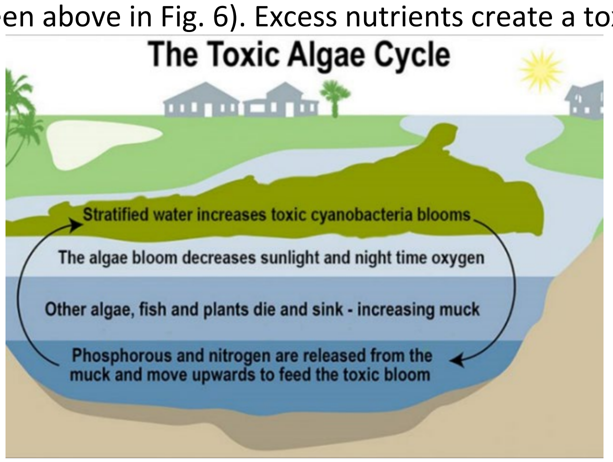

Figure 7. Toxic algae cycle (Goodwin 2020).

Between 1989 and 1994, the Geological Society of Alabama documented issues related to specific discharges in the upper watershed and impairment of whole sections of the river (see sec. 1-4 in first graph of Fig. 8). Although the habitat remained largely intact, this eutrophication affected both dissolved oxygen in section 2 and diversity in section 3 of the river where the species occurs, as evidenced by diversity measures (recorded in the second graph in Fig. 8) for the 1994 report (GSA 1997, p. 90).

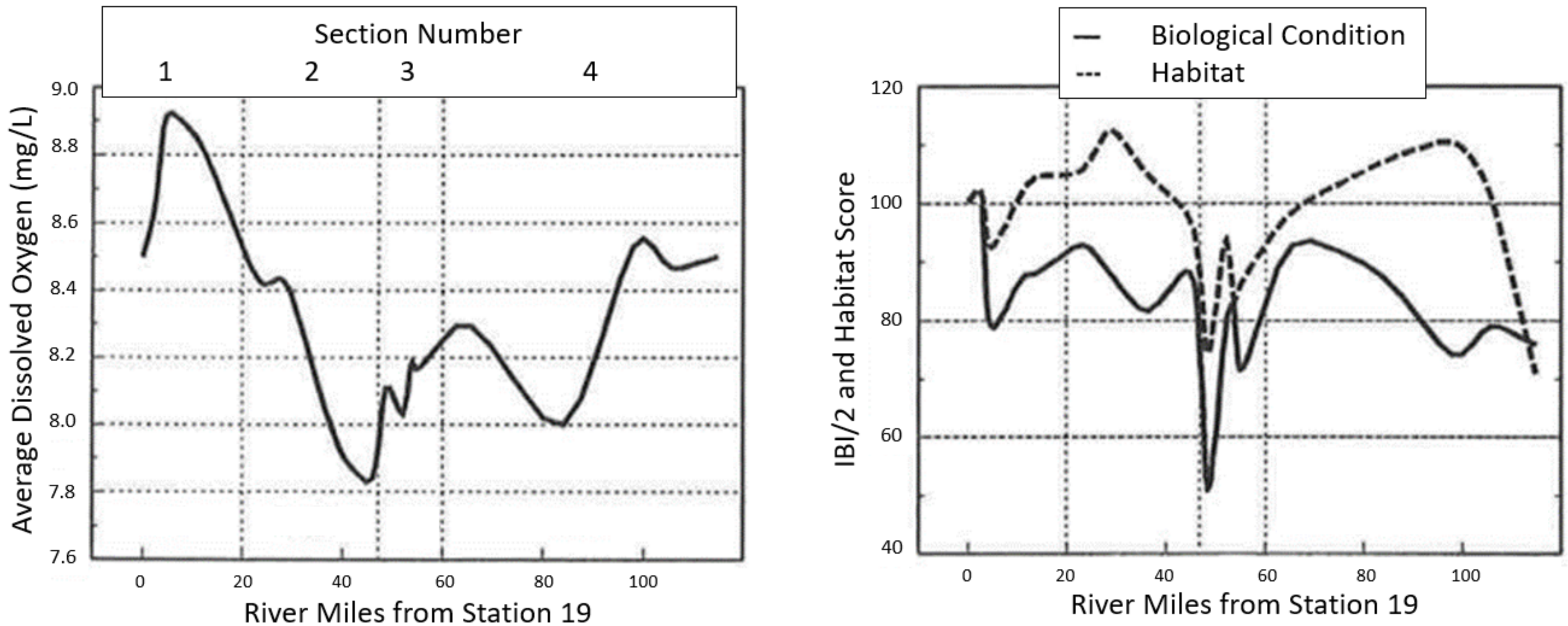

Figure 8. (LEFT) Average Dissolved Oxygen (mg/L) for river sections 1-4. (RIGHT) Diversity measures for river sections 1-4. Adapted from GSA 1997 (p. 90).

The upper Cahaba River watershed has been rapidly urbanizing since the 1990s (Dosdogru *et al.* 2020, p. 2). In 1990, there were discharge permits for three industrial facilities (including a facility for the manufacturer of fire extinguishers, another doing metal work, and a poultry packaging facility), and three coal mines (Pitt 2000, p. 73). Beyond the discharges at this time, sedimentation was recognized as a conservation challenge, as well. As recently as 2002, the Environmental Protection Agency (EPA) reported on the Cahaba River: "Because of excessive sedimentation, habitat evaluation scores in the middle reach were affected and fell into the suboptimal to marginal range. Quite apparent is the filling of crevices or spaces between the natural rock substrates by sediments thus affecting both fish and benthic macroinvertebrates." (EPA 2002, p. 31). The middle reach is also where snails were most abundant out of eight different study areas when the EPA (2002, pp. 19-20) conducted studies in the Cahaba River in spring 2002.

In recognition of these water quality challenges, EPA and the state of Alabama began working on measures to improve the water quality of the river under the auspices of the Clean Water Act. The Clean Water Act (CWA; 33 U.S.C. §1251 et seq.) regulates water quality standards for surface waters and discharges of pollutants into the waters of the U.S. The CWA made point source discharge into navigable waters without a permit unlawful in 1972. The EPA has authority to enforce the CWA, and with that authority, has developed national water quality criteria recommendations for pollutants found in surface waters and implemented various pollution control programs (i.e., wastewater standards for industry) (EPA 2021a, Entire).

Stormwater runoff containing pollutants is often transported through municipal separate stormwater sewer systems (MS4s), which discharge without treatment into local waters (See Fig. 9).

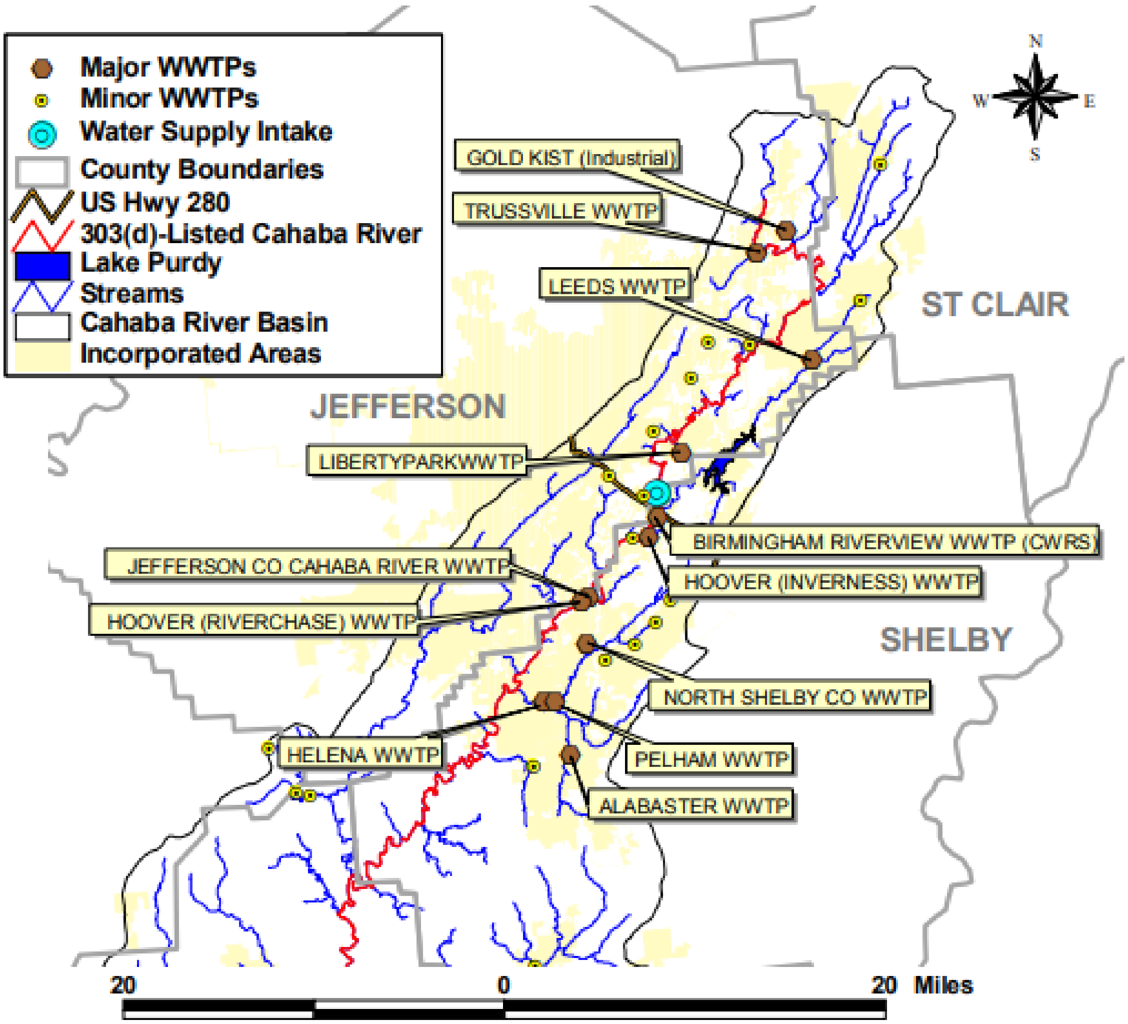

Figure 9. Locations of Major (≥1.0 MGD) NPDES-Permitted Point Source Discharges in the Upper Cahaba River Watershed (ADEM 2006).

An MS4 is designed to collect and convey stormwater owned by a public entity, which discharges to waters of the U.S.; it is not part of a combined sewer, publicly owned treatment facility, or works (EPA 2021b, entire). Administered under the National Pollution Discharge Elimination System (NPDES) permit program, MS4 permits require development and implementation of a comprehensive Storm Water Management Program (SWMP) that addresses prevention, treatment, removal, monitoring, and other measures to control the quality of stormwater that travels through storm drains to waters of the U.S. (EPA 2021c, introduction). All urban areas, as defined in the latest decennial census by the Bureau of Census, designated as a Phase II MS4 within the State of Alabama, are permitted to discharge storm water from small MS4s (ADEM 2021a, p. 1). Brent, AL, was classified as an urban cluster in the 2010 census (USCB 2010, p. 10) and is in the upper Cahaba watershed. Under new guidelines for the 2020 census, urban clusters will now be categorized as urban areas (86 FR 10237(1)). Small MS4s are defined as those “Owned or operated by the United States, a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the United States" (48 FR 14153). These permits are regulated under the NPDES system, are treated as point sources by the EPA, and receive Waste Load Allocations (WLAs) under the Total Maximum Daily Load (TMDL) program (see Fig. 10). Thereby, under the CWA, point source discharges of pollutants (including stormwater) are currently being regulated.

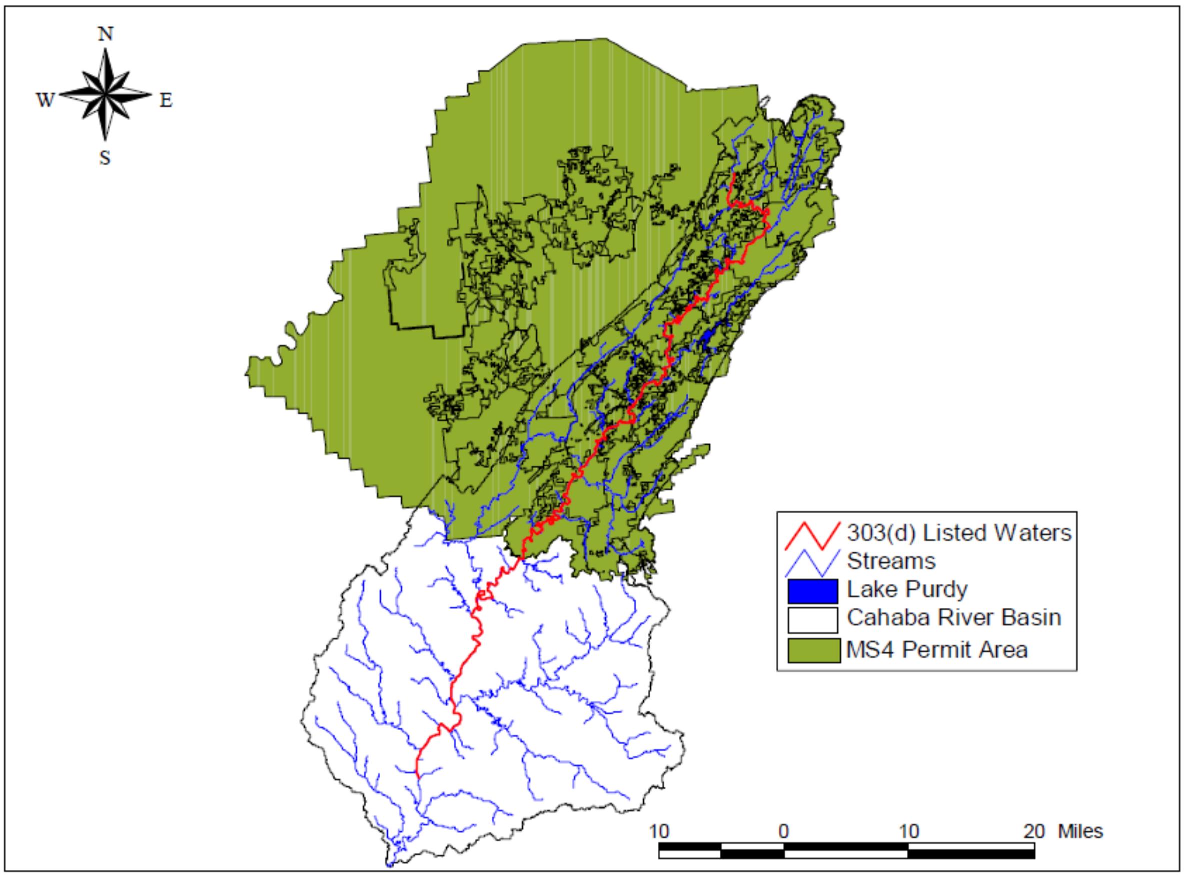

Figure 10. MS4 Boundaries pertinent to the Cahaba River Watershed (Urban Areas covered by MS4 permits within HUC 0315020205) TMDL Development (ADEM 2006, p. 59).

Excessive nutrients in the Cahaba are controlled as part of the TMDL program and largely relate to a variety of sources. A TMDL is a calculation of the maximum amount of a particular pollutant that can enter a water body and allow it to still meet water quality standards. TMDLs set pollution reduction targets, allocate load reductions to the pollutant's source, and include a margin of safety, while also accounting for variations across seasons in water quality (EPA 2021d, introduction). "Currently the TMDL for Buck Creek, Cahaba Valley Creek, and the Cahaba

River adhere to [Alabama Department of Environmental Management's] ADEM's water quality standards for the designated use classification of that stream." (City of Pelham 2021, p. 39).

In addition, there are processes in place to manage new discharges into the river from industrial sources (e.g., industrial plants, mining, and wastewater). The cities also continue to manage stormwater. Water quality has substantially improved in recent decades thanks in part to NPDES and NPDES MS4 permits in the upper watershed, the TMDL program, and a general trend towards better stormwater management and soil retention measures in the watershed. Overall, this has improved turbidity (see Figure 11 below) and improved nutrient loading near the population (ADEM 2020, Appendix E). It appears very likely that these measures will continue, though as explained later in section 6.3, climate change and future development may put additional burdens on this effort.

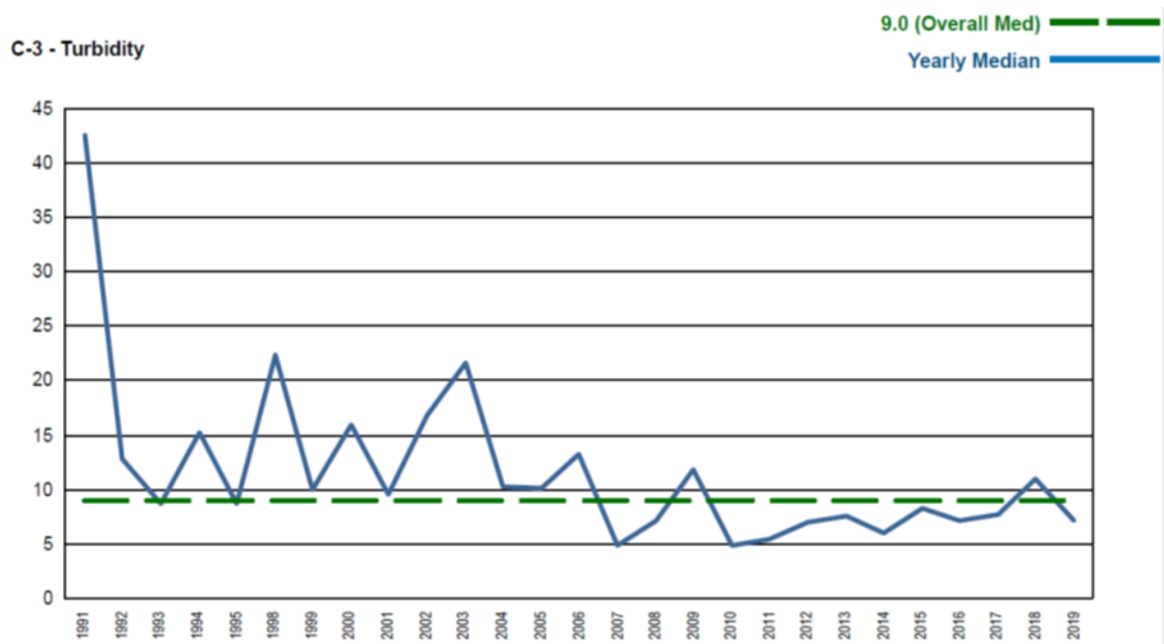

Figure 11. Trends in turbidity between 1991-2019 (ADEM 2020, Appendix E).

6.1.1. Long-term and Catastrophic Water Quality Impairment Issues

Water quality can be affected by point and nonpoint sources, and these sources may influence water quality chronically or catastrophically. Nonpoint sources of water quality impairment for the Cahaba River include urban runoff from upstream, the metropolitan area of Birmingham, roads, agricultural activities, and stormwater runoff. Point sources include spills, industrial sources, and municipal effluents. Point source discharges and land surface runoff (nonpoint pollution) can cause nutrification, decreased dissolved oxygen concentration, increased acidity and conductivity, and other changes in water chemistry that are likely to seriously impact aquatic snails (Gibson *et al.* 2016, pp. 1, 32-34; Gibson *et al.* 2018, pp. 239, 247, 249).

Water quality can be impaired through contamination or alteration of water chemistry. Contaminants, including metals, hydrocarbons, pesticides, and other potentially harmful organic and inorganic compounds, are common in urban streams. Chemical contaminants are ubiquitous throughout the environment and are a major reason for the current declining status of freshwater mollusk species nationwide (Augspurger *et al.* 2007, p. 2025). In general, oblong rocksnail and congeners are sensitive to water quality impairment; they breathe via gills which may allow toxicants to be more readily absorbed than in pulmonate gastropods, which breathe using highly vascularized respiratory surfaces (Gibson *et al.* 2018, p. 251). As it is difficult for the oblong rocksnail to move large distances, this also impairs the species' ability to survive a catastrophic water quality event by moving to an unimpaired location.

6.2. Contaminants and Sensitivity of the Oblong Rocksnail

In Alabama, chloride is common and occurs from numerous sources including oil and gas production, pesticide application, wastewater treatment plant effluent, urban runoff, and mining (Gibson *et al.* 2018, p. 240). Studies of the toxicity of chloride revealed that the round rocksnail exhibited sensitivity to chloride at concentrations 250 times less than current criteria set by the EPA and lower than average background levels in almost all watersheds in Alabama, including the Cahaba River watershed (Gibson *et al.* 2018, p. 247). Further, round rocksnail, which is currently in the same genus as the oblong rocksnail, was the most sensitive mollusk species tested, indicating species in the genus *Leptoxis* may be more sensitive overall to contaminants.

The round rocksnail, like other freshwater taxa, is very sensitive to potassium, nickel, zinc, and sodium dodecyl sulfate (a common surfactant in household detergents) (Gibson *et al.* 2016, p. 30; Gibson *et al.* 2018, pp. 249-250); this is corroborated by studies on other *Leptoxis* species who are similarly sensitive to copper and zinc (Reed-Judkins *et al.* 1997, p. 1675). The sensitivity of round rocksnail is below EPA criteria for all these chemicals (refer to summary Table 2 below).

Table 2. Contaminant Sensitivity of the Round Rocksnail (*L. ampla*) (Sources: Gibson *et al.* 2018[1], pp. 244-247; Gibson *et al.* 2016[2], p. 31; EPA 2021[3] pp. 4, 8, 11).

Contaminant	**EC50 (µg/L)[1,2]**	**Partial Kills**	**WQC – Acute[3]**	**WQC – Chronic[3]**	**Potential Source in Cahaba (Historic, Future)**
Nickel	33µg/L	N/A	470µg/L	52µg/L	Coal Mining (H)
Potassium	>1000µg/L	100 µg/L	N/A	N/A	Natural sources, industrial spills (H, C, F)
Zinc	67 µg/L	N/A	120 µg/L	120 µg/L	Urban Runoff (C, F)
Chloride	3414 µg/L	100 µg/L	860000µg/L	230000µg/L	Septic systems, landfills, fertilizers, WWTPs, other natural/human sources (H)
SDS (sodium dodecyl sulphate)	26µg/L	N/A	N/A	N/A	Unclear; widely used in shampoo, laundry, pharmaceuticals (H, C, F)

There are six large municipal wastewater treatment plants in the upper Cahaba River drainage upstream of Buck Creek with a combined permitted discharge of almost 19 million gallons per day (CRBPSC 2000, p. 4), and multiple wastewater discharges in Buck Creek with documented elevated ammonia levels (EPA 2002, p. 35). Mollusks are sensitive to ammonia, with freshwater mussels among the most sensitive of aquatic species (Augspurger *et al.* 2003, p. 2569). Nonpulmonate snails, which include gill breathers like the oblong rocksnail, have been shown to be extremely sensitive to ammonia, although slightly less sensitive than freshwater mussels (EPA 2013, p. 56; Besser *et al.* 2016, p. 33). The state of Alabama has not yet adopted the revised ammonia criteria that are more protective of these mollusks (EPA 2013, p. 67; Haslbauer 2020, personal communication).

Total phosphorus was chosen as a controlling nutrient in TMDL development, with the recommended range per EPA being "20 to 40µg/L total phosphorus" to both prevent filamentous algae growth and be protective of designated uses. Recent data for Total Phosphorus (mg/L) at station C-3 is provided in Figure 12 (below); it is the closest upstream station to the remaining population of oblong rocksnail. Between 2015 and 2020, there was increased gauge average flow, and median total phosphorus stayed under the EPA target level. However, this level is still above the upper limit for the round rocksnail. If oblong rocksnail is similarly sensitive, it could experience similar effects.

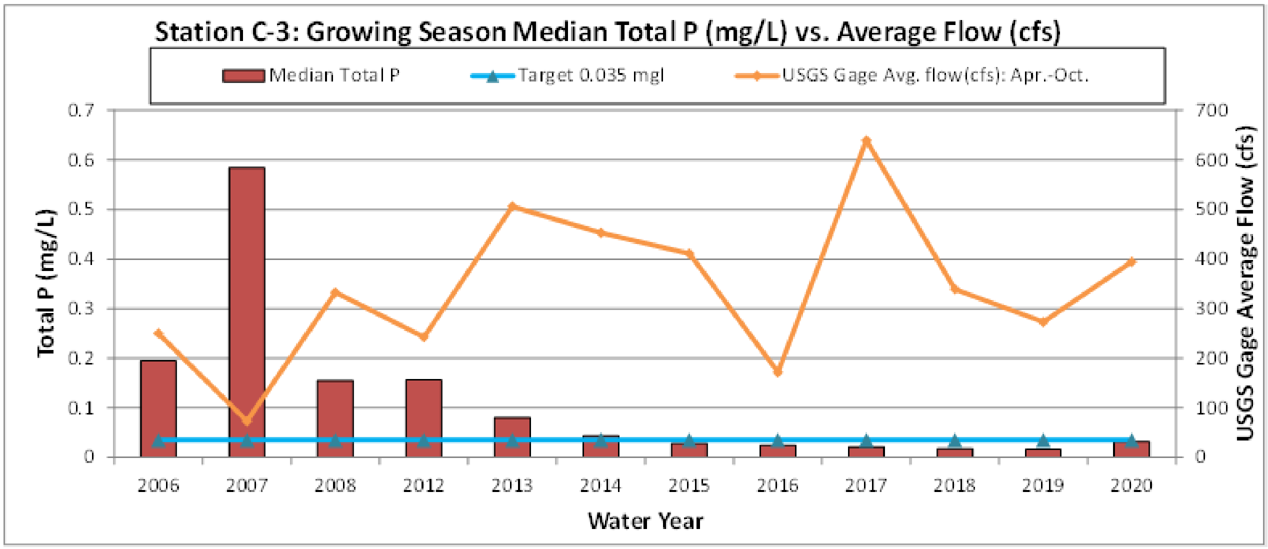

Figure 12. Total Phosphorus (mg/L) and Average Flow (cfs) by Water Year (ADEM 2021b, Entire).

Sedimentation Impacts on Oblong Rocksnail

The upper Cahaba River watershed, which drains a large part of Birmingham, AL, is rapidly urbanizing; despite the population of Birmingham decreasing between 1992 and 2011, urban cover has increased from 9.4 percent to 35.7 percent due to expansion of the metropolitan area (Dosdogru *et al.* 2020, p. 2). Sources of sedimentation include, but are not limited to, several aspects of urbanization: devegetation, logging, road maintenance, impoundments, and impervious surfaces (EPA 2021e, unpaginated). Excessive sediments are believed to impact riverine snails requiring clean, hard shoal stream and river bottoms by making the habitat unsuitable for feeding or reproduction.

Similar impacts resulting from sediments have been noted for many other components of aquatic communities. For example, sediments have been shown to abrade and/or suffocate periphyton (organisms attached to underwater surfaces, upon which snails may feed); affect respiration, growth, reproductive success, and behavior of aquatic insects and mussels; and affect fish growth, survival, and reproduction (Waters 1995, p. 5-7, 74-78, 79-118). The TMDL for sediment was introduced in 2013 and is currently being met within the section of the river where the species occurs.

Catastrophic Spills

Coalbed methane extraction results in saline production-water that at one point was discharged directly to receiving channels. While coalbed methane wells are common in the Cahaba River basin – there were approximately 400 wells in 2008 (EPA 2011, pp. 3-22) (See Fig. 13) -- At present no discharges of this type go directly to the Cahaba (O'Neil 2021, personal communication) and it is anticipated that future discharges of this type would require a permit to ensure integrity of the Cahaba for its designated use. It is still possible a spill could occur from these sources, however the probability of such an event, its volume and nature are unknown at this time.

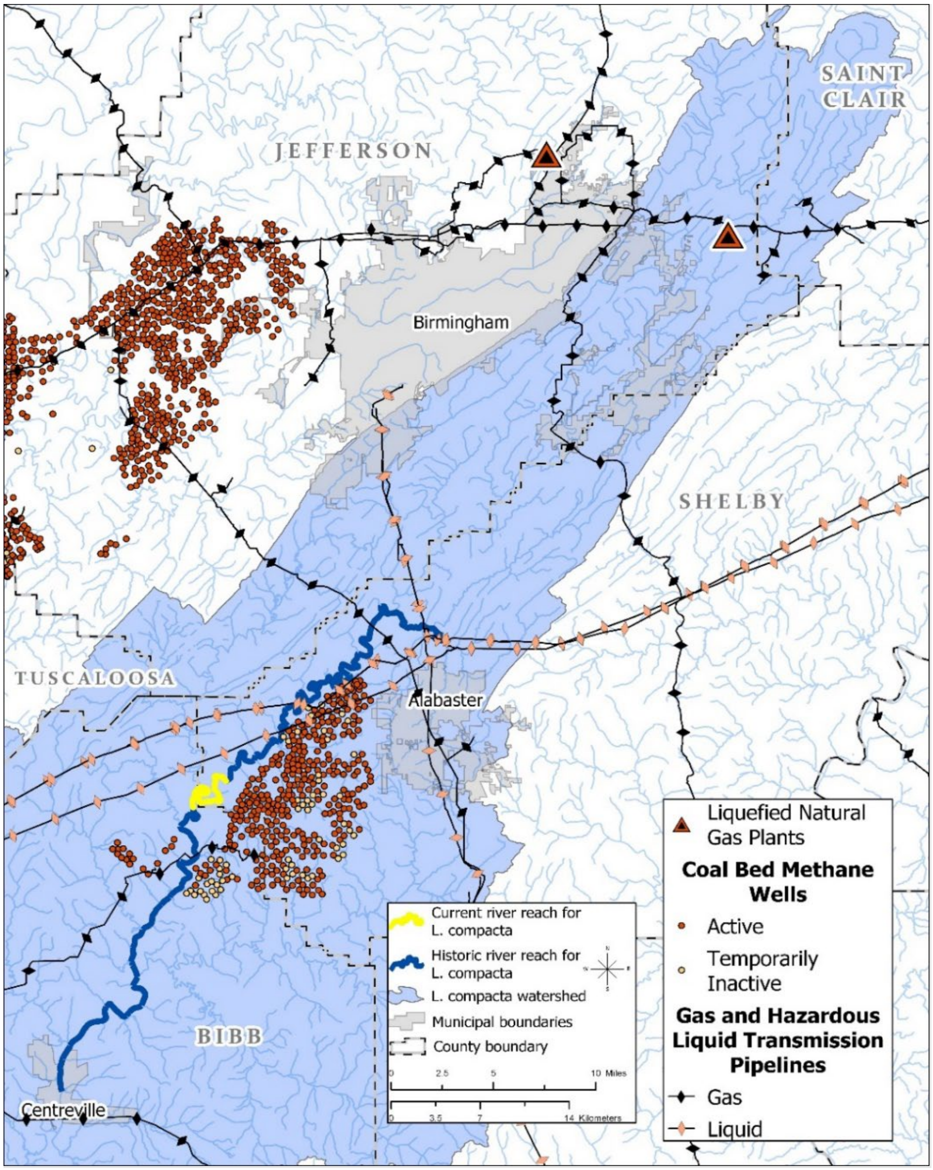

Figure 13. Pipelines and wells within the watershed of the oblong rocksnail (Service).

Pipelines remain one of the safest ways to transport fuel in the U.S. with a failure rate of 10^{-3} km/yr (Belvederesi *et al.* 2018, p. 1), and the majority of spills are small (NOAA 2020, Entire). Despite all of this, spills do occur along the mainline and can have significant environmental consequences to waterways, wildlife, and people (Belvederesi *et al.* 2018, p. 1). Several examples are provided in Table 3.

Table 3. Large Spills Affecting Inland Waterways in the U.S. (EPA 2020).

Location	Year	Product	Volume	Areas/Types of Effects
Reedy River, SC	1996	Diesel fuel	1,000,000 gallons (22,800 barrels)	Killed 35,000 fish; polluted a 34-mile (54.7 km) stretch of the River*
Goose Creek, TN	1999	Fuel oil	53,550 gallons (1275 barrels)	Polluted a tributary and 8 miles of the TN River*
Kalamazoo River spill, MI	2010	Diluted bitumen	843,000 gallons	Carried oil approximately 35-40 miles (56.3 – 64.4 km) downstream in heavy rains/flood waters.

Two major fuel transmission lines cross the Cahaba River or its tributaries at several points ranging from 3.7 to 18 km above the known locations (See Fig. 12). Two of these lines are 18-30" in diameter and transmit fuel oils from the Baton Rouge to Virginia and points between at a rate of 700,000 barrels per day. The second set is 36-40" in diameter and moves 3,000,000 barrels per day between Texas and New York. Operating pressures can vary throughout the line, but can exceed 500 psi (PHMSA 2021b, p. 3). For at least one of the companies the area around the Cahaba River is considered a High Consequence Area (HCA) (PHMSA 2021b, p.5). High consequence areas designate areas such as high population areas, drinking water sources, or sensitive ecological areas (Belvederesi *et al.* 2018, p. 6) and confer additional oversight.

Of the 11 counties crossed by these major pipelines in the state of Alabama, five have experienced spills associated with the lines or their infrastructure since 2005, ranging in size from 3 to upwards of 7,000 barrels (125 to 293,999 gallons). Most spills associated with these lines have occurred in Shelby County (with four having occurred along actual pipeline) and spill sizes with a known amount ranged up to 7,370 barrels (309,540 gallons; revised estimate in PHMSA 2021b, p. 4) with a total since 2011 of 478,574 gallons of oil and gasoline spilled. The largest spill in Shelby County occurred in 2016 (location identified in Fig. 14 as a black "X") and occurred within a mile (≤ 1.6 km) of the Cahaba River upstream of the occupied area (Birmingham Watch 2016, p. 1). More recently, in 2021, a leak from a pipeline resulted in 302 barrels of gasoline being spilled into Buck Creek (location identified in Fig. 14 as a red "X" next to Buck Creek label) and was a result of a leak from a previous repair (NRC 2021, unpaginated).

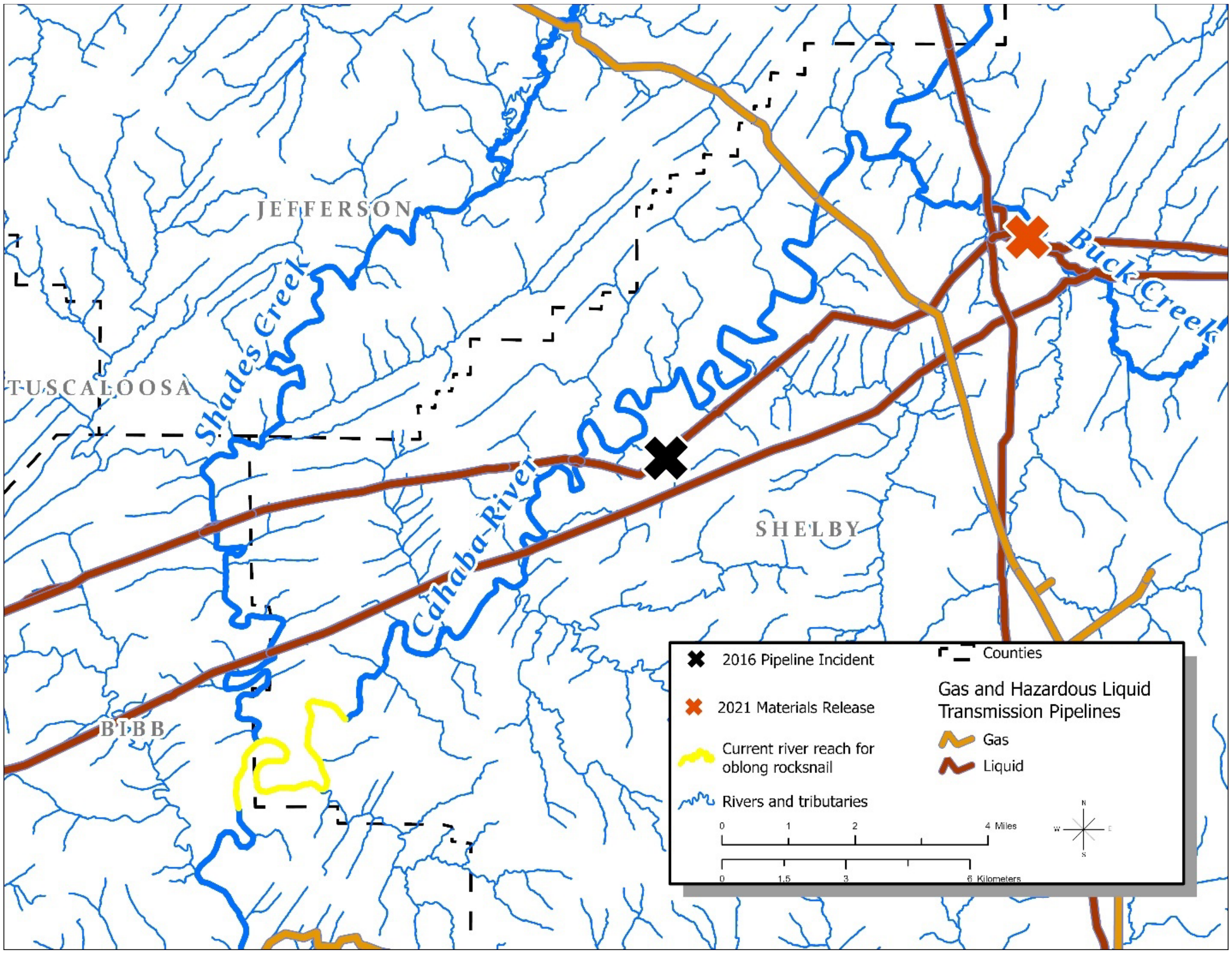

Figure 14. Locations of Shelby County spill in 2016 and 2021 Buck Creek spill (Service).

By chance, the Shelby County 2016 spill went into a retention pond, rather than Peel Creek. This event resulted in a nationally significant events (i.e., classified by PHMSA as a spill resulting in injury necessitating hospitalization, death, fire/explosion not set by the operator release of 5 gallons or more of hazardous liquid, or $50,000 worth of damage (Colonial 2019, entire; PHMSA 2021a, unpaginated)), though neither resulted in product in the river.

Additionally, the gas and hazardous liquid pipelines present a risk of explosion or ignition; heavy oils, on the other hand, while less acutely toxic, present a higher risk of smothering (NOAA 2021, entire). Barron (2017, p.2) reported that, “Overall, the majority of studies over the last two decades demonstrate that multiple crudes oils, middle distillates, fuel oils, weathered oils, and chemically dispersed oils are phototoxic to a variety of aquatic organisms (Barron and Ka’aihue 2001, p. 86; Lee 2003, Entire; Wernersson 2003, Entire; Kirby *et al.* 2007, Entire).” Amount of evaporation varies among petroleum types with heavy crude at about 10% to as much as 75% in gasoline (No. 2 fuel oil) (Albers 1991, p. 2). Rivers, given their flowing nature, can move even small quantities of oil over large areas and may move oil rapidly during periods of high flow. In shallow and high energy conditions, the product is more likely to mix throughout the entire water column (Albers 1991, p. 7). Overall, less than 5% of product is dissolved into water (Albers 1991, p. 2).

Large-volume spills or spills that occur in HCAs have a very low probability nationally. Belvederesi *et al.* (2018, p. 13) estimated the rate of these spills from 2010-2017 as 0.000504/km/year and only a small percentage occur at water crossings (e.g., 2010-2017 rate was 8%). However, there have been three spills within the HUCs surrounding the Cahaba above the population within the last six years and the risk of a catastrophic spill remains a possibility, particularly with multiple crossings in the system of both mainstem and tributaries.

6.3. Climate Change and Synergistic Effects

Dosdogru *et al.* (2020) explored land use/land cover (LULC) changes and climate change on the Cahaba River through 2045 (entire). The SWAT model (a process-based, continuous-time, watershed scale model) was used to simulate water quality and quantity in the system (Dosdogru *et al.* 2020, p. 4). Two SWAT (RCPs), referred to as RCP 2.6 and RCP 8.5, were used in the SWAT model to quantify future climate change effects, and represent high and low emissions, respectively (Dosdogru *et al.* 2020, pp. 1, 4).

Five scenarios were run following model calibration and validation including: (1) Baseline period; (2) Only Climate Change; (3) Only LULC; (4) Combined impact of LULC and Climate Change; and (5) Synergistic Impact (which accounts for more complex interactions). All the models predicted rising trends in temperature for all seasons, though winter and spring showed less total increase, ranging from 0.7 to 3.7 °C than summer and fall which ranged from 0.6 to 6.9 °C. Annual average precipitation is projected to increase (ensemble mean from 22 climate models) between 1.9% (-2.7 ~ 6.9%, RCP 2.6) and 2.3% (-1.5 ~ 3.7%, RCP 8.5) by the 2050s (Dosdogru *et al.* 2020, p. 7). In general, increased temperature, especially in summer and fall and increased precipitation in spring, summer, and winter are more likely (Dosdogru *et al.* 2020, p. 7). Therefore, the climate of the Upper Cahaba River Watershed could experience moderate to significant changes by the 2050s, especially under scenarios run for RCP 8.5.

Overall, the study projected more potential for flood and hydrologic drought events. Increasing summer temperatures and decreased flow could increase water temperatures and reduce dissolved oxygen, while flashier flows could increase soil erosion and muddy stream flows (Dosdogru *et al.* 2020, p. 14). Oxygen consumption increases with temperature in all freshwater molluscs, impacting metabolic activity. In general, developmental cues, rates of egg development, and juvenile growth are all strongly impacted by temperature regimes (Olden and Naiman 2010, p. 90).

Based on adaptive capacity attributes identified using the approach described by Thurman *et al.* (2020, entire), this species is likely to have trouble moving if conditions become unfavorable, given its limited dispersal ability and reliance on chance events to carry dispersers downstream. Flashier flows could present more opportunities to carry individuals to other downstream sites, but it could also carry them beyond the small reach of suitable habitat. In addition, flashier flows may result in unfavorable conditions for reproduction, or affect feeding through scouring of rock surfaces, which could abrade periphyton (Waters 1995, p. 5).

6.4. Summary

The historical decline of oblong rocksnail has been attributed to water quality declines in the watershed, even as early as the mid-1900s. Due to the species presence in a relatively short, straight-line section of the Cahaba River, the most significant risk to this species is from the lack of dendritic networking (which conveys no ability for natural rescue in the event the main channel population is lost), coupled with the risk of short or long-term decline in water quality. At present, water quality in the river is sufficient to support this and other rare species in the main channel. Several rare species of fish, including Goldline Darter (*Percina aurolineata*) and Cahaba Shiner (*Notropis cahabae*), are expanding their ranges. Since the rediscovery in 2011, the oblong rocksnails' contemporary range has been extended 1.83km downstream and 4.76km upstream (Wright *et al.* 2020, p. 8). It is unlikely it could expand much further downstream as habitat may be limiting, and expansion into side channels and upstream would be limited without human intervention.

Rapid decline of in-channel water quality or direct removal of most individuals could occur from a catastrophic spill, though the probability for this event is low. Alternatively, water quality could decrease as the result of urbanization in the watershed coupled with changes in flow/velocity resulting from climate change. Should these occur, the reduction in numbers would likely be more gradual, as it would impact the species more at the individual-level than the population-level; scouring removes individuals, their food sources, and causes changes in water quality that affect periphyton or individuals directly. Further increased sediment in the channel could limit the species ability to feed or breed successfully.

Climate change could also present a threat in the future if patterns of annual cooling (vernalizing) and heating in Spring shift substantially or the window for egg-laying changes such that the species cannot adapt. In addition, if timing of appropriate temperatures does not correspond to the species' readiness to produce gametes (as part of its own gametogenic cycle), the gamete production and thereby egg-laying may be negatively affected (Garner 2022, pers. comm.). Additional information would be needed on this annual cycle and future magnitude of expected change in water temperatures to answer such questions.

While we expect air temperatures to increase in the future, we also expect stream flow to be flashier overall and experience decreases in summer. However, we have inadequate data at present to determine exactly how future stream temperatures will change in Winter and Spring in the face of climate change and are uncertain of both what amount of vernalization is required by the species and when the window available for egg-laying/spawning becomes too narrow to support stable populations. Therefore, we are limited to looking at broad changes expected to flow and temperature when considering future condition. The Cahaba is a naturally flashy system so it is difficult to predict whether these events will be enough to drive populations down in the next few decades. In the future, the most substantial risk to the oblong rocksnail’s persistence is from water quality, either from a long-term decline related to increasing urbanization and climate change or from a catastrophic spill.

CHAPTER 7. FUTURE VIABILITY

We have considered what the oblong rocksnail needs for viability and the current condition of those needs, and we reviewed the risk factors that are driving the historical, current, and future conditions of the species. We now consider what the species' future conditions are likely to be. We apply our future forecasts to the concepts of resiliency, redundancy, and representation to describe the future viability of the oblong rocksnail.

7.1. Introduction

Given the species was thought extinct for several decades, authors have wondered how the species survived an 89% range reduction. Wright *et al.* 2020 (p. 10) offered a theory. These authors "speculate that the position of Cahaba River above Shades Creek provided a refugia where pollution may have been lowest across the historical range of *L. compacta*. In this scenario, the refugia persisted because the Cahaba River above Shades Creek site is far downstream from pollution sources in the Birmingham, Alabama metropolitan area but above Shades Creek, which was likely a conduit of pollution into the Cahaba River and is still considered to have poor water quality (ADEM 2007, Entire; ADEM 2012, Entire). Recent efforts have been made to improve the water quality in the Shades Creek drainage (FSC 2020, Entire) and monitoring by ADEM reported slightly improved water quality between 2007 and 2012 (ADEM 2007, p. 2; ADEM 2012, p. 2). These water quality improvements potentially resulted in newly suitable habitat for *L. compacta* in the Cahaba River below the Shades Creek confluence, including the sampled site Cahaba River at old Marvel slab."

Regardless of the cause of the species' current condition, future viability of the species would require resiliency via maintenance of existing populations (individuals and active reproduction), as it needs additional sites to provide for redundancy in the event of a catastrophic event (e.g., spill upstream of existing sites).

7.2. Water Quality - Long-Term Changes

Urban development around Birmingham will continue to affect water quality in the Cahaba River into the future. The Slope, Land use, Excluded area, Urban area, Transportation, Hillside area (SLEUTH) model simulates patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks (Terando *et al*. 2014, p. 2). While more sophisticated models exist, the SLEUTH model provides scalability, uses commonly available datasets, and is adaptable to focus on patterns of suburban and exurban development (Terando *et al*. 2014, p. 2).

Terando *et al*. (2014, p. 1) projected urban growth changes for the next 50 years for the fast-growing Southeastern United States, using simulations that point to a future in which the extent of urbanization in the Southeast is projected to increase by 101% to 192%. This projection is based on the "business-as-usual" (BAU) scenario in which the net effect of growth is in line with that which has occurred in the past (Terando *et al.* 2014, p. 1). The BAU scenario simulations do not consider alternative policies that could promote different urbanization patterns; however, the broad patterns of growth used do reflect recent trends in terms of the speed at which urbanization has progressed in the Southeast and in the locations that are most affected by it (Terando *et al*. 2014, p.7). As a result, the impacts to the Cahaba River due to urbanization (including roads, contaminants, and hydrological changes) will continue to increase. This is corroborated by the Regional Transportation plan for the Birmingham metropolitan area, which projects a 15 percent increase in human population in the metropolitan area (RPCGB 2019, p. 1). Projected urban growth in the Cahaba River watershed is shown below in Figure 15.

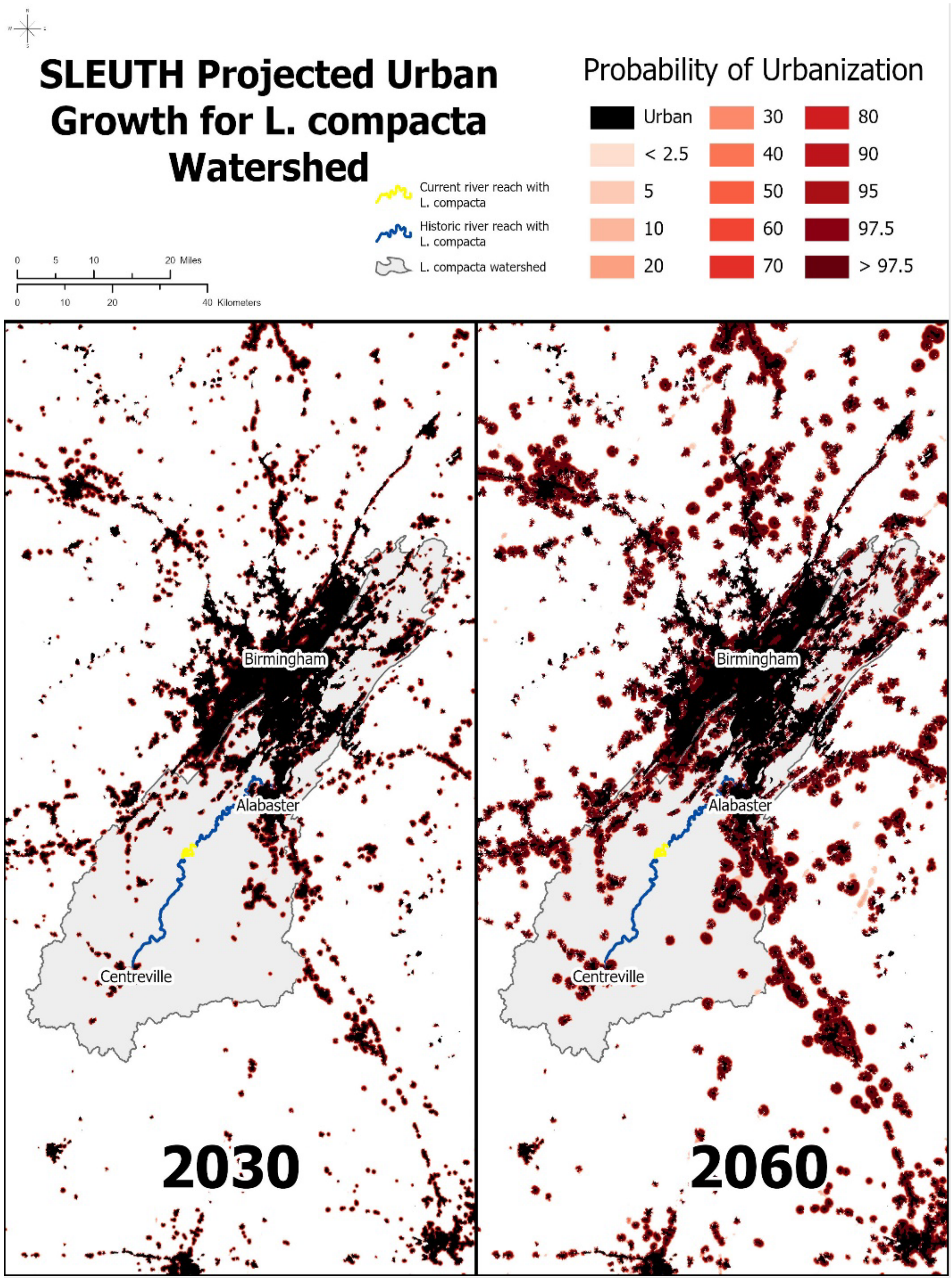

Figure 15. Projected urban growth in 10 and 40 years in the Cahaba River watershed (SLEUTH 2014).

As mentioned in section 6.2, Dosdogru *et al.* (2020) explored land use/land cover (LULC) changes and climate change on the Cahaba River through 2045 (entire). The SWAT model (a process-based, continuous-time, watershed scale model) was used to simulate water quality and quantity in the system (Dosdogru *et al.* 2020, p. 4). Annual average precipitation is projected to increase (ensemble mean from 22 climate models) between 1.9% (-2.7 ~ 6.9%, RCP 2.6) and 2.3% (-1.5 ~ 3.7%, RCP 8.5) by the 2050s (Dosdogru *et al.* 2020, p. 7). Overall, the study revealed more potential for flood and hydrologic drought events. Increasing summer temperatures and decreased flow could increase water temperatures and reduce dissolved oxygen, while flashier flows could increase soil erosion and muddy stream flows (Dosdogru *et al.* 2020, p. 14).

7.3 Water Quality – Spills

It is extremely difficult to know where a future spill may occur or exactly how much petroleum product could be released. Much of the monitoring data is proprietary and predicting the likelihood of a spill at a specific site along the lines is complicated by a variety of factors; integrity of the line itself (internal and external corrosion), substrate/soils, seismic activity, welds, valves and fittings, potential for construction damage, and others. The lines in this case are quite large, are pressurized and transport hundreds of millions of gallons of fuel oil and gasoline each day. While the probability of a catastrophic spill upstream of the populations is small, should one occur near the river, it could be catastrophic as even a small hole can lead to a large release like the one that occurred in 2016. Further, changes in flows associated with climate change could result in variable distances for spills traveling downstream. An in-depth assessment would need to be done to determine specific probabilities of various spill types, including a true worst-case spill risk and its likely impact on aquatic life.

7.4 Conservation Efforts

Reintroduction efforts for the oblong rocksnail are underway with the Alabama Department of Conservation and Natural Resources (ADCNR) (ADCNR 2021, Entire). During a survey in the historic Belle Ellen shoal complex in May 2019, several federally listed species were located, but the oblong rocksnail was not (ADCNR 2021, p. 2). Although a targeted survey in October 2020 again did not locate the oblong rocksnail, ADCNR and Service personnel agreed to consider the site for future reintroduction efforts (ADCNR 2021, p. 2). Culture efforts, as a part of reintroduction efforts, began in 2020 (ADCNR 2021, p. 3). A total of 220 oblong rocksnail brood stock was collected from a shoal adjacent to the Living River complex and brought back to the Alabama Aquatic Biodiversity Center (ADCNR 2021, p. 3) (see figure 17).

Figure 16. The location of a potential future reintroduction site, Belle Ellen shoal (red circle) in relation to the brood stock collection site, a shoal adjacent to the Living River complex (white square). Belle Ellen Shoals is located 5.5 miles (8.9 km) from the known population.

Encountered challenges included cooler than typical temperatures, followed by high daily temperatures, which may have disrupted normal annual thermal cycling during the mating and egg laying period (ADCNR 2021, p. 3). Severely diminished egg-laying in one production tank, and nearly non-existent egg-laying in the other, was attributed to this thermal disruption; sporadic egg-laying with successfully reproducing snails continued through mid-July 2021 and additional hatching occurred (ADCNR 2021, p. 3).

Due to low overall reproductive success, culture efforts continued with remaining juvenile snails until September 2021 (ADCNR 2021, p. 3). Mortality rate for adult brooders was low during the culture period (8.6%, N = 19) during the 11-month effort (ADCNR 2021, p. 3). A total of 544 juvenile and 201 brood stock were released adjacent to the right-descending bank at the Belle Ellen shoal (ADCNR 2021, p. 3). Future plans include the collection of more brood stock from the same shoal in spring 2022 for another culture attempt, evaluation of additional oblong rocksnail reintroduction sites in lower Buck Creek and lower Little Cahaba River, and a comprehensive reintroduction plan encompassing all approved reintroduction sites for the oblong rocksnail (ADCNR 2021, p. 3).

7.5 Future Condition Summary

An assessment for the future condition of the oblong rocksnail identified three potential scenarios based on threats discussed in Sections 6.2 and 6.3, as well as information from the literature on urbanization and climate change (see Dosdogru *et al.* 2020, Entire; Terando *et al.* 2014, Entire):

- Combined urbanization and climate change
- Combined urbanization and climate change – mitigated by existing management program
- Oil spill

Dosdogru *et al.* (2020, Entire) studied the impacts of LULC and climate change on the Upper Cahaba River Watershed. Their research predicts increased urbanization in the watershed, with urban cover increasing from 35% to 47% in 30 years, alongside a decrease in other habitat types, such as water and forest (Dosdogru *et al.* 2020, p. 7). In addition, the combined effects of LULC and climate change are predicted to impact the magnitude and duration of both monthly and annual stream flows (Dosdogru *et al.* 2020, p. 13). Terando *et al.* showed projected urbanization over the next 50 years through the SLEUTH model (2014, p. 1). Similarly, to Dosdogru *et al.* (Entire), Terando *et al.* (2014, p. 1) predicts further urbanization. The SLEUTH model BAU scenario, whose broad patterns for the southeastern U.S. reflect the speed urbanization is progressing, predicts further urbanization over the next 40 years (see Figure 16 in Section 7.2). As a result, the impacts to the Cahaba River due to urbanization (including roads, contaminants, and hydrological changes) will continue to increase, and informed two of these future scenarios.

Available information indicates the oblong rocksnail is currently restricted to 11% of its historical range in the Cahaba River, having been extirpated from 44.4 river miles (71.5 km), and with targeted survey efforts failing to locate the species at other sites within its historical range. As noted in Chapter 5, the species has a limited range and low availability of quality habitat, limited representation, and no redundancy. An inability to move large distances away from impaired water quality combined with linear arrangement of known sites in the single population could potentially lead to total extirpation of the species in the event of an oil spill or other catastrophic event originating upstream of the occupied reach. Based on national spill probabilities, the probability of a catastrophic spill scenario over future timeframes projected is extremely low, however, spills have occurred within the watershed within recent years. Scenarios of combined urbanization and climate change scenarios have a high probability of occurrence. The potential future condition of the species, lielihood of each scenario, and expected impact to each of the three R’s is summarized in Table 4 (below). A qualitive assessment of our understanding of information from the literature informed the percent ranges for each level of likelihood:

Table 4. Explanation of probabilities associated with each category for future condition of the oblong rocksnail.

Category	Probability (%)	Explanation
Extremely Low	<1%	Used to denote probability of an oil spill. The probability of a catastrophic spill upstream of the populations is small, but non-zero (see Fig. 14 for the location of the largest spill in Shelby County, which occurred within a mile (≤ 1.6 km) of the Cahaba River upstream of the occupied area, but without any product ending up in the river (Birmingham Watch 2016, p. 1)).
Low	1-33%	The expected magnitude and impacts to the 3 R's (described for each scenario in Table 5) is not likely to be fully realized in the specified timeframe for the scenario.
Medium	33-66%	It is uncertain whether the expected magnitude and impacts to the 3 R's (described for each scenario in Table 5) will be fully realized in the specified timeframe for the scenario.
High	66-100%	The expected magnitude and impacts to the 3 R's (described for each scenario in Table 5) are expected to be fully realized in the specified timeframe for the scenario, in the event that mitigation measures are not fully successful in increasing redundancy in additional potential suitable habitat sites.

Table 5. Summary of future viability for the Oblong Rocksnail. As there is only one population, all effects on the 3 R's (which collectively characterize future viability in each of the following scenarios) apply to the single known extant population and the entire known range of the species. Scenario probabilities showing (*) indicates a projection of both increased urbanization and temperatures in the Cahaba

Threat	Probability of Event within 10 years	Probability of Event within 40 years	Expected Magnitude	Expected Impact to Future Species' Viability (*Range of expected outcomes given uncertainty described*)
Combined Urbanization and Climate Change	Low/Medium*	High*	• Decreased water quality • Flashier flows (upstream sites likely most affected) • Limited recruitment • Limited food (periphyton) availability	• ***Reduced resiliency***, caused by lower abundance over time, particularly at upstream sites. • ***Reduced representation***, caused by lack of genetic diversity and limited ability to respond to environmental changes. • ***No redundancy***, caused by linear arrangement of only known population of species.
Combined Urbanization and Climate Change – Mitigated by Existing Management Program	Low/Medium*	High*	• Water quality maintained at most times, but poor water quality events could increase • Flashier flows, but with periodic perturbations	• ***Existing levels of resiliency, redundancy, and representation remain*** (see Ch.5 for characterization of current condition) **OR** • ***No redundancy,*** as well as ***reduced resiliency and representation***
Oil Spill	Extremely Low	Extremely Low	Refined Petroleum Product, 0 - 100,000+ gallons	• ***Existing levels of resiliency, redundancy, and representation remain*** (see Ch.5 for characterization of current condition) **OR** • ***No redundancy,*** as well as ***reduced resiliency and representation*** **OR** • ***No resiliency, redundancy, or representation*** caused by species extirpation.

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