Species Status Assessment Report for the Pearl River Map Turtle (*Graptemys pearlensis)*

Version 1.1



April 2021

U.S. Fish and Wildlife Service
Mississippi Basin Region
Atlanta, GA

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EXECUTIVE SUMMARY

The Pearl River map turtle (*Graptemys pearlensis*) is a freshwater turtle that inhabits rivers and large creeks with sand and gravel bottoms in the Pearl River drainage in Mississippi and Louisiana. The species was separated from the Pascagoula map turtle (*Graptemys gibbonsi*) in 2010, shortly after *G. gibbonsi* was petitioned for federal listing. This SSA is intended to provide the biological support for the decision on whether to propose to list the species as threatened or endangered. For the Pearl River map turtle to survive and reproduce, individuals need suitable habitat that supports essential life functions at all life stages. Several elements appear to be essential to the survival and reproduction of individuals: mainstem and tributary reaches within the Pearl River system that have sandbars, adequate flow, adequate supply of invertebrate prey items including insects and mollusks, and an abundance of emergent and floating basking structures of various sizes. Threats to the species include construction of reservoirs and dams, sand mining, excessive levels of development and agriculture, collection for the pet trade, invasive species, and long-term climate impacts such as prolonged flooding, drought, and sea level rise. Positive influences on the species include state laws and regulations that protect individual turtles and their habitat, and implementation of forestry best management practices, such as maintenance of riparian forested cover.

We delineated five resilience units of Pearl River map turtles based on HUC8 watersheds and in accordance with guidance from species experts (Upper Pearl, Middle Pearl-Silver, Middle Pearl-Strong, Bogue Chitto, and Lower Pearl). Historically, the majority of the range of the species was likely connected in a single interbreeding biological population, but we used the five analysis units in the SSA to most accurately describe trends in resiliency, forecast future resiliency, and capture differences in stressors among units. A recent genetics study for the species showed no distinct genetic structure and no evidence of isolation by distance, thus we consider the entire range of the Pearl River map turtle to be a single representative unit. We assessed current resilience using the following population and habitat factors: occupied tributaries, density, water quality, water engineering projects, forested riparian cover, and protected areas. The conditions of each of these factors were combined to classify the resilience of each population as high, moderate, or low. There are currently three Pearl River map turtle populations with moderate resilience, and two populations with low resilience (Figure EX-1).

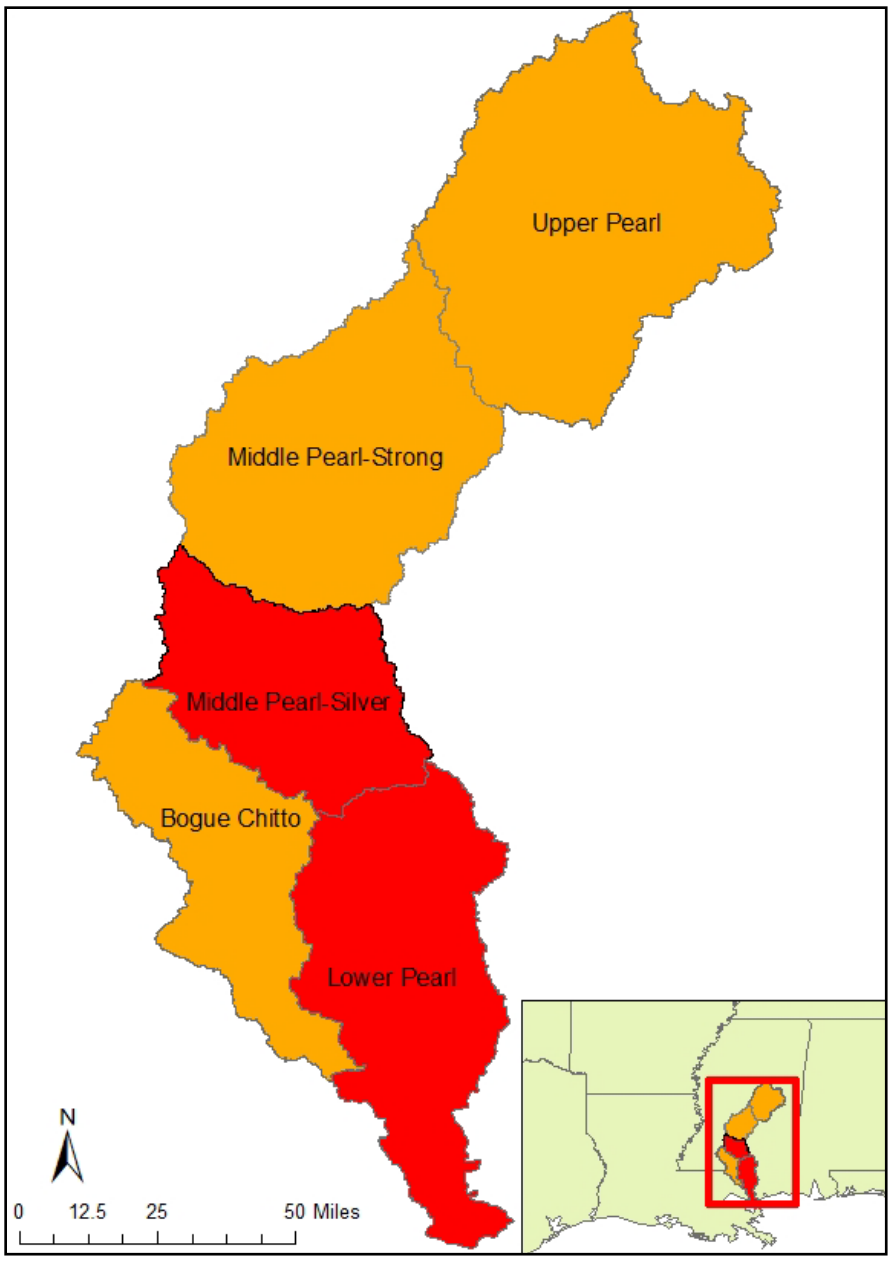


Figure EX-1-Resilience of the five units of Pearl River map turtles: low (red), moderate (orange), high (green).

To assess the future condition, we projected the primary current threats of land use (agriculture and development), potential future water engineering projects, and sea level rise into the future under six plausible scenarios, out to two different time steps: 2040 (20 years) and 2070 (50 years). The six scenarios capture the range of uncertainty in the changing human population footprint on the landscape, current emission models, implementation of water engineering

projects, and how the Pearl River map turtle will respond to these changing conditions. Based on these factors, there are two populations predicted to substantially decrease in resilience across most of the future scenarios: Lower Pearl and Middle Pearl Strong. The Lower Pearl unit faces a myriad of future threats, including impacts from sea level rise in the southern portion of the unit, substantial increases in development and agriculture, and loss of forested cover. For the Middle Pearl Strong, the magnitude of decrease is most closely tied to the One Lake project. If the One Lake Project moves forward within the next 50 years, areas in and around the project site are anticipated to be substantially negatively impacted. The Bogue Chitto, Middle Pearl Silver, and Upper Pearl units are anticipated to maintain their current resilience, or only slightly decrease, as the main threats assessed are not anticipated to increase markedly in the future. One caveat for the Bogue Chitto unit is that there is uncertainty in levels and patterns of mining in the future, and this has been identified as a current threat in some portions of the unit.

Table EX-1-Anticipated magnitude and direction of change in resilience for Pearl River map turtles based on land use, climate change, and future water project scenarios.

Unit	Future Resilience
Bogue Chitto	Likely to maintain moderate resilience across all scenarios
Lower Pearl	Low resilience is expected to further decrease across all scenarios
Middle Pearl Silver	Likely to maintain low resilience across all scenarios
Middle Pearl Strong	Moderate resilience likely to decrease substantially
Upper Pearl	Likely to maintain moderate resilience across all scenarios

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ii
EXECUTIVE SUMMARY iv
TABLE OF CONTENTS vii
LIST OF TABLES x
LIST OF FIGURES xi
CHAPTER 1 – INTRODUCTION AND ANALYTICAL FRAMEWORK 1
CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS 5
2.1 Taxonomy 5
2.2 Species Description 6
2.3 Range and Distribution 8
2.4 Diet 11
2.5 Behavior and Activity 11
2.6 Reproduction 12
2.7 Habitat 14
2.8 Population Structure 16
2.9 Predators 17
2.10 Summary of Resource Needs 18
CHAPTER 3 – SPECIES NEEDS FOR VIABILITY 20
3.1 Individual Needs 21
3.2 Population Needs 21
3.3 Species Needs 21
CHAPTER 4 – INFLUENCES ON VIABILITY 22
4.1 Climate Change 22
4.2 Water Quality 25
4.2.1 Channel and Hydrology Modifications and Impoundments 27
4.2.2 Agriculture 29
4.2.3 Development 30
4.2.4 Mining 30
4.3 Other Influences 31
4.3.1 Invasive Species 31
4.3.2 Collection 32

4.3.3 Disease 33
4.3.4 Data Deficiency 34
4.4 Conservation Measures 34
4.4.1 Federal 34
4.4.2 Convention on International Trade in Endangered Species of Wild Fauna and Flora-Appendix III 37
4.4.3 State/Louisiana 38
4.4.4 State/Mississippi 39
4.4.5 Voluntary 41
CHAPTER 5 – CURRENT CONDITION 42
5.1 Delineating Resilience Units 42
5.2 Population Resiliency 44
5.2.1 Population Factor: Presence using Occupied Tributaries 44
5.2.2 Population Factor: Density and Abundance 47
5.2.3 Population Factor: Composite Score 49
5.2.4 Habitat Factor: Water Quality 50
5.2.5 Habitat Factor: Channelization/Reservoirs/Gravel Mining 56
5.2.6 Habitat Factor: Protected Land 58
5.2.7 Habitat Factor: Forested Riparian Cover 60
5.2.8 Habitat Factor Composite Score 63
5.2.9 Current Resilience 64
5.2.10 Current Representation 65
5.2.11 Current Redundancy 66
5.2.12 Current Conditions Summary 67
CHAPTER 6 – FUTURE CONDITIONS AND VIABILITY 69
6.1 Introduction 69
6.2 Future Resilience Factors 69
6.2.1 Land Use and Water Quality 69
6.2.2 Sea Level Rise 71
6.2.3 Future Water Engineering Projects and Mining 72
6.3 Models and Scenarios 73
6.4 Results 75

6.4.1 Land Use and Water Quality 75
6.4.2 Riparian Forested Cover/Deadwood Abundance Results 82
6.4.3 Future Water Engineering: One Lake Project 84
6.4.4 Sea Level Rise 85
6.5 Summary of Future Conditions and Viability based on Resiliency, Representation, and Redundancy 91
6.5.1 Future Resiliency 91
6.5.2 Future Representation 100
6.5.3 Future Redundancy 101
6.5.4 Future Conditions Summary 102
LITERATURE CITED 104
APPENDIX A – LAND USE SUMMARIES FOR PEARL RIVER RESILIENCE UNITS 124
APPENDIX B – USFWS LEMIS REPORT 128

LIST OF TABLES

Table 2.1. Individual resource needs of Pearl River map turtle....19
Table 5.1. Assessment of tributaries occupied by the Pearl River map turtle....46
Table 5.2. Density of stream reaches within Pearl River map turtle....49
Table 5.3. Population composite scores for Pearl River map turtle....50
Table 5.4. Metrics used to categorize impacts of urbanization within units....53
Table 5.5. Metrics used to categorize impacts of agriculture within units....53
Table 5.6. Composite land use score for streams within the Bogue Chitto unit....54
Table 5.7. Composite land use score for streams within the Lower Pearl unit....55
Table 5.8. Composite land use score for streams within the Middle Pearl Silver unit....55
Table 5.9. Composite land use score for streams within the Middle Pearl Strong unit....55
Table 5.10. Composite land use score for streams within the Upper Pearl unit....56
Table 5.11. Categorization of Channelization/Reservoirs for Pearl River map turtles....58
Table 5.12. Protected Lands within the range of Pearl River map turtle....60
Table 5.13. Forested cover within Pearl River map turtle units....62-63
Table 5.14. Habitat factor composite scores for Pearl River map turtle units....64
Table 5.15. Current resiliency of Pearl River map turtle units....65
Table 6.1. Estimated inundation from sea level rise for the Pearl River basin....72
Table 6.2. Scenarios used to model future condition for Pearl River map turtle....74-75
Table 6.3. Future composite land use score for streams within the Bogue Chitto....76
Table 6.4. Future composite land use score for streams within the Lower Pearl unit....77-78
Table 6.5. Future composite land use score for the Middle Pearl Silver unit....79
Table 6.6. Future composite land use score for the Middle Pearl Strong unit....80
Table 6.7. Future composite land use score for the Upper Pearl unit....81
Table 6.8. Future percentage of forested cover within riparian areas....83
Table 6.9. Future overall composite scores for the habitat factor forested cover....84
Table 6.10. Estimated river miles projected to be inundated by sea level rise....86
Table 6.11. Future resiliency of Pearl River map turtle units....93-100

LIST OF FIGURES

Figure 1.1. Species Status Assessment Framework....4
Figure 2.1. Mature male Pearl River map turtle....7
Figure 2.2. Range of Pearl River map turtle....10
Figure 3.1. Influence diagram for Pearl River map turtle viability....20
Figure 5.1. Pearl River map turtle delineated resilience units....43
Figure 5.2. Surveyed streams across all Pearl River map turtle units....47
Figure 5.3. Resilience of Pearl River map turtle units....68
Figure 6.1. Land use modelling conceptual diagram....71
Figure 6.2. Range of Pearl River map turtle inundated by 1 foot of sea level rise....87
Figure 6.3. Range of Pearl River map turtle inundated by 2 foot of sea level rise....88
Figure 6.4. Range of Pearl River map turtle inundated by 3 foot of sea level rise....89
Figure 6.5. Range of Pearl River map turtle inundated by 5 foot of sea level rise....90
Figure 6.6. Current and future conditions of the Pearl River map turtle analysis units....103

CHAPTER 1 – INTRODUCTION AND ANALYTICAL FRAMEWORK

The Pearl River map turtle (*Graptemys pearlensis*) inhabits rivers and large creeks with sand and gravel bottoms in the Pearl River drainage in Mississippi and Louisiana (Lindeman 2013, p. 298). The species was separated from the Pascagoula map turtle (*Graptemys gibbonsi*) in 2010 (Ennen et al. 2010, entire), shortly after *G. gibbonsi* was petitioned for federal listing under the Endangered Species Act of 1973, as amended (Act), as a part of the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the Center for Biological Diversity (CBD 2010, p. 559-562). The Species Status Assessment (SSA) framework (USFWS 2016, entire) summarizes the information compiled and reviewed by the U.S. Fish and Wildlife Service (Service), incorporating the best available scientific and commercial data, in order to conduct an in-depth review of the species' biology and threats, evaluate its biological status, and assess the resources and conditions needed to maintain long-term viability. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Listing to Consultations to Recovery.

The Pearl River map turtle SSA is intended to provide the biological support for the decision on whether to propose to list the species as threatened or endangered and, if so, to determine whether it is prudent to designate critical habitat in certain areas. Importantly, the SSA Report is not a decisional document by the Service but provides a review of available information strictly related to the biological status of the Pearl River map turtle. 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, with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in its natural systems over time. Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf et al. 2015, entire).

To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311; Wolf et al. 2015, entire). To sustain populations over time, a species must have the capacity to withstand:

(1) environmental and demographic stochasticity and disturbances (Resiliency),
(2) catastrophes (Redundancy), and
(3) novel changes in its biological and physical environment (Representation).

A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311; Wolf et al. 2015, entire; Smith et al. 2018, p. 306).

- **Resiliency** is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature and rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

  We can best gauge resiliency by evaluating population level characteristics such as: demography (abundance and the components of population growth rate -- survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are also important considerations.

- **Redundancy** is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangal and Tier 1993, p. 1083).

We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

- **Representation** is 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 (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290-291; Sgro et al. 2011, p. 327; Zackay 2007, p. 1).

  We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity

occupied, and [3] effective population size. In our species status assessments, we assess all three facets to the best of our ability based on available data.

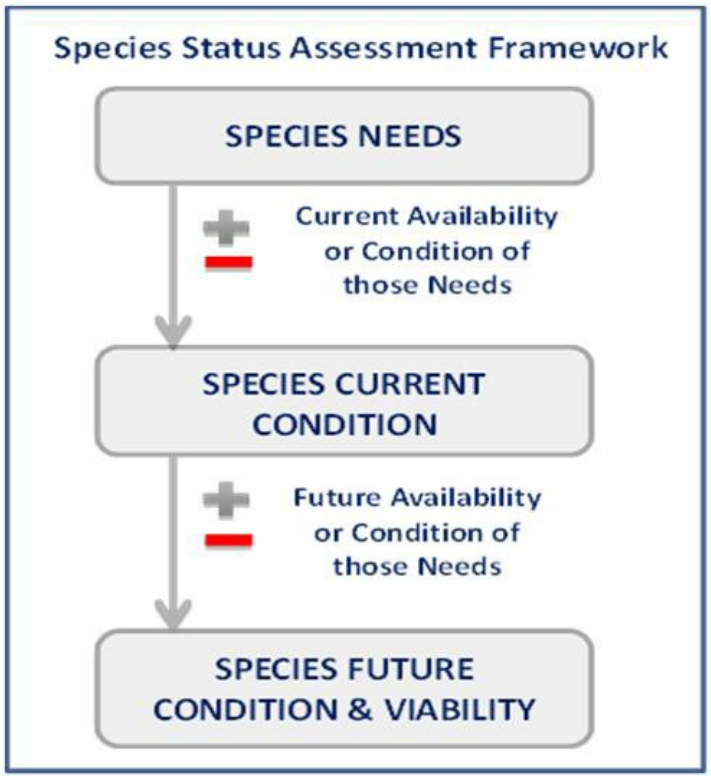


Figure 1.1. Species Status Assessment Framework

To evaluate the biological status of the Pearl River map turtle, 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 provides an 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.

The format for this SSA includes: (1) Species Biology (2) Species Needs (3) Influences on Viability (4) Current Conditions and (5) Future Conditions. 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 Pearl River map turtle.

CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS

In this chapter, we provide biological information about the Pearl River map turtle, including its taxonomic history, morphological description, historical and current distribution and range, and known life history. We then outline the resource needs of individuals.

2.1 Taxonomy

Kingdom: Animalia
Division: Chordata
Class: Reptilia
Order: Testudines
Family: Emydidae
Genus: *Graptemys*
Species: *Graptemys pearlensis*
Common name: Pearl River map turtle (= Pearl map turtle)

Before 1992, all megacephalic (big-headed) map turtles from the Pearl, Pascagoula, Mobile Bay, and Escambia-Conecuh river systems were recognized as the Alabama map turtle (*Graptemys pulchra*) (Baur 1893, p. 675-676; Lovich and McCoy 1992, p. 294). That changed when morphological features were analyzed among those river systems, resulting in the name *G. pulchra* being restricted to the Mobile Bay drainages, individuals from the Escambia-Conecuh River system being elevated to a new species *G. ernsti* (Escambia map turtle), and individuals from the Pascagoula and Pearl River systems being elevated to the new species *G. gibbonsi* (Pascagoula map turtle, Lovich and McCoy 1992, pp. 296-306). A molecular systematics study supported the division of *G. pulchra* into three species, although *G. gibbonsi* was only represented in the analysis by genetic material collected from individuals in the Pearl River drainage (Lamb et al. 1994, p. 554-559). The Pearl River map turtle was taxonomically separated from the Pascagoula map turtle (*G. gibbonsi*) in 2010 based on morphological and genetic differences (Ennen et al. 2010, p. 109-110). This separation was subsequently supported with a molecular analysis of the phylogeny of all map turtles (*Graptemys*; Thomson et al. 2018, p. 65). In contrast to these studies, another study found *G. gibbonsi* and *G. pearlensis* genetically

undifferentiated, both in nuclear and in mitochondrial DNA, and that previous analyses may represent population level variation rather than taxonomic variation (Praschag et al. 2017, p. 680-681). For the purposes of this assessment, the Pearl River map turtle is recognized as a separate species from the Pascagoula map turtle, Escambia map turtle, and Alabama map turtle, and is considered a valid species because of morphological and genetic (mtDNA and nuclear genes) support and recognition by the herpetological community (Iverson et al. 2017, p. 86; Ennen et al. 2012, p. 889.881-889.884).

2.2 Species Description

Map turtles (genus *Graptemys*) are named for the intricate pattern on the carapace that often resembles a topographical map. In addition to the intricate pattern, the shape of the carapace (top half of shell) in map turtles is very distinctive. The carapace is keeled, and many species show some type of knobby projections or spikes down the vertebral scutes (located down the midline of the carapace). Marginal scutes (located along the edge of the carapace) are also serrated and this trait is most pronounced in the three species of closely-related microcephalic (small-headed) map turtles, including the black-knobbed map turtle (*G. nigrinoda)*, ringed map turtle (*G. oculifera*), and yellow-blotched map turtle (*G. flavimaculata*). Among the megacephalic clade of map turtles these traits are present but less pronounced in adults (Lovich and McCoy 1992, p. 293). The megacephalic clade of map turtles includes the Pascagoula map turtle, Barbour's map turtle (*G. barbouri*), the Escambia map turtle, the Pearl River map turtle, and the Alabama map turtle. This group has the largest adult female body size and greatest degree of sexual dimorphism in the genus *Graptemys*, with adult females being over two times the carapace length of adult males on average. Megacephalic map turtles are defined by the following combination of characteristics (Lovich and McCoy 1992, p. 294).

1. Large female size reaching 29.5 – 33.0 centimeters (cm) (11.6 – 13.0 inches (in)) in maximum carapace length;
2. Extreme sexual dimorphism in adults, SDI ([sexual dimorphism index], size of larger sex divided by size of smaller sex, Gibbons and Lovich 1990, p. 2-3) is 2.42 – 2.58;
3. Head is broad, particularly in adult females, with greatly expanded alveolar surfaces (flattened surfaces for crushing; turtles do not have teeth) of jaws;

4. Head pattern consists of an interorbital blotch (between the eyes on the dorsal surface of the head) and large postorbital blotches (posterior to the eye); and
5. Vertebral scutes with salient spines.



Figure 2.1. A mature male Pearl River map turtle (*Graptemys pearlensis*).

Distinguishing among the Pearl River map turtle (Figure 2.1), Pascagoula map turtle, Barbour's map turtle, Escambia map turtle, and Alabama map turtle is easiest via locality information, but there is some genetic, morphological, and pattern variation among the three species. In the Pascagoula map turtle and the Pearl River map turtle, there is a single, yellow, vertical bar near the center of the dorsal surface of each marginal scute, while the Alabama map turtle has a spot surrounded by concentric yellow semicircles near the center of the dorsal surface of each marginal scute (Lovich and McCoy 1992, p. 302-303; Ennen et al. 2010, p. 100). The yellow bars on the dorsal surface of the marginals tend to be wider in the Pascagoula map turtle than in the Pearl River map turtle, and are bordered by concentric dark rings, which are often absent or faded in the Pearl River map turtle (Ennen et al. 2010, p. 101-102). In many individuals, the yellow bars on the posterior-most marginal scutes in the Pascagoula map turtle and the Pearl

River map turtle do not connect the outer margin of the carapace with the vertebral scutes, and on average, Pascagoula map turtle specimens have longer vertical bars on the posterior-most marginal scutes than in Pearl River map turtles (Ennen et al. 2010, p. 101). The darkened borders along the seams between the ventral surfaces of each marginal scute are relatively narrow in the Pascagoula map turtle when compared to the Alabama map turtle and the Pearl River map turtle (Lovich and McCoy 1992, p. 302-303; Ennen et al. 2010, p. 101-102). On the head of all three species, large, light-colored postorbital blotches are connected via a large interorbital blotch and supraoccipital (on the dorsal surface of the head but posterior to the eye) spots are absent (Lovich and McCoy 1992, p. 302-303). In the Pascagoula map turtle and more commonly in the Pearl River map turtle, the anterior end of the interorbital blotch often forms a three-pronged nasal trident shape that is absent in the Alabama map turtle and Barbour's map turtle, but especially prominent in the Escambia map turtle (Lovich and McCoy 1992, p. 302-303; Ennen et al. 2010, p. 101-102). In a 2010 study, interorbital blotches in 66 percent of Pascagoula map turtle specimens and 79 percent of Pearl River map turtle specimens exhibited a nasal trident shape (Ennen et al. 2010, p. 102). Both Pascagoula map turtles and Pearl River map turtles have a black or dark brown vertebral stripe along the keel of the carapace. In Pearl River map turtles, the stripe is continuous in most individuals but in Pascagoula map turtles the stripe is usually broken up by the ground color of the carapace (Ennen et al. 2010, p. 103). Hatchlings of megacephalic map turtles have more vivid colors and higher contrast than adults, are more circular, have a more pronounced dorsal keel, and each marginal scute is serrated (Lovich et al. 2009, p. 029.3). The midline plastron lengths for the Pearl River map turtles range from 5.8 to 9.8 cm (2.3 to 3.9 in) in mature males and reach 21.5 cm (8.5 in) in mature females (Lindeman 2013, p. 299).

2.3 Range and Distribution

The Pearl River map turtle is endemic to the Pearl River drainage in Mississippi and Louisiana. Counties with known records for the species in the state of Mississippi include: Attala, Copiah, Hancock, Hinds, Lawrence, Leake, Lincoln, Madison, Marion, Neshoba, Pearl River, Pike, Rankin, Smith, Simpson, and Walthall. Two parishes in Louisiana, St. Tammany and Washington, have records for the species. When the Pearl River map turtle was described as its

own taxon in 2010, its distribution in the Pearl River basin was not well known. Between 2015 and 2018, Lindeman (2019, entire) conducted surveys to document the extent of the range of the species. During this study, Lindeman documented an occupancy of 1279.6 river kilometers (rkm) (795.1 rm) in the drainage, with 647.0 km (402.0 rm) in tributaries and 632.6 km (393.1 rm) in the main channels of the Pearl and West Pearl rivers (Lindeman 2019, p. 19-47). Within this total distribution, presence in 188.3 rkm (117.0 rm) of the occupied range was unknown prior to these surveys (Lindeman 2019, p. 6-19). In an effort to determine the extent of the species distribution, Lindeman surveyed 16 connecting tributaries of the Pearl River and eight additional streams upstream of the known range but did not document presence in them (Lindeman 2019, p. 20). In his report, Lindeman advised not to overestimate the importance of the recent range extensions, pointing out that while the study increased the known range by 15 percent, the range-wide population estimates indicate that the newly reported stream reaches only account for 9 percent of the estimated global population of Pearl River map turtles because most of the extensions were in areas where visual surveys indicated either low or very low population densities (Lindeman 2019, p. 25).The occupied range of the Pearl River map turtle includes portions of the Pearl River, West Pearl River, Bogue Chitto, East Pearl River, Yockanookany River, Strong River, Holmes Bayou, Pearl Navigation Canal, Lobutcha Creek, Tuscolometa Creek, Pelahatchie Creek, Purvis Creek, Pushepatapa Creek, Topisaw Creek, Magees Creek, Hobolochitto Creek, and West Hobolochitto Creek (Figure 2.2). This species has also been reported in upper reaches of the Ross Barnett Reservoir (where conditions are more lotic and less lentic). It is likely that the species will be discovered in smaller creeks in the future but likely at low population densities (Selman pers. comm. 2020b, p. 16).

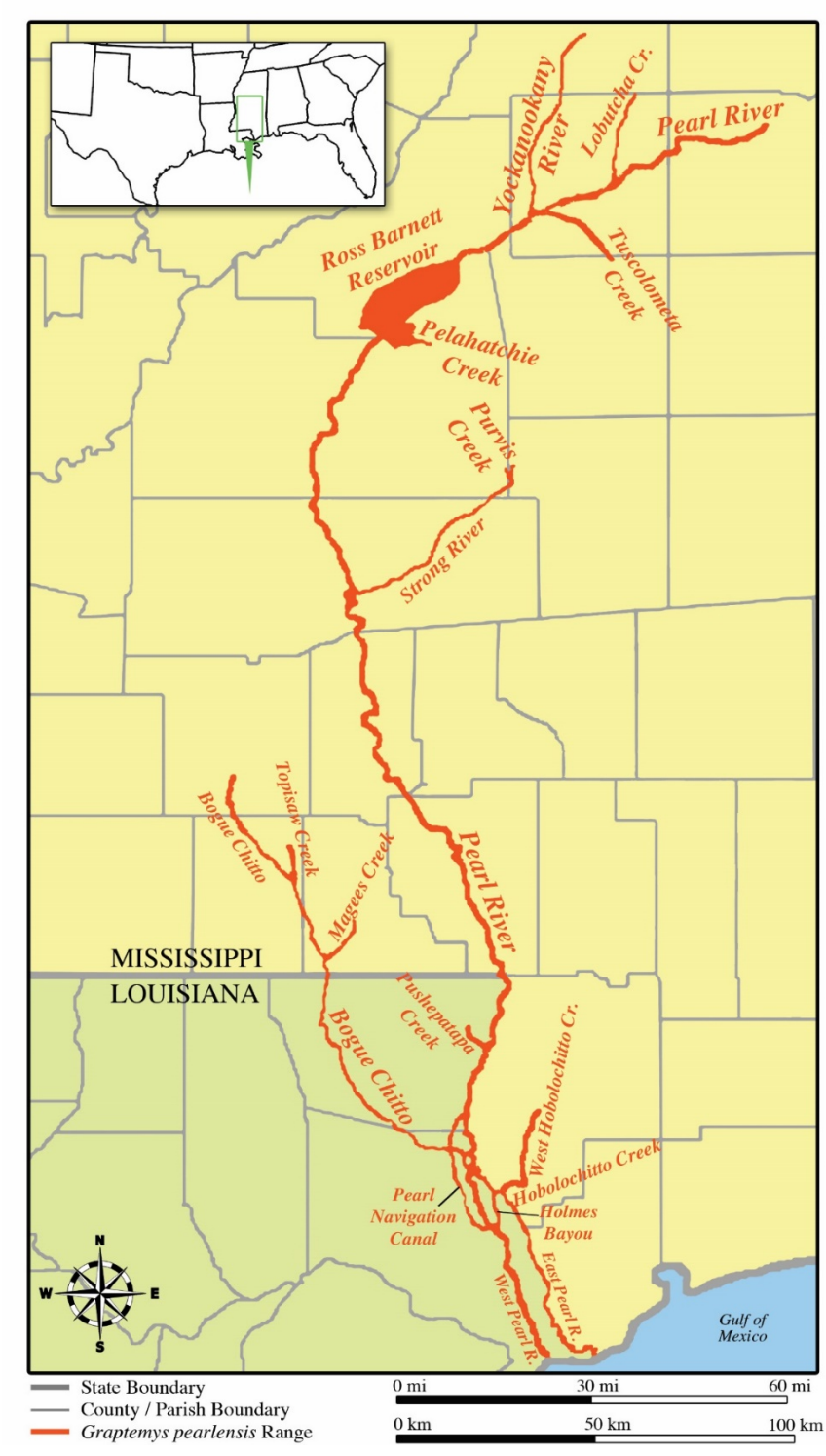


Figure 2.2. Known range of the Pearl River map turtle as of 2019 (Lindeman 2019, p. 50). Rivers and tributaries are drawn to the known upstream extent of the range of the species.

2.4 Diet

The diet of the Pearl River map turtle varies between females and males, and females grow proportionally larger heads and jaws as they age. A recent study on fecal samples of Pearl River map turtles found that mature females consume mostly Asian clams (*Corbicula fluminea*), while males and unsexed juveniles eat insects, with mature males specializing in caddisfly larvae and consuming more mollusks than juveniles (Vučenović and Lindeman 2020, entire). Moderately large native mussels had previously been reported in fecal samples from adult female Pearl River map turtles (R. Jones, pers. comm. reported in Lindeman 2013, p. 298-299), but an account from before the Pearl River map turtle was split from the Pascagoula map turtle also identified Asian clams (*Corbicula fluminea*) as a preferred prey item (Ernst, pers. obs. reported in Lovich 2009, p. 305-306). In stomach contents of specimens from the Pearl River, two adult males contained only insects, while a juvenile female contained only snails and clams (Cagle 1952, p. 228). In fecal samples from a site on the Pearl River, the diet for both sexes of all sizes combined was composed of 44 percent fish, 25 percent mollusks, and 25 percent insects, which is broader than the megacephalic species to the east, the Pascagoula map turtle; apparently Pearl River map turtles did not specialize as much on mollusks as the Pascagoula map turtle (McCoy and Vogt, unpubl. data reported in Lovich et al. 2009, p. 029.4). Several accounts published before the Pearl River map turtle and Pascagoula map turtle were split indicate that juveniles, small females, and mature males are predominantly insectivorous (Dundee and Rossman 1989, p. 187; Lovich et al. 2009, p. 029.4; J. Vučenović and P. Lindeman, unpubl. data reported in Lindeman 2019, p. 22-31). Another observation from before the species were taxonomically divided found stomach contents of immature females containing less than 15 percent mollusks by volume and found no mollusks in stomachs of males (Cagle, 1952 data reported in Lindeman 2000, p. 553-563). Snails are occasionally consumed by *G. pearlensis*, and made up ~1% by volume of female samples (adult and juvenile) in a recent study (Vučenović and P. Lindeman 2020, p. 19).

2.5 Behavior and Activity

Many behaviors of the Pearl River map turtle are poorly understood, but some have been documented from observations of the species; we describe behaviors of similar species in lieu of

Pearl River map turtles when available. At night, numerous males and juveniles have been observed clinging to submerged branches and tree limbs just below the water surface (Cagle 1952, p. 227), so it has been suggested that males and juveniles forage during the day and rest at night (Lovich 2009, p. 303). Female foraging behavior is unknown, but a study on the megacephalic species to the east (the Pascagoula map turtle) found wood fragments in fecal samples from males but absent from females, suggesting that males probably forage on submerged deadwood structure, while researchers inferred from the molluscivorous diet of mature females that females forage along sand or gravel directly at the river bottom (Selman and Lindeman 2015, p. 794-795).

Demographic and seasonal biases in basking behavior have not been studied for this species, but many existing publications that estimate abundance or relative abundance for map turtles, in general, rely on observation counts of basking individuals, so understanding basking behavior is important. A study on the sympatric (overlapping in distribution) microcephalic species, the ringed map turtle (*Graptemys oculifera*), found that Pearl River map turtles were more frequently seen basking later in the afternoon than ringed map turtles, and suggested that more Pearl River map turtles might have been detected if more surveys were conducted after 1500 hours (3 pm) (Dickerson and Reine 1996, p.8). Ecologically similar Pascagoula map turtles were found to also bask later in the afternoon (particularly males) (Selman and Lindeman 2015, pp. 789-793).

Available information on movements, home range, and dispersal is limited. However, an early account that combined data on the Pearl River map turtle and the Pascagoula map turtle states that males and juveniles often stay in the same area at night where they were found during the day, and that researchers returning to areas that had basking map turtles during the day resulted in frequent night captures by hand, while areas without basking individuals yielded no captures (Cagle 1952, p. 227).

2.6 Reproduction

Information on Pearl River map turtle reproductive biology is lacking; we have little information on species specific clutch frequency, age of maturity, and other reproductive parameters. Pearl River map turtles excavate nests and lay their eggs on sandbars and beaches along river banks during the

late spring and early summer months. A gravid female containing calcified eggs was collected from the Pearl River on June 8, 1951 (Cagle 1952, p. 228). In unpublished data on Pearl River map turtles and Pascagoula map turtles from the Chickasawhay River combined, McCoy and Vogt found gravid females from May to August (reported in Lovich et al. 2009, p. 029.4). A study on ringed map turtles reported incidentally finding three fresh nests from Pearl River map turtles during the month of June, identified by hatching them in captivity (Ennen et al. 2016, p. 094.4-094.6).

Five eggs incubated in captivity hatched in 62.8 days on average, and three clutches incubated in natural nests averaged 62 days to hatching; time from deposition to nest emergence by hatchlings in the natural clutches ranged from 67-79 days and averaged 69.3 days. The five lab-incubated hatchlings averaged 3.66 cm (1.44 in) in carapace length (Jones, unpublished data, summarized in Ennen et al. 2016, p. 094.4-094.6). Hatchlings typically emerge from the nest within three hours after sunset. During trials releasing hatchlings by hand, hatchlings moved to the nearest shade if released during the bright sunlight of day, even if released near the water (Anderson 1958, p. 212-215). Juvenile growth rates have not been studied, but one juvenile female from the Pearl River was 2.27 cm (0.89 in) in carapace length upon hatching, 4.24 cm (1.67 in) after one growing season, and 5.93 cm (2.33 in) after the second growing season (Cagle 1952, p. 228). Another early study on the megacephalic clade reported hatchling mean plastron length as 3.02 cm (1.19 in), and the following mean lengths among 29 individuals for subsequent years, estimated by counting growth rings: 4.37 cm (1.72 in) in the first year, 5.11 cm (2.01 in) in the second year, 6.09 cm (2.40 in) in the third year, and 6.74 cm (2.65 in) in the fourth year (Cagle 1952, p. 227).

At a site on the Pearl River 2 km (1.2 mi) downstream of the Strong River, the smallest gravid female had a carapace length of 20.5 cm (8.1 in) but authors suggested that maturation age and size may vary. A total of 22 clutches at that site ranged from 3 to 9 eggs (mean = 6.4 eggs; Vogt et al. 2019, p. 557-558). An average clutch size of 6.4 eggs with a range of 4-9 eggs was reported for the Pearl River map turtle and stated that females probably produce multiple clutches per year (Ennen et al. 2016, pp. 094.4-094.6). During the dissection of an adult female (plastron length of 17.0 cm (6.7 in)) specimen from the Pearl River, three calcified eggs were found and there was evidence of an additional clutch developing; the three eggs were 4.27-4.73 cm (1.68-1.86 in) in length and 2.5-2.7 cm (0.98-1.06 in) in width (Cagle 1952, p. 228). In another study, the length, width, and mass

among 33 eggs averaged 4.01 cm (1.58 in), 2.68 cm (1.06 in), and 16.4 grams (0.58 ounces), respectively (Ennen et al. 2016, pp. 094.4-094.6). Unpublished data combining Pearl River map turtles and Pascagoula map turtles found a 22.4 cm (8.8 in) mean carapace length among eight gravid females (reported in Lovich et al. 2009, p. 029.4).

2.7 Habitat

There are a lack of studies relating demographic parameters such as occupancy and abundance, however general habitat features have been defined. Pearl River map turtles occur in sand and gravel-bottomed rivers and creeks with dense accumulations of deadwood; they have not been documented in oxbow lakes or other floodplain habitats. They were notably absent from lakes where their sympatric microcephalic species, the ringed map turtle, is present, but do occur at the upstream reach of Ross Barnett Reservoir, an impoundment of the Pearl River (Lindeman 2013, p. 298). Accounts from before the Pearl River map turtle and Pascagoula map turtle were taxonomically divided described ideal habitat as rivers and creeks with sand or gravel bottoms, abundant basking structures, and swift currents (Lovich 2009, p. 304; USFWS 2006, p. 2). Although some species of *Graptemys* appear to handle some salinity increases, there is some evidence that the group is largely intolerant of brackish and saltwater environments (Selman and Qualls 2008 pp. 228-229; Lindeman 2013, pp. 396-397). We do not know the physiological effects of salinity on the Pearl River map turtle, however we do know that although there are some cases of microcephalic species entering brackish water, thus far there are no records of macrocephalic species exhibiting this behavior (Agha 2018, p. 7). Future research is needed to understand the impacts of sea level rise on the Pearl River map turtle (Agha et al. 2019, entire).

Emergent deadwood serves as thermoregulatory basking structure, foraging structure for males and juveniles (Selman and Lindeman 2015, pp. 794-795), and as an overnight resting place for males and juveniles (Cagle 1952, p. 227). Moderate-to-high basking densities of Pearl River map turtles were always associated with moderate-to-high deadwood densities, but some sites with ample deadwood structure did not have high densities of basking map turtles, indicating that those sites may lack other important characteristics (Lindeman 1999, pp. 37-40). Most deadwood structure observed on surveys was not occupied by basking turtles, and structures that were occupied

typically had enough surface area for additional turtles (Lindeman 1999, pp. 37-40). The importance of deadwood and its source in riparian forests to the abundance of riverine turtle species is documented (Sterrett, et al. 2011, entire). Comparisons have not been studied in map turtle abundance between deadwood-rich river reaches that have ample adjacent forest compared to river reaches that have little adjacent forest and less deadwood (Lindeman 2019, p. 31).

An early account with combined data for Pearl River map turtles and Pascagoula map turtles of all sizes suggested that the turtles select logs or debris emerging from deep water as basking structures and dive into the water at the slightest disturbance (Cagle 1952, p. 227), but demographic differences in basking behavior have not been studied in Pearl River map turtles. In several other species of map turtle, females occupy deeper waters farther from shore than males (Pluto and Bellis 1986, pp. 24-30; Craig 1992, pp. 43-49; Jones 1996, pp. 378-384). In Pascagoula map turtles, the megacephalic species one drainage to the east of Pearl River map turtle, the only well-documented habitat difference among demographic groups is that of basking structure choice (Selman and Lindeman 2015, pp. 789-793). In this study, observers found that adults typically basked on structures that had water between the structure and the bank; females preferred large logs or floating logs and basked less on smaller branches, while mature males basked on large logs and smaller branches about equally. Juveniles usually basked closer to the bank and preferred smaller branches and tangles, while tangles were rarely used by adult males or females. Adults have been observed basking directly on the bank during flood periods when deadwood structures were under high water.

Nesting habitat has been described. At a beach on the Pearl River downstream of the Strong River, a nest was found in fine sand 82 feet (ft) (25 meters (m)) from the water (Vogt et al. 2019, p. 557). Three confirmed Pearl River map turtle nests found on sandbars along the Pearl River were dug in relatively fine sand ranging from 23-180ft (7 to 55m) from the water's edge and averaging 5.2ft (1.6m) from the closest vegetation (Ennen et al. 2016, pp. 094.4-094.6). Another account states that nests are typically near the vegetation lines of sandbars (Anderson 1958, pp. 212-215).

Pearl River map turtles have been observed in several streams that were thought to be too shallow or narrow for the genus *Graptemys* by previous researchers (McCoy and Vogt 1979, p. 5; Selman et al. 2009, p. 34) and this indicates a potential difference in habitat selection. While the Pearl River

map turtle is present near the same dense accumulations of deadwood and large sandbars as the ringed map turtle, the Pearl River map turtle ranges farther upstream into smaller tributaries (Lindeman 2013, p. 298) and notable differences in relative abundance between the two species have been documented in specific streams on several occasions. Pearl River map turtle density was greater on mainstem reaches and large tributaries than on small tributaries, but they were outnumbered by ringed map turtles in mainstem reaches (Lindeman 2019, pp. 13-18). A suggested explanation for the difference in tributary tolerance between Pearl River map turtles and ringed map turtles is dietary requirements; ringed map turtles graze on algae, sponges, and other invertebrates on submerged deadwood, a community that is sunlight dependent, while Pearl River map turtles rely more heavily on benthic mussels that may be more tolerant of shaded tributary streams (Lindeman 2019, pp. 22-23).

2.8 Population Structure

While some population structure information has been reported for Pearl River map turtles, demographic bias among the various survey methodologies is likely (basking surveys, basking traps, and hand capture from emergent basking structures at night). In addition, demographic differences between sexes and between age classes in habitat and basking behaviors indicate that ratio estimates based on visual surveys and collecting efforts may not accurately represent the actual population structure (Lindeman 2019, pp. 25-32). Male to female sex ratio reports for adult Pearl River map turtles vary. In 1952, Cagle reported that among 98 individuals captured via dipnetting at night along the Pearl River, 5 were adult females, 12 were adult males, 6 were immature females, and 75 were juveniles, indicating a general sex ratio of 1.1:1, an operational sex ratio (ratio of mature males to mature females) of 2.4:1 (Cagle 1952, p. 233). A 1999 basking survey study on the Bogue Chitto reported that females outnumbered males at most sites (up to 1:3) and that adults outnumbered juveniles up to 1:45 (Shively 1999, p. 4). A later study reported a general sex ratio for captures larger than minimum male size of 1.8:1 and an operational sex ratio of 4.6:1 (Lindeman 2019, pp. 18-25). Another study reported 39 individuals captured to be comprised of 28 males, 10 females, and 1 juvenile, but without indication of the level of maturity of the individuals (Selman and Jones 2017, pp. 29-34). Buhlmann reported observations of 34 basking individuals to be 47 percent mature females (2014, pp. 17-18). Typically, male map turtles mature in 2-3 years, while

females mature much later (Lindeman 2013, p. 109). Maturity for adult female Pearl River map turtles may occur around 9 years of age (Vogt et al. 2019, pp. 557-558). Hatchlings and 1-year-old juveniles accounted for 18 percent of all Pearl River map turtles captured during trapping sessions (Lindeman 2019, p. 18-25), but most were captured via hand or dipnet, a method which may be demographically biased (Cagle 1952, p. 227). A study on another megacephalic species (the Pascagoula map turtle) suggested that variation in population structure at different sites may be driven by dietary differences and prey availability (Selman and Lindeman 2015, pp. 785-786), and prior surveys on other map turtle species have documented mostly males in degraded sections or impoundments (Buhlmann 2014, p. 11).

Pearl River map turtle population structure may be influenced by temperature-dependent sex determination (TDSD) during egg development in the nest, in which the sex determination of individuals is influenced by the temperature of incubation. While TDSD has not been studied in this species, it has been documented in the Ouachita map turtle (*Graptemys ouachitenis*), the false map turtle (*Graptemys pseudogeographica*) and the common map turtle (*Graptemys geographica*), and likely affects all members of the genus (Vogt and Bull 1982, entire; Vogt and Bull 1984, entire; Bull 1985, entire). In a laboratory study of 14 genera of turtles including the false and Ouachita map turtles, incubation temperatures of 77 degrees F (25 degrees C) yielded all males and incubation temperatures from 87.8 degrees F (31 degrees C) or higher yielded all females (Vogt and Bull 1982, entire).

2.9 Predators

Little has been documented on predators of this species. American alligators (*Alligator mississippiensis*) and humans are the only significant predators of mature individuals (Ennen et al. 2016, p. 094.6), and persecution by humans through shooting basking turtles has been related to local population reduction in some turtles (Marion 1986, p. 51; Buhlman and Gibbons 1997, p. 222). Predation of Barbour's map turtle by the river otter has been reported (Sterrett 2009, p. 73) and this mammal may be a predator of juvenile and adult Pearl River map turtles as well. A juvenile Pearl River map turtle was found in the stomach contents of a spotted bass (*Micropterus punctulatus*) (Carr and Messinger 2002, pp. 201-202). Alligator snapping turtles also prey on small

turtles, including *Graptemys*; turtle remnants were found in the gastrointestinal tract of alligator snapping turtles in Arkansas and Louisiana, including the Pearl River, and small turtles of multiple species have been identified as one of the most common prey items (Elsey 2009, p. 447). Nests and juveniles are likely to be the most vulnerable to predation, with the latter probably preyed upon by wading birds and small mammals (Selman and Lindeman 2015, p. 796, Lovich 2009, p. 306). Many large and small mammals such as raccoons, opossums, feral swine, and skunks, as well as snakes and bird species (such as crows) prey upon nests of other map turtle species, including the sympatric ringed map turtle (Lovich 2009, p. 306; Lindeman 2013, entire; Jones 2006, pp. 197-207), and are likely to be predators of Pearl River map turtles as well. Red imported fire ants have also been documented invading turtle nests in the southeastern United States and can cause nest failure and hatchling mortality (Buhlmann and Coffman 2001, entire).

2.10 Summary of Resource Needs

A summary of information related to the needs of the Pearl River map turtle's demographic life stage (or similar species as a proxy) is presented in Table 2.1., however more research is needed in some areas to improve our understanding of the Pearl River map turtle.

Table 2.1. Individual resource needs of the Pearl River map turtle.

Life Stage	Resources needed for <u>individuals</u> to complete each life stage	Resource Function	Information Source
Fertilized Eggs (Nesting: May-August; hatching: July-November)	- Presence of gravid females - Patches of fine sand adjacent to adult habitat with sparse vegetation, typically on sandbars - Adequate incubation temperatures to yield an appropriate sex ratio** - Adequate river flow to prevent nest mortality due to flooding**	Breeding	- Ennen et al. 2016, pp. 094.4-094.6 - Lindeman 2013, p. 275; Lovich et al. 2009, p. 029.4 - Valenzuela et al. 2019, pp. 2-8 - Horne et al. 2003, p. 732; Geller 2012, pp. 210-211; Dieter et al. 2014, pp. 112-117; Eisemberg et al. 2016, p. 6
Hatchlings (July-November)	- Adequate abundance of invertebrate prey* - Adequate abundance of emergent branches and tangles near the riverbank**	Feeding, Sheltering, Dispersal	- LovHarding ich et al. 2009, p. 029.4 - Lindeman 2019, pp. 22-31 - Selman and Lindeman 2015, pp. 789-793
Adult Males (2+ years) and **Juveniles** (1-2 years)	- Adequate abundance of insect prey - Emergent logs, branches, and tangles near the bank**	Feeding, Sheltering, Dispersal	- Cagle 1952, p. 228 - Selman and Lindeman 2015, pp. 789-793
Adult Females (9+ years) and **sub-adult Females** (2-9 years)	- Adequate abundance of native mussels or Asian clams - Deeper, sand or gravel-bottomed stretches for foraging - Emergent logs and branches **	Feeding, Sheltering, Dispersal	- Cagle 1952, p. 228 - Selman and Lindeman 2015, pp. 789-793

* information source combines Pearl River map turtle data with the Pascagoula map turtle
** data were collected on a different megacephalic map turtle species or all megacephalic map turtles.
*** data were collected on a different species of emydid turtle or all aquatic turtles.

CHAPTER 3 – SPECIES NEEDS FOR VIABILITY

In order to assess the current and future condition of the species it is necessary to identify the individual, population, and species needs (Figure 3.1). As defined earlier, resiliency is the ability to withstand stochastic disturbances. In this chapter, we consider the Pearl River map turtle's ecological needs at the individual, population and species level, and discuss these needs in relation to resiliency, redundancy, and representation.

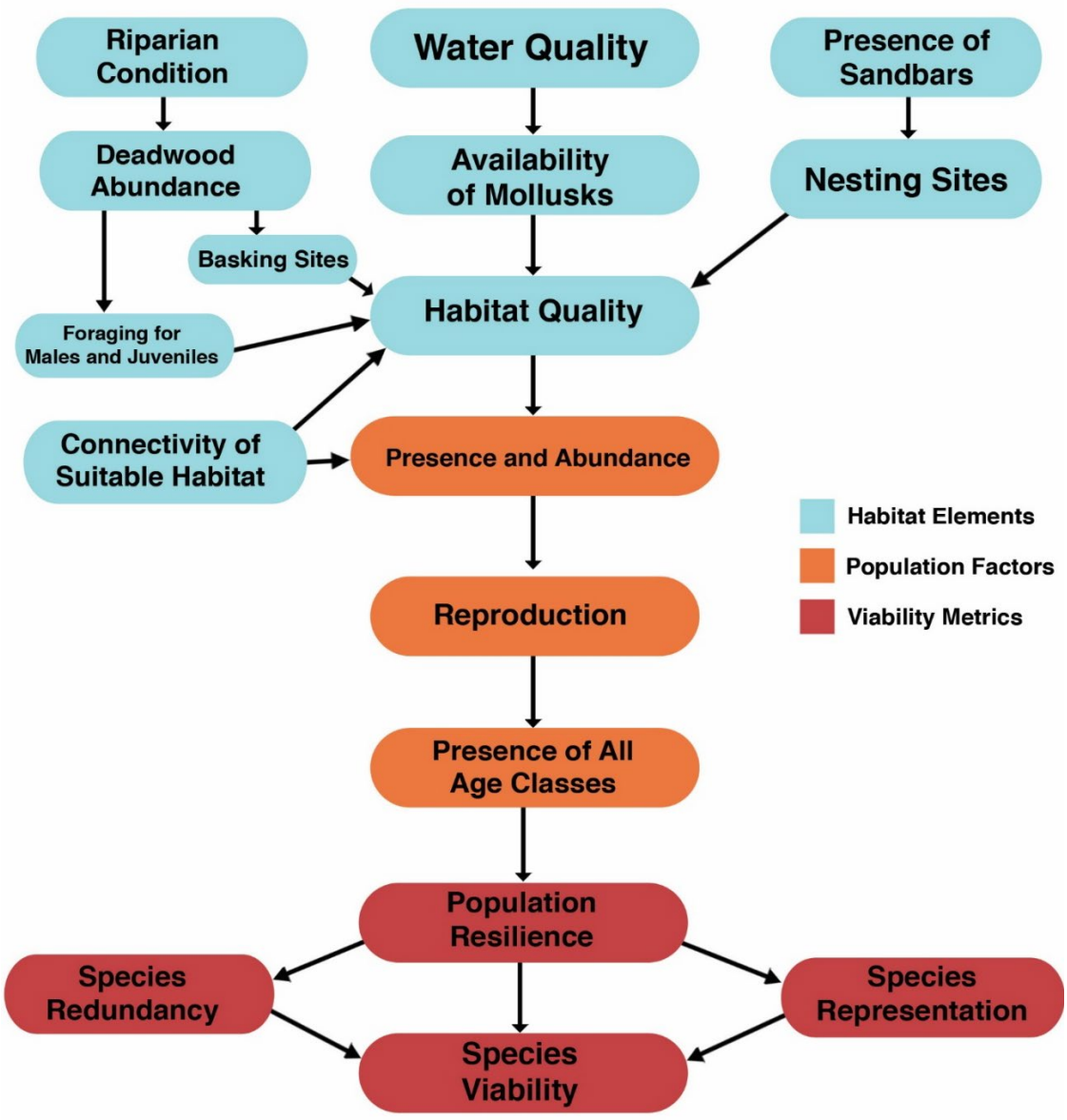


Figure 3.1. Influence diagram depicting the Pearl River map turtle's needs considering the primary habitat elements and population factors that influence the species' viability.

3.1 Individual Needs

For the Pearl River map turtle to survive and reproduce, individuals need suitable habitat that supports essential life functions at all life stages. Several elements appear to be essential to the survival and reproduction of individuals, as discussed in Section 2.10: mainstem and tributary reaches within the Pearl River system that have sandbars, adequate flow, adequate supply of invertebrate prey items including insects and mollusks, an abundance of emergent and floating basking structures of various sizes, and sand or gravel substrates.

3.2 Population Needs

For populations to be resilient, the needs of individuals (sandbars, natural hydrologic regimes, adequate supply of invertebrate prey items, basking structures, and sand, gravel, or rocky substrates) must be met at a larger scale. Tributary and mainstem reaches with suitable habitat uninterrupted by impoundments must be of adequate size to support a large enough population of individuals to avoid issues associated with small population sizes, such as inbreeding depression.

3.3 Species Needs

For the species to be viable, there must be adequate redundancy (suitable number of populations and connectivity to allow the species to withstand catastrophic events) and representation (genetic and environmental diversity to allow the species to adapt to changing environmental conditions). Redundancy improves with increasing numbers of populations (natural or reintroduced) distributed across the species range, and connectivity (either natural or human-facilitated) allows connected populations to "rescue" each other after catastrophes. Representation improves with the persistence of populations spread across the range of genetic and/or ecological diversity within the species. Long-term viability will require resilient populations to persist into the future; for the Pearl River map turtle, this will mean maintaining quality tributary and mainstem habitat and water quality to support many redundant populations across the species range, while preventing barriers to dispersal between populations such as dams or impoundments.

CHAPTER 4 – INFLUENCES ON VIABILITY

The following discussion provides a summary of the factors that have historically affected the species and are affecting or could be affecting the current and future condition of the Pearl River map turtle throughout some or all of its range. Research on delayed sexual maturity suggests that, as generally long-lived species, turtle populations may have a limited ability to respond to chronic stochastic disturbances such as prolonged flooding or drought (Congdon et al 1993, entire; Lovich et al. 2017, pp. 6-8). Effects due to climate change along with water quality issues provide major potential influences on the long-term viability of the species. Other factors that may influence species' viability are collection for the pet trade, invasive species and data deficiency. Conservation measures are considered positive influences on the species' viability and are also summarized in this chapter.

4.1 Climate Change

In the southeastern United States, climate change is expected to result in a high degree of variability in climate conditions with more frequent drought, more extreme heat (resulting in increases in air and water temperatures), increased heavy precipitation events (e.g., flooding), more intense storms (e.g., frequency of major hurricanes increases), and rising sea level and accompanying storm surge (IPCC 2013, entire). Warming in the southeast is expected to be greatest in the summer which is predicted to increase drought frequency, while annual mean precipitation is expected to increase slightly, leading to increased flooding events (IPCC 2013, entire; Alder & Hostetler 2013, unpaginated). This variability in climate may affect ecosystem processes and communities by altering the abiotic conditions experienced by biotic assemblages resulting in potential effects on community composition and individual species interactions (DeWan, et al., 2010, p. 7). These changes have the potential to impact Pearl River map turtles and/or their habitat.

Climate change could intensify or increase the frequency of drought events, such as the one that occurred in the southeastern U.S. in 2007. Based on down-scaled climate models for the Southeast U.S., the frequency, duration, and intensity of droughts are likely to increase in the southeastern U.S. as a result of global climate change (Keellings and Engstrom 2019, pp. 4-6). Stream flow is strongly correlated with important physical and chemical parameters that limit the distribution and

abundance of riverine species (Power et al. 1995, entire; Resh et al. 1988, pp. 438-439) and it affects the hydrology of the systems by regulating the ecological integrity of flowing water systems (Poff et al. 1997, p. 770).

Since 1996, there has been an increase in the frequency of hurricane landfalls in the southeastern United States that is predicted to continue for some years into the future (Goldenberg et al. 2001, p. 475; Emanuel 2005, entire; Webster et al. 2005, p. 1845). Individual storm characteristics play a large role in the types and temporal extent of impacts (Greening et al. 2006, p. 878). For example, direction and speed of approach, point of landfall and intensity, all influence the magnitude of storm surge and resultant flooding (Weisberg and Zheng 2006, p. 164) and consequent environmental damage. Areas with higher levels of anthropogenic land use activity are more susceptible to environmental damage and long-term effects from storms (Mallin and Corbett 2006, pp. 1057-1058).

As a result of climate change, the world's oceanic surface-waters and land are warming. Higher temperatures reduce the density of the water causing it to expand. This process of "thermal expansion," exacerbated by an influx of melt water from glaciers and polar ice fields, is causing sea levels to rise. During the 20th century, global sea level rose by 0.17m at an average annual rate of 0.002m per year, which was ten times faster than the average during the previous 3,000 years (IPCC 2007, p. 30-31). The rate of sea level rise continues to accelerate and is currently believed to be about 0.003m per year (Church and White 2006, pp. 2-4). It is estimated that sea level will rise by a further 0.18 to 0.59m by the century's end (IPCC 2007, p. 46). However, some research suggests the magnitude may be far greater than previously predicted due to recent rapid ice loss from Greenland and Antarctica (Overpeck et al. 2006, entire; Rignot and Kanagaratnam 2006, pp. 989-990). Accounting for this accelerated melting, sea level could rise by between 0.5 and 1.4m by 2100 (Rahmstorf et al. 2007, p. 709). Sea level rise is likely to impact downstream Pearl River map turtle populations, as local scenarios based on downscaled climate models predict between 2-10ft (0.6-3.0m) of sea level rise in the vicinity of the Pearl River (NOAA 2020, unpaginated).

Despite the recognition of climate effects on ecosystem processes, there is uncertainty about what the exact climate future for the southeastern United States will be and how the ecosystems and species in this region will respond. It should be recognized that the greatest threat to many species from climate change may come from synergistic and compounding effects. That is, factors

associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats.

The dual stressors of climate change and direct human impact have the potential to impact aquatic ecosystems by altering stream flows and nutrient cycles, eliminating habitats, and changing community structure (Moore et al. 1997, pp. 942). Increased water temperatures and a reduction in stream flow are the climate change effects that are most likely to affect stream communities (Poff, 1992, entire), and each of these variables is strongly influenced by land use patterns. For example, in agricultural areas, lower precipitation may trigger increased irrigation resulting in reduced stream flow (Backlund et al. 2008, pp. 42-43). In forested areas, logging patterns influence instream temperatures through the direct effects of shading. Reductions in temperature by vegetative cover may be particularly important in low-order streams, where canopy vegetation significantly reduces the magnitude and variation of the stream temperature compared with that of clear-cut regions (Ringler and Hall 1975, pp. 111-121).

While river flooding under natural hydrologic conditions may be important for sandbar construction and deposition of nesting sand on riverine beaches (Dieter et al. 2014, p. 112-117), an increase in hurricane frequency and stochastic catastrophic floods could cause an increase in nest mortality. Nest mortality from flooding has not been studied in the Pearl River map turtle but has been documented in several other riverine turtle species. A study on the sympatric yellow-blotched map turtle revealed that nest mortality from flooding can be as high as 86.3 percent in some years (Horne et al. 2003, p. 732). In a study on nests of the Ouachita map turtle (*Graptemys ouachitensis*), two ten-day floods (in 2008 and 2010) were believed to have caused the complete mortality of all nests existing before the floods, as hatchlings were found dead inside eggs after the flood. However, a shorter flooding event in 2011 (~4 days of inundation) caused no known nest mortalities (Geller 2012, p. 210-211). A study on freshwater turtles in South America indicated that as flooding incidents have increased since the 1970's, the number of days that nesting sandbars remain above the inundation threshold has been steadily and significantly decreasing, causing steep declines in the number of hatchlings produced per year (Eisemberg et al. 2016, p. 6).

Another area where climate change may affect the viability of the Pearl River map turtle is through TDSD during egg development in the nest. In turtle species with TDSD, increasing seasonal

temperatures may result in unnatural sex ratios among hatchlings. This could be an important factor as climate change drives increasing temperatures. Since male map turtles with TDSD develop at lower temperatures than females, rising temperatures during developmental periods may result in sex ratios that are increasingly female-biased.

4.2 Water Quality

Degradation of stream and wetland systems through reduced water quality and increased concentrations of contaminants can affect the occurrence and abundance of freshwater turtles (DeCatanzaro and Chow-Fraser 2010, p. 360). Infrastructure development increases the percentage of impervious surfaces, reducing and degrading terrestrial and aquatic habitats. Increased water volume and land-based contaminants (e.g. heavy metals, pesticides, oils) flow into aquatic systems, modifying hydrological and sedimentation regimes of rivers and wetlands (Walsh et al. 2005, entire). Aquatic toxicants can have both immediate and long-term negative impacts on species and ecosystems. Despite these effects, species vary widely in their tolerances and abilities to adapt to water quality degradation, including variation in stress and immune responses (French et al.2008, pp. 5-6), population structure (Patrick and Gibbs 2010, pp. 795-797), survival and recruitment (Eskew et al. 2010, pp. 368-371), and ultimately distribution and abundance (Riley et al. 2005, pp. 6-8).

Sedimentation and pollution can have adverse impact on the mollusk populations that the closely-related Pascagoula map turtles prey upon (Box and Mossa 1999, entire). Inputs of point (point source discharge from particular pipes, discharges, etc.) and nonpoint (diffuse land surface runoff) source pollution across the range are numerous and widespread. Point source pollution can be generated from inadequately treated effluent from industrial plants, sanitary landfills, sewage treatment plants, active surface mining, drain fields from individual private homes, and others (USFWS 2000, pp. 14-15). Nonpoint pollution originates from agricultural activities, poultry and cattle feedlots, abandoned mine runoff, construction, silviculture, failing septic tanks, and contaminated runoff from urban areas (Deutsch et al. 1990, entire; USFWS 2000, pp. 14-15). These sources contribute pollution to streams via sediments, heavy metals, fertilizers, herbicides, pesticides, animal wastes, septic tank and gray water leakage, and oils and greases. Glyphosate (found in Roundup and other herbicides) that is widely used as an herbicide has been found in many

waterways from agricultural run-off and exposure has been associated with endocrine and reproductive disorders in animals (Jerrell et al. 2020, entire; Medalie et al 2020, entire; Mesnage et al. 2015, entire). Water quality and native aquatic fauna decline as a result of this pollution, which causes nitrification, decreases in dissolved oxygen concentration, and increases in acidity and conductivity. These alterations likely have direct (e.g. decreased survival and/or reproduction) and indirect (e.g. loss, degradation, and fragmentation of habitat) effects. For aquatic species, submergent vegetation provides critical spawning habitat for adults, refugia from predators, and habitat for prey of all life stages (Jude and Pappas 1992, pp. 666-667), and degraded water quality and high algal biomass that result from pollutant inputs, cause loss of these critical submergent plant species (Chow-Fraser et al.1998, pp. 38-39).

A wide range of current activities and land uses can lead to sedimentation within streams that can include: agricultural practices, construction activities, stormwater runoff, unpaved roads, forestry activities, utility crossings, and mining. Fine sediments are not only input into streams during these activities, historical land use practices may have substantially altered hydrological and geological processes such that sediments continue to be input into streams for several decades after those activities cease (Harding et al. 1998, p. 14846). The negative effects of increased sedimentation are well understood for aquatic species (Burkhead et al. 1997, p. 411; Burkhead and Jelks 2001, p. 964). Sedimentation can alter food webs and stream productivity (Schofield et al. 2004, p. 907), force altered behaviors (Sweka and Hartman 2003, p. 346), and even have sub-lethal effects and mortality on individual aquatic organisms (Sutherland and Meyer 2007, p. 394; Wenger and Freeman 2007, p. 7).

Degradation of water quality from municipal and industrial effluents is recognized as a cause of decline in the ringed map turtle, a sympatric endangered species (Lindeman 1998, p. 137). Researchers also recorded lower numbers of ringed map turtles near gravel and sand mining operations (Shively 1999, p. 10). Native mussel and gastropod populations have likely already decreased due to sedimentation and other anthropogenic alterations (Jones at al. 2005, entire). Water quality may have impacted the Pearl River map turtle populations around Jackson, Mississippi (Selman 2020d, p. 194).

Water quality for the Pearl River map turtle is impacted by four processes that are further discussed below: channel and hydrology modifications and impoundments, agriculture, development (urbanization), and mining.

4.2.1 Channel and Hydrology Modifications and Impoundments

Dredging and channelization have led to loss of aquatic habitat in the Southeast (Warren Jr. et al. 1997, unpaginated). Dredging and channelization projects are extensive throughout the region for flood control, navigation, sand and gravel mining, and conversion of wetlands into croplands (Neves et al. 1997, unpaginated; Herrig and Shute 2002, pp. 542-543). Many rivers are continually dredged to maintain a channel for shipping traffic. Dredging and channelization modify and destroy habitat for aquatic species by destabilizing the substrate, increasing erosion and siltation, removing woody debris, decreasing habitat heterogeneity, and stirring up contaminants which settle onto the substrate (Williams et al. 1993, pp. 7-8; Buckner et al. 2002, entire; Bennett et al. 2008, pp. 467-468). Channelization can also lead to headcutting, which causes further erosion and sedimentation (Hartfield 1993, pp. 131-141). Dredging removes woody debris which provides cover and nest locations for many aquatic species (Bennett et al. 2008, pp. 467-468). Anthropogenic deadwood removal has been noted as a reason for decline in a microcephalic species, the ringed map turtle (Lindeman 1998, p. 137). Snags and logs are removed from some sites to facilitate boat navigation (Dundee and Rossman 1989, p. 187). Experiments with manual deposition of deadwood in stretches with less riparian forest have been suggested as potential habitat restoration measures (Lindeman 2019, p. 33).

Stream channelization, point-bar mining, and impoundments have been listed as potential threats in a report from before the Pascagoula map turtle and Pearl River map turtle were taxonomically separated (USFWS 2006, p. 2). Channel modification is recognized as a cause of decline in the ringed map turtle, a sympatric endangered species (Lindeman 1998, p. 137). Considerably low densities of Pearl River map turtles were observed in the lower reaches of the Pearl, where much channelization and flow diversion has occurred (Lindeman 2019, pp. 23-29).

Impoundment of rivers is a primary threat to aquatic species in the southeast (Folkerts 1997, p. 11; Buckner et al. 2002, entire). Dams modify habitat conditions and aquatic communities both upstream and downstream of an impoundment (Winston et al. 1991, pp. 103-104; Mulholland and Lenat 1992, pp. 193-231; Soballe et al. 1992, pp. 421-474). Upstream of dams, habitat is flooded and in-channel conditions change from flowing to still water, with increased depth, decreased levels of dissolved oxygen, and increased sedimentation. Sedimentation alters substrate conditions by filling in interstitial spaces between rocks which provide habitat for many species (Neves et al. 1997, unpaginated). Downstream of dams, flow regime fluctuates with resulting fluctuations in water temperature and dissolved oxygen levels, the substrate is scoured, and downstream tributaries are eroded (Schuster 1997, unpaginated; Buckner et al. 2002, unpaginated). Negative "tailwater" effects on habitat can extend many kilometers downstream (Neves et al. 1997, unpaginated). Dams fragment habitat for aquatic species by blocking corridors for migration and dispersal, resulting in population geographic and genetic isolation and heightened susceptibility to extinction (Neves et al. 1997, unpaginated). Dams also preclude the ability of aquatic organisms to escape from polluted waters and accidental spills (Buckner et al. 2002, unpaginated).

Damming of streams and springs is extensive throughout the southeast (Etnier 1997, unpaginated; Morse et al. 1997, unpaginated; Shute et al. 1997, unpaginated). Shute et al. (1997) report that "few Southeastern streams are spared from impoundment" (p. 458). Many streams have both small ponds in their headwaters and large reservoirs in their lower reaches. Small streams on private lands are regularly dammed to create ponds for cattle, irrigation, recreation, and fishing, with significant ecological effects due to the sheer abundance of these structures (Morse et al. 1997, unpaginated). Small headwater streams are increasingly being dammed in the southeast to supply water for municipalities (Buckner et al. 2002, unpaginated) and many southeastern springs have also been impounded (Etnier 1997, unpaginated). Dams are known to have caused the extirpation and extinction of many southeastern species, and existing and proposed dams pose an ongoing threat to many aquatic species (Folkerts 1997, p. 11; Neves et al. 1997, unpaginated; USFWS 2000, p. 15; Buckner et al. 2002, unpaginated).

The Ross Barnett Reservoir was constructed between 1960 and 1963 and provides a water supply for the City of Jackson and the associated area, as well as recreational opportunities on the 33,000 ac (13,355 ha) lake and the 17,000 ac (6,880 ha) surrounding it (Pearl River Valley Water

Management District 2020, entire). A total of 33.6 km (20.9 rm) of the Pearl River is submerged beneath the Ross Barnett Reservoir, which has 61.5 km (38.2 rm) of shoreline (Lindeman 2019, p. 19). Low population densities of Pearl River map turtles have been observed upstream of the Ross Barnett Reservoir, possibly due to recreational boating and extended recreational foot traffic or camping on sandbars by reservoir visitors (Selman and Jones 2017, pp. 32-34). Notable population declines also have been observed in the stretch of the Pearl River downstream of the Ross Barnett Reservoir (north of Lakeland Drive), but the exact reason for the decline is unknown (Selman 2020d, p. 194). Researchers have estimated that up to 170 individual Pearl River map turtles could be directly impacted by the One Lake Project (Selman 2020d, p. 192).

4.2.2 Agriculture

Agricultural practices such as traditional farming, feedlot operations, and associated land use practices can contribute pollutants to rivers. These practices degrade habitat by eroding stream banks, which results in alterations to stream hydrology and geomorphology. Nutrients, bacteria, pesticides, and other organic compounds are generally found in higher concentrations in areas affected by agricultural than forested areas. Contaminants associated with agriculture (e.g., fertilizers, pesticides, herbicides, and animal waste) can cause degradation of water quality and habitats through instream oxygen deficiencies, excess nutrification, and excessive algal growths, with a related alteration in aquatic community composition (Petersen et al. 1999, p. 6). Agricultural development can also reduce the amount of adjacent riparian forest available to produce deadwood; in another megacephalic map turtle species (Barbour's map turtle), abundance decreased in areas where adjacent riparian corridors had been disturbed by agriculture while the abundance of the red-eared slider (*Trachemys scripta*), a cosmopolitan species, increased (Sterrett et al. 2011, entire).

Agricultural practices such as use of glyphosate-based herbicides for weed control and animal waste for soil amendment are becoming common in many regions, and pose threats to biotic diversity in freshwater systems. Over the past two decades, these practices have corresponded with marked declines in populations of fish and mussel species in the Upper Conasauga River watershed in Georgia/Tennessee (Freeman et al. 2017, p. 419). A study in this watershed showed that nutrient enrichment of streams was widespread with nitrate and phosphorus exceeding levels associated with eutrophication, and hormone concentrations in sediments were often above those shown to cause

endocrine disruption in fish, possibly reflecting widespread application of poultry litter and manure (Lasier et al. 2016, entire). Researchers postulate that species declines observed in the Conasauga watershed may be at least partially due to hormones, as well as excess nutrients and herbicide surfactants (Freeman et al. 2017, p. 429).

4.2.3 Development

Urbanization is a significant source of water quality degradation that can reduce the survival of aquatic organisms. Urban development can stress aquatic systems in a variety of ways, including increasing the frequency and magnitude of high flows in streams, increasing sedimentation and nutrient loads, increasing contamination and toxicity, decreasing the diversity of fish, aquatic insects, plants, and amphibians, and changing stream morphology and water chemistry (Coles et al. 2012, entire; CWP 2003; entire). Sources and risks of an acute or catastrophic contamination event, such as a leak from an underground storage tank or a hazardous materials spill on a highway or by train, increase as urbanization increases.

4.2.4 Mining

The rapid rise in urbanization and construction of large-scale infrastructure projects are driving increasing demands for construction materials such as sand and gravel. Rivers are a major source of sand and gravel because transport costs are low; river energy produces the gravel and sand, thus eliminating the cost of mining, grinding, and sorting rocks; and the material produced by rivers tends to consist of resilient minerals of angular shape that are preferred for construction (Koehnken et al. 2020, p. 363). Impacts of sand and gravel mining can be direct or indirect. Direct impacts include physical changes to the river system and the removal of gravel and floodplain habitats from the system. Indirect impacts include shifting of habitat types due to channel and sedimentation changes; changes in water quality, which change the chemical and physical conditions of the system; and hydraulic changes which can impact movement of species and habitat availability.

Gravel mining is a major industry in southeastern Louisiana, particularly along the Bogue Chitto River (Selman 2020c, p. 20). In-stream and unpermitted point bar mining was observed in the late

1990s, and were considered to be the biggest concern for *Graptemys* species in the Bogue Chitto River (Shively 1999, pp. 10-11). Gravel mining is perhaps still the greatest threat to the Pearl River system in southeastern Louisiana (Selman 2020c, p. 20). A recent comparison of aerial imagery from the mid-1908s and late 1990s with images from 2019 reveal increases in distribution and magnitude of gravel mines in the Bogue Chitto River system, and recent surveys have reported several areas where mining appears to have degraded water quality significantly (Selman 2020c, pp. 20-21, and p. 40).

4.3 Other Influences

Several other influences may be impacting the viability of the species, including the introduction and persistence of invasive species, collection for the pet trade, potential impacts of disease, and the lack of understanding of important conservation components (data deficiency).

4.3.1 Invasive Species

It is estimated that 42% of Federally Threatened or Endangered species are significantly impacted by nonnative nuisance species across the nation and nuisance species are significantly impeding recovery efforts for them in some way (NCANSMPC 2015, pp.8-9). There are many areas across the Southeastern United States where aquatic invasive species have invaded aquatic communities; are competing with native species for food, light, or breeding and nesting areas; and are impacting biodiversity. When an invasive species is introduced it may have many advantages over native species, such as easy adaptation to varying environments and a high tolerance of living conditions that allows it to thrive in its nonnative range. There may not be natural predators to keep the invasive species in check; therefore, it can potentially live longer and reproduce more often, further reducing the biodiversity in the system. The native species may become an easy food source for invasive species, or the invasive species may carry diseases that wipe out populations of native species or displace the native species by consuming the resources that are needed to survive. The degree to which invasive species effect the Pearl River map turtle has not been studied, but the diet of mature females may have been broader before the introduction of Asian Clams (*Corbicula*

fluminea) and removal of invasive vegetation on sandbars has been suggested as nesting habitat management (Selman and Lindeman 2015, p. 794-795; Lindeman 2019, p. 33).

4.3.2 Collection

Due to the intricacy of the shell morphology, map turtles are popular in the pet trade (USFWS 2006, p. 2), both domestically and internationally. An analysis of online marketplace offerings in Hong Kong revealed that interest in turtles as pets is increasing, that many of the species offered for sale are from North America, and that there is a higher interest in rare species (Sung and Fong 2018, p. 221). The common map turtle (*Graptemys geographica*) is one of three key species in the international trade of wildlife, with individuals being sold both as pets and incorporated into Chinese aquaculture for consumption (Luiselli at al. 2016, p. 170). Exploitation of Pearl River map turtles for the pet trade domestically and in Asian markets has been documented, but the degree of impact is unclear, as it is unknown whether captive individuals were Pascagoula map turtles or Pearl River map turtles (Lindeman 1998, p. 137; Cheung and Dudgeon 2006, p. 756; USFWS 2006, p. 2; Selman and Qualls 2007, p. 32-34; Ennen et al. 2016, p. 094.6). In a recent report of surveys conducted in the lower Pearl River in Louisiana, Selman (2020, p. 23) stated his belief that wild turtles are being captured and collected in the Pearl River system, and similar to what has been observed in other states, they are likely destined for the high-end turtle pet trade in China and possibly other southeast Asian countries. Selman (2020, pp. 22-23) received information from three different local individuals, at three different locations, concerning turtle bycatch or harvesting in local Louisiana waterways occupied by Pearl River map turtles. These locations included the Pearl River south of Bogalusa (possible mortality resulting from bycatch in hoop nets), the West Pearl River Navigation Canal (turtles captured and sold, possibly for shipment to China), and the Bogue Chitto River (local comment that baby turtles were being captured and shipped to China). The specific species captured were not documented, however it is likely that at least some of these turtles were Pearl River map turtles.

U.S. Fish and Wildlife Service records information related to species exports in the Law Enforcement Management Information System (LEMIS). According to a LEMIS report from 2005 to 2019, there were over 300,000 turtles identified as *Graptemys* spp. or their parts exported from the United States into 29 countries (see APPENDIX B). The number of turtles recorded in each

shipment ranged widely. Due to the similarity in appearance, species of *Graptemys* are difficult to differentiate. However, in 2005 when the highest number of *Graptemys* were exported (APPENDIX B), there were records of over 35,000 turtles (*Graptemys* spp.) in a single shipment to Spain and a total of 172,645 individual *Graptemys* exported to 24 different countries. There is some uncertainty in the sources of the exported turtles as they could have originated from captive stock or wild-caught. The status and life history of map turtles makes them particularly vulnerable to overharvesting and it has been suggested that the trade in wild-caught animals should be halted or severally reduced (Schlaepfer et al. 2005, p. 263).

Wanton shooting of turtles (documented for *Graptemys* sp.) may also impact populations (Buhlmann and Gibbons 1997, p. 222; Lindeman 1998, p. 137; USFWS 2006, p. 2), although it is not frequently reported, and thus difficult to study and/or quantify.

4.3.3 Disease

Ranaviruses are capable of infecting turtles. Aquatic turtles share habitat with susceptible fish and amphibian populations and as a result may be more at risk of infection than terrestrial turtles (Wirth *et al.* 2018, p. 6). Ranaviral infections are systemic, and there is often extensive damage to multiple organs during infection, especially the liver and spleen in reptiles (Wirth et al. 2018, p. 8). Susceptibility to disease may be increased by immunosuppressive effects to immune systems of aquatic turtles due to stressors such as pesticides, herbicides, and heavy metals that enter aquatic systems (Wirth *et al.* 2018, p. 13). Ranaviruses are likely underreported in turtles due to lack of awareness, few long-term studies on the pathology of disease in turtles, and minimal population monitoring (Wirth *et al.* 2018, p. 7). Few data are available for ranaviruses in *Graptemys* species; however, Mississippi map turtles (*G. pseudogeographica kohni)* have been infected under experimental conditions (Brenes *et al.* 2014, entire). Evidence of shell damage caused by disease has been documented in another megacephalic map turtle (*G. barbouri*), but the underlying disease was unknown (Lovich et al. 1996, p. 261). More recently, a new species of fungal pathogen (Order Onygenales) was isolated from shell lesions on freshwater aquatic turtles (Woodburn et al. 2019, entire).

4.3.4 Data Deficiency

Data deficiency limits our understanding of this species, and a 2006 article ranking North American turtle and tortoise species by number of publications listed *G. gibbonsi* (before the Pearl River map turtle was taxonomically split and therefore combining publications on both species) as only the 46th of 58 species (Lovich and Ennen 2013, p. 22), indicating that 78% of the turtle and tortoise species in North America have been studied more thoroughly. Selman and Jones attributed the data deficiency on the Pearl River map turtle to it being overshadowed by the listing status of and subsequent funding direction toward the sympatric ringed map turtle, as well as the prior taxonomy of the Pearl River map turtle encompassing a much larger range (2017, p. 27). A recent report acknowledged demographic bias issues with prior studies, summarized suggestions for future research, and acknowledged that variation in survey type and location make it difficult to tell whether apparent changes in abundance over time are the result of actual declines or the result of data collection bias (Lindeman 2019, pp. 25-32). Surveys have not been standardized for long-term monitoring of *G. pearlensis*. Much of what we know about *G. pearlensis* is based on opportunistic natural history observations, and many aspects of their biology have not been studied in detail, including fecundity, spatial ecology, microhabitat requirements, estimates of survivorship, diet via stable isotope analyses, temperature-dependent sex determination, salinity tolerance, disease, nest predation and flood mortality, demographic differences in habitat use (beyond basking structure), and the population-level impacts of anthropogenic activities and natural disasters.

4.4 Conservation Measures

4.4.1 Federal

The Clean Water Act of 1972 regulates dredge and fill activities that would adversely affect wetlands. Such activities are commonly associated with dry land projects for development, flood control, and land clearing, as well as for water dependent projects such as docks/marinas and maintenance of navigational channels. The U.S. Army Corps of Engineers (Corps) and the Environmental Protection Agency (EPA) share the responsibility for implementing the permitting program under Section 404 of the Clean Water Act. Permit review and issuance follows a process

that encourages avoidance, minimizing and requiring mitigation for unavoidable impacts to the aquatic environment and habitats. This includes protecting the riverine habitat occupied by the Pearl River map turtle. These laws have resulted in some enhancement of water quality and habitat for aquatic life, particularly by reducing point-source pollutants.

The Endangered Species Act (Act) has as its primary purpose the conservation of endangered and threatened species and the ecosystems upon which they depend. Section 4 of the Act requires the Service to develop and implement recovery plans for the conservation of listed species in order to address the threats to their survival and recovery. Section 7 of the Act requires Federal agencies to evaluate their actions with respect to any listed species and their critical habitat, if designated. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into consultation with the Service and ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or destroy or adversely modify its critical habitat.

The Pearl River map turtle likely receives ancillary protection (i.e., water quality improvements, protection from proposed geomorphological changes) where it co- occurs with three other species listed under the Endangered Species Act of 1973 (Act), the inflated heelsplitter (*Potamilus inflatus)* (U.S. Fish and Wildlife Service 1990, entire), Gulf sturgeon (*Acipenser oxyrhynchus desotoi*) (U.S. Fish and Wildlife Service 1991, entire), and ringed map turtle (*G. oculifera*) (U.S. Fish and Wildlife Service 1986, entire). Conservation measures that could benefit the Pearl River map turtle include when projects affecting one of these listed species results in consultation that reduces or mitigates impacts. In addition, critical habitat is designated for the Gulf sturgeon (U.S. Fish and Wildlife Service 2003, entire) and includes areas of the Pearl River and Bogue Chitto River occupied by the Pearl River map turtle. Federal agency actions within the Pearl River map turtle's habitat that may require consultation due to affects to the above listed species include maintenance dredging for navigation in the lower Pearl River by the Corps and their issuance of section 404 Clean Water Act permits; construction and maintenance of gas and oil pipelines and power line rights- of-way by the Federal Energy Regulatory Commission; EPA pesticide registration; construction and maintenance of roads or highways by the Federal Highway Administration; and funding of various projects

administered by the U.S. Department of Agriculture's Natural Resources Conservation Service and the Federal Emergency Management Agency.

In 2000, the State Wildlife Grants (SWG) Program was created through the Fiscal Year 2001 Interior Appropriates Act and provided funding to states "for the development and implementation of programs for the benefit of wildlife and their habitat, including species that are not hunted or fished." The SWG Program is administered by the Service's Division of Federal Aid and allocates federal funding for proactive nongame conservation measures nationwide. Congress stipulated that each state fish and wildlife agency that wished to participate in the SWG program develop a Wildlife Action Plan to guide the use of SWG funds (see discussion below regarding the plans developed by the Louisiana Department of Wildlife and Fisheries (LDWF) and Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP).

The National Wildlife Refuge System Administration Act (NWRAA) represents organic legislation that set up the administration of a national network of lands and water for the conservation, management, and restoration of fish, wildlife, and plant resources and their habitats for the benefit of the American people. Conservation-minded management of public lands allows for: 1) natural processes to operate freely and thus changes to habitat occur due to current and future environmental conditions; 2) managing the use of resources and activities which minimizes impacts; 3) preservation and restoration to maintain habitats; and 4) reduction of the adverse physical impacts from human use. Amendment of the NWRAA in 1997 required the refuge system to ensure that the biological integrity, diversity, and environmental health of refuges be maintained. The Pearl River map turtle occurs on the Bogue Chitto National Wildlife Refuge which occupies Pearl River County in Mississippi and St. Tammany and Washington Parishes in Louisiana. A Comprehensive Conservation Plan (CCP) has been developed to provide the framework of fish and wildlife management on the refuge (U.S. Fish and Wildlife Service 2011, entire). Within the CCP, specific actions are described to protect the ringed map turtle that will also benefit the Pearl River map turtle. Actions include ongoing habitat management to provide downed woody debris for basking turtles and to maintain 330ft (100.6m) buffers along all named streams during forest habitat improvement and harvest to protect water quality in streams (U.S. Fish and Wildlife Service 2011, p. 21, 73, 89, 179).

The National Forests in Mississippi have adopted, and in most cases exceeded, the best management practices (BMPs) (see discussion below of state BMPs) established by the state of Mississippi (U.S. Forest Service 2014, p. 66). These include practices such as establishing streamside buffer zones, restricting vegetation management in riparian zones, and employing erosion control measures. The Bienville National Forest has no known records for the Pearl River map turtle, but does contain tributaries that flow into the Pearl and Strong Rivers thus these practices may provide some protective measures for habitat occupied by the species downstream.

The Sikes Act Improvement Act (1997) led to Department of Defense guidance regarding development of Integrated Natural Resources Management Plans (INRMP) for promoting environmental conservation on military installations. The U.S. Navy operates the Stennis Western Maneuver Area (Stennis WMA) located along the western edge of the NASA Stennis Space Center and incorporated into the Stennis Space Center Buffer Zone. The Stennis WMA encompasses a 4-mile reach of the East Pearl River and a smaller eastern tributary named Mikes River (Buhlman 2014, p. 4) in Hancock and Pearl River Counties, Mississippi. These river reaches are used by the Navy's Construction Battalion Center for riverboat warfare training. The western bank of the East Pearl River denotes the boundary of the Navy property and is managed as the Pearl River Wildlife Management Area by the state of Louisiana (see below under State/Louisiana). There are records of the Pearl River map turtle from Stennis WMA (Buhlman 2014, pp. 11-12, 31-32). The U.S. Navy has developed an INRMP for the Stennis WMA (U.S. Navy 2011, entire). Measures within the INRMP expected to protect listed species, and also provide a level of protection for the Pearl River map turtle, include erosion and storm water control, floodplain management, invasive plant species management, and the use of an ecosystem approach to general fish and wildlife management (U.S. Navy 2011, pp. 4-4 through 4-20). The work summarized in the Buhlman report (2014, entire) was conducted as part of rare, threatened and endangered species surveys implemented in compliance with the Act and described in the INRMP (U.S. Navy 2011, p. 9).

4.4.2 Convention on International Trade in Endangered Species of Wild Fauna and Flora-Appendix III

All species of *Graptemys* are included on the Convention on International Trade in Endangered Species of Wild Fauna and Flora's (CITES) Appendix III (CITES 2019, p. 43). The Pearl River map turtle was added to the CITES Appendix III list in 2006 (USFWS 2005, entire). Appendix III is a list of species included at the request of a Party that already regulates trade in the species and needs the cooperator of other countries to prevent unsustainable of illegal exploitation. International trade in specimens of species listed in this Appendix is allowed only on presentation of the appropriate permits or certificates.

4.4.3 State/Louisiana

The Pearl River map turtle is globally ranked G2G3 (imperiled) and state-ranked S3 (rare and local throughout the state or found in a restricted region of the state, or because of other factors making it vulnerable to extirpation) in Louisiana (Holcomb et al. 2015, p. 624). Protections under state law for collecting the Pearl River map turtle are limited to licensing restrictions for turtles. In Louisiana, a recreational basic fishing license is required but allows unlimited take of most species of turtles, including the Pearl River map turtle; exceptions are that no turtle eggs or nesting turtles may be taken (LDWF 2020a, p. 50-51). A recreational gear license would also be required for operating specified trap types (see Louisiana's regulations for details on trap types), for instance, five or less hoop nets; greater than five hoop nets requires a Commercial Fisherman License. The Pearl River map turtle has no state status under Louisiana regulations or law (LDWF 2020b, entire).

Louisiana Scenic Rivers Act (1988) was established as a regulatory program which is administered by LDWF through a system of regulations and permits. Certain actions that may negatively affect the Pearl River map turtle are either prohibited or require a permit on rivers included on the natural and scenic river list. Prohibited actions include channelization, channel realignment, clearing and snagging, impoundments, and commercial clearcutting within 100ft (30.5m) of the river low water mark (Louisiana Department of Agriculture and Forestry (LDAF) undated, p. 45). Permits are required for river crossing structures, bulkheads, land development adjacent to the river, and water withdrawals (LDAF undated, p. 45). Rivers with the natural and scenic river designation which are occupied by the Pearl River map turtle include the Bogue Chitto River, Holmes Bayou, and West

Pearl River in St. Tammany Parish; and Pushepatapa Creek in Washington Parish (LDAF undated, p. 48).

Additional protected areas of Pearl River map turtle habitat in Louisiana include the Pearl River Wildlife Management Area located in St. Tammany Parish and Bogue Chitto State Park located on the Bogue Chitto River in Washington Parish. A master plan for management of Wildlife Management Areas and State Refuges has been developed for Louisiana which describes the role of these lands in improving wildlife populations and their habitat including identifying and prioritizing issues threatening wildlife resources (LDWF and The Conservation Fund 2014, entire). Bogue Chitto State Park is managed by the Louisiana Department of Culture, Recreation, and Tourism to preserve and enhance Louisiana's heritage and natural landscape; provide cultural and recreational resources; and promote the use of these resources by the public (State of Louisiana 2019, p. 3).

The Louisiana State Comprehensive Wildlife Action Plan (Holcomb et al. 2015, entire) was developed as a roadmap for nongame conservation in Louisiana. The primary focus of the plan is the recovery of Species of Greatest Conservation Need (SGCN), those wildlife species in need of conservation action within Louisiana which include the Pearl River map turtle. Specific actions identified for the Pearl River map turtle include conducting ecological studies of the turtle's reproduction, nest success, and recruitment as well as developing general population estimates via mark and recapture studies (Holcomb et al. 2015, p. 69). Recent Pearl River map turtle survey work in Louisiana was conducting using funding from the SWG program (Selman 2020c, entire).

4.4.4 State/Mississippi

The Pearl River map turtle is globally ranked G2G3 (imperiled) and S2 (imperiled because of rarity or because of some factor making it very vulnerable to extinction) in Mississippi, (Mississippi Museum of Natural Science 2015, p. 38), but is not listed on the Mississippi state list of protected species (Mississippi Natural Heritage Program 2015, entire). Protections under state law are limited to licensing restrictions for take for personal use of nongame species in need of management (which includes native species of turtles). A Mississippi resident is required to obtain one of three licenses for capture and possession of Pearl River map turtles (Mississippi Commission on Wildlife,

Fisheries, and Parks, Mississippi Department of Wildlife, Fisheries, and Parks 2016, pp. 3-5). The three licenses available for this purpose are a Sportsman License, an All Game Hunting/Freshwater Fishing License, and a Small Game Hunting/Freshwater Fishing License. A Nonresident would require a Nonresident All Game Hunting License (Mississippi Department of Wildlife, Fisheries, and Parks 2020, entire). Restrictions on take for personal use include that no more than four turtles of any species or subspecies may be possessed or taken within a single year, and that no turtles may be taken between April 1st and June 30th except by permit from the Mississippi Department of Wildlife, Fisheries, and Parks (Mississippi Commission on Wildlife, Fisheries, and Parks, Mississippi Department of Wildlife, Fisheries, and Parks 2016, pp. 3-5).

The Mississippi Comprehensive Wildlife Action Plan (MMNS 2015, entire) was developed to provide a guide for effective and efficient long-term conservation of biodiversity in Mississippi. As in Louisiana, the primary focus of the plan is on the recovery of species designated as SGCN which includes the Pearl River map turtle. Specific actions identified for the Pearl River map turtle in Mississippi include planning and conducting status surveys for the species (MMNS 2015, p. 686).

Lands managed for wildlife by the state of Mississippi, which may provide habitat protections for the Pearl River map turtle, include the Old River Wildlife Management Area, Pearl River County and Pearl River Wildlife Management Area, Madison County. In addition, a ringed map turtle sanctuary was designated in 1990 by the Pearl River Valley Water Supply District (District) north of the Ross Barnett Reservoir, Madison County. One of the goals of management on Wildlife Management Areas in Mississippi is to improve wildlife populations and their habitat (MDWFP 2020, entire). The District sanctuary is approximately 19.3 rkm (12 rm) north from Ratliff Ferry to Lowhead Dam on the Pearl River (U.S. Fish and Wildlife Service 2010, p. 4). Within the sanctuary, the District is required to maintain informational signs to facilitate public awareness of the sanctuary and of the importance of the area to the species; conduct channel maintenance by methods which do not hinder the propagation of the species; and record a notation on the deed of the property comprising the sanctuary area that will in perpetuity notify transferees that the sanctuary must be maintained in accordance with the stated provisions (U.S. Fish and Wildlife Service 2010, p. 4).

4.4.5 Voluntary

Most of the land adjacent to the Pearl and Bogue Chitto Rivers in Louisiana and Mississippi is privately owned and much of it is managed for timber. Both states have developed voluntary BMPs for forestry activities conducted in their respective states. In addition, the forest industry has a number of forest certification programs, such as the Sustainable Forestry Initiative, which require participating landowners to meet or exceed state forestry BMPs. Silvicultural practices implemented with BMPs reduce negative impacts to aquatic species through reductions in nonpoint source pollution. Although nonpoint source pollution is a localized threat to the Pearl River map turtle, it is less prevalent in areas where certified BMPs are utilized. In Louisiana, BMPs include streamside management zones (SMZ) of 50ft (15.24m) measured from the top of the streambank, for streams of less than 20ft (6.1m) under estimated normal flow, to a width of 100ft (30.5m) for streams more than 20ft (6.1m) wide (LDAF undated, p. 15). BMP guidance includes maintaining adequate forest canopy cover for normal water and shade conditions as well as an appropriate amount of residual cover to minimize soil erosion (LDAF undated, p. 14). An overall rate of 97.4 percent of 204 forestry operations surveyed by the LDAF in 2018 complied with the state's voluntary guidelines; compliance with guidelines in SMZs was 98.6 percent (LDAF 2018, entire). The state of Mississippi has voluntary BMPs developed by the Mississippi Forestry Commission (MFC) (MFC 2008, entire). These BMPs include SMZs with the purpose of maintaining bank stability and enhancing wildlife habitat by leaving 50 percent crown cover during timber cuts (MFC 2008, p. 6). The width of SMZs is based on slope, with a minimum SMZ width of 30ft (9.14m) extending to 60ft (18.3m) at sites with over 40 percent slope (MFC 2008, p. 6). The most recent monitoring survey of 174 Mississippi forestry sites indicated that 95 percent of applicable sites were implemented in accordance with the 2008 guidelines (MFC 2019, p. 6).

CHAPTER 5 – CURRENT CONDITION

As the population is a biologically meaningful unit in an analysis of resilience, which is then scaled up to redundancy and representation at the species scale, appropriately defining and delineating populations is a crucial step to assess species viability. Below we discuss the challenges of delineating populations for the Pearl River map turtle and our approach. After delineating resilience units (i.e. populations), we then assessed the resilience of each unit as described in the following sections by synthesizing the best available information about observations and other important metrics thought to be important for viability of the Pearl River map turtle. Resilience of these units was used to assess current redundancy and representation for the species.

5.1 Delineating Resilience Units

Home range sizes and movements for Pearl River map turtle are not well known, so delineating biological populations is not feasible. Thus, we delineated what we term "resilience units" for the species to assess resilience. These units are not meant to represent "populations" in a biological sense; they may represent multiple or portions of groups of demographically-linked interbreeding individuals. As data are not available to delineate biological populations at this time, these units were intended to subdivide the species range in a way that facilitates assessing and reporting the variation in current and future resilience across the range.

Pearl River map turtle resilience units were delineated using HUC8 (8-digit hydrologic unit code) hydrologic units, taken from the USGS Water Boundary Dataset (USGS 2019a, unpaginated). HUC8 hydrologic units correspond to watersheds, with units denoted by fewer digits (e.g., HUC6) corresponding to larger units (basin), and those with more digits (e.g., HUC10 or HUC12) corresponding to smaller units or subwatersheds. Hydrologic units of smaller sizes (more digits) are nested within units of larger sizes (fewer digits). We used HUC 8 watersheds because that level best represented the distribution of the turtle in the mainstem and tributaries.

For the purpose of this SSA, we delineated five resilience units of Pearl River map turtles based on HUC8 watersheds and in accordance with guidance from species experts. These units are: Upper

Pearl, Middle Pearl-Silver, Middle Pearl-Strong, Bogue Chitto, and Lower Pearl (Figure 5.1). Historically, the majority of the range of the species was likely connected in a single interbreeding biological population, but we used the five analysis units in the SSA to most accurately describe trends in resiliency, forecast future resiliency, and capture differences in stressors among units.

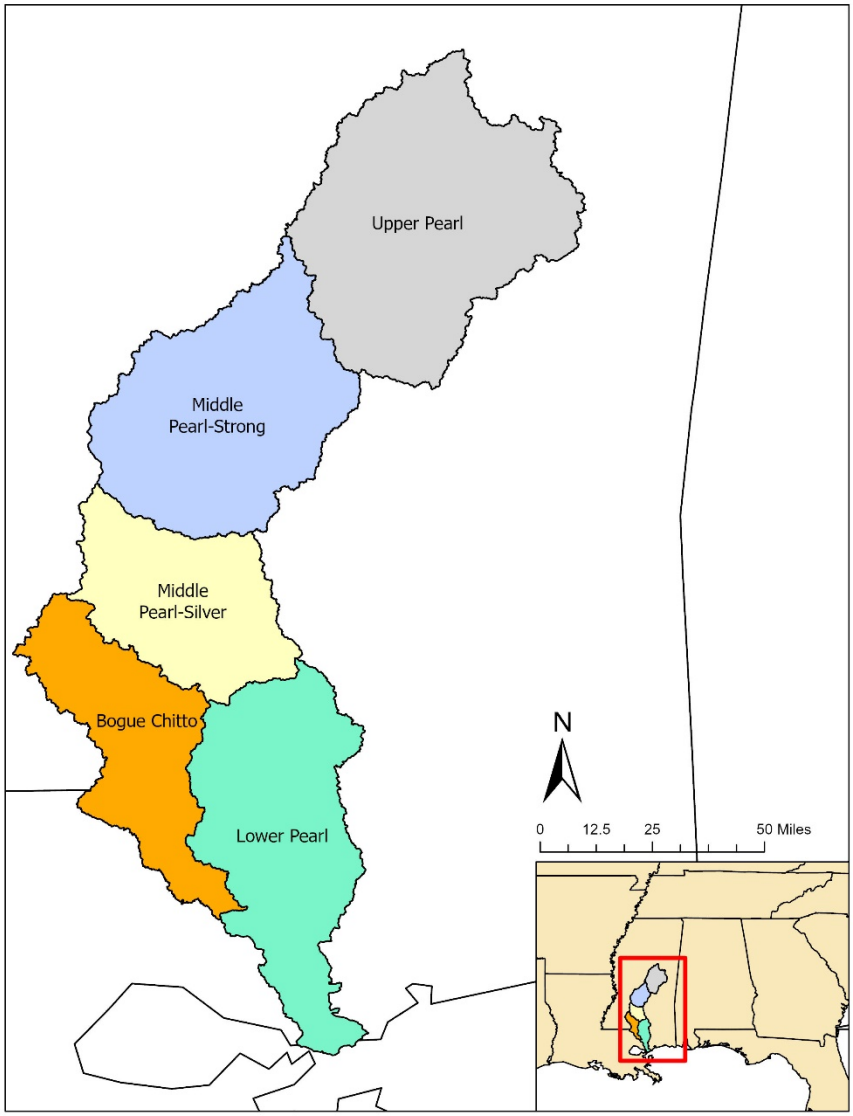


Figure 5.1-Pearl River map turtle resilience units delineated using HUC8 watersheds.

5.2 Population Resiliency

To assess current resiliency of Pearl River map turtle populations, we assessed the condition of two population factors within each analysis unit: 1) species presence using occupied tributaries and 2) density and abundance, and four habitat factors: 1) water quality, 2) forested riparian cover, 3) protected land, and 4) presence of channelization/reservoirs/gravel mining. These influences on population resiliency will hereafter be referred to as population and habitat factors, or collectively as resiliency factors.

5.2.1 Population Factor: Presence using Occupied Tributaries

For a given population to be resilient, the species must be present. Furthermore, although Pearl River map turtle relative abundance is typically much higher within mainstem reaches, presence of the species within tributary systems can contribute to resiliency by increasing the number of occupied miles of stream within a given unit, and also by providing refugia from catastrophic events, such as spill events or flooding. Insulation against threats in tributaries is important to the conservation status of the species, because the relatively tributary-poor Pearl River drainage (e.g. compared to the Pascagoula basin) has considerably more plans for projects that would degrade habitat for the species, including several proposed reservoirs (Lindeman 2013, pp. 202-203).

Forty-nine percent (49%) of the total range occupied by the Pearl River map turtle is in the mainstem Pearl and West Pearl rivers, with the remaining 51% of the occupied range found in various tributary systems (Lindeman 2019, p. 19). Tributary populations have been shown to be less densely populated compared to mainstem populations, although some tributaries (e.g. Bogue Chitto River) contain relatively large populations of Pearl River map turtles, including some that have only recently been discovered. For example, the species was first found in Yockanookany Creek in 1994, and extensive upstream range extensions have now been reported in several tributary systems, including Yockanookany Creek, Strong River, and Bogue Chitto River (Lindeman 1998, p. 139; Lindeman 2013, p. 298; Lindeman 2019, p. 50); these three tributaries together are inhabited by nearly one-third of the entire species, with nearly half occurring in stretches not known to be part of the species' range prior to the 21st century (Lindeman 2019, p. 23).

In order to assess occupied tributaries, we used survey data collected from 2005-2020. These data were collected by several different observers through a variety of survey types, including bridge surveys, basking surveys, and live trapping. Surveys were not repeated or standardized over time, thus we cannot assess trends in occupancy; rather, we consider a drainage occupied if it has been seen within the 2005-2020 time period. We used 2005 as the cutoff based on the species' biology and expert input. Females typically reach sexual maturity after eight years, so 15 years captures approximately two generations. Also, species experts noted that most surveys conducted for the species have occurred after 2005. When assessing occupancy of tributaries, we considered both occupied tributaries and tributaries that were surveyed, but no Pearl River map turtles were found (i.e. inferred absence; Figure 5.2). We established thresholds for occupied tributaries by applying the following rule set:

- Very Low: no currently occupied tributaries
- Low: between 1-24% of surveyed tributaries are currently occupied
- Moderate: between 25-49% of surveyed tributaries are currently occupied
- High: 50% or more of surveyed tributaries are currently occupied

Using this rule set, we found that one unit was determined to be ranked very low (Middle Pearl Silver); three ranked moderate (Upper Pearl, Bogue Chitto, and Lower Pearl); and one ranked high (Middle Pearl Strong) (Table 5.1). The Middle Pearl Silver unit has four surveyed tributaries, and there have been no detections within any of those tributaries, leading to the very low rank. In the Lower Pearl, although only 43% of surveyed tributaries were found to be occupied, this unit had by far, the most occupied tributaries (7), thus the moderate rank is likely more a function of survey effort. Half of the tributaries surveyed within the Middle Pearl Strong unit were found to be occupied, giving it a high rank.

Table 5.1-Assessment of tributaries found to be occupied for the Pearl River map turtle. Rank is based off of the % of occupied tributaries surveyed: very low (no occupied tributaries); low (1-24% occupied tributaries); moderate (25-49% occupied tributaries); high (50% or more occupied tributaries).

Unit	# Surveyed Tributaries	# Occupied Tributaries	% Occupied Tributaries	Rank
Upper Pearl	7	3	43%	Moderate
Middle Pearl Strong	6	3	50%	High
Middle Pearl Silver	4	0	0	Very Low
Bogue Chitto	5	2	40%	Moderate
Lower Pearl	15	7	43%	Moderate

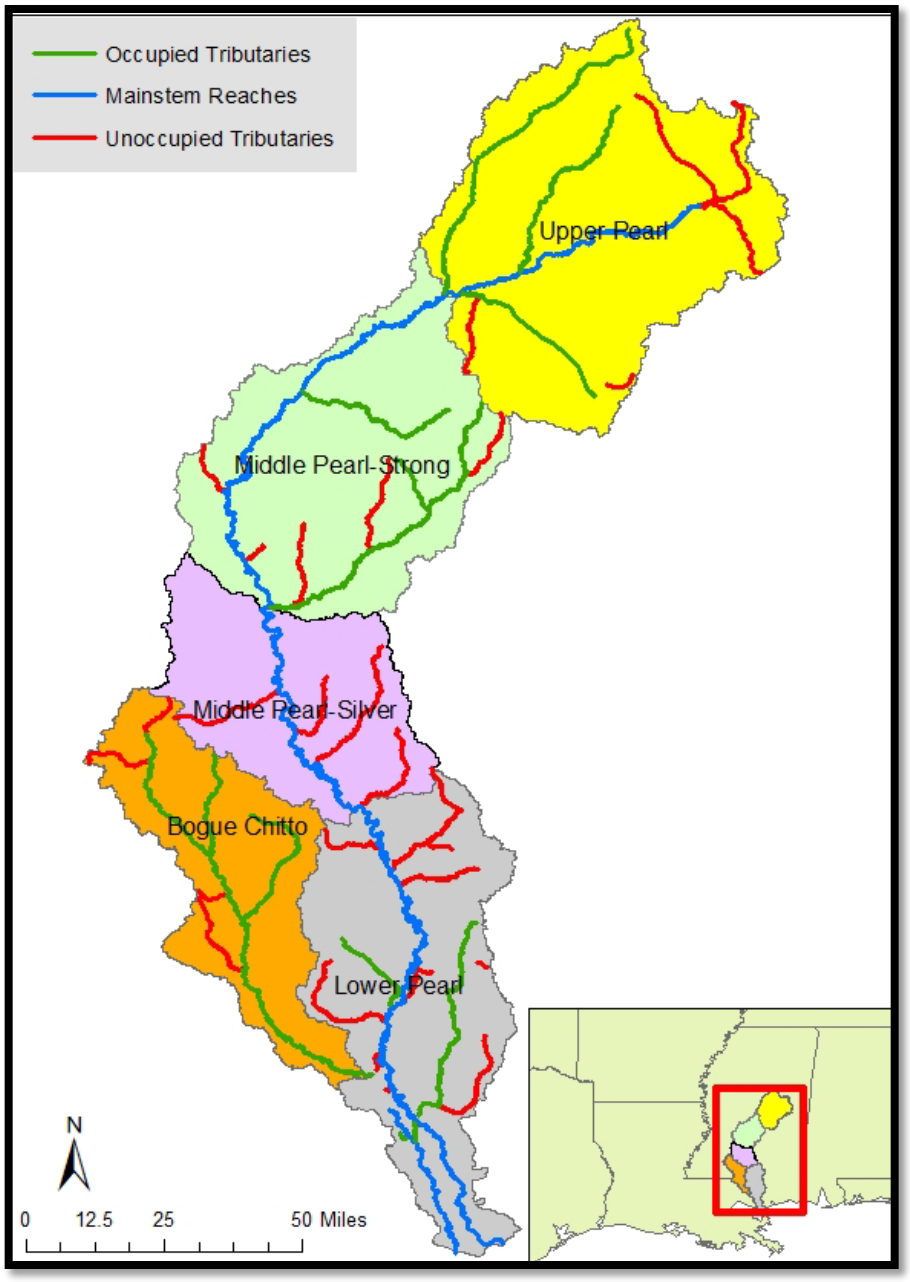


Figure 5.2-Surveyed streams across all Pearl River map turtle units. Occupied tributaries (green), unoccupied tributaries (red), and mainstem reaches (blue) shown.

5.2.2 Population Factor: *Density and Abundance*

The influence of stochastic variation in demographic (reproductive and mortality) rates is much higher for small populations than large ones. Stochastic variation in demographic rates causes small populations to fluctuate randomly in size. In general, the smaller the population, the greater the

probability that fluctuations will lead to extinction. There are also genetic concerns with small populations, including reduced availability of compatible mates, genetic drift, and low genetic diversity or inbreeding depression. Small populations of Pearl River map turtles inherently have low resilience, leaving them particularly vulnerable to stochastic events.

Because we do not have historical surveys to use as a baseline to compare current abundance estimates, we cannot make inferences as to whether populations are decreasing, increasing, or stable through time. However, a recent study combined data from point counts, basking density surveys, and trapping from 2006–2018 to estimate density and abundance for stream segments throughout the range of the Pearl River map turtle (Lindeman 2019, p. 11-12). The global population was estimated to be 21,841 individuals, with 61% occurring on mainstem reaches, 34% occurring in four large tributaries, and the remaining 5% spread amongst other smaller tributaries (Lindeman, 2019 p. 21). Generally, abundance of the species declined with the size of the river reach surveyed, where tributaries generally had lower numbers of turtles compared to mainstem reaches (Lindeman 2019, p. 13). For example, basking density was found to be 2.2 times higher on mainstem reaches as on tributary reaches and 2.1 times higher on large tributaries than on small tributaries (Lindeman 2019, p. 15).

Based on basking density surveys and on results of point counts, each river drainage was divided into river reaches that were categorized as high, moderate, low, and very low density. Lindeman (2019, p. 20) assigned these categories based on typical basking densities of 10, 3, 1, and 0.7 individuals/rkm, respectively, and these categories comprised 3%, 68%, 16%, and 14%, respectively, of the total range of the Pearl River map turtle.

We used the density categories from Lindeman (2019, p. 47) to assess density of mainstem reaches and large tributaries as a population factor for this SSA. As discussed in the next section, we then combined the density score and occupied tributary score for each unit to come up with a composite population factor.

Table 5.2-Density of mainstem reaches and large tributaries within the analysis units (in bold) of Pearl River map turtles based on Lindeman (2019, p. 47). *a 19.5 rkm (12.1 rm) stretch was assessed as very low by Lindeman, however most of the occupied tributary was classified as moderate. **a 33.4 rkm (20.7 rm) stretch of mainstem reach was assessed as high by Lindeman, however the majority of the mainstem within this unit was classified as moderate.

Unit/Stream	Density Class
Bogue Chitto	**Moderate**
Bogue Chitto (large trib)	*Moderate/Very Low**
Lower Pearl	**Low**
East Pearl (large trib)	Low
Pearl River (mainstem)	*Moderate*
West Pearl (mainstem)	*Low*
Middle Pearl Silver	**Moderate**
Pearl River (mainstem)	*Moderate*
Middle Pearl Strong	**Moderate**
Pearl River (mainstem)	*Moderate*
Strong River (large trib)	*Moderate*
Upper Pearl	**Moderate**
Pearl River (mainstem)	*Moderate/High***
Yockanookany Creek	*Moderate*

5.2.3 Population Factor: Composite Score

To determine a composite score for population factors within individual units, we combined the results of the assessment of occupied tributaries (Table 5.1) and density classes of mainstream reaches and large tributaries (Table 5.2). Classifications were averaged together for each population factor as if very low, low, moderate, and high were equal to values of 1, 2, 3, and 4 respectively. If averaging the two factors resulted in a value ending in .5, the score was weighted more heavily towards the density factor. For example, if the occupied tributary's rank was assessed as low, and density was assessed as moderate, the composite score would be moderate due to heavier weighting given to density. Composite population factor scores were then categorized on a very low (1), low (2), moderate (3), and high (4) scale.

Table 5.3-Population factor composite score for each unit based on the combination of the occupied tributaries and density population factors. Density was weighted slightly higher in the assessment.

Unit	Occupied Tribs	Density	Composite Score
Bogue Chitto	Moderate	Moderate	Moderate
Lower Pearl	Moderate	Low	Low
Middle Pearl Silver	Very Low	Moderate	Low
Middle Pearl Strong	High	Moderate	Moderate
Upper Pearl	Moderate	Moderate	Moderate

5.2.4 Habitat Factor: Water Quality

As mentioned previously, water quality is an important component of Pearl River map turtle resilience because it affects how well they survive and reproduce. In the absence of site-specific water quality measurements taken at occurrence locations within each unit, we used data available at the resiliency unit scale from land cover data that were compiled from the 2016 National Land Cover Dataset (NLCD) Version 1, accessed via the Multi-Resolution Land Characteristics (MRLC) consortium online to characterize nonpoint source pollution (i.e., development and agriculture) (MRLC 2016, unpaginated).

Land use can be an indicator of overall watershed health and provide insight into water quality. Agricultural land use within riparian zones has been shown to directly impact biotic integrity when assessed within the intermediate-sized zones (i.e., 200ft (61m) buffer) surrounding the streams in the region (Diamond et al. 2002, p. 1150). Urbanization has also been shown to impair stream quality by impacting riparian health (Diamond et al. 2002, p. 1150). We assessed watershed health by combining several metrics within each resilience unit: percent urbanization and agriculture land use at the watershed level, as well as riparian effects, which included urbanization and agriculture within close proximity to the stream 200ft (61m)) buffer from the center of the waterbody). Many riparian BMPs stipulate maintaining a natural buffer of 100ft (30m) to protect water quality, thus the buffer chosen for our analysis captures the area adjacent to the stream that is believed to be most important to water quality (EPA 2005, p. 9).

5.2.4.1 Watershed Health

Increased agricultural land use within a watershed has the potential to increase nutrient and other pollutant-loading to stream systems. In addition to other impacts on aquatic habitat structure and quality, urban cover increases runoff volume into streams, likely increasing loads of sediments, nutrients, metals, pesticides, and other nonpoint source pollutants (CWP 2003, entire). Watershed health within populations boundaries and riparian buffers were calculated using urban and agricultural land use information. Land cover data were compiled from the 2016 NLCD land use land cover data set. We combined the low, medium, and high intensity development into a single developed land class. We combined hay/pasture and cultivated crops land use classes into a single agriculture land class. To calculate percentages of development and agriculture across the unit, we simply divided the corresponding land class by the total acreage of the unit. To calculate percentages of development and agriculture within riparian buffers, we divided the corresponding land class by the total acreage of the buffer around each occupied stream.

To establish current water quality levels within a unit, we created thresholds of low, moderate, and high threats to Pearl River map turtles. By creating these levels, we enable an assessment of the projected changes in the levels of these threats in future scenarios, as well as subsequent predictions about changes in resilience. The scaling of urban watershed impacts was derived from the Impervious Cover Model (ICM) and studies on amphibians and other taxa (Schueler 1994, entire) which is widely used in planning and zoning. An updated model includes ranges of impervious cover likely impacting stream quality (Schueler et al. 2009, p. 313) and indicates good stream quality is <5-10% impervious cover, fair quality (i.e., impacted) ranges from 5-25% impervious cover, and poor quality occurs at >20-25% impervious cover within the watershed. Several other studies have found impacts of urbanization on biotic health occur at 8-12% impervious cover (Wang et al. 2001 p. 259), although results from a recent study in the Etowah (Wenger et al. 2008, pp.1260-1261) indicate some species could become rare at impervious cover as low as 2%.

5.2.4.2 Riparian Health

Riparian impairment, either through urbanization or agriculture use, can amplify negative effects of nonpoint source pollution within the watershed as well as impact stream quality independent of land use within the watershed. Impacts from impervious cover can be mitigated through riparian forest cover and good riparian health (Roy et al 2005, p. 2318; Walsh et al. 2005, entire); however, several studies have indicated benefit of the riparian cover diminishes when impervious cover (i.e. urban cover) exceeds ~10% within the watershed (Booth and Jackson 1997, p. 1084; Goetz *et al*. 2003, p. 205). Diamond et al. (2002, entire) assessed the relationship between human land uses (urban and agriculture) and fauna in the Clinch and Powell River watersheds in Tennessee and Virginia. They found that when urban areas and major highways approached 12.2% cover within 200ft (61m) of the stream, the stream was more likely to be classified as impaired within the Clinch River, Powell River, and Copper Creek while unimpaired sections of those streams averaged 5.6% urban cover (Diamond et al. 2002, p. 1151). We calculated percent cover of urban land use within 200ft (61m) of each stream in each population and classified percentages to a low(<6%)-moderate(6-12%)-high(>12%) threat scale (Table 5.4).

Like the effects of urban use in riparian zones, agricultural impacts can directly decrease riparian vegetation cover and health. Agricultural practices within the riparian zones can further impact water quality and aquatic organisms via increased exposure to chemical fertilizers, pesticides, livestock waste, and sedimentation which has been implicated in amphibian malformation, susceptibility to disease, and declines in population numbers, reproductive success, and biodiversity (Beja and Alcazar 2003, entire; Montag *et al*. 2019, entire; Burkholder *et al*. 2007, pp. 309-310). There is little information regarding the threshold for agriculture land use within a riparian area that will begin to have an impact on stream water quality. Therefore, we used the thresholds for urban land use to inform thresholds for agricultural land cover. However, because the relationship between area of agricultural land and water quality is less certain than the relationship between urban area and water quality, we reduced the number of classifications used to assess agricultural land use threats (Table 5.5). A threshold of 10%, rather than the 5% threshold used for urban development, to distinguish between low and moderate levels of threats is reasonable because it is in line with suggested values from the literature (i.e. 8-12% threshold; Wang *et al*. 2001 p. 259;

Schueler et al. 2009, p. 313), and agriculture is typically not associated with high amounts of impervious cover, thus % agriculture of <10% is unlikely to significantly impact infiltration capacity, and thus water quality.

Table 5.4. Metrics used to categorize impacts of urbanization within units.

		% Urban in unit			
		0-5%	5-10%	10-20%	>20%
Urban Cover in Riparian Areas	Low (0-6%)	Low	Low	Moderate	High
	Moderate (6-12%)	Low	Moderate	Moderate	High
	High (>12%)	High	High	High	High

Table 5.5. Metrics used to categorize impacts of agriculture within units.

		% Agriculture in unit		
		0-10%	10-20%	>20%
Ag Cover in Riparian Areas	Low (0-10%)	Low	Moderate	High
	Moderate (10-20%)	Low	Moderate	High
	High (>20%)	High	High	High

5.2.4.3 Land Use Composite Score

In our analysis, overall watershed health within a population is considered to be influenced by a combination of direct impacts by urbanization and agriculture. To generate a single composite score for watershed health for each unit, all agriculture and urban composite water quality scores were combined. Classifications were averaged together for each composite watershed score as if low, moderate, and high threats were equal to values of 1, 2, and 3, respectively. If averaging the two factors resulted in a value ending in .5, the overall water quality score was rounded down (rather than typical mathematical convention of rounding up) to be conservative (i.e. to avoid underestimating threats derived from land use). Composite population land use scores were then categorized on a low (1)-moderate (2)-high (3) threat scale.

5.2.4.4 Results

Results for land use across the watersheds and within riparian areas, along with their overall composite classification scores, are summarized in Appendix A and Tables 5.6-5.10. Land use composite scores for all 5 units were moderate. In fact, the only stream that was assessed as having a relatively high degree of threat based on land use, was the Lower Pearl, driven primarily by a high degree of development within the riparian buffer (33%). In general, development is low throughout the Pearl River basin, although there is significant development across the Middle Pearl Strong Unit (12% development), where the city of Jackson is located. Agriculture is generally high across the Pearl River basin, where levels of agriculture within the units ranged from 12-23%, with the Bogue Chitto Unit having the highest levels of agriculture.

Table 5.6-Composite land use score for streams within the Bogue Chitto unit, and for the entire unit, based on development and agriculture levels. Streams in bold are mainstem reaches; all other streams are considered tributaries.

Stream	**Developed**	**Agriculture**	**Composite Land Use Score**
Bogue Chitto	Low	High	Moderate
Magees	Low	High	Moderate
Topisaw	Low	High	Moderate
Bogue Chitto Unit			**Moderate**

Table 5.7-Composite land use score for streams within the Lower Pearl unit, and for the entire unit, based on development and agriculture levels. Streams in bold are mainstem reaches; all other streams are considered tributaries.

Stream	Developed	Agriculture	Composite Land Use Score
East Pearl	Low	Moderate	Moderate
Hobolochitto	Low	Moderate	Moderate
Holmes Bayou	Low	Moderate	Moderate
Lower Pearl	High	Moderate	Low
Navigation Canal	Low	Moderate	Moderate
Pushepatapa	Low	Moderate	Moderate
West Hobolochitto	Low	Moderate	Moderate
West Pearl	Low	Moderate	Moderate
Lower Pearl Unit			**Moderate**

Table 5.8- Composite land use score for streams within the Middle Pearl Silver unit, and for the entire unit, based on development and agriculture levels. Streams in bold are mainstem reaches; all other streams are considered tributaries.

Stream	Developed	Agriculture	Composite Land Use Score
Middle Pearl Silver	**Low**	**Moderate**	**Moderate**

Table 5.9-Composite land use score for streams within the Middle Pearl Strong unit, and for the entire unit, based on development and agriculture levels. Streams in bold are mainstem reaches; all other streams are considered tributaries.

Stream	Developed	Agriculture	Composite Land Use Score
Middle Pearl Strong	Moderate	Moderate	Moderate
Pelahatchie	Moderate	Moderate	Moderate
Purvis	Moderate	Moderate	Moderate
Strong	Moderate	Moderate	Moderate
Middle Pearl Strong Unit			**Moderate**

Table 5.10-Composite land use score for streams within the Upper Pearl unit, and for the entire unit, based on development and agriculture levels. Streams in bold are mainstem reaches; all other streams are considered tributaries.

Stream	Developed	Agriculture	Composite Land Use Score
Lobutcha	Low	Moderate	Moderate
Tuscolometa	Low	Moderate	Moderate
Upper Pearl	Low	Moderate	Moderate
Yockanookany	Low	Moderate	Moderate
Upper Pearl Unit			**Moderate**

5.2.5 Habitat Factor: *Channelization/Reservoirs/Gravel Mining*

Channel modification is recognized as a cause of decline in the similar and sympatric species, the ringed map turtle (*G. oculifera*), which is federally threatened (Lindeman 1998, p. 137). Stream channelization, point-bar mining, and impoundment have been listed as potential threats in a report from before the Pascagoula map turtle and Pearl River map turtle were taxonomically separated (USFWS 2006, p. 2). Gravel mining has been identified as perhaps the greatest threat to the Pearl River system in southeastern Louisiana (Selman 2020c, p. 20). Gravel mining can degrade water quality, increase erosion, and ultimately impact movement and habitat quality for aquatic species such as the Pearl River map turtle (Koehnken et al. 2020, p. 363). We assume that substantial channelization, the presence of a major reservoir, or evidence of gravel mining operations has a negative impact on resiliency, and include these as a resilience factor. Below we describe several areas where alteration of streams has likely led to declines in Pearl River map turtles, and assess the condition category for each unit (Table 5.11).

Considerably low densities of Pearl River map turtles were observed in the Lower Pearl unit, where much channelization and flow diversion has occurred (Lindeman 2019, p. 23-29). Low densities of Pearl River map turtles in the West and East Pearl rivers, have been attributed to flow alteration due to the construction of the Pearl River Navigation Canal, which also has very low densities, suggesting that substantial loss of population in the lower reaches of the Pearl River drainage has occurred historically due to river engineering (Lindeman 2019, p. 27). Significantly lower basking

densities of Pearl River map turtles have been reported in the West Pearl (0.1/rkm) compared to the upper Pearl (1.8/rkm) (Dickerson and Reine 1996, Table 4, unpaginated; Selman 2020c, pp. 17-18). Because of these stream alterations, we assessed the Lower Pearl unit as low (i.e. high degree of threats) for this factor.

Within the Middle Pearl Strong unit, 33.6 rkm (20.9 rm) of the middle Pearl River is inundated by the Ross Barnett Reservoir. The Ross Barnett Reservoir has greatly reduced habitat suitability of 5% of the mainstem Pearl River by altering the lotic (flowing water) habitat preferred by Pearl River map turtles to lentic (lake) habitat. In addition, declines in population densities have been observed upstream and downstream of the Ross Barnett Reservoir. Declines in population densities upstream of the reservoir are possibly due to recreational boating and extended recreational foot traffic or camping on sandbars by reservoir visitors (Selman and Jones 2017, p. 32-34). Between the late 1980s and early 2010s, notable population declines have been observed in the stretch of the Pearl River downstream of the Ross Barnett Reservoir (Selman 2020d, p. 194). It is unknown why the population declined, but altered hydrology of this reach may have had an impact. Plans for new reservoirs on the Pearl River both upstream and downstream of Jackson have been or are being considered (Lindeman 2013, pp. 202-203). Researchers have estimated that up to 170 individual Pearl River map turtles could be directly impacted, and up to 360 indirectly impacted, both upstream and downstream, by the One Lake Project, one of several proposed impoundments (Selman 2020d, p. 192). Near Jackson, Mississippi, river channelization has also impacted the species habitat negatively, and Pearl River map turtles are almost non-existent in a highly channelized stretch of the Pearl River (Selman 2020d, p. 194). However, upstream and downstream of this section, the species occurs in low numbers (Selman 2020d, pp. 192-194). Due to the presence of the Ross Barnett Reservoir, and the river channelization that has occurred in and around Jackson, we assessed the Middle Pearl Strong unit as low for this factor.

In the Upper Pearl unit, channelization has occurred along Tuscolameta Creek and the upper Yockanookany River. In 1924, the Tuscolameta Creek received a 39 km (24-mi) channelization and Yockanookany River received a 58 km (36-mi) canal, which was completed in 1928 (Speer et al. 1964, p. 8). In the Yockanookany, low water stages in 1960 were six feet (1.82m) higher than those of 1939, as the channel silted significantly during that period (Speer et al. 1964, pp. 26-27). In some areas of the Yockanookany, water continues to flow in the river's old natural channel

(Speer et al. 1964, pp. 26-27). Although stream alteration has occurred within these streams, there has yet to be any reported evidence of Pearl River map turtle decline, thus we assessed this factor as moderate for the Upper Pearl unit.

In-stream and unpermitted point bar mining in the Bogue Chitto unit was a concern in the late 1990s (Shively 1999), and although these activities no longer occur, gravel mining operations within floodplains does occur (Selman 2020c, pp. 20-21). Recent surveys have reported several areas where mining appears to have degraded water quality significantly (Selman 2020c, pp. 20-21). There is also a concern that historical in-stream and point bar mining can have deleterious legacy effects that could be negatively impacting the species (Selman 2020c, p. 21). For these reasons, we assessed this factor as low for the Bogue Chitto unit.

Table 5.11-Categorization of habitat factor "Channelization/Reservoirs" for Pearl River map turtle resilience units.

Population	**Channelization/Reservoir/Mining (Y/N)**	**Condition Category**
Bogue Chitto	Yes	Low
Lower Pearl	Yes	Low
Middle Pearl Silver	No	High
Middle Pearl Strong	Yes	Low
Upper Pearl	Yes	Moderate

5.2.6 Habitat Factor: *Protected Land*

A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN 2008, unpaginated). Protected areas are a generally accepted, although not always uncontroversial, mechanism for halting the global decline of biodiversity. Some examples of the positive effects that protected areas can have on freshwater biodiversity have been reported, such as increased local abundance or size classes of some fish species (Suski and Cooke, 2007, entire).

From an indirect standpoint, the presence of protected lands will function to minimize human disturbance in an area, which may benefit freshwater environments at multiple levels. First,

enforcement of restrictions in protected areas can serve to minimize boat traffic that has been shown to have deleterious impacts to other *Graptemys* species (Selman et al. 2013, entire; Heppard and Buchholz 2019; entire). Also, conflict between various users of freshwater resources has been documented (Jones 2006, p. 208), and will likely continue to escalate as human demands on freshwater resources continue to increase. The presence of protected areas may help ameliorate some of these conflicts by segregating user groups into defined areas (Suski and Cooke 2007, p. 2024). Finally, the more land within a unit that is under some sort of protection (e.g. easement, state and federal ownership), the less likely land will be developed. Because development can have negative impacts to aquatic fauna, as discussed previously, the more protected land in a unit, the more resilient that unit is assumed to be.

Numerous refuges and conservation areas have been established along the Pearl River that have positively influenced riparian forest along the river or forest land cover in the basin. Riparian conservation areas include Nanih Waiya WMA (Neshoba County), Mississippi Band of Choctaw Indian Reservation (Neshoba County), Pearl River WMA (Madison County), Fannye Cook Natural Area (Rankin County), Old River WMA (Pearl River County), Bogue Chitto NWR (St. Tammany and Washington Parishes), and Pearl River WMA (St. Tammany Parish). Bienville National Forest contributes positively to increased forest cover in headwater streams that drain into the Pearl River, especially the Strong River. The most extensive habitat preservation on the Pearl River is the Bogue Chitto National Wildlife Refuge along the upper West and East Pearl and lower Bogue Chitto Rivers, which is contiguous with the Pearl River WMA, which protects the area between the West and East Pearl Rivers downstream to the Gulf of Mexico.

To assess the contribution of protected areas to the resilience of Pearl River map turtle analysis units, we calculated the percentage of the HUC8 that was in protected status. We used the Protected Areas Database of the U.S. version 2.0 (PAD-US 2.0), released in 2019 (USGS 2019b, unpaginated). The database is a national inventory of lands held by cities, counties, special park and open-space districts, state parks and preserves as well as federally administered lands, including national parks and forests, national wildlife refuges, public lands and more. We calculated the total area of land within each unit that was considered protected in the PAD-US 2.0, and divided by the total area of the HUC8. We then created categories of low, moderate, and high based off of the

percentage of protected land within a unit as follows: low (0-10% protected), moderate (10-20% protected), and high (>20% protected). These categories were based off of natural breaks in the data from both the Pearl and Pascagoula basins, and serve as a relative measure of protected lands between all of the units; there are no data that we are aware of that suggests biologically significant breaks between the low, moderate, and high classes.

The results of the analysis of protected lands show that the Pearl River basin in general has relatively small amounts of land in protected status (Table 5.12). Four of the units have a low condition (i.e. <10% of land protected), and one unit has a moderate condition (10-20% of land protected). The Middle Pearl Strong Unit has by far the greatest amount of land in protection with 147,597 acres in protection (11.67%), with all other units having less than 6% of land in protected status.

Table 5.12-Summary of the resilience unit area, percentage of protected lands, along with the condition category, for each Pearl River map turtle resilience unit.

Resilience Unit	Total Acres/Hectares	% areas protected	Condition
Bogue Chitto	773546 ac/ 313042 ha	0	Low
Lower Pearl	1165616 ac/ 471708 ha	4.44%	Low
Middle Pearl Silver	779923 ac/ 315623 ha	0.16%	Low
Middle Pearl Strong	1265209 ac/ 512011 ha	11.67%	Moderate
Upper Pearl	1576500 ac/ 637986 ha	5.36%	Low

5.2.7 ***Habitat Factor:*** *Forested Riparian Cover*

Correlations of Pearl River map turtle density with deadwood density have been shown to be positive, and high basking densities have yet to be associated with low deadwood densities (Lindeman 1999, pp. 35-38). Abundance of basking substrates has shown to be an important habitat component driving *Graptemys* abundance in Kansas and Pennsylvania (Pluto and Bellis 1986, pp.

26-30; Fuselier and Edds 1994, entire), and radiotelemetry work with yellow-blotched map turtles (*G. flavimaculata*) has indicated the importance of deadwood to habitat selection on the lower Pascagoula River (Jones 1996, pp. 383, 376, 379-380). Anthropogenic deadwood removal, mainly through dredging, has been noted as a reason for decline in the sympatric microcephalic species, the ringed map turtle (*G. oculifera*) (Lindeman 1998, p. 137). Experiments with manual deposition of deadwood in stretches with less riparian forest have been recommended as potential habitat restoration measures (Lindeman 2019, p. 33).

An intact riparian habitat provides numerous benefits to map turtles including the stabilization of stream banks, and the reduction of erosional processes and channel sedimentation. Under normal erosional processes, riparian forests also provide material for in-stream deposition of deadwood, and deadwood is known to be important basking sites for thermoregulation and also foraging sites for prey items (Lindeman 1999, entire). To assess the contribution of riparian forests to the resilience of Pearl River map turtle units, we calculated the percentage of forest within a 200ft (61m) riparian buffer using the 2016 NLCD land use land cover data. We further describe forests to include four land use classes: deciduous forest, evergreen forest, mixed forest, and woody wetlands. We categorized the percent forested cover into three classes: <60% forested cover (low), 60-80% forested cover (moderate), and >80% forested cover (high). These classes were based on natural breaks in the data, and serve as relative comparisons of forested cover between the resilience units.

An assessment of forested cover (Table 5.13 A-E) resulted in 3 units in high condition (Lower Pearl, Middle Pearl Strong, and Upper Pearl), and 2 units in moderate condition (Bogue Chitto and Middle Pearl Silver). Forested cover within riparian buffers ranged from 60-98% across the 5 resilience units. Forested cover was highest in the Upper Pearl, where cover ranged from 90-96% across the occupied streams within the unit, and lowest in the Middle Pearl Silver, where forested cover was 60% across the single occupied river segment. The Bogue Chitto unit was assessed as moderate for forested cover, primarily due to the Bogue Chitto and Topisaw having relatively low cover compared to other streams across the range.

Table 5.13-Summary of forested cover with riparian areas and the associated condition class for each of the 5 resilience units for the Pearl River map turtle. A) Bogue Chitto B) Lower Pearl C) Lower Pearl Silver D) Lower Pearl Strong and E) Upper Pearl.

A) Bogue Chitto Unit

Stream	**Total Acres Riparian**	**% Forested Riparian**	**Condition**
Bogue Chitto	4962.29 ac/ 2008.17 ha	72.37	Moderate
Magees	1821.63 ac/737.19 ha	89.83	High
Topisaw	1305.68 ac/528.39 ha	75.68	Moderate
TOTAL	**8089.60 ac/3273.74 ha**	**76.83**	**Moderate**

B) Lower Pearl Unit

Stream	**Total Acres Riparian**	**% Forested Riparian**	**Condition**
East Pearl	860.22 ac/348.12 ha	85.37	High
Hobolochitto	291.78 ac/118.08 ha	98.32	High
Holmes Bayou	134.99 ac/54.63 ha	95.06	High
Lower Pearl	2539.97 ac/1027.89 ha	61.21	Moderate
Navigation Canal	28.91 ac/11.70 ha	84.62	High
Pushepatapa	1210.72 ac/489.96 ac	96.62	High
West Hobolochitto	2452.79 ac/992.61 ha	97.33	High
West Pearl	526.19 ac/212.94 ha	60.36	Moderate
TOTAL	**8045.57 ac/3255.93 ha**	**82.05**	**High**

C) Middle Pearl Silver Unit

Stream	Total Acres Riparian	% Forested Riparian	Condition
Middle Pearl Silver	**1844.54 ac/746.46 ha**	**60.42**	**Moderate**

D) Middle Pearl Strong Unit

Stream	Total Acres Riparian	% Forested Riparian	Condition
Middle Pearl Strong	2606.91 ac/1054.98 ha	70.99	Low
Pelahatchie	1876.34 ac/759.33 ha	91.10	Moderate
Purvis	825.31 ac/333.99 ha	82.73	Low
Strong	4237.06 ac/1714.68 ha	92.39	Moderate
TOTAL	**9545.62 ac/ 3862.98 ha**	**85.46**	**High**

E) Upper Pearl Unit

Stream	Total Acres Riparian	% Forested Riparian	Condition
Lobutcha	2917.59 ac/ 1180.71 ha	95.54	High
Tuscolometa	1604.35 ac/ 649.26 ha	94.01	High
Upper Pearl	3363.72 ac/1361.25 ha	89.82	High
Yockanookany	3650.38 ac/1477.26 ha	92.17	High
TOTAL	**11536.05 ac/4668.47 ha**	**92.59**	High

5.2.8 Habitat Factor Composite Score

To determine a composite score for habitat factors, we combined the results of the water quality, channelization/reservoirs, protected lands, and deadwood abundance assessments. Classifications were averaged together for each habitat factor as if low, moderate, and high were equal to values of 1, 2, and 3 respectively. If averaging the four factors resulted in a value ending in .5, the overall habitat factor composite score was rounded down (rather than typical mathematical convention of

rounding up) to be conservative (i.e. to avoid underestimating threats derived from our habitat factor surrogates). Composite habitat scores were then categorized on a low (1), moderate (2), and high (3) scale.

Table 5.14-Habitat factor composite scores for all Pearl River map turtle units as a function of 4 habitat factors (water quality, channelization/reservoirs, protected land, and deadwood abundance).

Unit	**Water Quality**	**Channelization/ reservoirs**	**Protected Land**	**Deadwood**	**Composite Score**
Bogue Chitto	Moderate	Low	Low	Moderate	Low
Lower Pearl	Moderate	Low	Low	High	Low
Middle Pearl Silver	Moderate	High	Low	Moderate	Moderate
Middle Pearl Strong	Moderate	Low	Moderate	High	Moderate
Upper Pearl	Moderate	Moderate	Low	High	Moderate

5.2.9 Current Resilience

We assessed each unit's current resilience as a function of both population and habitat factors. To do this, we determined a composite resilience score by averaging the composite population factor and composite habitat factor for each unit as if low, moderate, and high were equal to values of 1, 2, and 3, respectively. If averaging resulted in a composite resilience score ending in .5, the score was weighted more heavily towards the population factor, as presence and density of turtles is a more important metric associated with resilience of populations. For example, if the composite habitat factor for a given unit was assessed as low, and the composite population score was assessed as moderate, the composite resilience score would be moderate due to heavier weighting being given to the population factor. Composite resilience scores were then categorized on a low (1), moderate (2), and high (3) scale.

Current resilience results are as follows: two populations have low resilience (Bogue Chitto and Lower Pearl) and three populations have moderate resilience (Middle Pearl Silver, Middle Pearl Strong, and Upper Pearl) (Table 5.15). The Lower Pearl seems particularly vulnerable, as both the

population and habitat composite scores were low. The Lower Pearl has significant channelization issues, low amounts of protected land, and a low density of individual turtles, all of which are driving the low resilience of this unit. Although the Middle Pearl Silver unit scored moderate for composite habitat score, the low composite population score (mainly a function of there being no occupied tributaries) is what is driving the low resilience of this unit. When looking at the three units with moderate resilience, the Middle Pearl Strong and Bogue Chitto units appear to be vulnerable to further decreases in resiliency. For the Bogue Chitto unit, low amounts of protected land, and substantial mining activity make this unit vulnerable. For the Middle Pearl Strong, development in the Jackson area and the presence of the Ross Barnett reservoir, make this unit vulnerable. If development increases substantially in this unit, or if proposed reservoir projects move forward, it is likely there would be population level impacts that would drop the resilience to low.

Table 5.15-Current resiliency of Pearl River map turtle units based off of composite habitat and population factors.

Unit	Composite Habitat Score	Composite Population Score	Current Resilience
Bogue Chitto	Low	Moderate	Moderate
Lower Pearl	Low	Low	Low
Middle Pearl Silver	Moderate	Low	Low
Middle Pearl Strong	Moderate	Moderate	Moderate
Upper Pearl	Moderate	Moderate	Moderate

5.2.10 Current Representation

Representation refers to the breadth of genetic and environmental diversity within and among populations, which influences the ability of a species to adapt to changing environmental conditions over time. Differences in life history traits, habitat features, and/or genetics across a species range often aid in the delineation of representative units, which are used to assess species representation.

Between 2005 and 2018, researchers genotyped 124 Pearl River map turtles from 15 sites across the Pearl River basin (Pearson et al. 2020, pp. 6-7). No distinct genetic structure was found throughout the Pearl River system. A single genetic population was recovered, and there was no evidence of isolation by distance (Pearson et al. 2020, pp. 11-12). For this reason, we consider the entire range of the Pearl River map turtle to be a single representative unit.

It has been suggested that the Strong River, located in the Pearl River Strong unit, may have some unique habitat features that could confer unique adaptative pressure (Lindeman pers. comm. 2020, p. 4). Perhaps most notably, the Strong River has some very rocky stretches that are unlike anything else in the drainage and could conceivably have a population with a distinct diet or life history, though no studies to date have addressed this question (Lindeman pers. comm. 2020, p. 4). Although we do not consider the Strong River to be a separate representative unit, we consider the Strong River to be a potentially significant stream from a habitat diversity perspective.

The Strong River is a large tributary and occupies an estimated 87.4 rkm (54.3 rm) range, with an estimated 1,749 individuals, accounting for 8% of the global population estimate (Lindeman 2019, p. 47). Lindeman (2019, p. 47) assessed density as moderate, which is relatively high for a tributary. The Strong River does not appear to have a high degree of threats, habitat factors are relatively high, and population factors appear stable. For this reason, the Strong River is currently contributing to the overall representation of the species.

5.2.11 Current Redundancy

Redundancy refers to the ability of a species to withstand catastrophic events and is measured by the amount and distribution of resilient populations across the species range. Catastrophic events that could severely impact or extirpate entire Pearl River map turtle units include chemical spills, changes in upstream land use that alters stream characteristics and water quality downstream, dam construction with a reservoir drowning lotic river habitat, and potential effects of climate change such as rising temperatures and sea level rise. The Middle Pearl Silver unit is perhaps the most vulnerable to a catastrophic spill, as there are no known occupied tributaries at this time. Extant

units of the species are distributed relatively widely, and several of those units are classified as moderate or better resilience, thus it is highly unlikely that a catastrophic event would impact the entire species' range. Because of all of this, the Pearl River map turtle exhibits a moderate-high degree of redundancy, and that level of redundancy has stayed relatively stable over time.

5.2.12 Current Conditions Summary

We assessed current resilience as a function of two population factors (occupied tributaries and density) and four habitat factors (water quality, protected areas, deadwood abundance, and reservoirs/channelization). Based on these factors, there are two populations with low resilience (Lower Pearl and Middle Pearl-Silver) and three populations with moderate resilience (Upper Pearl, Middle Pearl Strong, and Bogue Chitto; Table 5.15; Figure 5.3); no units were assessed as highly resilient. Because three of the five units are classified as moderate resilience, and those units are distributed relatively widely, the Pearl River map turtle exhibits a moderate-high degree of redundancy (i.e. it is unlikely that a catastrophic event would impact the entire range of the species). We did not assess multiple representative units for the species due to recent research indicating no significant genetic structuring. Species experts indicated the Strong River might be unique from a habitat perspective (i.e. distinctly rocky stretches), so it is notable that the Strong River does not appear to have a high degree of threats, habitat factors are relatively high, and population factors appear stable. If the Strong River is indeed conferring different adaptive pressures due to the unique habitat type found there, the Strong River does appear to be currently contributing to representation for the species.

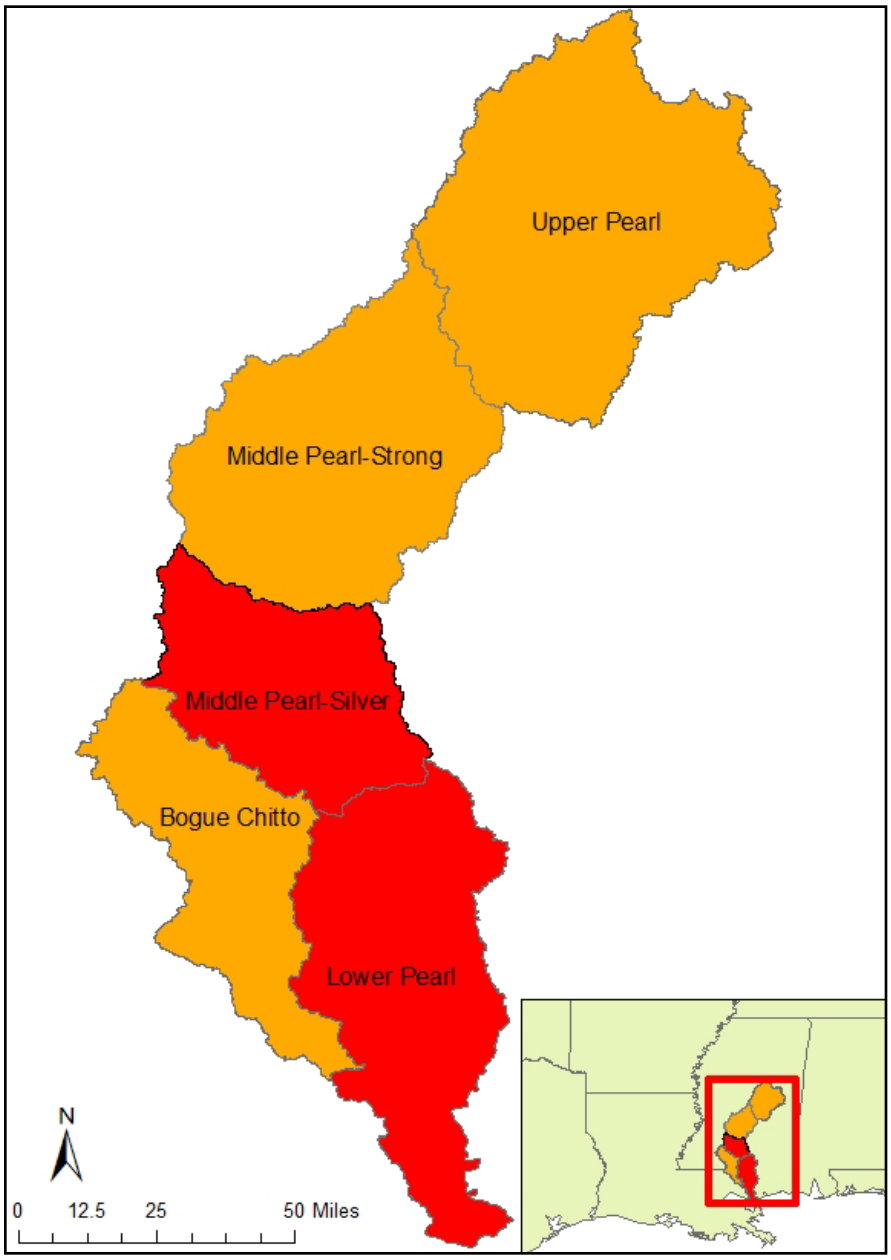


Figure 5.3-Resilience of the five units of Pearl River map turtles: low (red), moderate (orange), high (green).

CHAPTER 6 – FUTURE CONDITIONS AND VIABILITY

We have considered what the Pearl River map turtle needs for viability and the current condition of those needs (Chapters 3 and 5), and we reviewed the factors that are driving the current and future conditions of the species (Chapter 4). We now consider what the species' future condition is likely to be. We apply our future forecasts to the concepts of resiliency, representation, and redundancy to describe the future viability of the Pearl River map turtle.

6.1 Introduction

To assess future condition of Pearl River map turtle units, we projected the primary current threats of land use (agriculture and development), potential future water engineering projects, and sea level rise into the future under six plausible scenarios. The six scenarios capture the range of uncertainty in the changing human population footprint on the landscape, current emission models, implementation of water engineering projects, and how the Pearl River map turtle will respond to these changing conditions.

All six scenarios were projected out to two different time steps: 2040 (20 years) and 2070 (50 years). These time frames are based on input from species experts, generation time for the species, and the fact that beyond 50 years, the ability to predict patterns of urbanization and agriculture, and how these land uses will interact with the species and its habitat diminishes.

6.2 Future Resilience Factors

6.2.1 Land Use and Water Quality

We considered projected land-use changes in regards to agricultural and developed land in assessing future resilience of each unit for the Pearl River map turtle. We consider these land use classes as surrogates for potential changes in water quality, a primary risk factor for the species. We used data available at the resiliency unit scale from the USGS Forecasting Scenarios of Land-use

Change (FORE-SCE) modelling framework (USGS 2017, unpaginated) to characterize nonpoint source pollution (i.e., development and agriculture). The FORE-SCE model provides spatially explicit historic, current, and future projections of land use and land cover. The projections were originally created as part of the "LandCarbon" project, an effort to understand biological carbon sequestration potential in the United States. However, the projections are being used for a wide variety of purposes, including analyses of the effects of landscape change on biodiversity, water quality, and regional weather and climate. The 1992 to 2005 period is considered the historical baseline, with datasets such as the National Land Cover Database, USGS Land Cover Trends, and U.S. Department of Agriculture's Census of Agriculture used to guide the recreation of historical land cover. The future projection time frame is available at annual time steps up to the year 2100. Four scenarios were modeled, corresponding to four major scenario storylines from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES). The global IPCC SRES (A1B, A2, B1, and B2 scenarios) were downscaled to ecoregions in the conterminous United States, with the USGS Forecasting Scenarios of land use (FORE-SCE) model used to produce landscape projections consistent with the IPCC SRES. The land-use scenarios focused on socioeconomic impacts on anthropogenic land use (demographics, energy use, agricultural economics, and other socioeconomic considerations; Figure 6.1.

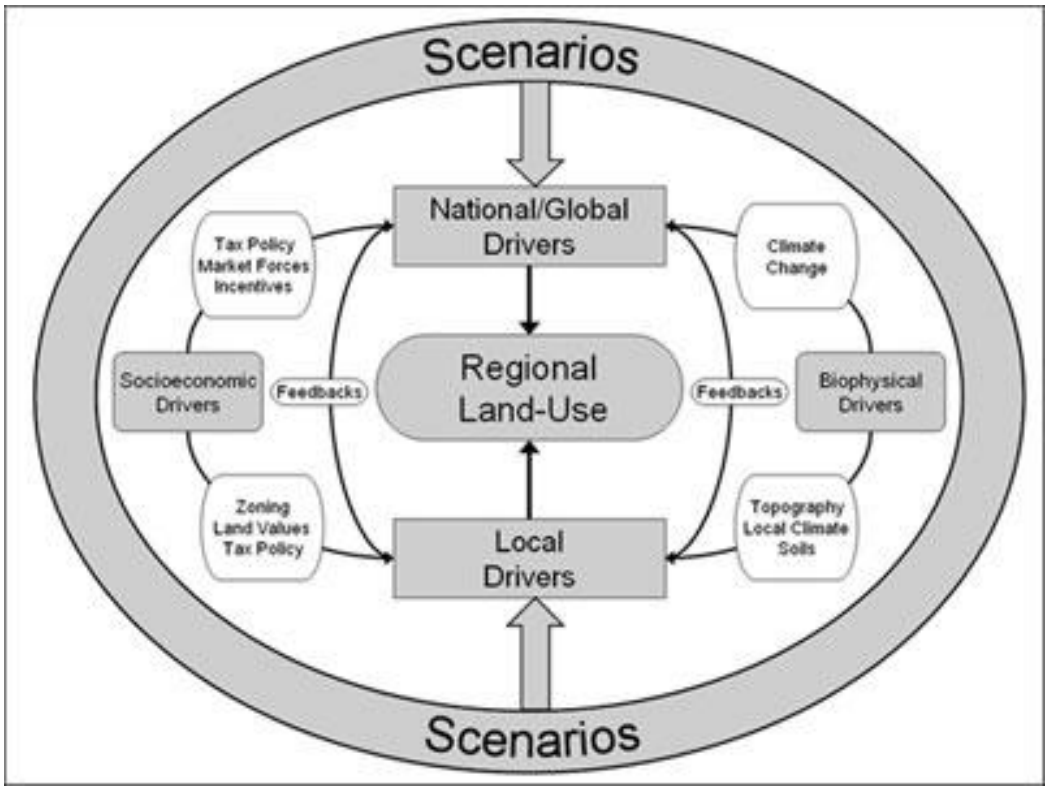


Figure 6.1- Forecasting scenarios of land-use change modeling framework to provide spatially explicit projections of future land-use and land-cover change (USGS 2017, unpaginated).

6.2.2 Sea Level Rise

Sea level rise (SLR) impacts future resilience of Pearl River map turtles by influencing the area occupied and suitable habitat available through increased salinity of the freshwater system. Although some species of *Graptemys* appear to handle some salinity increases, there is some evidence that the group is largely intolerant of brackish and saltwater environments (Selman and Qualls 2008 pp. 228-229; Lindeman 2013, pp. 396-397). To estimate loss/degradation of habitat due to inundation from sea level rise, we used NOAA's shapefiles available at their online sea level rise viewer (NOAA 2020, unpaginated). Projected sea level rise scenarios from NOAA provide a range of inundation levels from low to extreme. We chose NOAA's intermediate-high and extreme scenarios, which correspond to the representative concentration pathways (RCP) of RCP6 and RCP8.5 emission scenarios, the most likely RCP scenarios (IPCC 2013, p. 20). Local scenarios are available at a location near Mobile Bay,

providing estimates of sea level rise at decadal time steps out to the year 2100. We found the average sea rise level estimate for the intermediate high and extreme NOAA scenarios from this station, and used the estimate (rounded to the nearest foot, because shapefiles are only available at 1-foot increments) to project estimated habitat loss at years 2040 and 2070. If SLR estimates overlap with known occupied portions of the river system, we assume that area is no longer suitable, or occupiable, thus resilience would decrease.

Table 6.1-Estimated inundation from sea level rise, in and around the Pearl River basin, according to NOAA's Sea Level Rise Viewer, Dauphin Island local scenarios. (https://coast.noaa.gov/slr/#/layer/sce/0/-9960877.61950826/3551130.846077425/9/satellite/11/0.8/2070/interHigh/midAccretion).

Year	Intermediate-High SLR	Extreme SLR
2040	1 feet (0.30 meters)	2 feet (0.61 meters)
2070	3 feet (0.91 meters)	5 feet (1.52 meters)

6.2.3 Future Water Engineering Projects and Mining

Stream channelization, point-bar mining, and impoundment have been listed as potential threats in a report written before the Pascagoula map turtle and Pearl River map turtle were taxonomically separated (USFWS 2006, p. 2). Between the late 1980s and early 2010s, notable population declines were observed in the stretch of the Pearl River downstream of the Ross Barnett Reservoir (Selman 2020d, p. 194). It is unknown why the population declined, but altered hydrology of this reach may have had an impact.

Plans for new reservoirs on the Pearl River both upstream and downstream of Jackson, Mississippi have been or are being considered as areas of interest (Lindeman 2013, pp. 202-203). Of particular note is the proposed One Lake project. The project proposes a new dam and commercial development area 14.5 km (9 mi) south of the current Ross Barnett Reservoir Dam near Interstate 20. The goal of the One Lake project is to dredge the Pearl River in order to widen, deepen and

straighten an additional 16.1 km (10 mi) of waterway for flood control protection and commercial development opportunities.

The One Lake project is still being debated, and there is uncertainty on whether the project will move forward. Because of this uncertainty, we have created 2 scenarios based around the proposed One Lake project: one in which the project goes online, and another assuming the project does not occur within the next 50 years. Because of the likely negative impacts of the proposed One Lake project, we assume a decrease in resilience of the Middle Pearl Strong unit if the project moves forward.

6.3 Models and Scenarios

In order to assess future viability for the Pearl River map turtle, we project two land use and two sea level rise scenarios out to the years 2040 (20 years) and 2070 (50 years). The two land use scenarios are based on two SRES emission scenarios embedded within the FORE-SCE model (A2 and B1) as described in the previous section. The two sea level rise scenarios are based on NOAAs intermediate-high (RCP 6.0) and extreme (RCP 8.5) local scenarios, as described in the previous section. We also include two scenarios regarding the proposed One Lake project, as described in the previous section. This results in eight plausible scenarios at two time steps (2040 and 2070), with the A2-Extreme-One Lake project scenarios representing the highest threat scenario, the B1-Intermediate High-no One Lake project scenario the lowest threat scenario, and the other four scenarios representing moderate threat scenarios (Table 6.2 A-B).
Because data for population factors (occupied tributaries and density) are not comparable through time or space, we do not assess these factors in our future condition analysis. Additionally, we assume the amount of protected land within each unit stays the same within our projection timeframes, although it is possible that additional land could be converted to a protected status or lands could degrade over time. Rather than attempting to categorize future resilience as was done in the current conditions analysis, we indicate a magnitude and direction of anticipated change in resilience of Pearl River map turtle units.

Table 6.2-Scenarios used to model future condition for Pearl River map turtle. Scenarios were built around three factors: land use (emission scenarios A2 and B1), sea level rise (emission scenarios Intermediate High [IH] and Extreme [EX]), and water engineering projects (One Lake Project Yes/No). Scenarios were projected to two time steps: 2040 (A) and 2070 (B).

A) 2040

One Lake Project (Yes)			
		Sea Level Rise	
		Intermediate High	Extreme
Land Use	A2	A2-IH-OneLake 2040	A2-EX-OneLake 2040
	B1	B1-IH-OneLake 2040	B1-EX-OneLake 2040

One Lake Project (No)			
		Sea Level Rise	
		Intermediate High	Extreme
Land Use	A2	A2-IH-NoProject 2040	A2-EX-NoProject 2040
	B1	B1-IH-NoProject 2040	B1-EX-NoProject 2040

B) 2070

One Lake Project (Yes)			
		Sea Level Rise	
		Intermediate High	Extreme
Land Use	A2	A2-IH-OneLake 2070	A2-EX-OneLake 2070
	B1	B1-IH-OneLake 2070	B1-EX-OneLake 2070

One Lake Project (No)			
		Sea Level Rise	
		Intermediate High	Extreme
Land Use	A2	A2-IH-NoProject 2070	A2-EX-NoProject 2070
	B1	B1-IH-NoProject 2070	B1-EX-NoProject 2070

6.4 Results

6.4.1 Land Use and Water Quality

6.4.1.1 Bogue Chitto Unit

Table 6.3 summarizes the results of the future land use projections by climate scenario (A2 and B1) and year (2040 and 2070) for the Bogue Chitto Unit. Development remains low across the entire unit under all scenarios. Agriculture is projected to be high across the entire unit under all scenarios, as was assessed in current conditions, except under the B1 scenario in 2070, where rates of agriculture drop to moderate. Overall, land use was assessed as an overall moderate condition class within the Bogue Chitto Unit across both climate scenarios and future time steps, resulting in no change from current condition.

Table 6.3-Composite land use score for streams within the Bogue Chitto unit, and for the entire unit, based on development and agriculture levels. Climate scenarios (A2 and B1) are separated by projection time steps (2040 and 2070). Streams in bold are mainstem reaches; all other streams are considered tributaries.

2040

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Bogue Chitto	Low	High	Moderate	Low	High	Moderate
Magees	Low	High	Moderate	Low	High	Moderate
Topisaw	Low	High	Moderate	Low	High	Moderate
Bogue Chitto Unit	**Low**	**High**	**Moderate**	**Low**	**High**	**Moderate**

2070

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Bogue Chitto	Low	High	Moderate	Low	Moderate	Moderate
Magees	Low	High	Moderate	Low	Moderate	Moderate
Topisaw	Low	High	Moderate	Low	Moderate	Moderate
Bogue Chitto Unit	**Low**	**High**	**Moderate**	**Low**	**Moderate**	**Moderate**

6.4.1.2 Lower Pearl Unit

The Lower Pearl Unit is the most southern unit that connects to the Gulf of Mexico. This unit will endure effects of sea level rise due to its proximity to the coast. Development is also expected to increase in this unit. Table 6.4 summarizes the results of the future land use projections by climate scenario (A2 and B1) and year (2040 and 2070) for the Lower Pearl Unit. In 2040, under the A2 scenario, development remains low across much of the unit, although the Hobolochitto and West

Pearl are projected to have high amounts of development; agriculture is projected to be high across the entire unit. In 2070, under the A2 scenario, development is anticipated to increase substantially across the entire unit, with East Pearl, Navigation Canal, Hobolochitto and West Pearl, all projected to have high levels of development, and the rest of the unit projected to have moderate development; agriculture is projected to be high across the entire unit. The B1 scenarios, at both 2040 and 2070, predict low levels of development, and moderate levels of agriculture across the entire unit. Based on these predictions, this unit appears relatively stable under the B1 scenarios, but is anticipated to decrease in water quality under the A2 scenarios due to increases in both development and agriculture.

Table 6.4- Composite land use score for streams within the Lower Pearl unit, and for the entire unit, based on development and agriculture levels. Climate scenarios (A2 and B1) are separated by projection time steps (2040 and 2070). Streams in bold are mainstem reaches; all other streams are considered tributaries.

2040

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
East Pearl	Low	High	Moderate	Low	Moderate	Moderate
Hobolochitto	High	High	Low	Low	Moderate	Moderate
Holmes Bayou	Low	High	Moderate	Low	Moderate	Moderate
Lower Pearl	Low	High	Moderate	Low	Moderate	Moderate
Navigation Canal	Low	High	Moderate	Low	Moderate	Moderate
Pushepatapa	Low	High	Moderate	Low	Moderate	Moderate
West Hobolochitto	Low	High	Moderate	Low	Moderate	Moderate
West Pearl	High	High	Low	Low	Moderate	Moderate

Lower Pearl Unit	**Low**	**High**	**Moderate**	**Low**	**Moderate**	**Moderate**

2070

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
East Pearl	High	High	Low	Low	Moderate	Moderate
Hobolochitto	High	High	Low	Low	Moderate	Moderate
Holmes Bayou	Moderate	High	Low	Low	Moderate	Moderate
Lower Pearl	Moderate	High	Low	Low	Moderate	Moderate
Navigation Canal	High	High	Low	Low	Moderate	Moderate
Pushepatapa	Moderate	High	Low	Low	Moderate	Moderate
West Hobolochitto	Moderate	High	Low	Low	Moderate	Moderate
West Pearl	High	High	Low	Low	Moderate	Moderate
Lower Pearl Unit	**High**	**High**	Low	**Low**	**Moderate**	**Moderate**

6.4.1.3 Middle Pearl Silver Unit

Table 6.5 summarizes the results of the future land use projections by climate scenario (A2 and B1) and year (2040 and 2070) for the Middle Pearl Silver unit. Development remains low across the entire unit under all scenarios. Agriculture increases from moderate to high across the entire unit under the A2 scenarios at both time steps. Agriculture stays moderate in 2040 under the B1 scenario, and actually decreases by 2070. Because of this decrease in agriculture across the unit under the B1 scenario, the overall condition class for land use increases from moderate to high in 2070.

Table 6.5- Composite land use score for streams within the Middle Pearl Silver unit, and for the entire unit, based on development and agriculture levels. Climate scenarios (A2 and B1) are separated by projection time steps (2040 and 2070). Streams in bold are mainstem reaches; all other streams are considered tributaries.

2040

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Middle Pearl Silver	**Low**	**High**	**Moderate**	**Low**	**Moderate**	**Moderate**

2070

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Middle Pearl Silver	**Low**	**High**	**Moderate**	**Low**	**Low**	**High**

6.4.1.4 Middle Pearl Strong Unit

Table 6.6 summarizes the results of the future land use projections by climate scenario (A2 and B1) and year (2040 and 2070) for the Middle Pearl Strong Unit. In 2040, development remains moderate across the entire unit under both climate scenarios; agriculture increases from moderate to high across the entire unit under both climate scenarios. In 2070, under the A2 climate scenario, the mainstem Pearl River, is projected to have high levels of development and agriculture, driving the overall score to low; the rest of the unit maintains a moderate overall score. In 2070, under the B1 climate scenario, development and agriculture remains moderate, the same as current condition.

Table 6.6- Composite land use score for streams within the Middle Pearl Strong unit, and for the entire unit, based on development and agriculture levels. Climate scenarios (A2 and B1) are separated by projection time steps (2040 and 2070). Streams in bold are mainstem reaches; all other streams are considered tributaries.

2040

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Middle Pearl Strong	Moderate	High	Moderate	Moderate	High	Moderate
Pelahatchie	Moderate	High	Moderate	Moderate	High	Moderate
Purvis	Moderate	High	Moderate	Moderate	High	Moderate
Strong	Moderate	High	Moderate	Moderate	High	Moderate
Middle Pearl Strong Unit	**Moderate**	**High**	**Moderate**	**Moderate**	**High**	**Moderate**

2070

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Middle Pearl Strong	High	High	Low	Moderate	Moderate	Moderate
Pelahatchie	Moderate	High	Moderate	Moderate	Moderate	Moderate
Purvis	Moderate	High	Moderate	Moderate	Moderate	Moderate
Strong	Moderate	High	Moderate	Moderate	Moderate	Moderate
Middle Pearl Strong Unit		**High**	**Moderate**	**Moderate**	**Moderate**	**Moderate**

6.4.1.5 Upper Pearl Unit

Table 6.7 summarizes the results of the future land use projections by climate scenario (A2 and B1) and year (2040 and 2070) for the Upper Pearl Unit. In 2040, development remains low across the entire unit under both climate scenarios; agriculture increases from moderate to high across the entire unit under both climate scenarios. In 2070, under the A2 climate scenario, development is

projected to be low, and agriculture is projected to be high; for the B1 climate scenario, development is projected to be low, and agriculture is projected to be moderate, the same as current condition.

Table 6.7- Composite land use score for streams within the Upper Pearl unit, and for the entire unit, based on development and agriculture levels. Climate scenarios (A2 and B1) are separated by projection time steps (2040 and 2070). Streams in bold are mainstem reaches; all other streams are considered tributaries.

2040

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Lobutcha	Low	High	Moderate	Low	High	Moderate
Tuscolometa	Low	High	Moderate	Low	High	Moderate
Upper Pearl	Low	High	Moderate	Low	High	Moderate
Yockanookany	Low	High	Moderate	Low	High	Moderate
Upper Pearl Unit	Low	High	Moderate	Low	High	Moderate

2070

Stream	A2 Developed	A2 Agriculture	A2 Overall	B1 Developed	B1 Agriculture	B1 Overall
Lobutcha	Low	High	Moderate	Low	Moderate	Moderate
Tuscolometa	Low	High	Moderate	Low	Moderate	Moderate
Upper Pearl	Low	High	Moderate	Low	Moderate	Moderate
Yockanookany	Low	High	Moderate	Low	Moderate	Moderate
Upper Pearl Unit	Low	High	Moderate	Low	Moderate	Moderate

6.4.2 Riparian Forested Cover/Deadwood Abundance Results

Table 6.8 and 6.9 summarize the percentage of riparian area in forested cover currently, and under both climate scenarios at years 2040 and 2070. Although forested cover remains generally high across all of the units, there are some streams that see substantial decreases. For example, in the Lower Pearl unit, the West Pearl is projected to have low (<60%) cover under all climate scenarios. Furthermore, the East Pearl is projected to drop from high (>80%) to low under the A2 2070 scenario, and moderate (60-80%) under the rest of the scenarios. In the Middle Pearl Strong, substantial decreases in forested cover are anticipated in the Strong River and Purvis Creek. In the Upper Pearl Unit, forested cover remains high across the entire unit under all scenarios, thus deadwood availability does not appear to be a limiting factor in this unit. Based on the thresholds established in the current condition chapter, below is a summary of overall forested cover condition classes for the 27 occupied streams:

- Current Condition: 14 high; 6 moderate
- A2 2040: 14 high; 4 moderate; 2 low. East Pearl and Strong drop from high to moderate; Purvis creek drops from high to low; West Pearl drops from moderate to low; all other streams are projected to have a high ranking for forested riparian cover.
- A2 2070: 10 high; 6 moderate; 4 low. Magees, Hobolochitto, and Strong drop from high to moderate; Pearl Navigation Canal, East Pearl and Purvis drop from high tall other streams are projected to have a high ranking for forested riparian cover; all other streams are projected to have a high ranking for forested riparian cover.
- B1 2040: 17 high; 2 moderate; 1 low. East Pearl and Purvis drop from high to moderate; West Pearl drops from moderate to low; all other streams are projected to have a high ranking for forested riparian cover.
- B1 2070: 16 high; 3 moderate; 1 low. East Pearl and Purvis drop from high to moderate; West Pearl drops from moderate to low; Topisaw remains moderate; all other streams are projected to have a high ranking for forested riparian cover.

Table 6.8-Percentage of forested cover within riparian areas for occupied within resilience units, currently, and under 2 land use/climate scenarios (A2 and B1) at 2 time steps (2040 and 2070).

		Current	**A2 2040**	**A2 2070**	**B1 2040**	**B1 2070**
Unit	Stream	Forested %	Forested %	Forested %	Forested %	Forested %
Bogue Chitto	Bogue Chitto	72.37	85.29	82.05	86.99	88.47
	Magees	89.83	80.52	67.01	84.64	87.90
	Topisaw	75.68	71.64	66.08	80.22	77.37
Lower Pearl	East Pearl	85.37	66.48	41.70	69.53	69.51
	Hobolochitto	98.32	81.80	79.36	99.26	100.01
	Holmes Bayou	95.06	95.22	92.18	95.22	95.22
	Lower Pearl	61.21	94.17	92.41	95.44	95.87
	Navigation Canal	84.62	94.08	37.08	93.92	93.92
	Pushepatapa	96.62	88.83	89.05	87.53	96.52
	West Hobolochitto	97.33	90.35	82.26	92.81	94.24
	West Pearl	60.36	46.05	35.44	58.63	58.09
Middle Pearl Silver	Middle Pearl Silver	60.42	82.94	77.17	89.18	88.91
Middle Pearl Strong	Middle Pearl Strong	70.99	79.96	70.89	87.29	86.39
	Pelahatchie	91.10	86.86	80.85	91.61	90.75
	Purvis	82.73	58.89	46.43	73.01	75.91
	Strong	92.39	75.68	68.46	82.53	82.84
Upper Pearl	Lobutcha	95.54	90.81	86.35	93.18	93.43
	Tuscolometa	94.01	93.89	91.10	98.70	96.07
	Upper Pearl	89.82	95.43	94.89	97.02	97.74
	Yockanookany	92.17	89.18	85.87	93.32	91.44

Table 6.9-Overall composite scores for the habitat factor forested cover, within riparian areas for resilience units, currently, and under 2 land use/climate scenarios (A2 and B1) at 2 time steps (2040 and 2070).

		Current	A2 2040	A2 2070	B1 2040	B1 2070
Unit	Stream	Forested %	Forested %	Forested %	Forested %	Forested %
Bogue Chitto	Bogue Chitto	Moderate	High	High	High	High
	Magees	High	High	Moderate	High	High
	Topisaw	Moderate	Moderate	Moderate	High	Moderate
Lower Pearl	East Pearl	High	Moderate	Low	Moderate	Moderate
	Hobolochitto	High	High	Moderate	High	High
	Holmes Bayou	High	High	High	High	High
	Lower Pearl	Moderate	High	High	High	High
	Navigation Canal	High	High	Low	High	High
	Pushepatapa	High	High	High	High	High
	West Hobolochitto	High	High	High	High	High
	West Pearl	Moderate	Low	Low	Low	Low
Middle Pearl Silver	Middle Pearl Silver	Moderate	High	Moderate	High	High
Middle Pearl Strong	Middle Pearl Strong	Moderate	Moderate	Moderate	High	High
	Pelahatchie	High	High	High	High	High
	Purvis	High	Low	Low	Moderate	Moderate
	Strong	High	Moderate	Moderate	High	High
Upper Pearl	Lobutcha	High	High	High	High	High
	Tuscolometa	High	High	High	High	High
	Upper Pearl	High	High	High	High	High
	Yockanookany	High	High	High	High	High

6.4.3 Future Water Engineering: One Lake Project

If the One Lake project is implemented, it will alter the hydrologic regime of this stretch of the Pearl River substantially, converting habitat from lotic to lentic, which will have negative consequences on the Pearl River map turtle (Selman 2020d, p. 194). The conversion of riverine habitat to a lake setting will reduce water velocity, limiting the input of deadwood, a critical

component of Pearl River map turtle habitat (Lindeman 1999, p. 40; Selman 2020d, p. 194). This project could impact instream riverine habitat (i.e., altered flows may alter prey resources) and adjacent nesting habitat (i.e., reduced flooding during spring, could prevent sandbar scouring and narrow nesting habitat) (Selman 2020d, p. 194). Researchers have estimated that up to 170 individual Pearl River map turtles could be directly impacted, and up to 360 indirectly impacted, both upstream and downstream, by the One Lake Project (Selman 2020d, p. 194). For all scenarios in which we assume the One Lake Project comes on line, we predict a substantial drop in resilience for the mainstem Pearl River within the Middle Pearl Strong.

6.4.4 Sea Level Rise

We used NOAA estimates of sea level rise inundation under the intermediate-high and extreme emissions scenarios for the years 2040 and 2070. Estimated inundation levels for the intermediate-high scenario are one foot (0.30m) in 2040, and three feet (0.91m) in 2070. For the extreme scenario, estimated inundation levels for the intermediate-high scenario are two feet (0.61m) in 2040, and five feet (1.52m) in 2070 and may be exacerbated by salt water intrusion due to storm surge from increased storm frequency. As anticipated, only the southern coastal unit, the Lower Pearl, is predicted to be impacted by sea level rise. Portions of the Lower Pearl unit are projected to be inundated by sea level rise, such as the mainstem West and East Pearl rivers, and these impacts are seen as soon as 2040 under both climate scenarios. Table 6.10 shows the estimated amount of known occupied habitat anticipated to be inundated for one (0.30m), two (0.61m), three (0.91m), and five feet (1.52m) of sea level rise. Between 13.7-17.4 rkm (6.3-10.8 rm) of occupied habitat in the East Pearl River is projected to be inundated under the various sea level rise scenarios (Figures 6.2-6.5). This area in the East Pearl River, which is directly adjacent to Stennis Space Center, is an area where there have been many detections of Pearl River Map turtles. Although we would expect individual turtles to move in response to inundation, the fact remains that suitable habitat will be lost in an area that supports a fairly robust population of the species. Only under five feet (1.52m) of sea level rise is there projected to be any impacts in the West Pearl River, where one isolated detection is projected to be inundated.

Table 6.10-estimated number of known occupied river miles for Pearl River map turtles projected to be inundated at 1ft (0.30m), 2ft (0.61m), 3ft (0.91m), and 5ft (1.52m) of sea level rise.

Sea Level Rise (feet/meters)	River Miles/Kilometers Inundated
1ft (0.3m)	6.3rmi/10.1rkm (East Pearl)
2ft (0.6m)	8.5rmi/13.68rkm (East Pearl)
3ft (0.9m)	9.9rmi/15.9rkm (East Pearl)
5ft (1.5m)	10.8rmi/17.4rkm (East Pearl); small portion of West Pearl

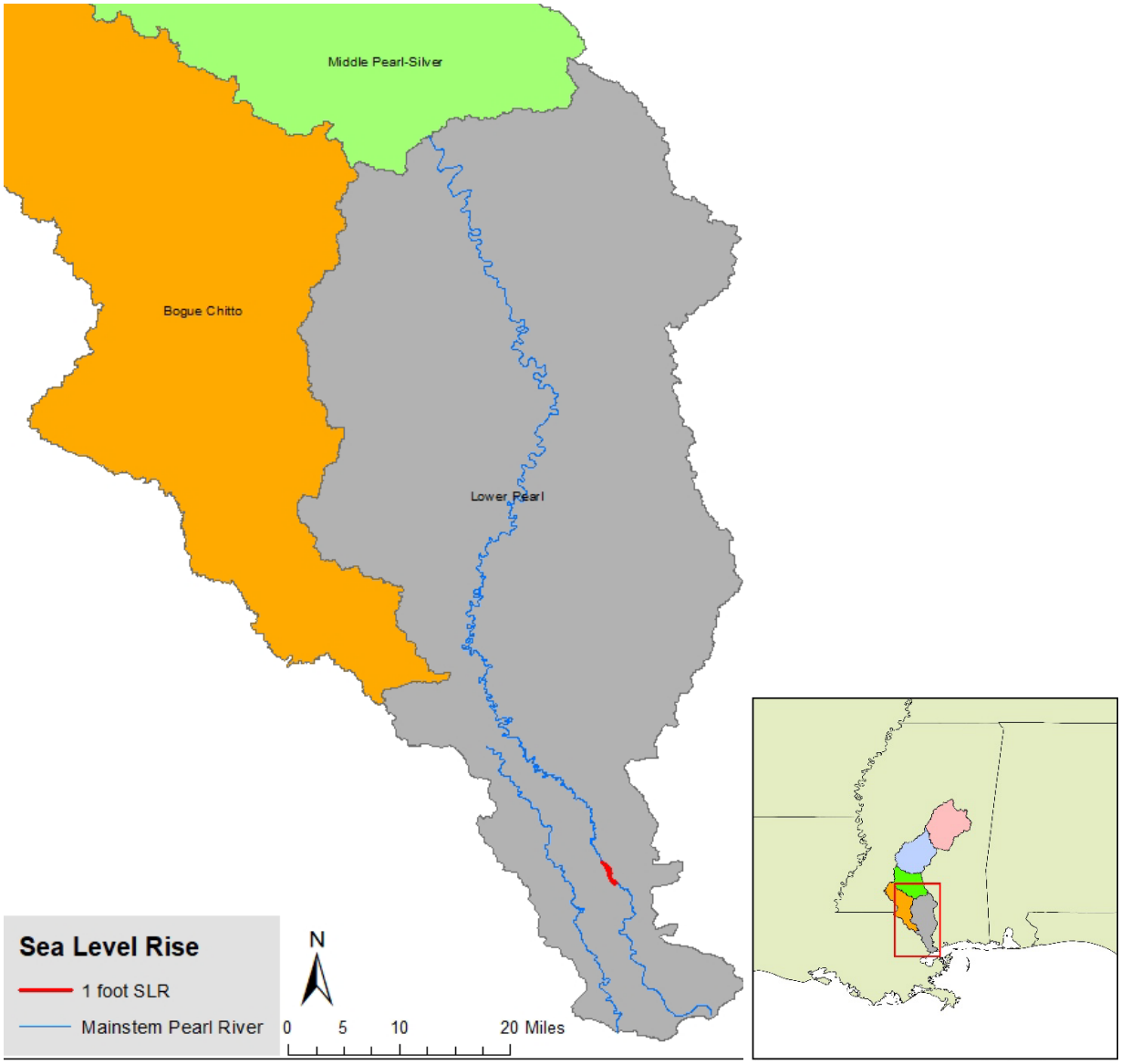


Figure 6.2-Occupied portion of the range of the Pearl River map turtle, anticipated to be inundated by 1 foot of sea level rise (red).

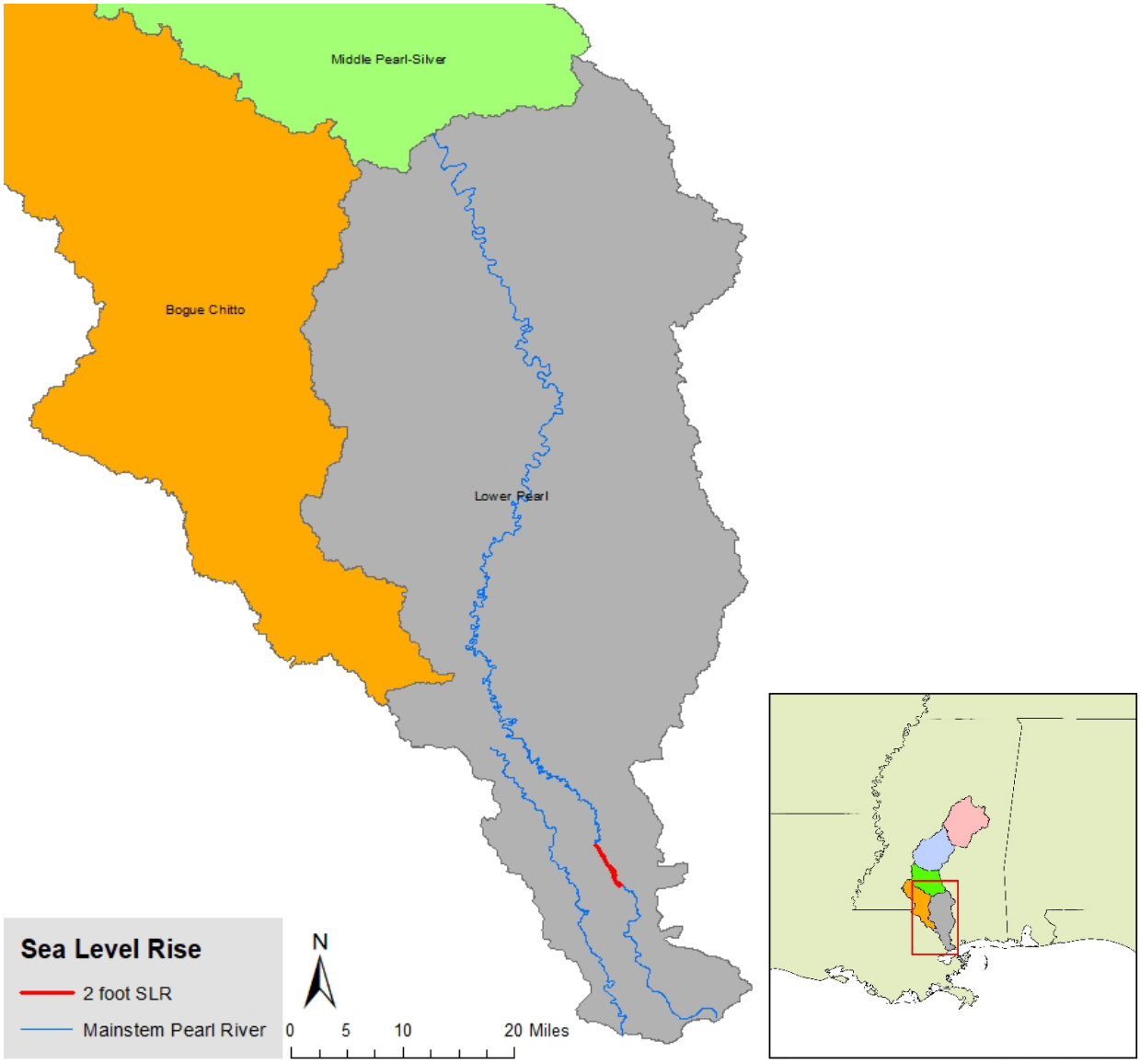


Figure 6.3-Occupied portion of the range of the Pearl River map turtle, anticipated to be inundated by 2 feet (0.61m) of sea level rise (red).

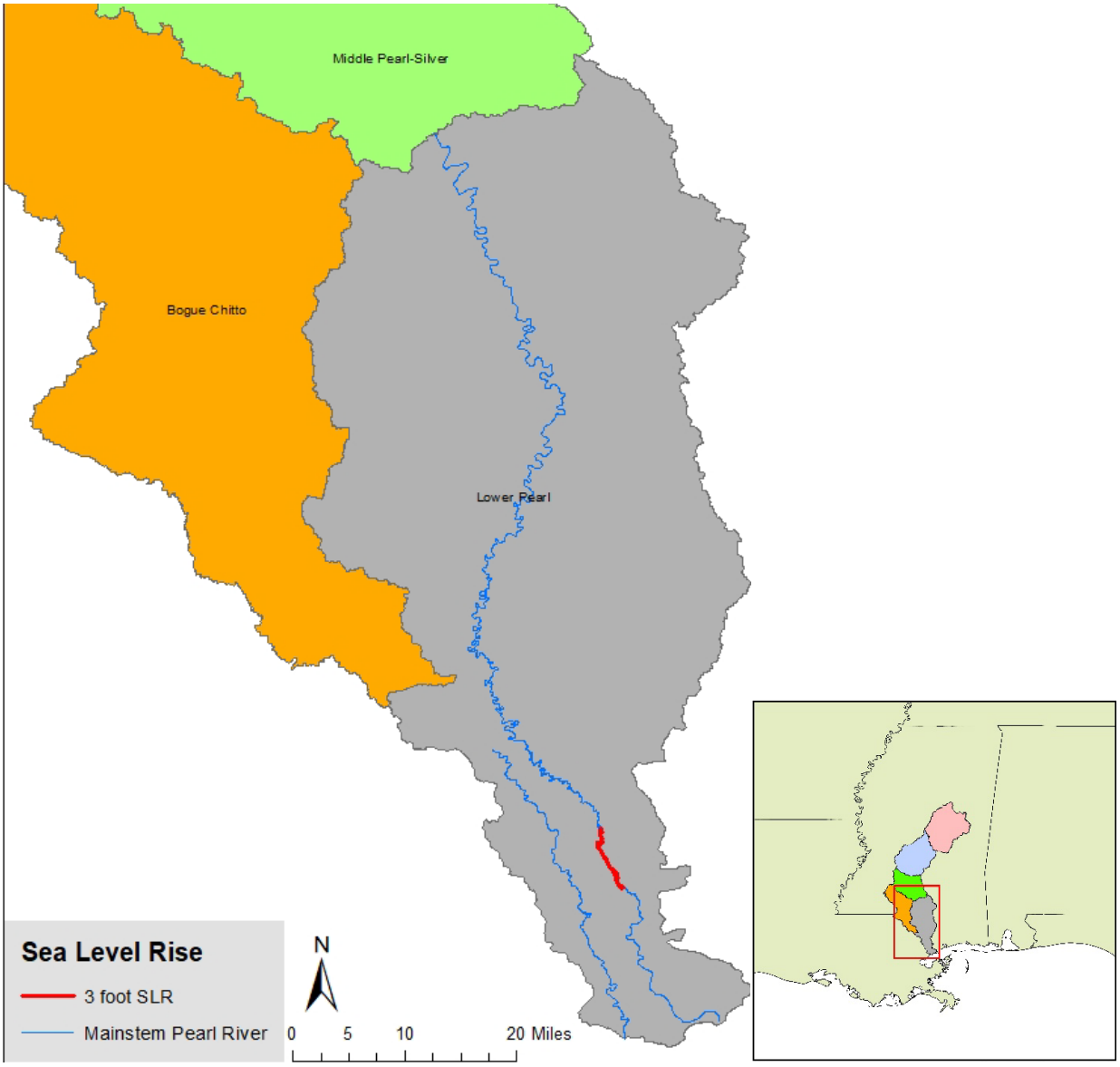


Figure 6.4-Occupied portion of the range of the Pearl River map turtle, anticipated to be inundated by 3 feet (0.91m) of sea level rise (red).

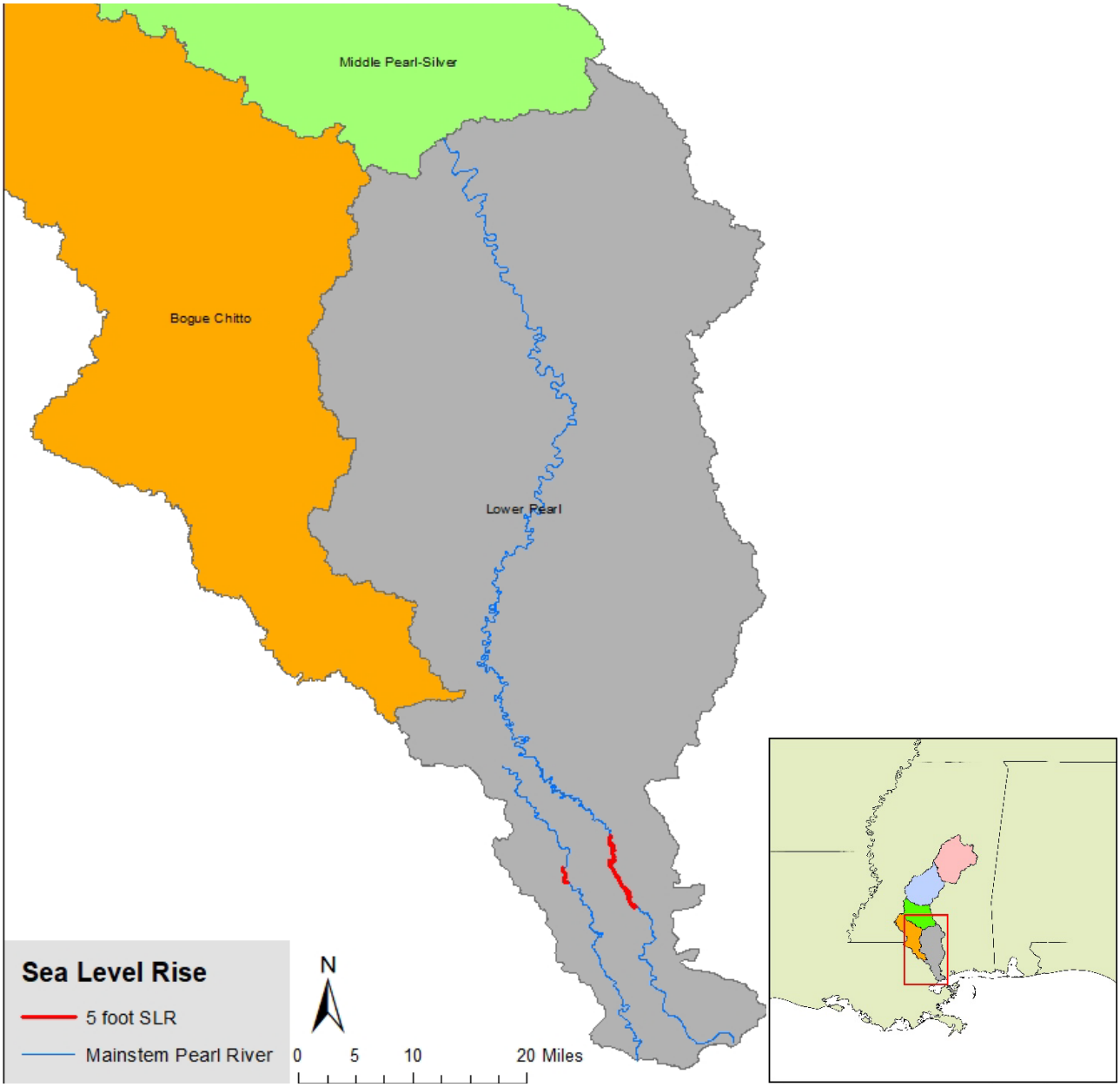


Figure 6.5-Occupied portion of the range of the Pearl River map turtle, anticipated to be inundated by 5 feet (1.52m) of sea level rise (red).

6.5 Summary of Future Conditions and Viability based on Resiliency, Representation, and Redundancy

6.5.1 Future Resiliency

To assess future resiliency of Pearl River map turtle resilience units, we assessed the potential impacts of sea level rise and the predicted change in the condition of three habitat factors: land use/water quality, forested riparian cover, and construction of major reservoirs. We assess future resiliency at the years 2040 and 2070, under two climate/land use scenarios (A2 and B1), two sea level rise scenarios (intermediate high and extreme), and two water engineering project scenarios (One Lake project: yes/no). Below, and in Table 6.11, we summarize the results of the future scenarios.

- ***Bogue Chitto***- Under all scenarios, development remains low across the Bogue Chitto unit. Agriculture is high across the entire unit in all scenarios, except for the B1 scenarios in the year 2070, where agriculture is moderate. Forested cover is relatively high across the unit under all scenarios; thus, deadwood does not appear to be a limiting factor. There are no predicted sea level rise or water engineering project impacts. It is likely that the unit maintains a moderate resilience, though there is uncertainty in future mining activity, which has the potential of significantly decreasing resiliency.
- ***Lower Pearl***- *S*ea level rise impacts this unit under all scenarios, although the impacts of inundation are localized to the southern portion of the unit, mainly in the East Pearl River. Under the A2 scenarios, there are a few streams that are impacted by high levels of development, although most of the unit has low levels of development; under the B1 scenarios, development is low across the entire unit. Agriculture is predicted to be high across the unit under the A2 scenarios, and moderate across the unit under the B1 scenarios. There are no predicted water engineering projects, and forested cover is anticipated to be relatively high. Current resilience for this unit is low, and resilience is anticipated to decrease across all scenarios, with the A2 scenarios with extreme sea level rise will see the most substantial decreases.

- ***Middle Pearl Silver***- Development remains low across the unit under all scenarios at both time steps. Agriculture increases to high under the A2 scenarios and stays moderate under the B1 scenarios. There are no predicted sea level rise or water engineering project impacts. Forested cover is relatively high across the unit under all scenarios, and is actually predicted to increase under B1 scenarios, thus deadwood does not appear to be a limiting factor. Current resilience for this unit is low, and it is likely there will not be any decreases in resilience in the future based on the factors assessed.
- ***Middle Pearl Strong***- Development is substantial in a few areas within this unit, particularly around Jackson, Mississippi. Agriculture is predicted to be high across the unit under all scenarios. If the One Lake project goes online, there is predicted to be a substantial decrease in resilience within and adjacent to the project area. A few streams are predicted to lose a substantial amount of forested cover. No sea level rise impacts are predicted in this unit. The Middle Pearl Strong unit is perhaps the most vulnerable unit, as development, agriculture, and water engineering projects are all potential stressors to the species.
- ***Upper Pearl***- Development remains low across the entire unit under all scenarios. Agriculture is high across the entire unit in all scenarios, except for the B1 scenarios in the year 2070, where agriculture is moderate. Forested cover is relatively high across the unit under all scenarios; thus, deadwood does not appear to be a limiting factor. There are no predicted sea level rise or water engineering project impacts. The Upper Pearl Unit is likely to remain at a moderate level of resilience, and is likely a stronghold for the species, as threats are projected to be low, and this unit has the highest amount of protected land compared to all other units.

Table 6.11-Summary of projected habitat factors and resilience for resilience units at A) Year 2040 Land Use/Climate Scenario A2 + 1ft (0.30m) Sea Level Rise, B) Year 2040 Land Use/Climate Scenario A2 + 2ft (0.61m) Sea Level Rise, C) Year 2040 Land Use/Climate Scenario B1 + 1ft (0.30m) Sea Level Rise, D) Year 2040 Land Use/Climate Scenario B1 + 2ft (0.61m) Sea Level Rise, E) Year 2070 Land Use/Climate Scenario A2 + 3ft (0.91m) Sea Level Rise, F) Year 2070 Land Use/Climate Scenario A2 + 5ft (1.52m) Sea Level Rise, G)Year 2070 Land Use/Climate Scenario B1 + 3ft (0.91m) Sea Level Rise, and H) Year 2070 Land Use/Climate Scenario B1 + 5ft (1.52m) Sea Level Rise.

A) Year 2040 Land Use/Climate Scenario A2 + 1ft (0.30m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development remains low across much of the unit, although the Hoblochitto and West Pearl are projected to have high amounts of development; agriculture is projected to be high across the entire unit; forested cover remains stable; SLR impacts approximately 6 river miles of known occupied habitat in the southern extent of the East Pearl.	Likely a decrease in resilience due to loss of habitat in the southern portion of the unit due to SLR, high levels of agriculture across the unit, and high development in two streams.
Middle Pearl Silver	Development remains low; agriculture increases from moderate to high; forested cover increases; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (low) due to increase in agriculture, although this could be offset by increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development remains moderate; agriculture increases to high; 2 streams (Strong and Purvis) decrease substantially in forested cover; no SLR or reservoir projects predicted.	Likely decrease to current resiliency (moderate) due to increased agriculture and decreased forested cover within unit.
Middle Pearl Strong (One Lake Project)	Development remains moderate; agriculture increases to high; 2 streams (Strong and Purvis) decrease substantially in forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals	Likely to substantially decrease resiliency. Although the unit is highly likely to remain extant, there will likely be substantial loss of habitat and degradation of remaining habitat due to One Lake project and increased levels of development and agriculture.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

B) Year 2040 Land Use/Climate Scenario A2 + 2ft (0.61m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development remains low across much of the unit, although the Hoblochitto and West Pearl are projected to have high amounts of development; agriculture is projected to be high across the entire unit; forested cover remains stable; SLR impacts approximately 8 river miles of known occupied habitat in the southern extent of the East Pearl.	Likely a significant decrease in resilience due to loss of habitat in the southern portion of the unit due to SLR, high levels of agriculture across the unit, and high development in two streams.
Middle Pearl Silver	Development remains low; agriculture increases from moderate to high; forested cover increases; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (low) due to increase in agriculture, although this could be offset by increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development remains moderate; agriculture increases to high; 2 streams (Strong and Purvis) decrease substantially in forested cover; no SLR or reservoir projects predicted.	Likely decrease to current resiliency (moderate) due to increased agriculture and decreased forested cover within unit.
Middle Pearl Strong (One Lake Project)	Development remains moderate; agriculture increases to high; 2 streams (Strong and Purvis) decrease substantially in forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals	Likely to substantially decrease resiliency. Although the unit is highly likely to remain extant, there will likely be substantial loss of habitat and degradation of remaining habitat due to One Lake project and increased levels of development and agriculture.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

C) Year 2040 Land Use/Climate Scenario B1 + 1ft (0.30m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Low levels of development, and moderate levels of agriculture across the entire unit; forested cover remains stable; SLR impacts approximately 6 river miles of known occupied habitat in the southern extent of the East Pearl.	Decrease in resilience in the southern portion of the unit because of loss of habitat due to SLR. The rest of the unit is likely to maintain current resilience (low).
Middle Pearl Silver	Development remains low; agriculture stays moderate; forested cover increases; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development remains moderate; agriculture increases to high; stable forested cover; no SLR or reservoir projects predicted.	Likely a slight decrease to current resiliency (moderate) due to increased agriculture.
Middle Pearl Strong (One Lake Project)	Development remains moderate; agriculture increases to high; stable forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals.	Likely to substantially decrease resiliency. Although the unit is highly likely to remain extant, there will likely be substantial loss of habitat and degradation of remaining habitat due to One Lake project and increased levels of development and agriculture.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

D) Year 2040 Land Use/Climate Scenario B1 + 2ft (0.61m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Low levels of development, and moderate levels of agriculture across the entire unit; forested cover remains stable; SLR impacts approximately 8 river miles of known occupied habitat in the southern extent of the East Pearl.	Decrease in resilience in the southern portion of the unit because of loss of habitat due to SLR. The rest of the unit is likely to maintain current resilience (low).
Middle Pearl Silver	Development remains low; agriculture stays moderate; forested cover increases; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development remains moderate; agriculture increases to high; stable forested cover; no SLR or reservoir projects predicted.	Likely a slight decrease to current resiliency (moderate) due to increased agriculture.
Middle Pearl Strong (One Lake Project)	Development remains moderate; agriculture increases to high; stable forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals.	Likely to substantially decrease resiliency. Although the unit is highly likely to remain extant, there will likely be substantial loss of habitat and degradation of remaining habitat due to One Lake project and increased levels of development and agriculture.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

E) Year 2070 Land Use/Climate Scenario A2 + 3ft (0.91m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development and agriculture increase significantly across the entire unit. Forested cover decreases substantially in the East Pearl, Hoblochitto, and Pearl Navigation Canal. SLR impacts approximately 9 river miles of known occupied habitat in the southern extent of the East Pearl.	Likely a significant decrease in resilience due to loss of habitat in the southern portion of the unit due to SLR, high levels of agriculture across the unit, significant increases in development, and substantial decreases in forested cover in 3 streams.
Middle Pearl Silver	Development remains low; agriculture increases from moderate to high; stable forested cover; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (low) due to increase in agriculture.
Middle Pearl Strong (No One Lake Project)	Development is high in the mainstem, and moderate in all other streams; agriculture increases to high; forested cover decreases across most of the unit; no SLR or reservoir projects predicted.	Likely a significant decrease to current resilience, potentially from moderate to low due to high levels of development and agriculture and decreases in forested cover.
Middle Pearl Strong (One Lake Project)	Development is high in the mainstem, and moderate in all other streams; agriculture increases to high; forested cover decreases across most of the unit; no SLR predicted; One Lake project results in loss of habitat and individuals.	Likely a significant decrease to current resilience, likely from moderate to low due to high levels of development and agriculture and decreases in forested cover. Compounding these issues is the One Lake Project, which will result in significant loss and degradation of habitat.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

F) Year 2070 Land Use/Climate Scenario A2 + 5ft (1.52m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development and agriculture increase significantly across the entire unit. Forested cover decreases substantially in the East Pearl, Hoblochitto, and Pearl Navigation Canal. SLR impacts approximately 10 river miles of known occupied habitat in the southern extent of the East Pearl and a small portion of occupied habitat in the West Pearl just north of I-10.	Likely a significant decrease in resilience due to loss of habitat in the southern portion of the unit due to SLR, high levels of agriculture across the unit, significant increases in development, and substantial decreases in forested cover in 3 streams.
Middle Pearl Silver	Development remains low; agriculture increases from moderate to high; stable forested cover; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (low) due to increase in agriculture.
Middle Pearl Strong (No One Lake Project)	Development is high in the mainstem, and moderate in all other streams; agriculture increases to high; forested cover decreases across most of the unit; no SLR or reservoir projects predicted.	Likely a significant decrease to current resilience, potentially from moderate to low due to high levels of development and agriculture, and decreases in forested cover.
Middle Pearl Strong (One Lake Project)	Development is high in the mainstem, and moderate in all other streams; agriculture increases to high; forested cover decreases across most of the unit; no SLR predicted. One Lake project results in loss of habitat and individuals.	Likely a significant decrease to current resilience, likely from moderate to low due to high levels of development and agriculture, and decreases in forested cover. Compounding these issues is the One Lake Project, which will result in significant loss and degradation of habitat.
Upper Pearl	Development remains low; agriculture increases to high; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely a slight decrease to current resilience (moderate) due to increase in agriculture, although this could be offset by high levels of forested cover.

G) Year 2070 Land Use/Climate Scenario B1 + 3ft (0.91m) Sea Level Rise, and H) Year 2070 Land Use/Climate Scenario B1 + 5ft (1.52m) Sea Level Rise

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture remains high; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development is low across the entire unit. Agriculture remains moderate across the entire unit. Forested cover is high. SLR impacts approximately 9 river miles of known occupied habitat in the southern extent of the East Pearl.	Likely a slight decrease to resilience due to SLR impacts in the southern portion of the unit. Land use and forested cover remain stable.
Middle Pearl Silver	Development remains low; agriculture stays moderate; forested cover increases; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development and agriculture stay at moderate levels; stable forested cover; no SLR or reservoir projects predicted.	Resilience is likely to stay moderate; the same as current condition.
Middle Pearl Strong (One Lake Project)	Development and agriculture stay at moderate levels; stable forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals.	Resilience will decrease in the areas in and adjacent to the One Lake Project area due to significant loss and degradation of habitat. The rest of the unit will likely remain stable due to no significant increases in other threats.
Upper Pearl	Development remains low; agriculture remains moderate; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to increases in forested cover.

H) Year 2070 Land Use/Climate Scenario B1 + 5ft (1.52m) Sea Level Rise.

Unit	Future Habitat Factors	Future Resilience
Bogue Chitto	Development remains low; agriculture decreases to moderate; stable forested cover; no SLR or reservoir projects predicted.	Likely to maintain moderate resilience, although uncertainty remains regarding future mining activity.
Lower Pearl	Development is low across the entire unit. Agriculture remains moderate across the entire unit. Forested cover is high. SLR impacts approximately 10 river miles of known occupied habitat in the southern extent of the East Pearl and a small portion of occupied habitat in the West Pearl just north of I-10.	Likely a slight decrease to resilience due to SLR impacts in the southern portion of the unit. Land use and forested cover remain stable.
Middle Pearl Silver	Development remains low; agriculture decreases from moderate to low; forested cover increases; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to decreased agriculture and increases in forested cover.
Middle Pearl Strong (No One Lake Project)	Development and agriculture stay at moderate levels; stable forested cover; no SLR or reservoir projects predicted.	Resilience is likely to stay moderate; the same as current condition.
Middle Pearl Strong (One Lake Project)	Development and agriculture stay at moderate levels; stable forested cover; no SLR predicted. One Lake project results in loss of habitat and individuals.	Resilience will decrease in the areas in and adjacent to the One Lake Project area due to significant loss and degradation of habitat. The rest of the unit will likely remain stable due to no significant increases in other threats.
Upper Pearl	Development remains low; agriculture remains moderate; forested cover is very high across the entire unit; no SLR or reservoir projects predicted.	Likely to maintain current resilience (low), or potentially increase slightly due to increases in forested cover.

6.5.2 Future Representation

Representation refers to the breadth of genetic and environmental diversity within and among populations, which influences the ability of a species to adapt to changing environmental conditions over time. Differences in life history traits, habitat features, and/or genetics across a species range often aid in the delineation of representative units, which are used to assess species representation.

We consider the entire range of the Pearl River map turtle to be one representative unit based on a recent study that found no distinct genetic structure was present across the species range (Pearson et al. 2020, pp. 11-12). However, the Strong River, located in the Pearl River Strong

unit, may have some unique habitat features that could confer unique adaptive pressure (Lindeman pers. comm. 2020, p. 4), most notably, the Strong River has some very rocky stretches that are unlike anything else in the drainage, water quality appears to be better than most of the rest of the drainage, and fish diversity is high in these rocky areas (Selman pers. comm. 2020a, p. 7). Although we do not consider the Strong River to be a separate representative unit, we consider the Strong River to be a potentially significant stream because of the unique characteristics of the habitat.

When looking at projections of threats within the Strong River, a few general trends can be seen. First, for land use, development is projected to remain low. In the A2 climate scenarios, agriculture increases from moderate to high; in the B1 climate scenarios, agriculture stays moderate. Also, forested cover within the riparian zone of the Strong River remains relatively high (68-83%), although it does drop across all climate scenarios from current condition (92%). Sea level rise does not impact this river in any of our scenarios, as the Strong River is far enough inland to avoid the effects of inundation. Finally, the One Lake project is not anticipated to directly impact the Strong River due to the location of the project (i.e. mainstem Pearl River). Given all of this information, although the resilience of the Strong River might decrease slightly due to land use projections, it is likely the Strong River will support a moderate density of individual turtles, and thus contribute to representation through maintenance of potential genetic diversity based on unique habitat features. It is noteworthy that a recent genetics study has revealed that genetic diversity is lower in Pearl River map turtles compared to Pascagoula map turtles (Pearson et al. 2020, pp. 11-12). Declining populations generally have reduced genetic diversity, which can potentially elevate the risk of extinction by reducing a species' ability and potential to adapt to environmental changes (Spielman et al. 2004, entire). Future studies could help to elucidate whether levels of genetic diversity seen in Pearl River map turtles are low enough to suggest potential genetic bottlenecks, thus clarifying the species level of representation.

6.5.3 Future Redundancy

Redundancy refers to the ability of a species to withstand catastrophic events and is measured by the amount and distribution of resilient populations across the species range. Catastrophic events

that could severely impact or extirpate entire Pearl River map turtle units include chemical spills, changes in upstream land use that alters stream characteristics and water quality downstream, dam construction with a reservoir drowning lotic river habitat, and potential effects of climate change such as rising temperatures and sea level rise. Although we do not project any of the units to be extirpated in any scenarios, we do anticipate resilience to drop significantly in several units across many scenarios. For example, the Middle Pearl Strong unit will likely lose a substantial amount of habitat and individuals under all scenarios in which the One Lake project is initiated. Also, the Lower Pearl unit will be impacted by sea level rise under all scenarios, and this is compounded by projected increases in both development and agriculture. All other units are anticipated to remain relatively stable. Because extant units of the species are predicted to be distributed relatively widely, it is highly unlikely that a catastrophic event would impact the entire species' range, thus the Pearl River map turtle is predicted to exhibit a moderate degree of redundancy in the future under all scenarios.

6.5.4 Future Conditions Summary

We assessed future resilience as a function of four habitat/threat factors (land use, sea level rise, riparian forested cover, and future water engineering projects). Based on these factors, there are two populations predicted to substantially decrease in resilience across most of the future scenarios: Lower Pearl and Middle Pearl Strong. The Lower Pearl unit faces a myriad of future threats, including impacts from seal level rise in the southern portion of the unit, substantial increases in development and agriculture within the A2 climate scenarios, and loss of forested cover within the A2 climate scenarios. For the Middle Pearl Strong, the magnitude of decrease is most closely tied to the One Lake project. If the One Lake Project moves forward within the next 50 years, areas in and around the project site are anticipated to be substantially negatively impacted. The Bogue Chitto, Middle Pearl Silver, and Upper Pearl units are anticipated to maintain their current resilience, or only slightly decrease, as the main threats assessed are not anticipated to increase markedly in the future. One caveat for the Bogue Chitto: there is uncertainty in levels and patterns of mining in the future, and this has been identified as a current threat in some portions of the unit.

Regarding redundancy, all five units are predicted to remain extant under all scenarios, and those units are distributed relatively widely, thus it is unlikely that a catastrophic event would impact the entire range of the species. We did not assess multiple representative units for the species due to recent research indicating no significant genetic structuring. Species experts indicated the Strong River might be unique from a habitat perspective (i.e. distinctly rocky stretches), so it is notable that the Strong River is not predicted to significantly increase any primary threats. If the Strong River is indeed conferring different adaptive pressures due to the unique habitat type found there, the Strong River is predicted to continue contributing to representation for the species.

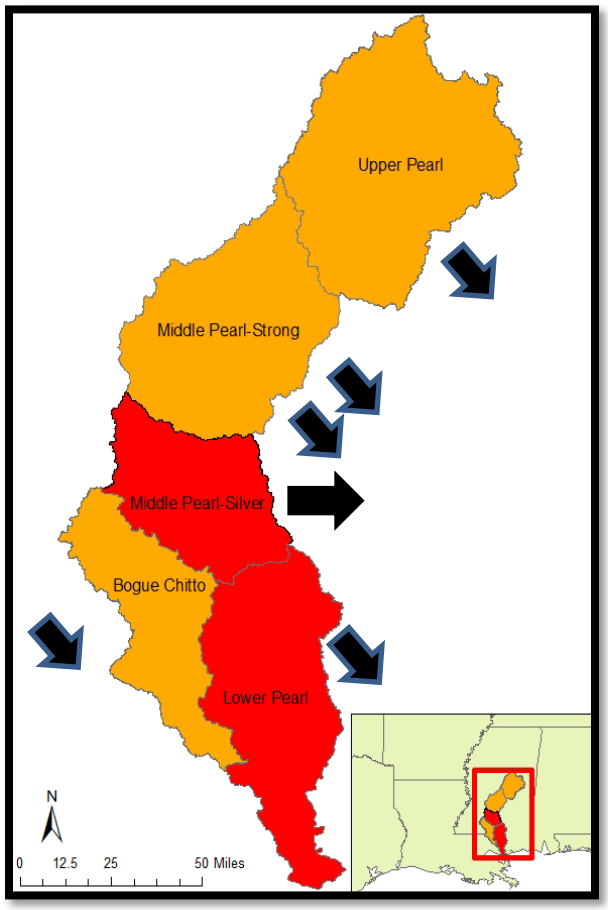


Figure 6.6- Future resiliency of Pearl River map turtle analysis units. The arrows indicate direction of change from current to future conditions. The color of the units indicates the current condition; red=low, orange=moderate, and green= high.

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APPENDIX A – LAND USE SUMMARIES FOR PEARL RIVER RESILIENCE UNITS

Table 1-A) Summary of current development across the Bogue Chitto unit and within riparian areas. B) Summary of current agriculture across the Bogue Chitto unit and within riparian areas. Streams in bold are mainstem reaches; all other streams are considered tributaries.

A)

Stream	Total Acres	Current Acres Developed	% Developed Current	Total Acres Riparian	Current Acres Developed Riparian	% Developed Riparian
Bogue Chitto	773543.88	51073.79	6.60	6074.26	60.94	1.00
Magees	773543.88	51073.79	6.60	1834.75	25.80	1.41
Topisaw	773543.88	51073.79	6.60	1306.12	18.90	1.45

B)

Stream	Total Acres	Current Acres Agriculture	% Agriculture Current	Total Acres Riparian	Current Acres Agriculture Riparian	% Agriculture Riparian
Bogue Chitto	773543.88	175388.53	22.67	6074.26	92.74	1.53
Magees	773543.88	175388.53	22.67	1834.75	69.39	3.78
Topisaw	773543.88	175388.53	22.67	1306.12	185.48	14.20

Table 2-A) Summary of current development across the Lower Pearl unit and within riparian areas. B) Summary of current agriculture across the Lower Pearl unit and within riparian areas. Streams in bold are mainstem reaches; all other streams are considered tributaries.

A)

Stream	Total Acres	Current Acres Developed	% Developed Current	Total Acres Riparian	Current Acres Developed Riparian	% Developed Riparian
East Pearl	1165606.50	77706.64	6.67	1987.98	10.67	0.54
Hobolochitto	1165606.50	77706.64	6.67	291.34	2.22	0.76
Holmes Bayou	1165606.50	77706.64	6.67	204.38	0.00	0.00
Lower Pearl	1165606.50	77706.64	6.67	5920.59	33.14	0.56

Navigation Canal	1165606.50	77706.64	6.67	84.07	0.44	0.53
Pushepatapa	1165606.50	77706.64	6.67	1210.94	19.35	1.60
West Hobolochitto	1165606.50	77706.64	6.67	2456.35	24.91	1.01
West Pearl	1165606.50	77706.64	6.67	1868.34	12.68	0.68

B)

Stream	**Total Acres**	**Current Acres Agriculture**	**% Agriculture Current**	**Total Acres Riparian**	**Current Acres Agriculture Riparian**	**% Agriculture Riparian**
East Pearl	1165606.50	144723.89	12.42	1987.98	4.45	0.22
Hobolochitto	1165606.50	144723.89	12.42	291.34	0.00	0.00
Holmes Bayou	1165606.50	144723.89	12.42	204.38	0.00	0.00
Lower Pearl	1165606.50	144723.89	12.42	5920.59	5.56	0.09
Navigation Canal	1165606.50	144723.89	12.42	84.07	0.00	0.00
Pushepatapa	1165606.50	144723.89	12.42	1210.94	8.90	0.73
West Hobolochitto	1165606.50	144723.89	12.42	2456.35	8.23	0.33
West Pearl	1165606.50	144723.89	12.42	1868.34	0.00	0.00

Table 3-A) Summary of current development across the Middle Pearl Silver unit and within riparian areas. B) Summary of current agriculture across the Middle Pearl Silver unit and within riparian areas. Streams in bold are mainstem reaches; all other streams are considered tributaries.

A)

Stream	**Total Acres**	**Current Acres Developed**	**% Developed Current**	**Total Acres Riparian**	**Current Acres Developed Riparian**	**% Developed Riparian**
Middle Pearl Silver	779923.50	37647.61	4.83	3798.50	15.79	0.42

B)

Stream	Total Acres	Current Acres Agriculture	% Agriculture Current	Total Acres Riparian	Current Acres Agriculture Riparian	% Agriculture Riparian
Middle Pearl Silver	779923.50	117150.98	15.02	3798.50	81.17	2.14

Table 4-A) Summary of current development across the Middle Pearl Strong unit and within riparian areas. B) Summary of current agriculture across the Middle Pearl Strong unit and within riparian areas. Streams in bold are mainstem reaches; all other streams are considered tributaries.

A)

Stream	Total Acres	Current Acres Developed	% Developed Current	Total Acres Riparian	Current Acres Developed Riparian	% Developed Riparian
Middle Pearl Strong	1265209.88	152007.75	12.01	5612.35	61.16	1.09
Pelahatchie	1265209.88	152007.75	12.01	2114.75	23.80	1.13
Purvis	1265209.88	152007.75	12.01	825.53	6.00	0.73
Strong	1265209.88	152007.75	12.01	4351.15	29.36	0.67

B)

Stream	Total Acres	Current Acres Agriculture	% Agriculture Current	Total Acres Riparian	Current Acres Agriculture Riparian	% Agriculture Riparian
Middle Pearl Strong	1265209.88	202578.92	16.01	5612.35	219.50	3.91
Pelahatchie	1265209.88	202578.92	16.01	2114.75	34.25	1.62
Purvis	1265209.88	202578.92	16.01	825.53	89.18	10.80
Strong	1265209.88	202578.92	16.01	4351.15	142.11	3.27

Table 5-A) Summary of current development across the Upper Pearl unit and within riparian areas. B) Summary of current agriculture across the Upper Pearl unit and within riparian areas. Streams in bold are mainstem reaches; all other streams are considered tributaries.

A)

Stream	Total Acres	Current Acres Developed	% Developed Current	Total Acres Riparian	Current Acres Developed Riparian	% Developed Riparian
Lobutcha	1576498.75	81862.08	5.19	2921.60	21.57	0.74
Tuscolometa	1576498.75	81862.08	5.19	1611.47	10.90	0.68
Upper Pearl	1576498.75	81862.08	5.19	3660.61	23.80	0.65
Yockanookany	1576498.75	81862.08	5.19	3655.28	20.68	0.57

B)

Stream	Total Acres	Current Acres Agriculture	% Agriculture Current	Total Acres Riparian	Current Acres Agriculture Riparian	% Agriculture Riparian
Lobutcha	1576498.75	263492.78	16.71	2921.60	28.02	0.96
Tuscolometa	1576498.75	263492.78	16.71	1611.47	28.91	1.79
Upper Pearl	1576498.75	263492.78	16.71	3660.61	18.68	0.51
Yockanookany	1576498.75	263492.78	16.71	3655.28	129.43	3.54

APPENDIX B – USFWS LEMIS REPORT

U.S. Fish and Wildlife Service Law Enforcement Management Information System (LEMIS) *Graptemys* report for exports from the United States from 2005 to 2019.

Year	Genus	Species	Specific Name	Generic Name	Wildlife Desc	Quant	Ctry IER	IE	Year	Quant
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	150	AR	E	2005	150
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,500	AU	E	2005	1,500
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	11,700	BE	E	2005	11,700
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,100	CH	E	2005	1,100
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	100	CN	E	2005	100
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	19,400	CZ	E	2005	19,400
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	12,176	DE	E	2005	12,176
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	56	DK	E	2005	56
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	35,158	ES	E	2005	35,158
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,000	FR	E	2005	2,000
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,374	GB	E	2005	2,374
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,380	HK	E	2005	1,380
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	6,705	HU	E	2005	6,705
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	22,517	IT	E	2005	22,517
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,699	JP	E	2005	4,699
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	9,275	KR	E	2005	9,275
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	25	MO	E	2005	25
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	14,531	MX	E	2005	14,531
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	50	MY	E	2005	50
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,550	NL	E	2005	4,550
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	6,800	PL	E	2005	6,800
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	25,350	PT	E	2005	25,350
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,009	TW	E	2005	1,009
2005	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,000	UA	E	2005	1,000
2006	GRAPTEMYS	GIBBONSI	PASCAGOULA MAP	TURTLE	LIV	4	DE	E	2006	4
2006	GRAPTEMYS	GIBBONSI	PASCAGOULA MAP	TURTLE	LIV	143	JP	E	2006	143
2006	GRAPTEMYS	GIBBONSI	PASCAGOULA MAP	TURTLE	LIV	31	TW	E	2006	31
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	250	AR	E	2006	250
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	500	BE	E	2006	500
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	17	CH	E	2006	17
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,450	DE	E	2006	2,450
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,000	ES	E	2006	4,000
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	500	GB	E	2006	500
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,000	HK	E	2006	1,000
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,500	HU	E	2006	2,500
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	25	ID	E	2006	25
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,500	IT	E	2006	1,500
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,435	JP	E	2006	1,435
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,200	KR	E	2006	4,200
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,575	MX	E	2006	3,575

Year	Genus	Species	Specific Name	Generic Name	Wildlife Desc	Quant	Ctry IER	IE	Year	Quant
2006	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	100	MY	E	2006	100
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	450	BE	E	2007	450
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,900	CZ	E	2007	1,900
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,000	ES	E	2007	3,000
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	350	GB	E	2007	350
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,000	HR	E	2007	2,000
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,000	HU	E	2007	2,000
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,000	IT	E	2007	4,000
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,000	KR	E	2007	1,000
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,300	MX	E	2007	3,300
2007	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	18,700	PT	E	2007	18,700
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,500	BE	E	2008	1,500
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,000	CZ	E	2008	3,000
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	2,100	DE	E	2008	2,100
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	6,050	ES	E	2008	6,050
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,450	GB	E	2008	3,450
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	500	HK	E	2008	500
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,900	HU	E	2008	1,900
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	12,000	IT	E	2008	12,000
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	4,600	MX	E	2008	4,600
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	20,000	PT	E	2008	20,000
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	1,000	RO	E	2008	1,000
2008	GRAPTEMYS	SPECIES	MAP	TURTLE	LIV	3,000	TW	E	2008	3,000
2013	GRAPTEMYS	GIBBONSI	PASCAGOULA MAP	TURTLE	SPE	2	CA	E	2013	2
2013	GRAPTEMYS	SPECIES	MAP	TURTLE	SPR	1	CA	E	2013	1
2018	GRAPTEMYS	PEARLENSIS	PEARL RIVER MAP	TURTLE	LIV	6	AT	E	2018	6
2019	GRAPTEMYS	SPECIES	MAP	TURTLE	SPR	1	FR	E	2019	1

Wildlife Desc- Wildlife Description

LIV- Live specimens (live animals or plants)
SPE- Specimen (scientific or museum)
SPR- Shell product (mollusc or turtle)

Ctry IER-Country Code

AR-Argentina	DE-Germany	HU-Hungary	MY-Malaysia
AT-Austria	DK-Denmark	ID-Indonesia	NL-Netherlands
AU-Australia	ES-Spain	IT-Italy	PL-Poland
BE-Belgium	FR-France	JP-Japan	PT-Portugal
CA-Canada	GB-England	KR-Republic of Korea (South)	RO-Romania
CH-Switzerland	HK-Hong Kong	MO-Macao	TW-Taiwan (Province of China)
CN-China	HR-Croatia	MX-Mexico	UA-Ukraine
CZ-Czech Republic			

Notes: