Species Status Assessment Report for Fat Threeridge (*Amblema neislerii*)

Version 1.0

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VERSION UPDATES

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EXECUTIVE SUMMARY

This report summarizes the results of a Species Status Assessment completed for the Fat Threeridge (*Amblema neislerii*) to assess the species' overall viability. The Fat Threeridge is an endangered freshwater mussel endemic to the Apalachicola River and two major tributaries, the Flint River (Georgia), and Chipola River (Florida). The primary threats to the species are habitat loss and modification, loss of connectivity, water quality degradation, and water flow reduction.

To evaluate the viability of the Fat Threeridge, we characterized the needs, estimated the current condition, and predicted the future condition of the species in terms of resiliency, representation, and redundancy. Briefly, resiliency describes the ability of a population to withstand environmental and demographic stochasticity; representation describes the ability of the subspecies to adapt over time to long-term changes in the environment (for example, climate change); and redundancy describes the ability of the subspecies to withstand catastrophic events (for example, droughts, hurricanes). In general, the more redundant and resilient a subspecies is and the more representation it has, the more likely the species will sustain populations over time, even under changing environmental conditions.

We delineated six analysis units: the (1) Lower Flint River, (2) Upper (3) Middle and (4) Lower Apalachicola River, (5) Lower Chipola River and (6) Chipola River North of Dead Lakes (Chipola NDL). For each unit we assessed the current condition in terms of species abundance, evidence of recruitment, habitat occupancy, water quality, and water quantity. Currently, all units are resilient (ranked as either moderate or high). Three out of the six analysis units display moderate resiliency due to stressors to water quality and/or relatively lower habitat occupation (Upper Apalachicola, Lower Flint, Chipola NDL). The other three have high resiliency exhibiting high abundance and limited threats (Middle and Lower Apalachicola, Lower Chipola). Populations appear to be stable or increasing in these three units, but trends in the units where Fat Threeridge is less are difficult to discern given limited sampling and/or periods of no detection. Current redundancy is moderate to high, given the species remains largely intact and resilient throughout its known range, except for the Upper Flint River (last observation year: 1981). The species is abundant in the core of its range which may make it more likely to persist through catastrophic events (e.g. extreme drought or spill). The species is present in three river basins.

We assessed the future condition in 2070, under two scenarios defined by differences in climate projections and land use, with Scenario 1 described as a status quo scenario under more extensive greenhouse gas emissions, and Scenario 2 as a more conservation-based scenario under more moderate emissions. Land use changes depended on the climate scenario, and are predicted to either remain similar to current conditions in Scenario 2, or show a transition of some natural lands to agricultural land in Scenario 1. Because rivers occupied by the species are buffered by natural land cover, much of which is in conservation, the predicted land use changes may not have a strong effect on population resiliency; only the Middle Apalachicola may experience a reduction in resiliency from landuse change under Scenario 1. Agricultural land use is estimated to increase the most in the Lower Flint which could lead to a reduction of resiliency if adequate vegetated buffer is not maintained. Water quantity projections are likely to remain similar to the current condition or change in ways favoring Fat Threeridge persistence, leading to no categorical changes between the current and future conditions, although the water quantity model available is limited in that it does not incorporate anthropogenic water withdrawal.

Sea level rise projections may negatively impact population resilience in the southern part of the species range. Conditions may be maintained as they are currently with intermediate and intermediate-high NOAA sea level rise projections. The Lower Apalachicola and Lower Chipola analysis units could experience loss of resiliency under high and extreme NOAA SLR projections, respectively. There do not appear to be overlapping impacts from water quality degradation and habitat removal from sea level rise based on the future condition scenarios.

Depending on the extent of sea level rise, Fat Threeridge could continue to exhibit characteristics of high to moderately resiliency in the core or throughout the entirety of its range. Fat Threeridge may experience no to moderate reduction in redundancy depending on the extent of sea level rise. The most severe impacts could occur within the southern extent of the range, but under all scenarios considered, the core of the species range containing the majority of known individuals remains in either high to moderate condition and representation is not expected to be impacted.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 - INTRODUCTION

The Species Status Assessment (SSA) framework (USFWS 2016*a*, entire) is intended to support an in-depth review of a species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA to be a living document, easily updated as new information becomes available, and to support all functions of the Endangered Species Program from Candidate Assessment, to Listing, to Consultations, to Recovery.

The Fat Threeridge (*Amblema neislerii*; Lea 1858) is a freshwater mussel endemic to the Apalachicola and Flint River basins in Florida, and Georgia. The U.S. Fish and Wildlife Service listed Fat Threeridge as endangered under the Endangered Species Act of 1973, as amended (Act) in 1998 (54 FR 554). This Fat Threeridge SSA is intended to provide a review of the best available information strictly related to the biological status of the species, in support of a 5-year status review. Importantly, the SSA does not result in any decisions or actions by the U.S. Fish and Wildlife Service (hereafter, Service). Rather, this SSA provides a review of the available information strictly related to the biological status of Fat Threeridge. Any future decisions will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of any proposed decisions will be announced in the *Federal Register*, with appropriate opportunities for public input.

For the purpose of this assessment, we define viability as the ability of a species to sustain populations in the wild beyond a biologically meaningful time frame. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (USFWS 2016a, p. 9). Using the SSA framework (Figure 1-1) we consider what the species needs to maintain viability by characterizing its ability to withstand environmental and demographic stochasticity (resiliency), catastrophes (redundancy), and novel changes in its biological and physical environment (representation) (Shaffer and Stein 2000, pp. 308 -311; Wolf et al. 2015, entire, Smith et al. 2018, entire). 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 (Smith et al. 2018, p. 306).

- **Resiliency** describes the ability of populations to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, 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.

- **Redundancy** describes the ability of a species to withstand catastrophic events by spreading risk among multiple populations or across a large area. 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).

- **Representation** describes the ability of the 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 environments 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 at al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural slection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290 -291; Sgro et al. 2011, p. 327; Zackay 2007, p. 1).

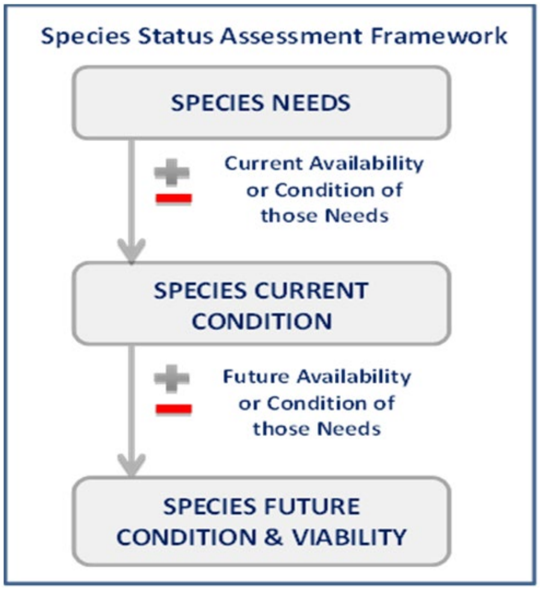


Figure 1-1. Species Status Assessment Framework.

To evaluate the current and future biological status of the Fat Threeridge, we assessed a range of conditions that reflect the species' resiliency, redundancy, and representation (together, the "3Rs"). This document is a compilation of the best available scientific and commercial information and a description of limiting factors to Fat Threeridge viability.

1.1 Species Protection Status

The Service first recognized Fat Threeridge as a candidate for listing under the Act on January 6, 1989 (54 FR 554). It was federally listed as endangered under the Endangered Species Act (Act) of 1973, as amended, on March 16, 1998 (63 FR 12664, USFWS 1998). A recovery plan was completed in 2003 (USFWS 2003, entire). Critical Habitat was designated November 15, 2007 (72 FR 64286, USFWS 2007a), and a 5-year review was completed in 2007 (USFWS 2007*b*). Most recently, a Recovery Plan Revision was completed (USFWS 2019, entire), and a 5-year review of the species status was initiated (83 FR 38320).

In addition to federal protection, the State of Florida (Florida Rule Chapter: 68A-27) and Georgia (Georgia Rule Chapter: 391-4-10) have identified Fat Threeridge as an endangered species with protection from take and harassment. In July 1996, the State of Florida enacted a moratorium on commercial mussel harvest, and limited collection of mussels under a State permit is allowed for scientific or other non-commercial purposes. A scientific collecting permit is required in the State of Georgia to collect mussels for scientific purposes; State-listed mussels are not permitted for any other purpose. Commercial harvest (excluding protected species) in Georgia is allowed for mussels that will not pass through a 4 inch ring. Mechanical harvest of mussels is illegal, and hand-picking mussels requires a resident or non-resident fishing license if used for bait, or a commercial license (USFWS 1998, p. 12682).

CHAPTER 2 – SPECIES' BACKGROUND AND ECOLOGY

In this chapter, we provide a concise summary of Fat Threeridge taxonomy, life history characteristics (i.e. multi-staged life cycle), and basic ecology. Individuals at each life stage have specific resource and life history requirements that must be met in order to progress to the next stage. We present fundamental information necessary to understand Fat Threeridge ecology and facilitate analyses of resiliency, representation, and redundancy.

2.1 Taxonomy and Nomenclature

Fat Threeridge (*Amblema neislerii*; Lea 1858) belongs to the family Unionidae, a large group of freshwater mussels represented by 298 species in North America (Williams et al. 2017, p. 45). The genus *Amblema* (Rafinesque, 1820) currently contains three species within the United States and Canada (Williams et al. 2017, p. 36). Two of the *Amblema* species occur only in the southeastern United States, while the third, Threeridge (*A. plicata*), is wide-ranging (NatureServe 2020, n.p.). Genetic analysis supports Fat Threeridge as a unique evolutionary unit (Mulvey et al. 1997, p. 876). However, the molecular evidence used to delineate species boundaries between *A. elliottii* and *A. neisleri* would benefit from a more robust assessment using additional molecular markers.

Fat Threeridge was originally described as *Unio neislerii* by Isaac Lea in 1858 from specimens collected from the Flint River, Macon County, Georgia. This taxon was assigned to the genera *Quadrula* and *Crenodonta* by Simpson (1914, p. 829) and Clench and Turner (1956, p. 159), respectively. Subsequent investigators (e.g., Williams et al. 2011, p. 48) have placed the Fat Threeridge in the genus *Amblema*, which has been retained during recent review (Williams et al. 2017, p. 46). Both The Integrated Taxonomic Information System (2020, n.p.) and the Service recognize *Amblema neislerii* as valid, with *Unio neislerii* a synonym for the species (Figure 2-1).

2.2 Species Description

Unless otherwise indicated, the description of the species is from Clench and Turner (1956, p. 159 -160). The Fat Threeridge is a medium-sized to large, almost square, inflated, solid, and heavy shelled mussel that reaches a length of 102 millimeters (mm) (4.0 inches (in)). Older, larger individuals are so inflated that their width approximates their height. The external shell is composed of two hinged halves or valves. The umbos (most prominent, highest part of each valve) are in the anterior quarter of the shell. The dark brown to black shell is strongly sculptured with seven to eight prominent horizontal parallel ridges (Figure 2-1). The prominent, parallel ridges and inflated shell (older specimens, especially) distinguish this species from other mussels within its range. Internally, there are two subequal pseudocardinal teeth (structures located near the anterior-dorsal margin) in the left valve and typically one large and one small tooth in the right valve. The nacre (inner shell) is bluish white to light purplish and very iridescent.

Figure 2-1. Lectotype of *Unio neislerii* (= *Amblema neislerii*), USNM 83993. A) Figure from Lea (1858); and B) photograph (from Williams et al. 2011, p. 48).

The parasitic larvae of mussels, known as glochidia, are miniature bivalves; they have two shells attached by a hinge ligament and a single adductor muscle (Haag 2012, p. 8). Glochidia form into three basic variations: hooked, hookless, and ax-head shaped, with Fat Threeridge glochidia being hookless. Female Fat Threeridge release the glochidia as a mass. The glochidia of Fat Threeridge are very small (204 um long) and sub-elliptical (O'Brien and Williams 2002, p. 152).

2.3 Life History

2.3.1 Diet

Adult freshwater mussels are suspension-feeders and filter particles from the water column. Mussels may also obtain food by deposit feed using cilia on their foot to move food particles into the shell (Haag 2012, pp. 27–28), though reasons for this are poorly known and may depend on flow conditions or temperature. For their first several months, juvenile mussels ingest food through their foot and are thus deposit feeders, although they may also filter interstitial pore water and soft sediments (Yeager et al. 1994, p. 221; Haag 2012, p. 26-27). Mussel diets consist of a mixture of algae, bacteria, detritus, and microscopic animals (Gatenby et al. 1996, p. 606; Strayer et al. 2004, p. 430). It has also been surmised that dissolved organic matter may be significant source of nutrition; such an array of foods, containing essential long-chain fatty acids, sterols, amino acids, and other biochemical compounds, may be necessary to supply total nutritional needs (Strayer et al. 2004, p. 431). Food availability and quality are affected by habitat stability, floodplain connectivity, flow, and water quality. Excessive sedimentation (e.g., habitat instability) can impair filter feeding and dilute the food source (Ellis 1936, p. 30). Adequate flows can alleviate water quality impacts from sedimentation, and maintain the exchange of nutrients and detritus with the floodplain of a river (Mattraw and Elder 1983, entire). Food availability may also be affected by the presence of moderate to high densities of Asian Clams (*Corbicula fluminea*), which have similar diets and can remove a substantial amount of suspended food materials from the water column (See Chapter 5: Factors Influencing Viability).

2.3.2 Reproduction and Life Cycle

Freshwater mussels have a complex, multi-staged life cycle (Figure 2-2). Reproduction begins with males releasing sperm into the water column, which is taken in by the female through the incurrent aperture. The sperm fertilizes eggs that are held within the female's gills in the marsupial chamber. O'Brien and Williams (2002, p. 150) studied various aspects of life history of the Fat Threeridge, determining that it is likely a short-term summer brooder of its glochidia. Females appear to be gravid in Florida when water temperatures reached 23.9°C (75°F), in late May and June. Gravid females have not been documented in July, August, or September. The developing larvae (called glochidia) remain in the gill chamber until they mature and are ready for release in early June (O'Brien and Williams 2002, p. 150). However, detailed data on the fecundity of Fat Threeridge are limited. Information regarding sex ratios, gravidity and length-maternity relationships specific to Fat Threeridge are lacking (Miller 2011, p. 5).

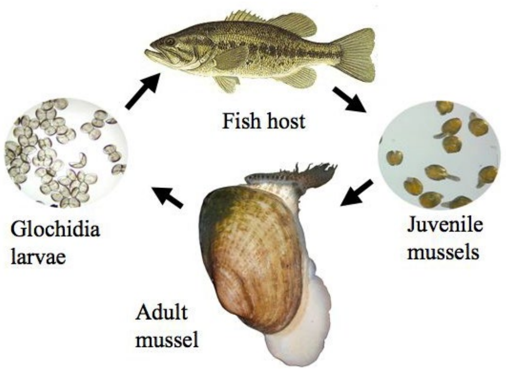
The glochidia of Fat Threeridge, like most freshwater mussels, are obligate parasites on fish and must attach to a fish host in order to transform into juvenile mussels (Figure 2-2). In the Fat Threeridge, the glochidia are hookless which suggests that the gills are the primary target for infection (Williams et. al. 2014, p. 82). Fat Threeridge glochidia are released in a white, sticky, web-like mass, which expands and wraps around a fish, thus facilitating attachment; this method of glochidia release is considered broadcasting, often seen in host generalists because passive entanglement is nonselective (Haag 2012, pp. 155-156).

Reproductive studies have confirmed that Fat Threeridge is a host generalist, completing transformation on 23 species of fish including common river species [e.g. bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*)] (O'Brien & Williams 2002, p. 149; Fritts and Bringolf 2014, p. 56). However, there is high variation in host suitability between host species (Fritts and Bringolf 2014, p. 56): Fat Threeridge mean percent metamorphosis (glochidia transitioning to juvenile lifestage) was highest in darters (*Etheostoma;* 42.6 and 56.5%); similar suitability was seen in green sunfish (*Lepomis cyanellus*; 58 percent) and Apalachee shiner (*Pteronotropis grandipinnis;* 46.2 percent); with lower but robust metamorphosis in striped bass (*Morone saxatilis;* 28 percent) and yellowfin shiner (*Notropis lutipinnis*; 25 percent). In an assessment of the mean number of juvenile Fat Threeridge produced per fish, O'Brien and Williams (2002, p. 150) found bluegill averaged 27, with Blackbanded darter (*Percina nigrofasciata*) averaged 22. These were the highest averages (ranging 3 to 27) among the five fish hosts that had successful transformation of Fat Threeridge juveniles. The ability of Fat Threeridge to metamorphose robustly on migratory species (i.e., striped bass) suggests that population structure may be influenced by long distance dispersal of fish hosts to a greater extent than mussel species that are specialists on more sedentary fish species (Fritts and Bringolf 2014, p. 57).

Gravid female mussels release thousands to millions of glochidia, but only a few will contact a suitable host fish (Haag 2012, pp. 423–425). In laboratory trials, glochidia were viable for two days after release and transformation of the glochidia on host fishes required 10 to 18 days (O'Brien and Williams 2002, p. 150; Fritts and Bringolf 2014, p. 56). Glochidia that attach to an appropriate host fish, will encyst in the gill, skin, or fin tissue. Glochidia that attach to a non–host fish species, will be rejected by the fish's immune system (Haag 2012, pp. 41–42). When the transformation is complete, the newly metamorphosed juveniles drop from their fish host and sink to the stream bottom. Juveniles that drop into unsuitable substrates will die because their limited mobility prevents them from relocating to more favorable habitat. Juveniles that encounter suitable substrates burrow into the substrates and grow to a larger size that is less susceptible to predation and displacement during high flow events (Yeager et al. 1994, p. 220).

While adult freshwater mussels can move short distance with the use of their muscular foot, generally, mussels remain within the same small area where they dropped from the host fish (< 10 m; Irmscher and Vaughn 2018, p. 268). Parasitism serves as the primary dispersal mechanism for this relatively immobile group of organisms (Haag 2012, p. 145). The intimate relationship between freshwater mussels and their host fish plays a major role in mussel distributions on both a landscape and community scale (Haag and Warren 1998, p. 304).

Adult females are gravid from late May to early June. Once developed, glochidia are released and grow within a host over 10-18 days.



Glochia metamorphose into juveniles, and drop from the host. Juveniles are usually < 25 mm in size and 3 years of age or younger, with adults larger than this and older (See Section 2.3.4).

Figure 2-2. Generic illustration of the freshwater mussel reproductive cycle (FMCS 2019). The duration of life stages of the Fat Threeridge are included.

2.3.3 Movement

Mussels are generally immobile but experience their primary opportunity for dispersal and movement within the stream as glochidia attached to a mobile host fish (Smith 1985, p. 105). Juvenile freshwater mussels burrow into the interstitial space of substrates and grow to a larger size that is less susceptible to predation and displacement from high flow events (Yeager et al. 1994, p. 220). Throughout the rest of their life cycle, mussels generally remain within the same small area where they excysted from the host fish.

Moving is a strategy utilized by adults to avoid stranding. Gough et al. (2012, entire) assessed the linkage between physiological tolerance, behavioral response, and survival of three species of freshwater mussels subjected to drought and identified three behavioral strategies used to mitigate drought conditions and thermal intolerance. The three strategies observed included tracking (moving to remnant pools during drying events), track and then burrow, and burrowing (Gough et al 2012, p. 2,364). Survival results suggest that drought poses the greatest threat to trackers, while burrowers are the most resistant to drought conditions (Gough et al 2012, p. 2,363). Mussel species capable of burrowing in response to stress may have a greater ability to survive. A congener of Fat Threeridge, *A. plicata*, was noted to seal its valves tightly and predominantly move vertically to avoid stranding (Newton et al. 2015, p. 12). Kaeser and Herrington (2011, entire) have documented both tracking and burrowing behavior in Fat Threeridge. Fat Threeridge are capable of moving laterally 50-100 cm per day to avoid exposure (Kaeser and Herrington 2011, p. 8). While only a small percentage (8%) of individuals buried completely into the substrate, survival of these mussels was much higher (7 to 27 days) under low-flow conditions compared to the majority of mussels (one to six days; Kaeser and Herrington 2011, p. 11).

2.3.4 Age, Growth, and Recruitment

Some freshwater mussels are long–lived and slow–growing, while others grow quickly and have short life spans. Life span varies widely by mussel species, but most species fall between 15–40 years (Haag 2012, p. 181; Sansom et al. 2016, p. 23). Generally, thin–shelled species grow faster and have shorter life spans, while heavy–shelled species, such as Fat Threeridge grow slowly and tend to reach higher maximum ages (Haag and Rypel 2011, p. 239). Mussels exhibit plasticity in growth rates (Haag and Rypel 2011, p. 225); growth patterns are more synchronous at local sites compared to river and regional scales (Sansom et al. 2016, p. 19).

Fat Threeridge exhibits low to moderate growth and intermediate to high longevity relative to other mussel species (Haag and Rypel 2011, pp. 234- 235). In an age study examining data from 2007 through 2010 completed by the Service, Fat Threeridge (n = 2568) size ranged from 11-86 mm (0.4-4.25 in) total length, and estimated ages ranged from 1-26 years old (USFWS, unpublished data); A study of eight shells conducted in 2006 estimated the largest individual examined (82 mm) to be 32 years old (USFWS 2007, p. 16). The maximum known reported length for Fat Threeridge is 115 mm, collected in 2018 in the lower Flint River near Newton, Georgia (USFWS, unpublished data).

The stage class containing Fat Threeridge individuals 11 – 25 mm in size is referred to as sub-adults in this SSA based on non-breeding status and suspension-feeding behavior, with very small young-of-year individuals (≤ 10 mm; Miller 2011, p. 4) referred to here as juveniles given their non-breeding status and pedal feeding behavior. It is important to note possible impacts of uncertainty in age at maturity to population dynamics; we consider all individuals ≤ 25 mm as evidence of recent recruitment (See Chapter 4: Current Condition). The estimated age at maturity is 3 years, derived from a close congener, *A. plicata*, and supported by age/growth data for *A. neislerii* (Miller 2011, p. 4). Given uncertainty in the maximum age range of Fat Threeridge, we consider 30 years the presumed lifespan and age-3 the presumed age at maturity.

Fat Threeridge fecundity was assumed to vary with aged based on data from *A. plicata* (Miller 2011, p. 5). Therefore it is not unexpected that Miller 2011 (p. 20) found the survival and growth in mid-size and large adults would be important to the long-term demographic stability of Fat Threeridge. These and other traits of Fat Threeridge suggest an equilibrium life history (e.g., typical of Amblemini; Haag 2012, p. x). Populations exhibiting these traits are favored by, and will typically achieve dominance under, stable environmental conditions (Haag 2012, p. x). The general life history characteristics of mussels are described in Table 2-1.

Table 2-1. Life history strategies and their traits as proposed by Haag (2012, p. x)

Traits	**Opportunistic**	**Periodic**	**Equilibrium**
Lifespan (years)	Low (≤10)	Moderate (8–30)	High (>25)
Age at maturity(years)	Low (0–2)	Low–moderate (1–3)	High (>3)
Fecundity	Moderate–high	Low–moderate (1–3)	Variable; typically low, but broadcasters high
Max. adult size (mm)	Moderate–large	Small–moderate	Moderate-large
Brooding strategy	Long-term or multicyclic	Mostly long-term	Mostly short-term
Growth rate (*K*)	High	Moderate–high	Low–moderate

The relationship between Fat Threeridge and flow regime may also be inferred from *A. plicata*. The following is summarized from a five year (2008-2012) field study by Ries et al. 2016 (p. 712) in the Upper Mississippi River where flow patterns are regulated by a series of dams. The greatest recruitment of *A. plicata* occurred in years with lower than average minimum flows in April, coinciding with the timing of fertilization. It was postulated that reduced spring discharge might prevent over-dispersal of sperm and improve fertilization success. A positive relationship was also observed between July maximum flow and recruitment of *A. plicata*. Higher summer flows may extend the distance glochidium could travel while maintaining position in the water column, increasing their chance of encountering a host fish. Poor recruitment was seen during 2006 extreme low flows for all species studied.

2.4 Genetics

Fat Threeridge in the Apalachichola are hypothesized to be one genetic population (Robinson et al., 2011, entire), however, genetic information for Fat Threeridge from the Flint or Chipola River basin are not available. Novel microsatellite loci for Fat Threeridge were isolated from 35 individuals from the Apalachicola River (Diaz-Ferguson et al. 2001, p. 758). Robinson et al. 2012 (entire) assessed the 16 loci reported by Diaz-Ferguson et al. (2011, p. 758) and one additional locus to test for genetic diversity (in the form of average number of alleles, observed heterozygosity, and expected heterozygosity) and population structure (assessments of Hardy-Weinberg equilibrium (HWE) and clustering analysis). Despite an inferred bottleneck in the late Pleistocene, this species has maintained relatively high levels of heterozygosity and allelic richness. The presence of multiple populations in the Apalachicola River is not supported by HWE or the cluster analysis.

2.5 Resource Needs

For individual level needs when species-specific data are not available we assume that Fat Threeridge has similar resource requirements as other riverine freshwater mussels of this region. Freshwater mussels have a complex life cycle, and needs must be met at all stages for recruitment, survival, and reproduction to occur and maintain persistence of the species (Table 2-2). Limited directed research is available on Fat Threeridge specific environmental thresholds, but primary biological features (PBFs) are identified and discussed in the 2006 proposed Critical Habitat Rule (71 FR 32746). The habitat features that will be discussed below are: flow regime, habitat stability, and water quality (USFWS 2007*a*, p. 64298-64302).

2.5.1 Natural Flow Regime

The Fat Threeridge inhabits permanently flowing rivers with natural hydrologic regimes. While freshwater mussels can survive seasonally low flows and random, short-term drying events, intermittent stream habitats generally cannot support mussel populations. Fat Threeridge requires lotic (flowing water) habitats, and does not tolerate impoundments or persist in intermittent streams (Brim Box and Williams 2000, p. 1–141). The species must have adequate flow to deliver oxygen, enable passive reproduction, deliver food items to the sedentary juvenile and adult life stages, remove wastes, and maintain good water quality. Further, to maintain Fat Threeridge populations over time, a natural flow regime (including magnitude, frequency, duration, and seasonality of discharge) is critical for the exchange of nutrients, movement and spawning activities of fish hosts, and maintenance of instream habitats (USFWS 2007a, p. 64299 – 64300).

Because a natural flow regime is a critical need for the species and its habitats, perturbations that disrupt natural hydrologic patterns have a potential negative influence on Fat Threeridge viability. Basin stream flows vary according to the season (with higher flows in winter/spring and lower flows in summer/fall), and climate events such as droughts or floods. Altered flow regimes are attributable to human activities such as groundwater pumping, land use change, flow regulation via impoundments, and global climate change. Regulated streams exhibit a variable pattern, with daily variations due to hydroelectric power generation operations (most prominent below peaking projects), navigation releases, lower flood peaks, and higher sustained minimum flows through dry periods as the upstream reservoirs augment low flows. Natural (unregulated) rivers exhibit a more consistent pattern, responding to precipitation and drought periods as expected with short periods of high flows and prolonged periods of low flows, respectively. If critical time periods (e.g., for recruitment) were better understood, the flow regulation provided by dams might be attuned to better benefit mussel recruitment if conflicts with navigation and other uses could be overcome. These activities are discussed further in Chapter 5 (Factors Influencing Viability).

2.5.2 Stable Habitats

Because freshwater mussels are relatively long-lived and have limited mobility, habitat stability is a requirement shared by nearly all unionids (Haag 2012, p. 106). These substrates are dependent on channel stability and intact riparian areas (Allan et al. 1997, p. 149). Channel stability exhibits natural spatiotemporal variation, where some areas are more stable than others, and the location and proportion of habitat on the landscape shifts through time. Stable stream channels are formed and maintained by natural flow regimes, channel features (dimension, pattern, and profile), and natural sediment input to the system through periodic flooding, which maintains connectivity and interaction with the floodplain. Stable stream channels consistently transport their sediment load, such that the stream bed neither degrades nor aggrades (Rosgen 1996, pp. 1–3). Stable stream channels also have lower suspended sediment loads which mussels require for feeding, respiration, and reproduction. Channel instability is induced by changes in natural sediment or flow regimes, and by physical modifications to the stream channel or floodplain, which is discussed in Chapter 5 (Influences on Viability).

The Fat Threeridge, similar to other mussels, is dependent upon areas with low shear stress and where stream bottom sediments remain stable during high flow events (Hastie et al. 2001, pp. 111–114; Gangloff and Feminella 2007, p. 71; Strayer 2008, pp. 48-51). Recent habitat work incorporating side-scan sonar has determined that Fat Threeridge primarily occupy fine sediment mesohabitats, characterized by smooth or plane bedforms as opposed to ripple/dune bedforms (Smit and Kaeser 2016 n.p.; Kaeser et al. 2019, p. 653). Suitable mesohabitat for Fat Threeridge consists of hardbottom, smooth bank-attached, inner recirculation zone, outer recirculation zone, and pool/outer bend, with unsuitable mesohabitat including main channel, manmade structures, rip rap, and point-bar areas (Kaeser et al. 2019, p. 662). Point/outer bend (POB) mesohabitat occurs in deeper water that may be subject to high shear stress, but this disturbance and instability is thought to be mitigated by the presence of submerged wood; the presence of wood creates favorable fish habitat and substrate for dispersing juveniles as well as low flow refugia for adult mussels (Smit and Kaeser 2016, p. 12). Hardbottom (HB) mesohabitat also occurs in deeper waters, with Fat Threeridge occupying pockets of fine sediments or among loose rocks; these locations are attractive as cover for host fish and as low flow refugia for mussels in this otherwise high-velocity mesohabitat type (Kaesar et al. 2019, p. 667). Recirculation zones (IRZ and ORZ) and smooth bank attached (SBA) mesohabitats typically occur in shallow water and represent hydraulic refugia for mussels during flood disturbances. In addition, these habitats are used by a variety of fish species that may serve as hosts, potentially enhancing juvenile mussel deposition (Smit and Kaeser 2016, p. 11). Fat Threeridge are often associated with willow stands in the IRZ and ORZ mesohabitats (Kaeser 2020, pers. comm.)

Fat Threeridge appears to be particularly sensitive to the effects of sediment instability and completely reliant on stable fine sediment habitat patches. Where Fat Threeridge has been found in abundance, it is likely that stream stability (i.e., low rates of lateral migration, no or limited historic dredging) coupled with high woody debris loading contributed to the creation of high quality and quantity of stable, fine sediment habitat (Kaeser et al. 2019, p. 667 - 668). These areas support fish hosts, provide variation in substrate characteristics, and create hydraulic refugia for mussels during high and low flow events; both flow extremes are negatively correlated with mussel survival and recruitment (Peterson et al. 2011, p.120-121). Fat Threeridge may be particularly dependent on stable, fine sediments (i.e., fine sand/silt/mud) during one (or more) life history phases, and that the availability of this habitat may help explain its restricted distribution pertaining to the occupation of mainstem versus tributary environments (Kaeser et al. 2019, p. 653). Fat Threeridge has never been found in a tributary stream. This strongly indicates that this species is ecologically restricted/isolated to only large river systems in low gradient areas with stable, very fine sediment patches as part of its fundamental niche.

2.5.3 Adequate Water Quality

Freshwater mussels, as a group, are particularly sensitive to changes in water quality, including (but not limited to) low dissolved oxygen (DO) concentration, elevated temperature, and excessive total suspended solids. As relatively sedentary animals, mussels must be able to tolerate the range of physical and chemical conditions that occur naturally within their environment, but many species are considered sensitive to disturbance. DO and water temperature are important parameters for freshwater mussel early life stages which are more sensitive to deviations from normal ranges. Water temperature also plays an indirect role in the overall water quality because oxygen solubility and ammonia toxicity are temperature-dependent. Stream temperature is largely influenced by air temperature and flow. Oxygen is dissolved into the water in streams through diffusion, aeration, and as the waste product of plants that are photosynthesizing. The amount of DO found in water can vary due to several factors including water temperature, nutrient levels, and water velocity. Prolonged drought may expose mussels to low DO concentrations (e.g., in general <5.0 mg/L) and high water temperatures (in general > 35°C) for extended periods (Haag and Warren 2008, pp. 1174–1176; Johnson et al. 2001, p. 9). Mussels may suffer lethal and non-lethal effects to low dissolved oxygen levels and elevated stream temperatures (Fuller 1974, pp. 240–245; Dimock and Wright 1993, pp. 188-190; Gagnon et al. 2004, p. 675), and are particularly susceptible to these conditions during their early life stages (Sparks and Strayer 1998, pp. 132–133; Pandolfo et al. 2010, p. 965; Archambault et al. 2013, p. 247).

Specific water temperature and dissolved oxygen parameters for the Fat Threeridge are unknown. In a movement and mortality study conducted on the species in 2011, Kaeser and Herrington (p. 8) found substantial differences between water and air temperatures experienced by submerged or exposed mussels. Water temperatures in the area of study ranged from ~27 to 32 °C and fluctuated 2 -3 °C daily; the air temperature where many mussels were stranded and died fluctuated 15 -18 °C daily, reaching highs of ~38°C. Studies of other species show water temperatures of not more than 32°C (91°F) represent important thresholds for freshwater mussel early life stages (Sparks and Strayer 1998, pp. 132–133; Pandolfo et al. 2010, p. 965; Khan et al. 2019, p. 1207). A study of drought responses of mussels in lower Flint River basin streams found that DO concentrations below 5.0 mg/L correlated to significant increases in adult mussel mortality, especially for certain species considered sensitive to disturbance (Gagnon et al. 2004, p. 675). A laboratory study of biochemical marker indicators of thermal stress found two mussel species (*Elliptio crassidens* and *Villosa vibex*) collected from the lower Flint River basin began to show stress at water temperatures of 30°C and showed increased stress at 35°C (Fritts et al. 2015, p. 10). Fat Threeridge may tolerate elevated temperatures; *A. plicata,* was found to be "thermally tolerant" (i.e., highest rate of clearance, oxygen consumption, and still assimilating energy) at water temperatures of 35°C (Spooner and Vaughn 2008, p. 313). In some mussel-fish relationships, the associated host fish species is less thermally tolerant than the mussel (Pandolfo et al. 2012, p. 72). While some Fat Threeridge host fish are known to be thermally intolerant (e.g., striped bass; Kraus et al. 2015, entire), as a host generalist Fat Threeridge may not be limited by host fish temperature tolerance.

Appropriate substrates containing stable fine sediment are an important characteristic of Fat Threeridge habitat. Excessive amounts of sediment and particulate matter can interfere with key aspects of mussel biology. High levels of suspended inorganic and organic particles have been shown to reduce mussel fertilization success in females by disrupting sperm capture, and by affecting their ability to meet energetic demands (Gascho Landis et al. 2013, p. 76; Gascho Landis and Stoeckel 2015, pp. 232-235). High levels of suspended solids have also been shown to reduced mussel feeding and respiratory efficiency (Dennis 1984, p. 212; Aldridge et al. 1987, p. 26; Tuttle-Raycraft et al. 2017, p. 1164; Tuttle-Raycraft and Ackerman 2018, p. 1563; Tuttle-Raycraft and Ackerman pp. 2019 and 2530), and alter behavior (Ellis 1936, p. 30); however, these types of effects are less studied and may not be comparable to conditions within the range of Fat Threeridge. Still, the potential for physiological stress due to high particle levels exists for mussels of the region. For example, during a long-term study conducted in Bruce Creek (Choctawhatchee River Basin), mussel mantel cavities were observed to contain considerable amounts of sediment, detritus, and mucous when examined within days of a high flow event (S. Pursifull, pers. obsv.). A recent review of sediment impacts on unionid mussels identifies some important thresholds in relation to total suspended solids: declines in fertilization success and glochidial development were observed at 15 mg/L, and reproductive failure occurred at 20 mg/L. and relative shear stress (substrate stability in response to scour and entrainment) values > 1 resulted in significant declines in mussel biodiversity (Goldsmith et al. 2020, in prep.)

An environment free from toxic levels of pollutants is critical to unionid mussels. Freshwater mussel early life stages are more sensitive to pollution than many other organisms, and are among the first to respond to degradation (Haag 2012, p. 355). Mussel early life stages are uniformly sensitive to many chemical compounds including chlorine and ammonia, heavy metals, and certain commonly used pesticides and surfactants. These pollutants are discussed further in Chapter 5 (Factors Influencing Viability). There is no specific information on the sensitivity of the Fat Threeridge to known mussel toxicants, but information on *A. plicata* has been added when studies were available (e.g, Spooner and Vaughn 2008, Nobles and Zhang 2015). In general, the species requires water quality that meets or exceeds the current aquatic life criteria established under the Clean Water Act (CWA) (33 U.S.C §§ 1251 et seq.).

2.5.4 Summary

Table 2-2. Life history and resources needs of Fat Threeridge.

Life Stage	Resources Needs
All	• Flowing water • Moderate water temperature (in general ≤35°C) • Adequate dissolved oxygen (in general ≥5.0 mg/L) • Low concentrations of toxicants (chlorine, unionized ammonia, heavy metals, salts, pesticides)
Fertilized eggs (short-term brooder)	• Normal suspended solid levels • Appropriate spawning temperatures • Mature males upstream from mature females • Suitable flows for fertilization to occur
Glochidia Spring	• Presence of host fish • Suitable flows to permit host-glochidia interactions
Juveniles Excystment to 10 mm	• Adequate water quantity • Areas with low shear stress during high flows • Appropriate substrates (stable fine sediment) • Suitable interstitial water quality including moderate temperature and adequate DO, and absence of toxicants • Adequate food availability (bacteria, algae, diatoms, detritus) in sediment. • Suitable temperatures to maximize growth • Limited predators to juveniles (e.g., flatworms). Predation risk declines as size increases.
Sub-adults and Adults (> 11 mm)	• Adequate water quantity • Areas with low shear stress during high flows • Appropriate substrates (stable fine sediment) • Adequate food availability (bacteria, algae, diatoms, detritus) in water column.

CHAPTER 3 – HABITAT AND DISTRIBUTION

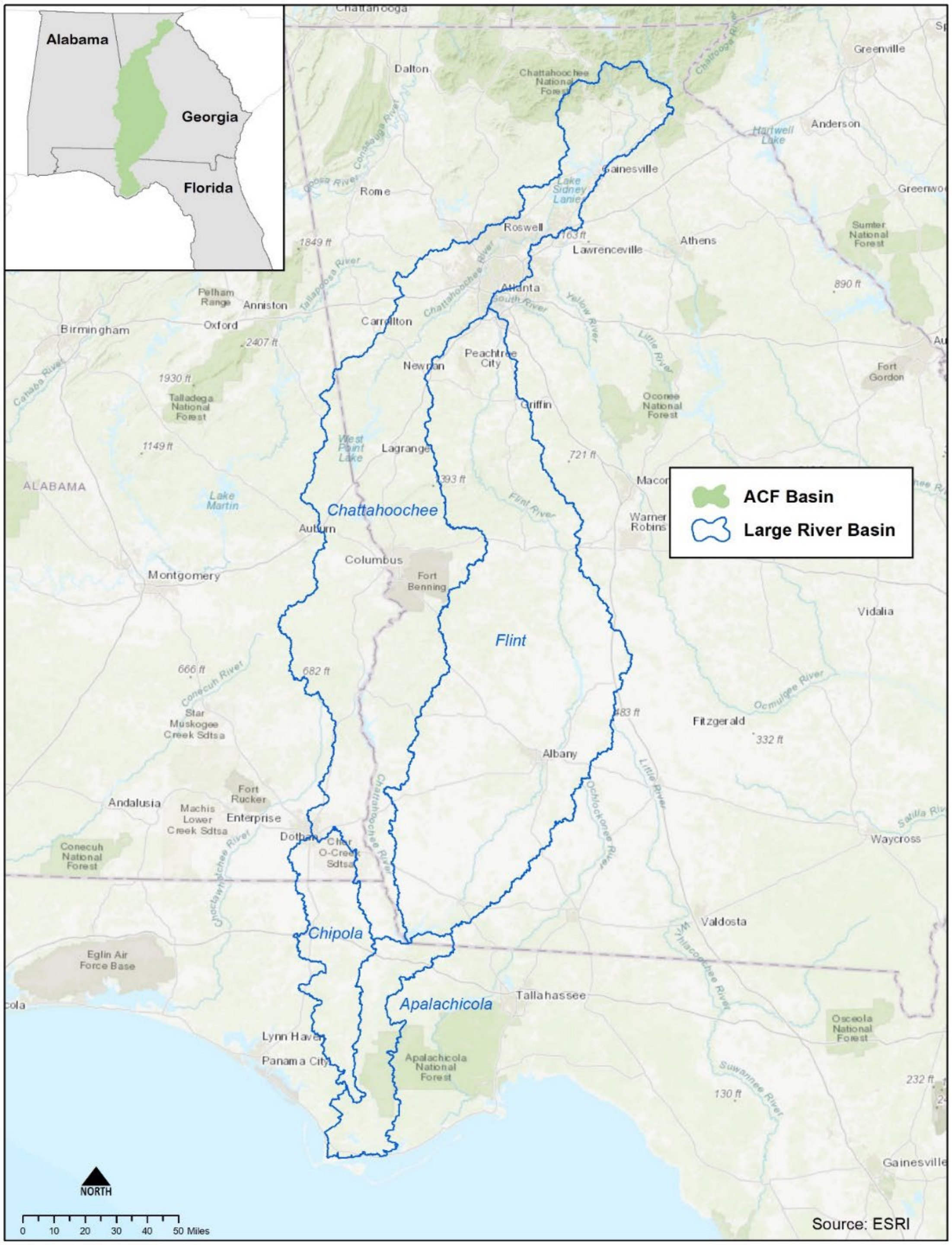
3.1 The Apalachicola-Chattahoochee-Flint River Basin

From headwaters in north Georgia, to the Apalachicola Bay and estuary, the Apalachicola-Chattahoochee-Flint (ACF) Basin is a focal geography in the Southeast with numerous federally listed and at-risk species.The high profile and importance of the ACF Basin has driven development of surface flows and groundwater flow models, as well as considerable water use and planning policy. Differences in river basin characteristics, water sources, land use, and water management are critical to interpreting the influences on viability and both the current and future condition of aquatic species such as the Fat Threeridge. Within its range in the ACF Basin, Fat Threeridge is found only in mainstem habitats in the Flint, Apalachicola, and Chipola rivers; there are no known collections from the Chattahoochee River (Figure 3-1).

3.1.1 River Basin Characteristics

Although generally referred to collectively as the ACF Basin, the river basin is correctly titled the Apalachicola Basin. We use the term Apalachicola Basin to refer directly to the basin surrounding the Apalachicola River, and use ACF for the basin encompassing the four large rivers. The ACF Basin extends approximately 620 km (385 mi) and includes four rivers: the Chattahoochee, the Flint, the Apalachicola, and the Chipola. The ACF Basin spans fifty counties in Georgia, eight in Florida, and ten in Alabama.

The Chattahoochee River is the largest tributary, originating in the Blue Ridge Mountains of north Georgia, and covers a distance of 434 mi from the Blue Ridge Mountains to Lake Seminole. While waters of the Chattahoochee River ultimately contribute to the flow of the Apalachicola River, it is not part of the range of Fat Threeridge and we will not discuss this basin in detail.



Source: ESRI

Figure 3-1. Large river basins within the Apalachicola Drainage of Alabama, Georgia, and Florida. The Apalachicola Basin is commonly referred to by the names of the three largest rivers, the Apalachicola, Chattahoochee, and Flint (ACF).

The Flint River originates just south of Atlanta and flows about 563 km (350 mi) in a southerly direction, curving to the west to join the Chattahoochee River at Lake Seminole in the southwest corner of Georgia. The Flint River is composed of three sub-basins: Upper, Middle, and Lower Flint. In addition, the Spring, Ichawaynochaway and Kinchafoonee-Muckalee sub-basins flow into the Flint River. The drainage area of the Flint River measures 21,900 km^2 (8,456 mi^2). There are only two limited-storage-capacity reservoirs on the Flint River (Lake Blackshear and Lake Worth) and they do not substantially modify the flow in the river. The Flint River is generally fed by surface waters upstream of the Dougherty Plain (described further in Ecoregion and Aquifer descriptions, Section 2.6.1). When the basin reaches this point groundwater from the Floridan aquifer is able to enter into the streams through numerous in-channel and off-channel springs so there is a substantial groundwater-to-surface water transfer in the lower portions of the Flint River, which helps to sustain higher winter flows in the river. The significant groundwater contribution to the Flint River complicates water management in this basin because of uncertainties in the surface-groundwater interactions in the mid to lower Flint basin as well as effects on groundwater and spring discharge from groundwater withdrawals (Jones and Torak 2006, entire; Rugel et al. 2011, p. 530-533). During low flow periods, the Flint basin is typically an important contributor to meeting the U.S. Army Corps of Engineers' (USACE) minimum flow requirements to the Apalachicola River, as combined flow from the regulated Chattahoochee River, and largely unregulated Flint River, contribute to water released from the USACE Jim Woodruff Lock and Dam into the Apalachicola.

The Flint and Chattahoochee Rivers converge at Lake Seminole, which is impounded by the Jim Woodruff Lock and Dam (JWLD), and then flow into the Apalachicola River. The Apalachicola River is composed of a single sub-basin. The Apalachicola River is entirely within the State of Florida and flows unimpeded for approximately 170 km (106 mi) from JWLD to the Gulf of Mexico at Apalachicola Bay. The slope of the Apalachicola River is fairly flat at 9.5 to 13.3 cm/km (0.5 to 0.7 ft/mi) over its entire length (USACE 2017, p. 2-3), and consequently the width of the river ranges from several hundred feet when confined to its banks, to nearly 7 km (4.5 mi) during flood flows.

The Chipola River is the only sizable tributary to the Apalachicola River besides the Flint and Chattahoochee Rivers. It is composed of a single sub-basin. The headwaters are in Alabama, and the Chipola River begins at the confluence of Marshall and Cowarts Creeks in Jackson County, FL. The Chipola River Basin encompasses approximately 1,277 mi^2 (3307.415 km^2), which accounts for about one-half of the Apalachicola River's drainage area in Florida. At RKM 67 (RMI 41.5) in the middle reach of the Apalachicola River, a naturally-formed, anabranch channel called the Chipola Cutoff intersects the mainstem Apalachicola River and captures approximately 25-30% of the river's discharge (USACE 2001 p. 209; Mossa et al. 2017 p. 4). Therefore, flows in the Apalachicola River directly affect flows in the Chipola River downstream of the Chipola Cutoff. Within 5 km (3.1 mi), the Chipola Cutoff joins the Chipola River, and downstream from this junction the channel is referred to as the Lower Chipola River. The irregular, wandering channel of the lower Chipola rejoins the Apalachicola River at RKM 45 (RMI 28), and this stretch of the Chipola River has been shown to support a high diversity and density of freshwater mussels (Kaeser et al. 2019, p. 664). North of the Chipola Cutoff, a geologic feature known as Dead Lakes occurs which extends from Wewahitchka in Gulf County northwards into Calhoun County. The Dead Lakes are thought to have formed when the Chipola River was naturally dammed by sandbars, and were formerly dammed at the outflow of the lakes near Wewahitchka.

3.1.2 Ecoregions and Aquifers

A north to south (longitudinal) gradient across the geography of the ACF Basin captures differences in geology, hydrology, and local weather that affect the water sources and channel characteristics of the streams and rivers of the ACF Basin, which are all important to aquatic organisms that require permanently flowing water, including unionid mussels. Within the ACF Basin, rainfall occurs throughout the year, but is less abundant in August through November. In all portions of the ACF Basin, runoff as a percentage of rainfall is lowest in July through September (USACE 2017, p. 2-24).

The ACF Basin spans four level III ecoregions. These ecoregions include (from north to south): the Blue Ridge, Piedmont, Southeastern Plains, and Southern Coastal Plain (USEPA 2013*b*) (Figure 3-2). The following descriptions are from Frick et al. 1996 (p. 3-6) and USACE 2016*b* (p. 36) unless otherwise noted. The northern-most portion of the upper Chattahoochee River Basin lies in the Blue Ridge ecoregion, constituting only about one percent of the ACF Basin. Mountain ridges ranging up to 1 km (3,500 ft) in elevation characterize this ecoregion. The balance of the upper Chattahoochee River Basin and the upper Flint River Basin are in the Piedmont ecoregion. Most streams in the Chattahoochee River have trellised and rectangular drainage patterns due to the Brevard fault.

The Flint River and streams in its basin have dendritic drainage patterns, resembling a branching tree. The streams in the Piedmont are fast flowing and are characterized by rapids and riffles. The Southeastern Plains begin at the “Fall Line”, which is the contact point between the crystalline bedrock of the Piedmont and unconsolidated sediments of the Plains (Figure 3-2). The Dougherty Plain district in the south is underlain by limestone, and its karst topography is very flat and has numerous sinkhole-created marshes and wetlands. North of the Fall Line, the Flint River receives groundwater by diffuse leakage into the river bottom; south of the Fall Line, groundwater flow from springs becomes more prevalent. Streams in the Southeastern Plains are relatively low-gradient and sandy bottomed, and rivers are wide and sinuous with large floodplains. During times of heavy rainfall events, the wide floodplains are able to store large quantities of water. The Southern Coastal Plain is a flat, lowland area that contains barrier islands, coastal lagoons, marshes, and swampy lowlands. Soils in the area are generally hydric and have a high capacity to hold and store water. The Southern Coastal Plain is dominated by large alluvial rivers, such as the Apalachicola River. Sediment conditions most suitable to Fat Threeridge occur primarily within the Southern Coastal Plain.

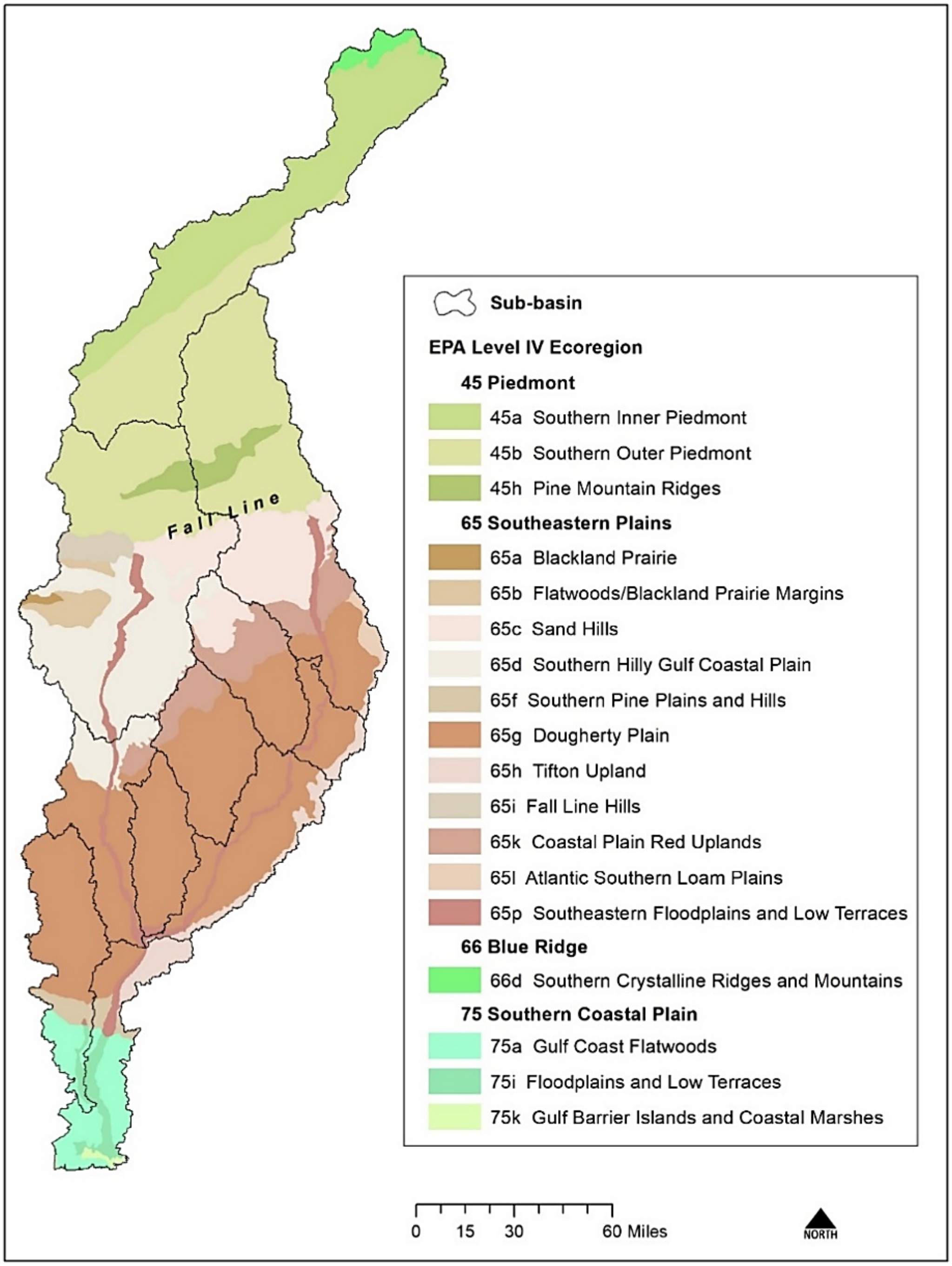


Figure 3-2. Ecoregions show a longitudinal gradient across the ACF basin. Geology, soils and vegetation affect surface flows and river channel characteristics that influence hydrology.

Streams in the ACF Basin can be deeply entrenched into aquifers, and many receive significant contributions from groundwater from one of five major aquifers including the surficial aquifer system, the Upper Floridan aquifer system, the Southeastern Coastal Plain aquifer (specifically the Claiborne aquifer, Clayton aquifer, Providence aquifer), and the Piedmont and Blue Ridge Crystalline-rock aquifer (Frick et al 1996, p. 6 - 7; Figure 3-3). The Upper Floridan aquifer is hydraulically connected to the Flint River and, consequently, groundwater discharge contributes more significantly to baseflow in the lower Flint River than in the upper portion of the Flint Basin or the Chattahoochee River. Groundwater discharge to the Chattahoochee River is roughly 20 percent of the amount discharged to the Flint River (Couch et al. 1996, p. 23). The Chipola and Apalachicola Rivers are typical of Southern Coastal Plain rivers and are both more influenced by groundwater than surface water. The Chipola River originates in southeastern Alabama, and it is characterized by several large spring inputs throughout its upper reaches. The Chipola River is hydrologically connected to the Apalachicola River in its lower reaches.

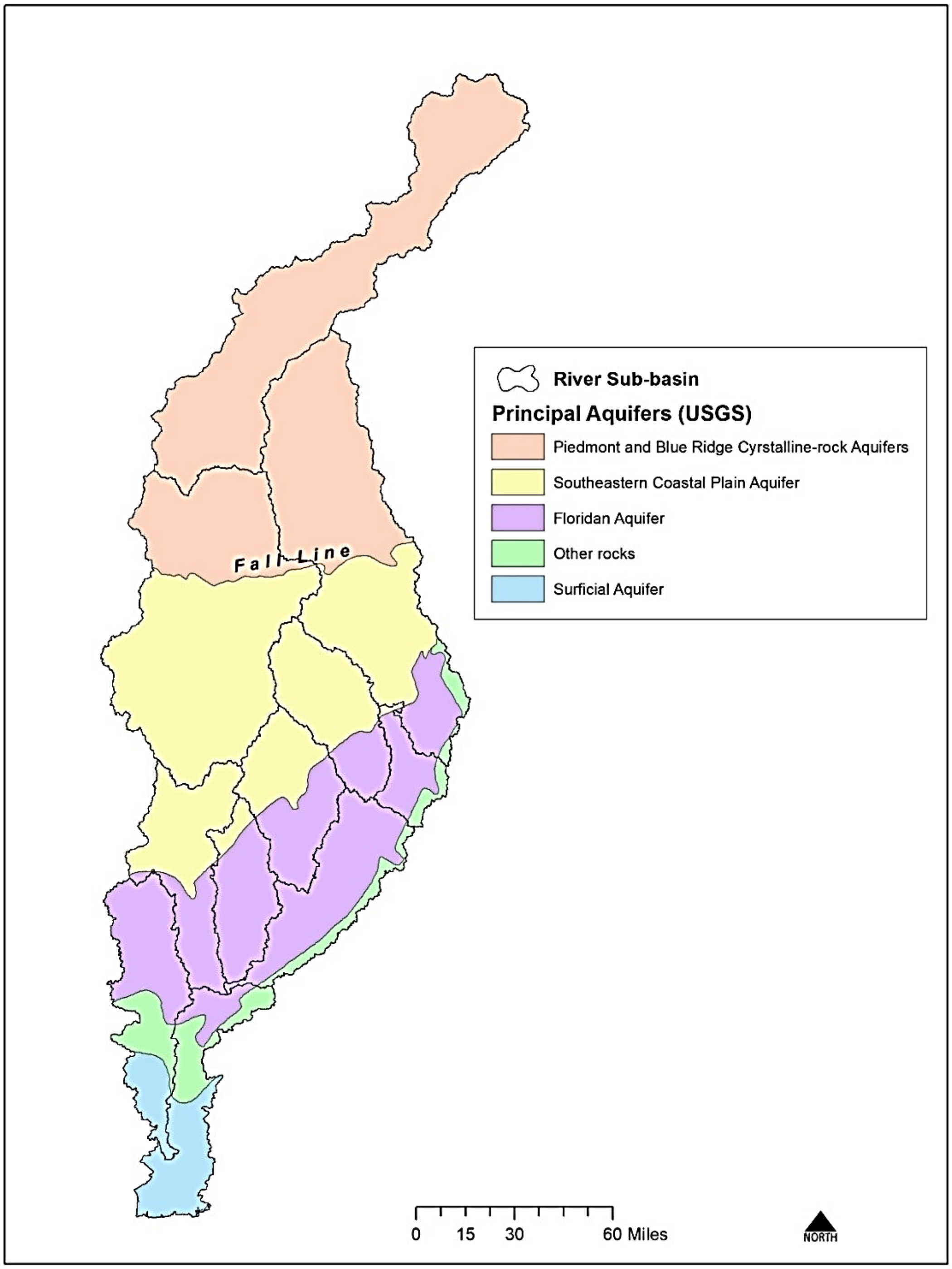


Figure 3-3. Aquifers are the source for groundwater and show variation along a longitudinal gradient in the ACF. Aquifers closer to the surface, such as the Floridan Aquifer, provide more flow directly into streams and rivers, and may be more likely to be used for agricultural irrigation.

3.1.3 Land Use

Forested areas are prominent in the uppermost areas of the Flint and the Apalachicola Basin (Figure 3-4). Approximately 20 percent of the ACF Basin is in cropland based on the USGS National Land Cover Database (NLCD) 2016. Agricultural influences on the landscape are most apparent in the lower areas of the Chattahoochee (Alabama and Georgia) and Flint (Georgia) Basins, the Chipola Basin (Alabama and Florida), and the northern areas of the Apalachicola Basin in Florida (Figure 3-4). The seventh largest metropolitan area in Georgia (Albany) is located in the Flint River basin (2019 population estimates 0.15 million, US Census Bureau 2020, n.p.). The Apalachicola and Chipola River watersheds are rural with a combined total population of 88,413 in 2010 (NFWMD 2017, pp. 12-13). We discuss urbanization in more detail in Section 5.1.3.

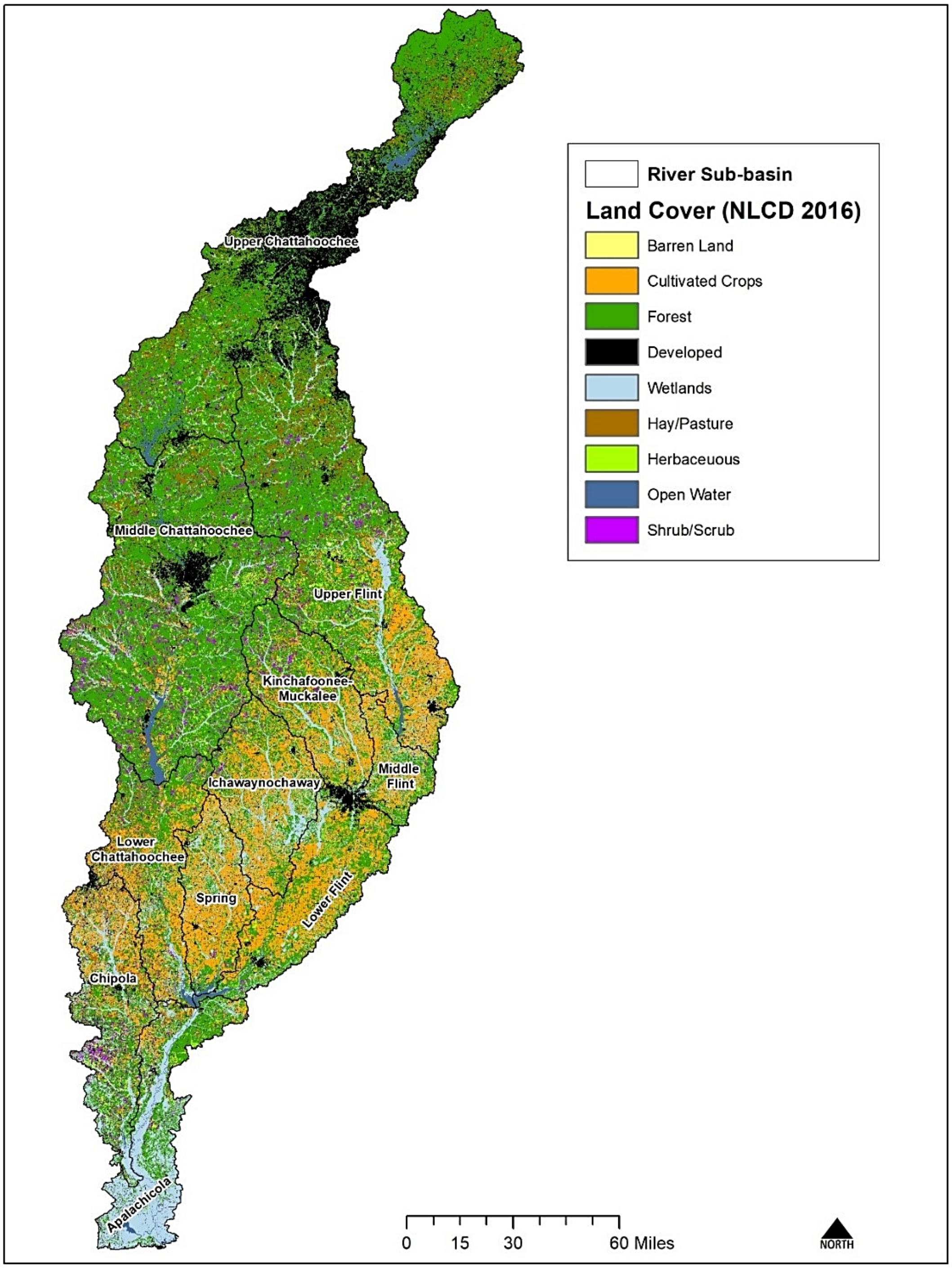


Figure 3-4. Land use in the ACF Basin from NLCD 2016. Within sub-basins, urban development is most apparent in the Lower Flint portion of the Fat Threeridge range, near Albany, GA. Land cover trends show a transition from urbanized/developed and heavy agricultural use in the northern portion of the Fat Threeridge range, to forested areas in the southern portion of the range.

3.1.4 Water Management

Water management and effects of dams and reservoirs will be discussed in more detail in Chapter 5, but the topic is presented briefly here to orient readers to the important dams and water management features of the ACF that have in the past, and continue now, to influence freshwater mussel ecology and distribution. Rivers in the ACF Basin include both natural (unregulated) rivers and regulated rivers. Two major reservoirs are located on the Southeastern Plains of the Flint River (Figure 3-5). Warwick Dam impounds the Flint River and is operated by Crisp County Power, and Lake Chehaw is formed by a dam in Albany, Georgia, and impounds the Flint River and the lower portions of the Kinchafoonee-Muckalee (Muckafoonee) sub-basin. Lake Chehaw is a hydroelectric generation lake operated by Georgia Power Company. In addition, the Flint River Basin contains numerous private ponds used for surface water withdrawal irrigation.

The USACE ACF Project includes five federal dams and associated impoundments (Figure 3-5): Buford Dam and Lake Lanier; West Point Dam and Lake; Walter F. George Lock, Dam, and Lake; George W. Andrews Lock, Dam, and Lake; and Jim Woodruff Lock and Dam (JWLD) and Lake Seminole. The Master Water Control Manual (WCM, USACE 2017, entire) governs decisions on system-wide water storage and release. As part of Section 7 of the Act, which requires federal agencies to coordinate to ensure their actions do not jeopardize listed species or adversely affect critical habitat. Outflows from JWLD are regulated to maintain a minimum flow of 141.5 m3/s (5,000 ft3/s, cfs) at the USGS gage in Chattahoochee, Florida during seasonally dry periods of the year (USACE 2017, p.7-11, 7-22), although under extreme drought operations this flow may drop to 4,500 cfs. This regulation affects all waters of the Apalachicola River, the Chipola Cutoff, and the Lower Chipola River.

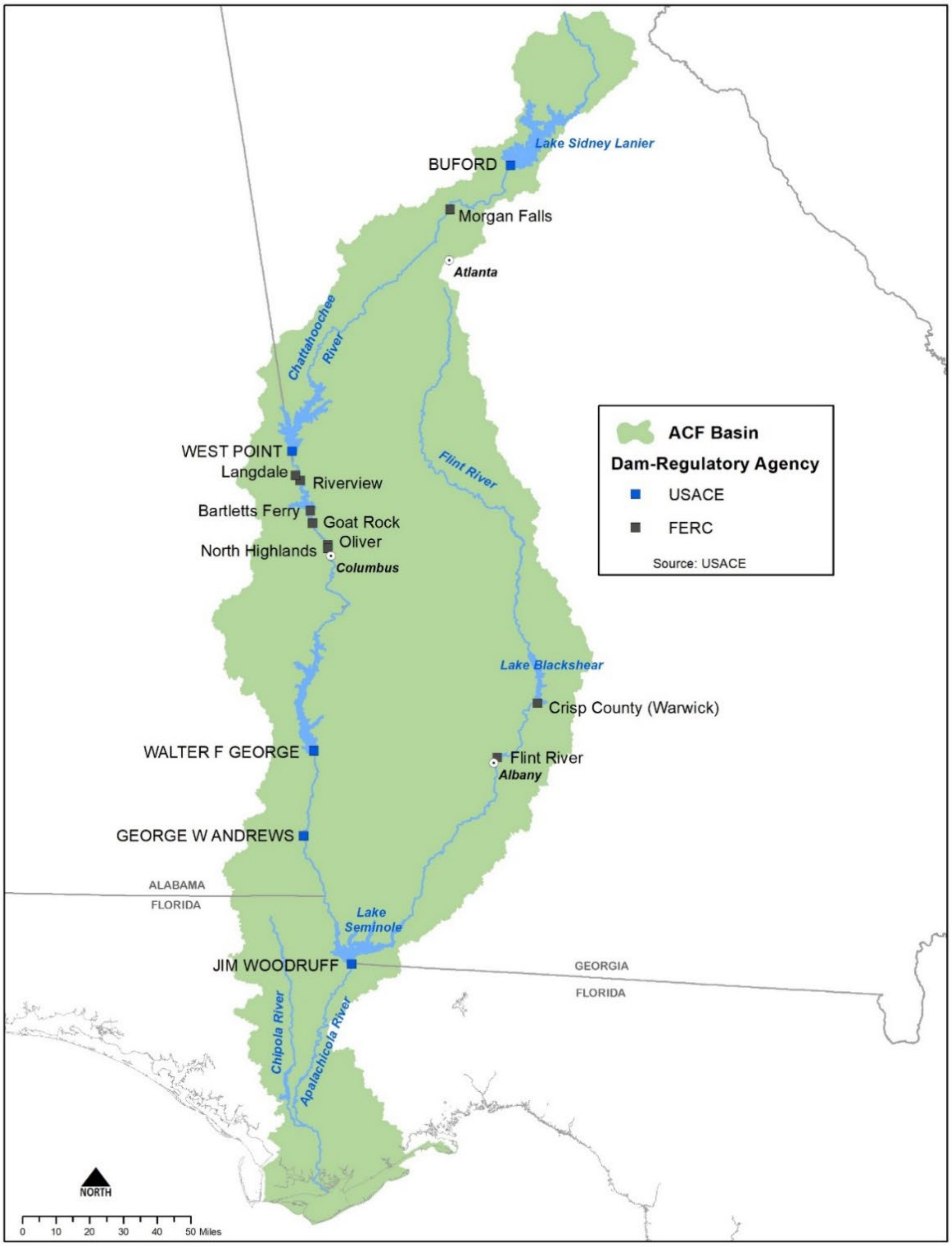


Figure 3-5. Locations and names of both federal and non-federal dams in the ACF Basin. The USACE dams (blue squares) are all part of the ACF Project on the Chattahoochee River, with the southernmost dam in the system located at the Georgia-Florida border. Locations and names of both federal and non-federal dams in the ACF Basin. Non-federal dams are located on the mainstem Chattahoochee and Flint Rivers as well. The Apalachicola and Chipola Rivers have no mainstem dams.

3.2 Distribution and Abundance

Seminal works for understanding freshwater mussel diversity and distribution in the ACF Basin are Clench and Turner (1956, entire) and Brim Box and Williams (2000, entire). The latter source compiled all historical records as well as sampling by the authors and colleagues during the 1990s, which expanded what was known about distribution and status of mussel species in the ACF Basin and informed the listing decision for the other ACF mussels in 1998. The collection records for Fat Threeridge used in this SSA were compiled from various sources including museums, scientific publications, Georgia Department of Natural Resources (GADNR), Florida Fish and Wildlife Conservation Commission (FWC), the Service, unpublished survey reports, and personal communications (Figure 3-6).

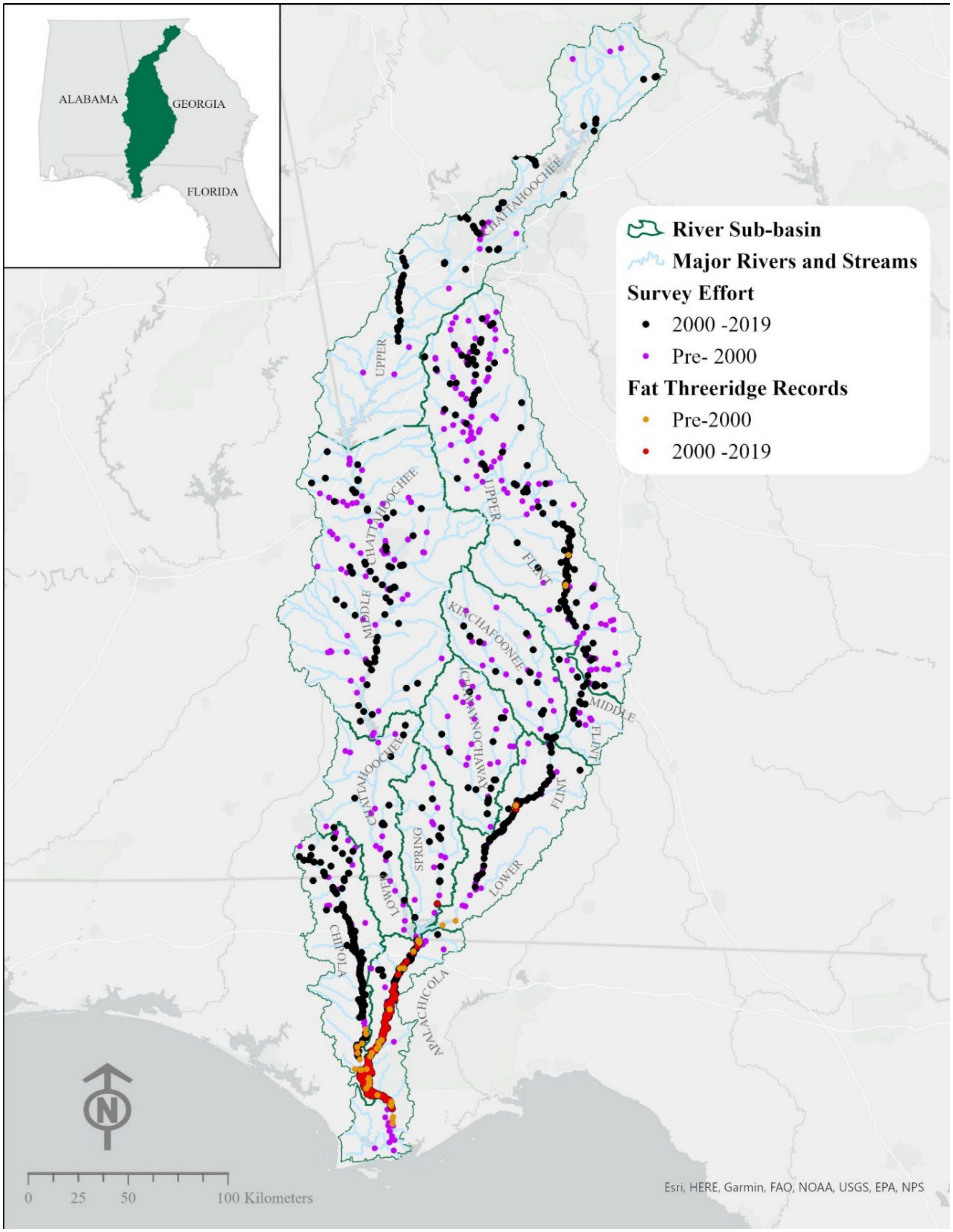
Interpretations of the historical records benefited from summaries in Brim Box and Williams (2000, p. 29 -31, 89). Sampling increased in the ACF Basin in recent years (generally since 2010) as efforts by state agencies and the Service were targeted to better understand status of freshwater mussels in the ACF Basin after drought conditions in 2006-2008 and 2011-2012 prompted new concerns about the status of the listed ACF mussels. These more recent mussel sampling effort and methodologies in the ACF Basin are well documented in Wisniewski et al. (2013*a*, 2014, 2015, entire), and Kaeser et al. (2019, entire). Expansion of the sampling frame for this species to deeper waters and different habitat types than previously considered suitable for the species has updated our knowledge of distribution and habitat use (Kaeser et al. 2019, entire).

In all figures in this SSA report, and for characterizing current condition, we consider collection records prior to 2000 as the historical time period, and those 2000-2019 as the current time period for our analyses in Chapter 4, so we present distribution within each river basin with the same time distinctions. Although our defined current time span does not exceed the possible maximum lifespan of Fat Threeridge (30 years, see Section 2.6), freshwater mussel experts at our initial SSA workshop in August 2018 agreed that the time period since 2000 was the best representation of current time period for the analyses of species' condition.

Surveys conducted in Florida waters of the ACF since 2010 now include density estimation (Kaeser et al. 2019, entire) and increased collaboration and standardization of methods among Florida agencies in recent years has improved data transferability and comparisons. Allocation of sampling effort to additional habitat types and depths than previous targeted studies at the river margins, and identified mesohabitat types associated with high Fat Threeridge density (Kaeser et al. 2019, entire). A series of research and monitoring efforts in Georgia waters expanded the understanding of unionid populations and habitat association by using occupancy estimation and accounting for incomplete detection (Shea 2011, entire; Shea et al. 2013, entire; Wisniewski et al. 2013*a*, 2014, 2015, entire), as well as capture-mark-recapture designs to estimate population size and demographics of various species (Peterson et al. 2011, entire; Shea

2011, entire; Wisniewski et al. 2013, entire; Wisniewski et al. 2015, entire; GADNR unpublished data). Freshwater mussel detection during sampling is influenced by numerous factors, and detection probability is an important parameter to include in estimates of abundance or density (Wisniewski et al. 2013*a*, p. 1133). The detection probability estimated for the species during surveys in the Flint River was found to be relatively high (0.4; Wisniewski et. al 2013*a*, p. 1126), but failure to detect any individuals during sampling, or possibly lack of sampling in some areas, does not conclusively indicate the species is absent or extirpated. For example, sections of the ACF without historical records (e.g., Chattahoochee River) may have contained some historical habitat, but no occurrences were recorded (Figure 3-6). In addition, recent sampling USFWS has employed the use of fixed areal plots; detection probability for this method has not been estimated but it is likely greater than 0.4. These surveys conducted over the past decade provide greater certainty regarding the current distribution and abundance of the Fat Threeridge than surveys completed prior to 2010, and provide a more statistically sound baseline for future monitoring of Fat Threeridge and other unionid species in the ACF Basin. In addition, these recent efforts also began more consistently recording lengths of freshwater mussels, data that are necessary to gain additional inference about size/age structure of a population, and determine if reproduction and/or recruitment are occurring.

Finally, misidentification of unionid mussels can bias population and presence records, but Fat Threeridge are reliably identified. Fat Threeridge have distinctive shell ridges and this species was the only one not falsely identified in a study on identification error (n = 48 were correctly identified); however, 5 individuals were misidentified as other species, leading to a 9 percent false negative identification rate (Shea et al. 2011, p. 448). Concerted effort was made by experts to confirm and correct major eastern US museum collections containing mussels from Florida in 2012, 2015 (Rowe, 2015, p. 2) and 2020.



Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

Figure 3-6. Survey effort within the ACF Basin through 2019. Comprehensive sampling of the basin increased and covered more mainstem habitats post-2000.

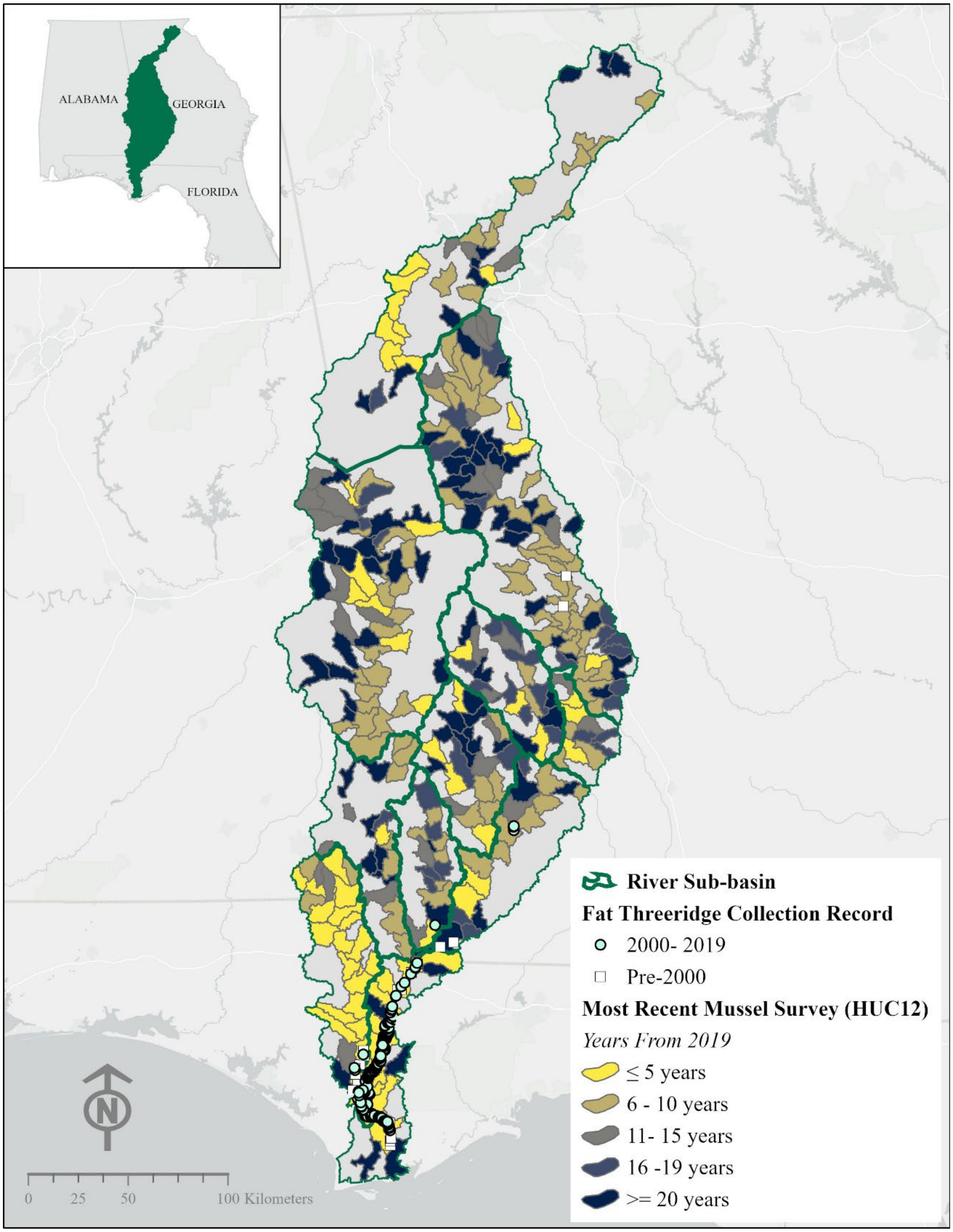


Figure 3-7. Time since last known sampling for Unionid mussels occurred, plotted by sub-watersheds. Fat Threeridge records are summarized as collection records (samples within 100-m of each other were grouped together. Some areas where Fat Threeridge are known to occur, such as the Flint River, have relatively more area that has not been sampled in the last 5 years.

3.2.2 Distribution in the ACF Basin

Review of the collection records before and after 2000 indicates that Fat Threeridge persists in most watersheds where it was found historically. There are currently no records from the Upper Flint River sub-basin. However, the known range of Fat Threeridge appears to have expanded in the Chipola and Apalachicola Rivers in Florida at least partially due to increased sampling efforts and an improved understanding of the species mesohabitat associations. The distribution of Fat Threeridge is discussed in more detail in the following sections.

3.2.2.1 The Flint River

<u>The Upper Flint River</u>

Fat Threeridge is only known from historical records in the Upper Flint River. The type specimen of Fat Threeridge was described from the Flint River from Lanier, about 10 miles (16.1 km) north of Oglethorpe, in Macon County, Georgia (Lea, 1858, discussed in Clench and Turner 1956, p. 160). Nearly a century later, Clench and Turner (1956, p. 160) reported that no collections of the species had occurred in the Flint River since the late 1800s, thus the six Flint River sites reported by Brim-Box and Williams (2000, p. 30) likely date back to the 19th century. A survey of sixty sites along the Flint River mainstem in the early 1990s yielded no live specimens (Brim-Box and Williams 2000, p. 30). At the time of listing (63 FR 12664; USFWS 1998, p. 12666) Fat Threeridge is presumed extirpated from the Upper Flint River, with the last observation of a live individual in the Upper Flint River in 1981 (Figure 3-8). Fat Threeridge was not detected during 2013-2014 tactile and snorkel surveys despite the presence of suitable habitat. Habitat upstream of Lake Blackshear, between Lake Blackshear and State Road 96 near Fort Valley was noted to be more suitable for Fat Threeridge (e.g., more characteristic of a large Coastal Plain river like the Apalachicola River) than elsewhere within the Upper Flint River (Wisniewski 2015, p. 17).

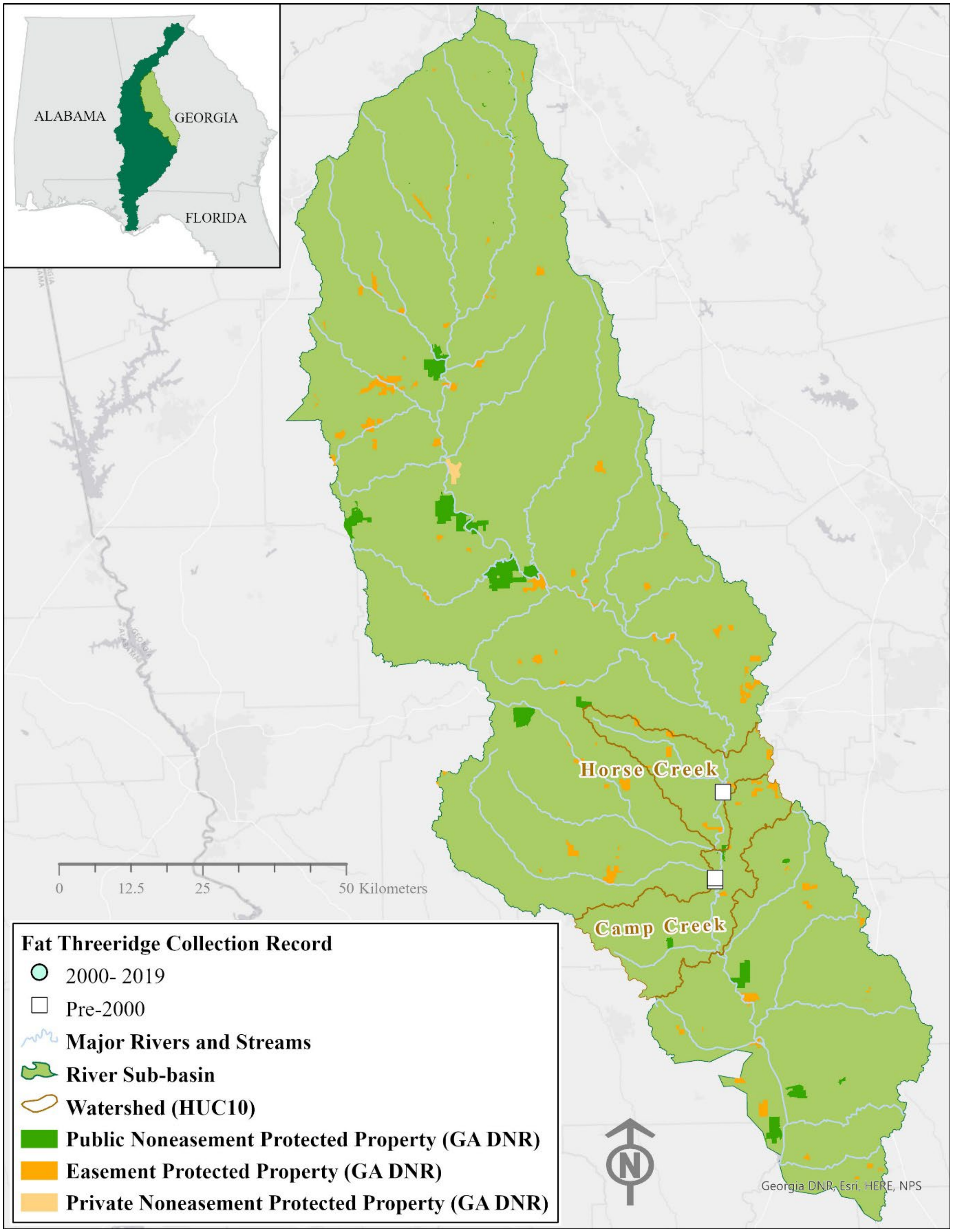


Figure 3-8. Fat Threeridge collections in the Upper Flint River are historical, with collection records located in two watersheds within close proximity in the mainstem of the river. Conservation lands are included as important landscape features.

Lower Flint River and Spring Creek

In the Lower Flint River, the Fat Threeridge was known historically from one live individual collected from Baker County, Georgia, near the city of Newton, in 1988, and relict shells from Lake Seminole area collected in 1991 during the Brim-Box and Williams (2000, p. 30) surveys. The consistent rarity of Fat Threeridge within the Flint River was speculated to be the result of insufficient suitable habitat in the river (Wisniewski et al. 2014, p. 37). With no live individuals collected since 1988, it was unclear if Fat Threeridge still persisted in the Flint River Basin. While relict shells were found in Lake Seminole in 1991, the habitat there has been inundated and the remainder of the Lower Flint south of Newton is dominated by rocky shoals with small areas of deposition unlikely to offer suitable habitat for Fat Threeridge. The Albany dam north of Newton has likely also scoured some of the sediment out of the Flint upstream of Newton, restricting suitable habitat in the Lower Flint to the vicinity of Newton (J. Wisniewski 2020*b,* pers. comm.). However, ten living Fat Threeridge were rediscovered in the Flint River near Newton in 2006-2007 (USFWS 2007*b*, p.7).

Since this "rediscovery" of Fat Threeridge in the Flint River, a small population has persisted in a reach approximately 2-3 RKM (1.2-1.9 mi) in length near Newton, Georgia (Figure 3-9). Abundance of the population at this location is likely low, but has not been quantified. Ten individuals in this area were tagged and their sizes recorded in 2008; their lengths ranged from 47 to 69 mm (S. Abbott, USFWS, 2008). A quantitative survey of 39 sites distributed throughout 119 RKM (74 mi) of the lower Flint River mainstem from Albany Dam to Lake Seminole detected the species only at the Newton location; these 5 individuals ranged from 41-70 mm (Wisniewski et al. 2014, p. 36). Estimated occupancy rate throughout the entire lower Flint River was low (Wisniewski et al. 2013*a*, p. 1126). An annual mussel identification training workshop often samples at this location and has yielded additional opportunistic sampling in some years when flow is low enough to cross the river. At least one individual was encountered near Newton during these opportunistic surveys in 2019 (Matt Rowe [GA DNR], pers. comm. 2020).

Fat Threeridge shell records have been noted in the Spring Creek, which drains directly into Lake Seminole. No live individuals have been found in this sub-basin and mussel habitat is limited and largely ephemeral; drought has caused portions of Spring Creek to run dry, such as in 2000-2001 and in 2006-2007 (USFWS 2007, p.18). In 2004, a private landowner on Spring Creek showed a Fat Threeridge shell to experts reportedly from Seminole County within Dry Creek, a tributary of Spring Creek (S. Abbott and J. Wisniewski pers. comm. 2020). A weathered shell was found in the Spring Creek-Lake Seminole subwatershed in 2015, during SCUBA surveys related to a bridge replacement at Spring Creek at State Road 253 (Crow 2015, p. 7). Within the survey area, suitable mussel habitat seemed to be restricted to a small area upstream of the bridge where current maintained substrate free of silt, and a mixture of stable sand, gravel, cobble, and boulder was present (Crow 2015, p. 9). There are no historical Fat Threeridge records in the Spring sub-basin (Figure 3-9).

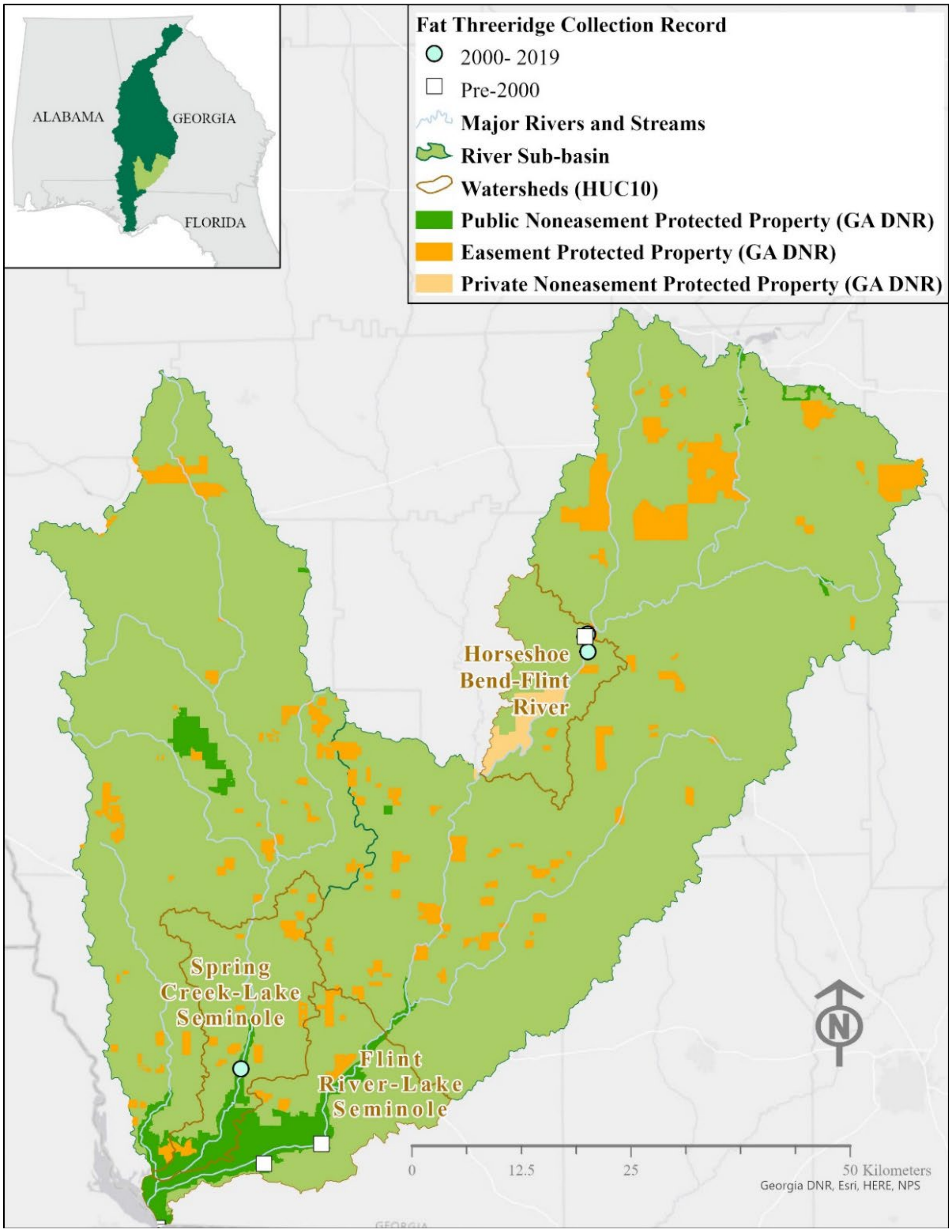


Figure 3-9. Collection records (shell only) from the Spring Creek- Lake Seminole (west sub-basin) were obtained during the current time period (since 2000). The two collection records in Lower Flint River (east sub-basin) are historical, while Horseshoe Bend- Flint River contains current and historical records. Conservation lands are included as important landscape features.

3.2.2.2 The Apalachicola River

Changes in channel geomorphology along the Apalachicola River supports the classification of three distinct regions: the upper, middle, and lower non-tidal reaches. Light et al. (2006, p. viii) and Kaeser et al. (2019, p. 656) describe three distinct reaches within the Apalachicola River, as follows. The upper reach (Upper Apalachicola, river kilometer (RKM) 171-104; river mile (RMI) 106-77.5) exhibits a relatively straight, low sinuosity channel that cuts through geologic formations associated with the Apalachicola Bluffs and Ravines Province. The middle reach (Middle Apalachicola, RKM 104 to RKM 56 (RMI 77.5 to RMI 41.8) exhibits a regular and repeating meandering pattern typical of alluvial, Coastal Plain rivers, and is characterized by medium and fine sand bed substrates, patches of silt and mud deposition, and clay outcrops along some of the river margins. The non-tidal lower reach (Lower Apalachicola, RKM 56 to RKM 33 (RMI 41.8 to RMI 20.6) displays an irregular and wandering channel. Relevant abundance, density, size, and occupancy data is summarized according to these reaches when possible to provide better insight into potential variation in viability within the core of the species range, and key components of these data are presented in the analysis of current condition (Chapter 4).

Clench and Turner (1956, p. 160) indicated that Fat Threeridge was rare, but locally abundant. For the status survey (1991-1992), 86 sites were sampled using a combination of handpicking and snorkel/SCUBA equipment within the historical range of the Fat Threeridge, including eight of the 12 (67 percent) known historical sites; Fat Threeridge were detected at only one of the eight (13 %; USFWS 1998, pp. 12665 - 12666). Live Fat Threeridge were found at six of the 86 (7 %) sampled sites within the species known range, three each on the Apalachicola River (except the Middle Apalachicola). Field notes from this survey suggest the Middle Apalachicola may have been under sampled, with seven sites surveyed. In total, 32 live individuals were encountered during the status survey, with these restricted to the Chipola and Apalachicola rivers (Brim Box and Williams 200, p. 30). Richardson and Troy (1996, entire) conducted substratum removal and sieving using six quadrats at three sites previously surveyed in 1991/92. Surveys did not occur within the Middle Apalachicola; however, two sites from the Upper Apalachicola did not contain Fat Threeridge while the Lower Apalachicola site contained one fresh dead juvenile (24 mm), and individuals (n = 4) of a variety of sizes (34 to 64 mm, 3 individuals ≤50 mm; Richardson and Troy 1996, p. 137).

Between 1996 and 1999, more evidence of Fat Threeridge abundance and recruitment was found than was documented during the listing. The Middle Appalachicola appeared not to contain live mussels during the status survey, but individuals were found in this reach at two locations in 1996 surveyed by USGS and partners (Brim Box and Williams 2000, p. 30; USFWS 2020). USACE funded mussel surveys from 1996 to 1998 at potential or existing dredge material disposal areas on the Apalachicola River; 79 live Fat Threeridge were found across nine (20 percent) of 45 sites surveyed using a combination of diving and wading (Miller 1998, p. 54). A continuation of this effort in 1999 again found Fat Threeridge present at nine sites; 50 Fat

Threeridge were detected in the Upper Apalachicola, while 272 individuals were encountered in the Middle Apalachicola, and 16 in the Lower Apalachicola (USFWS 2020, n.p.).
Fat Threeridge was frequently encountered during the current time period (> 2000). USACE continued funding work from the late 90s into the early 2000s, ultimately surveying 100 sites and processing more than 600 live Fat Threeridge within the Apalachicola River ranging from 30 to 90 mm in length (Miller and Payne 2006, pp. 29, 31). Abundance was summarized as Catch Per Unit Effort (CPUE; mussels collected per person hour). Fat Threeridge averaged a CPUE of 2.2 (range 0.5 to 20.2) across all sites, with a CPUE of 13.6 in moderately depositional sites where they comprised 61 percent of the fauna (Miller and Payne 2005, p.7; Miller and Payne 2006, pp. 31). Fat Threeridge was the fourth most common species detected (average CPUE of 6.5 from 125 sites) during transect sampling (n=14) of the Apalachicola River commissioned by Florida Department of Environmental Protection in 2005; the species was found along river margins at depths <5ft as well as within Swift Slough, and also unexpectedly burrowed into the river bank within the top 3 ft of sheer clay banks adjacent to deep (~20ft) water and high flows (EnviroScience 2006a, pp. 29, 31). Live Fat Threeridge were not encountered in the Upper Apalachicola, but individuals within excavated plots ranged from 47 mm to 75 mm within the Middle Apalachicola (n= 270, CPUE 9.0) and 50 mm to 79 mm in the Lower Apalachicola (n =43, CPUE 28.8) suggesting a range of sizes and abundance was present in the majority of the Apalachicola River; only 12 Fat Threeridge were found in the same areas using more qualitative methods designed to detect presence or absence of mussels (EnviroScience 2006a, pp. 18-19, 2170, 2184 - 2187). Miller and Payne 2007 (entire) made a preliminary population estimate for Fat Threeridge within the Middle Apalachicola, based on abundances from samples obtained by wading at 25 sites; CPUE varied widely (0 to 1080), with density ranging from 0.2 to 12.7/ m^2 and lengths from 11.7 to 76.4 mm (Miller and Payne 2007, p. 1). However, under the assumption Fat Threeridge occupied a narrow 1-m band along the shore, the population size was estimated to be 19,000 individuals at the 25 locations considered in the study (Miller and Payne 2007, p. 11).

Abundance estimates continued to be refined, ultimately resulting in a broadly-based and largely range-wide estimate of the population size for Fat Threeridge. Targeted sampling efforts between 2008 and 2010 informed nearshore density in response to concerns about mortality during USACE drawdowns and indicated higher density/abundance in the Apalachicola than previously known (Gangloff 2011 pp. 23-24, 30-31; Gangloff 2012 p. 24; USFWS 2016*b*, p. 187 -188). This preliminary population estimate was restricted to an estimate of the channel bank habitat; it was derived from 26 sites sampled by substratum removal within quadrats (n = 546) utilizing a hydraulic gold dredge along a series of transects, to determine the abundance and size of individuals in habitats existing within 1 to 2-m depth of the low water river margin (Gangloff 2012, p. 12). The Fat Threeridge population estimate was scaled from the area of sampled habitat to the river-reach according to the total proportion of suitable bank habitat in each river reach sampled during the study. The resultant Fat Threeridge population estimates (with densities and shell lengths) from this work were: Upper Apalachicola 24,261 (0.53/m^2, 10 - 90 mm), Middle Apalachicola 118,863 (3.9/m^2, 5 to 90 mm), Lower Apalachicola 70,117 (1.4/m^2, 10 to 85 mm) (Gangloff 2012, pp. 14-15, 30).

Sampling efforts from 2012 to 2017 provided a broader understanding of the distribution, habitat use, and population size of Fat Threeridge within the Apalachicola River. Sonar mapping combined with mussel sampling better depicted the species distribution throughout the Apalachicola River (Smit and Kaeser 2016, entire; Kaeser et al. 2019, entire). Mussel sampling (using large 5 or 10-m^2 radial plot) occurred in 2012 (Middle Apalachicola, n = 164), 2015 (Lower Apalachicola, n = 67) and 2017 (Upper Apalachicola, n = 231), with the objective to obtain a balanced spatial distribution and proportional sampling effort between mesohabitats (Kaeser et al. 2019, pp. 657-659). These samples represent the majority of the collection records within the current period (2000 - 2019) included in Figure 3-10. The resultant Fat Threeridge mean population estimates (with densities and percent occupied habitat) from this work were: Upper Apalachicola 350,170 (0.97/m^2, 19.3%), Middle Apalachicola 4,752,000 (3.96/m^2, 80.9%), Lower Apalachicola 230,100 (0.65/m^2, 52.1%) (Kaeser et al. 2019, pp. 665, 667; USFWS 2020). Above 150 RKM in the Apalachicola River, Fat Threeridge was very rare, as suggested by the low occupancy in suitable habitats (Kaeser et al. 2019, p. 669). In general, Fat Threeridge is more abundant and widely distributed among mesohabitats than previously thought (USFWS 2012, p. 29), including within deep habitats (EnviroScience 2006a, p. 29; Smit and Kaeser 2016, p. 12). Small individuals (between 15 mm and 40 mm) were observed within most sites surveyed (Kaeser et al. 2019; USFWS 2020), corroborating earlier demographic work (Gangloff 2012, p. 30). USACE continues monitoring Fat Threeridge at three locations in the Middle Apalachicola using 15 radial plots; the average Fat Threeridge density in 2019 was 6.48/m^2 (range: 0.2 – 66.80/m^2; USACE 2020).

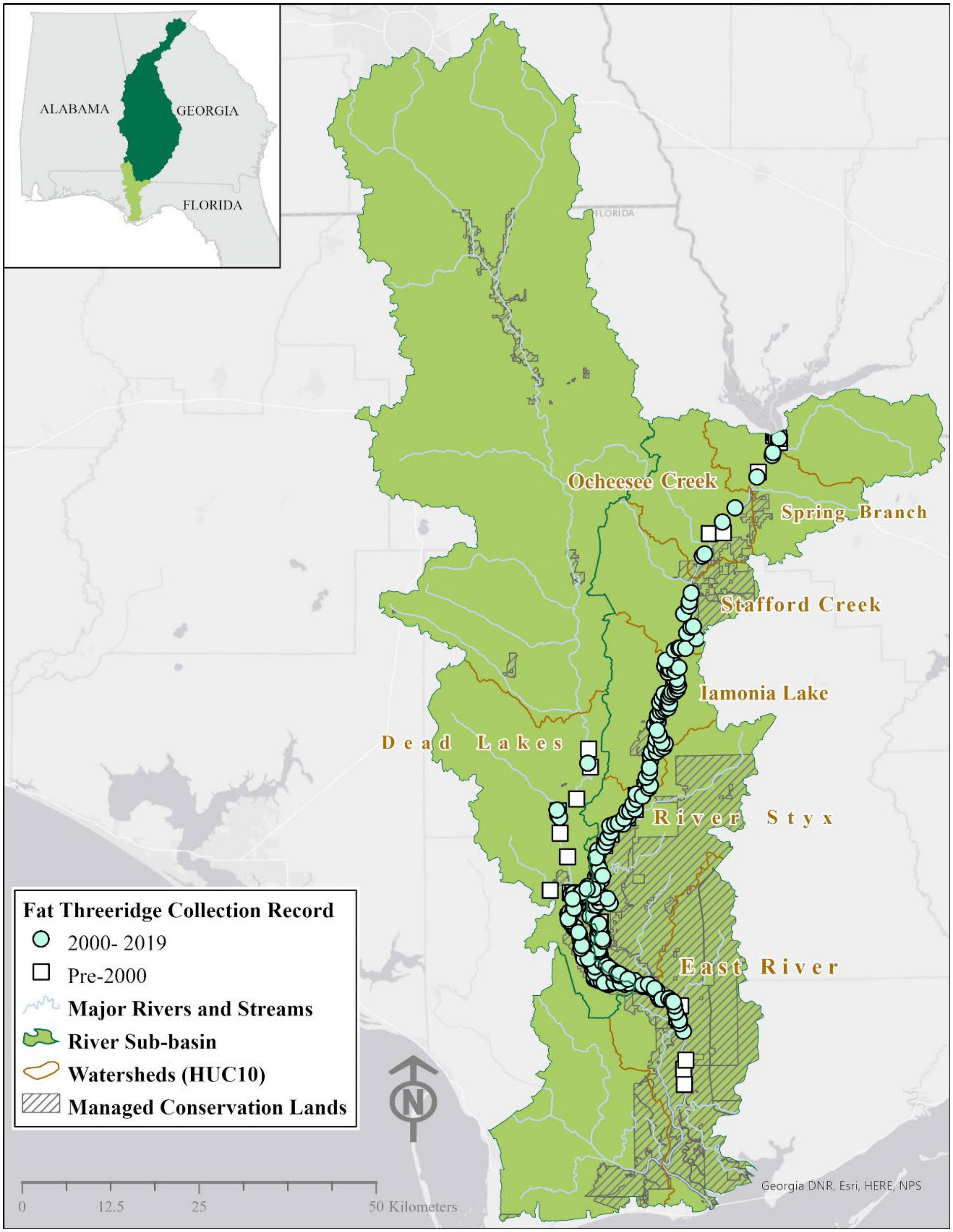


Figure 3-10. Collection records for Fat Threeridge from the Apalachicola (east) and Chipola River (west) sub-basins. Sampling efforts by the Service and FWC since 2000 has resulted in documenting Fat Threeridge at many sites throughout the historical range.

3.2.2.3 The Chipola River

The Fat Threeridge is not known to have ever occurred in the upper Chipola River. The northern extent of the historical Fat Threeridge distribution in the Chipola River is approximately at the Florida Route 71 crossing of the Chipola River (Scotts Ferry), which is upriver of Dead Lakes. We defined this section of the Chipola River upstream from Chipola Park near the junction of the Chipola River with Cypress Creek, through the northern portion of Dead Lakes up to RM 31.5 (RKM 50.7) near Scotts Ferry and refer to it as the Chipola River North of Dead Lakes (NDL). The paucity of stable, fine sediment mesohabitats in the Chipola River in this area north of Dead Lakes is likely a factor contributing to the rarity of Fat Threeridge in the area (Kaeser et al. 2019, p. 669), as it represents less suitable habitat than the larger mainstem river habitats where the species is more abundant. The remainder of the Chipola River occupied by Fat Threeridge is referred to as the Lower Chipola River; this reach includes the Chipola Cutoff and the Chipola River downstream of Dead Lakes.

The historical distribution of Fat Threeridge within the Chipola River was largely contained within the Lower Chipola. Van der Schalie (1940, p. 200) reported 17 live specimens from two of 24 sites (16 from a Dead Lakes site near Chipola Park, and one from the Scotts Ferry, Calhoun County site located approximately 2 km north of Dead Lake) from sampling completed between 1915 to 1918. This early survey work focused largely within the upper half of the Chipola River where the species has never been reported. Van der Schalie (1940, p. 200) characterized Fat Threeridge as occurring only within a small zone on either side of the Gulf and Calhoun County border. This zone did not extend into the Lower Chipola as this region was not sampled.

Subsequently, Clench and Turner (1956, p. 160) documented ten to 15 mussels per square meter (0.9 to 1.4 mussels per ft) over 200 m (656 ft) within an unknown stretch of Dead Lakes shoreline. One hundred live individuals were reported south of Dead Lakes in the Lower Chipola in 1988 (Brim Box and Williams 2000, p.30). As mentioned previously, during the 1991/92 status survey 86 sites were sampled with live Fat Threeridge found at six (7 percent) of these sites; three of the sites containing live Fat Threeridge were located in the Lower Chipola River; only shells were encountered in the Chipola NDL (Brim Box and Williams 2000, p. 30; USFWS 2020). USACE investigated population structure and evidence of recent recruitment in 1999 at one site at the Chipola Cutoff in the Lower Chipola. Quantitative samples were collected using a 0.25-m^2 quadrat, including the measurement and density of individuals through total substratum removal; approximately 65 individuals were collected with sizes ranged from 12.8 to 63.7 mm, with a density of 27.2/m^2 (Miller and Payne 2006, pp. 29 – 30).

The abundance and distribution of Fat Threeridge, particularly within the Lower Chipola River, has been examined more thoroughly since 2000. While not sampled extensively, Fat Threeridge was consistently encountered in deep stable mid-channel habitats in the Lower Chipola in 2005 (EnviroScience 2006*a*, pp. 20, 29). A combination of timed searches, quadrat sampling, and transects were used; Fat Threeridge was locally abundant with a CPUE of 67.8 from 227 individuals, a density of 3.15/m^2, and a size distribution of 32 to 76 mm (EnviroScience 2006*a*, pp. 20, 2169 - 2170, 2187). Subsequently, a similar approach was utilized with a focus on sampling bank habitats to assess stranding potential (Gangloff 2012, entire). Fat Threeridge was the most dominant mussel encountered at the 10 bank sites surveyed by hydraulic gold dredge in the Lower Chipola River in 2008 and 2010 (56 percent of total catch; Gangloff 2012, p. 13). The species was abundant (n = 2031, 8.86 mussels/m^2), with individuals ranging from 2.5 to 75 mm (Gangloff 2012, p. 13, 27, 40 - 42). The Fat Threeridge population in the Lower Chipola was estimated to comprise 72 percent of the total population at 553,779 individuals, much more abundant than the Apalachicola reaches studied (Gangloff 2012, p. 14). Extensive habitat mapping (Smit and Kaeser 2016, entire) and dive surveys in 2014 (Kaeser et al. 2019, entire) documented a 91.3 percent occupancy rate in suitable habitat within the Lower Chipola, with Fat Threeridge occurring at a density of 6/m^2; Kaeser et al. (2019) noted the presence of small individuals between 20 and 30 mm within the Lower Chipola at most locations sampled (USFWS 2020), evidence of recruitment consistent with earlier work (Gangloff 2012, p. 27). Surveying continued further north in the Chipola NDL but no density or population estimates were made (Kaeser et al. 2019, p. 662; Figure 310). In 2017, nine Fat Threeridge in the Chipola NDL were measured (range: 39 to 52 mm; Kaeser pers. comm. 2020*b*), and in 2018 two 10-m^2 radial plots were completed that contained Fat Threeridge at a density of 0.1/m^2 (USFWS 2020).

CHAPTER 4 –CURRENT CONDITION

To assess current condition we define analysis units within the range of Fat Threeridge appropriate to analyze resilience, and then evaluate the distribution of resilient populations on the landscape to discuss redundancy and representation.

4.1 Delineating Analysis Units

Reproductive isolation (e.g., breaks in connectivity), habitat features (e.g., differences in river geomorphology), and stressors are relevant to understanding the current condition of Fat Threeridge. Six analysis units were defined based on reproductive isolation, current (2000 to present) occurrence records and expert input as discussed in detail in Chapter 3: Lower Flint River, Upper, Middle, and Lower Apalachicola River, Chipola River North of Dead Lakes (Chipola NDL), and the Lower Chipola River (Figure 4-1). As no live Fat Threeridge were collected in Spring Creek or the Upper Flint River during our defined current time period, these areas are not considered in the analysis of current condition.

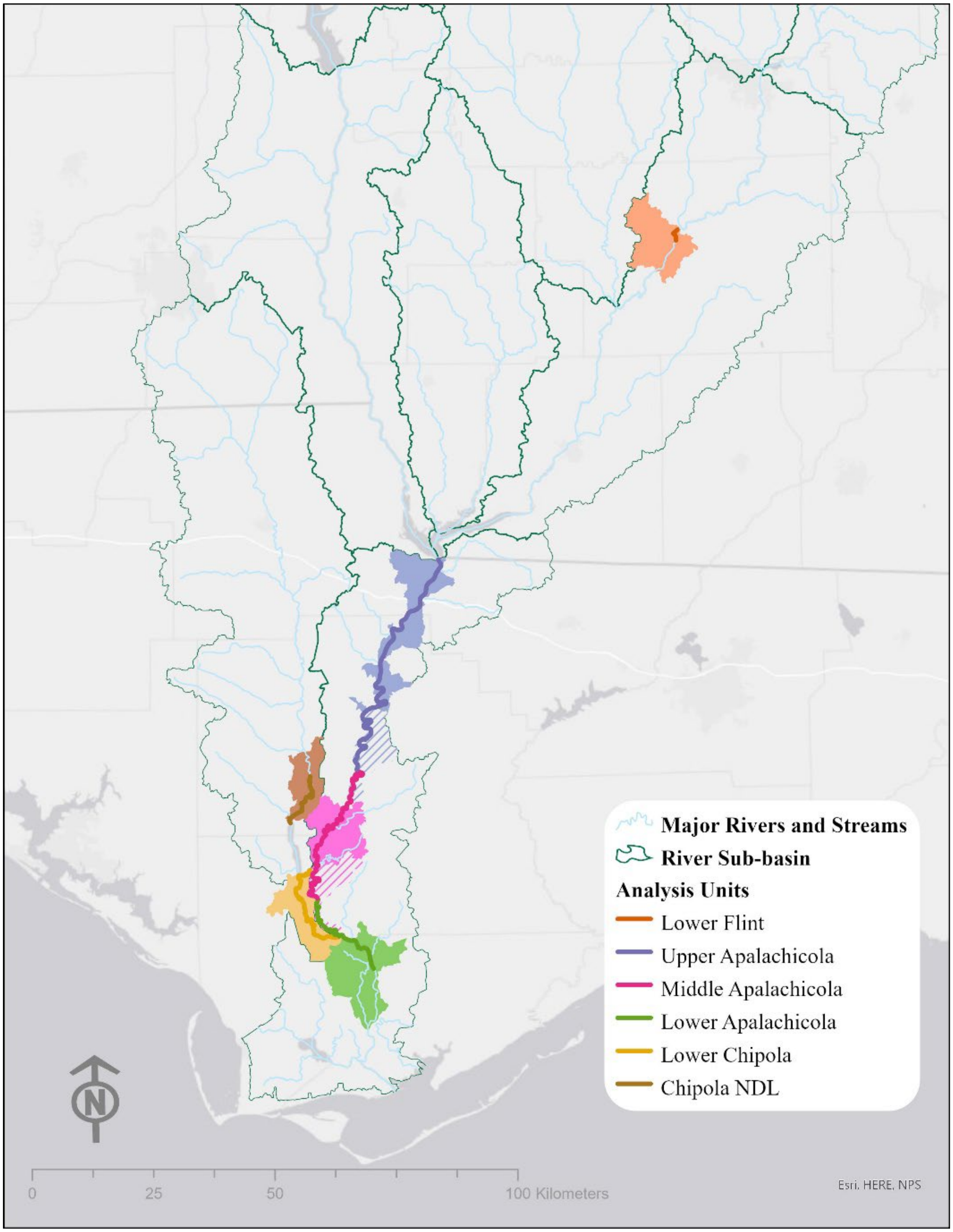


Figure 4-1. Analysis units (lines) and analysis subwatersheds (shaded) for the Fat Threeridge current condition, identified by reaches that exhibit reproductive isolation and/or unique geomorphology. Units do not necessarily align with subwatershed boundaries; hatched subwatersheds drain into two analysis units.

4.2 Resiliency

Resiliency reflects a species' ability to withstand stochastic events (arising from random factors). Resiliency is measured at the population-level using metrics that characterize population health such as demographic rates and population size. We also need to consider the nature and extent of stressors to a species that could limit resiliency. Populations demonstrating resiliency are better able to withstand perturbations associated with demographic stochasticity (e.g. fluctuations in birth or mortality rates), environmental stochasticity (e.g. variation in precipitation or temperature), and anthropogenic activities. Characteristics of resiliency for Fat Threeridge include: evidence of stable or increasing population trends, evidence of reproduction (either direct observation of juveniles, or of multiple age classes as inferred by length data). An adequate number of resileint populations should be distributed throughout the species range to both protect adaptive capacity of the species, and protect from catastrophic events (USFWS 2003, entire). Additionally, threats to the species must be eliminated or managed to the extent that they do not negatively affect viability (USFWS 2019, entire; Figure 4-2).

There must be at least four populations (analysis units) that exhibit a stable or increasing trend (evidenced by natural recruitment, and multiple age classes), and these must be distributed such that

- at least one occupies each of the Flint and Chipola sub-basins.
- In the Apalachicola sub-basin, at least one analysis unit with the aforementioned characteristics must occupy two of the three reaches of the Apalachicola (Upper, Middle, or Lower).

Threats have been addressed and/or managed.

Figure 4-2. Recovery criteria for Fat Threeridge (adapted from USFWS 2019, p. 6).

Some insights regarding the current status of Fat Threeridge population can be gleaned from similar species. *Amblema plicata,* a close congener of Fat Threeridge, has been described as an equilibrium life history strategist (Haag 2012, p. xx; see Section 2.3.4) that inhabits downstream reaches of higher order rivers similar to the Apalachicola River. *A. plicata* is intolerant of channelization or other impacts that destabilize streambeds (Haag 2012, p. xx). If Fat Threeridge shares these characteristics, the cessation of dredging (including associated dredge spoil disposal, and snag removal) in the Apalachicola River nearly 20 years ago and the management of minimum discharge levels and river drawdown rates have likely served to restore a degree of habitat stability and equilibrium to the system (Kaeser et al. 2019, p. 669), to the benefit of Fat Threeridge. While we discuss factors influencing viability in more detail in Chapter 5, this serves as an introduction to the conceptual framework for the assessment of current condition in the Fat Threeridge.

In this section we assess the resiliency of Fat Threeridge analysis units by considering metrics that support the existing recovery criteria for both population demographics and habitat stressors. We assess demographic resiliency factors including abundance, recruitment, and occupation which relate to the recovery criteria of stable or increasing population trends, and recruitment within the population. We also evaluate habitat resiliency factors related to water quality and water quantity to establish a baseline from which to project future condition. These habitat factors are related to the recovery criteria regarding the management of stressors that degrade habitat quality for the species.

We assessed the condition of each resiliency factor as either high, moderate, low, and very low based generally on rankings presented by NatureServe (2020b, pp. 2-4). A resiliency factor is in high condition if an optimal or exceptionally favorable environment is present and remains so (i.e., the species is thriving); a moderate condition rank indicates a similar environment as the present may persist but some characteristics of the resiliency factor are not optimal and condition may decrease (i.e., the species is essentially stable, not necessarily thriving or expanding its range); low condition indicates the species is surviving and observable but the population is likely declining; and very low condition indicates a lack of individuals or an environment that does not support the species. The condition of Demographic and habitat resiliency factors were then combined to categorize the overall resilience of each analysis unit (Section 4.1.7).

4.2.1 Demographic Factor—Abundance

Abundance is both a direct contributor to resiliency and an indirect indicator of resiliency. Analysis units with few individuals are more susceptible to demographic and environmental stochastic events than units with greater abundance. A high abundance helps buffer Fat Threeridge from the effects of drought or other disturbances that may temporarily reduce the population size. Indirectly, large population sizes are likely indicative of other conditions that contribute to resiliency (e.g., water quality, substrate stability).

Demographic information for Fat Threeridge presented in Section 3.2 is summarized for each analysis unit in Table 4-1. Recent surveys provide a perspective on the abundance and distribution of Fat Threeridge in the Apalachicola and Chipola River that differs from that presented during the status survey of the early 1990s. Since 2000, the species has repeatedly been described as numerically dominant (EnviroScience 2006a, p. 29, Miller and Payne 2006, p. 29),with surveys within the last decade identifying Fat Threeridge as either the second-most or most abundant species within the reaches of the Apalachicola and Lower Chipola River (Gangloff 2012, p. 24; Kaesar 2019, p. 662). Fat Threeridge was ubiquitous in some areas;

roughly 90% of the sampling plots in suitable habitats of the Middle Apalachicola and Lower Chipola River contained the species (Kaeser et al. 2019, p. 668).

Kaeser et al. 2019 (p. 669) provided an overview of the species distribution and possible drivers for current Fat Threeridge abundance. Fat Threeridge appears to exhibit a bell-shaped, unimodal distribution in the Apalachicola and Chipola River in response to an environmental gradient. The occurrence and abundance of Fat Threeridge declines with increasing distance from its range center both upstream and downstream, likely related to its fundamental niche in stabilized fine sediments of mainstem rivers (See Section 2.5.2). Fat Threeridge is rare at the periphery of its range where habitat is less suitable, and as such, locations upstream of RKM 150 on the Apalachicola River, upstream of Dead Lakes in the Chipola River, and the Lower Flint River support smaller populations.

We use measures of abundance to determine trends. However, the available data do not enable a statistically rigorous assessment of trends in abundance over time as they are confounded by an expansion of the sampling frame for this species and differences in sampling approach. (See Section 3.2.1 & 3.3). Additionally, it should be reiterated that counts of mussels from qualitative sampling are *not* interpreted as a population or abundance estimate, however, when those are the best data available in a given area they can still be used as a coarse measure of abundance, in that we know at least that many individuals were collected. Regardless of differences in survey effort and methods among sites and through time, the available data indicate an increasing trend (e.g., rarely encountered in 1990s to abundant) or stability for most analysis units since the time of listing.

Table 4-1. Summary of Fat Threeridge presence and abundance by sub-basin and reach. Data are summarized by decade and include actual counts (the most live individuals collected during a survey) or abundance estimates (denoted by an *). Data for mean density largely derived from Kaeser et al. 2019.

Sub-basin	**Reach**	**Current**	**Historical**	**Last Observed**	**Last Surveyed**	**# 1990**	**# 2000s**	**# 2010s**	**Mean Density (#/m^2)**
Lower Flint	-	X	X	2019	2011	0	10	1 to 5	n/a
Apalachicola	Upper	X	X	2017	2017	50	24k*	350k*	0.97
	Middle	X	X	2019	2019	272	118k*	4.7mil*	3.96
	Lower	X	X	2018	2018	16	70k*	230k*	0.65
Chipola	Lower	X	X	2018	2018	65	553k*	3.5mil*	6.00
	NDL	X	X	2018	2018	0	4	10	0.1

We categorized populations into four condition classes. Although our current condition time period extends from 2000 to 2019, we use the most recent data available for each unit for this factor (Table 4-1). We measure abundance according to the number of live individuals within an analysis unit (either those encountered directly through surveying or those anticipated to be present from population estimates) and included the average density of Fat Threeridge for relative comparisons (Table 4-2). These estimates do not account for detection probability and are considered conservative. That is, Fat Threeridge may have been present but not detected during some surveys, and when raw numbers are used without correcting for incomplete detection, that represents an underestimate of the individuals likely present.

Table 4-2. Condition categories for Fat Threeridge relative abundance.

Condition Category	**Abundance**
High	Recent density and population estimate at high end of known range (>1 /m^2; > 1 million). Increasing or stable population trend.
Moderate	Recent density and population estimate at lower end of known range (≤ 1/m^2 to 0.11/m^2; $>$ 100k to 1 million). Increasing or stable population trend.
Low	No population estimate, generally known to be present at low density (5-10 individuals minimum and/or ≤ 0.1/m^2). Possible stable trend since 2000, but undetectable in the past.
Ø	None

Fat Threeridge abundance in the Middle Apalachicola and Lower Chipola is characterized as **High,** with the Upper and Lower Apalachicola as **Moderate,** and Chipola NDL and Lower Flint as **Low.**

4.2.2 Demographic Factor—Evidence of Recruitment

Recruitment describes not only successful biological reproduction, but also survival through excystment into the juvenile life stage. Mussel populations with only older/senescing individuals may be more susceptible to extirpation because they have few young individuals to sustain the population into the future, while the trajectory of populations with many young individuals and multiple age classes will likely increase or stay stable.

Within a population, recruitment can be documented either by direct collection of juveniles (<25 mm) or by observation of multiple size classes, which we interpret here as individuals both <50 mm and >50 mm. While a shell length < 25 mm is a good benchmark for evidence of recruitment and has been used as such within the Flint River (Wisniewski et al. 2014, p. 35), detecting very young juvenile mussels during surveys happens rarely due to sampling bias (Shea et al. 2013, p. 383). Mussel surveys involve underwater, tactile and visual searches, and small mussels can be difficult to detect (Wisniewski et al. 2013*b*, p. 242). Surveying methodologies may also only note the number of small individuals as a measure of recruitment. We were able to summarize the presence of smaller individuals as a size class < 35 mm based on available data, and clarified the context in which these small individuals were found, given hydraulic dredge is a more reliable method of detection.

Table 4-3. Fat Threeridge demographic information (size range, individuals < 35 mm) summarized by sub-basin (HUC 8) and reach from 2010 to 2020. Size ranges are largely from Gangloff 2012 and Wisniewski et al. 2014.

Sub-basin	Reach	Size Range (mm)	Individuals < 35 mm in hydraulic dredge
Lower Flint	-	35 to 70	Not used
Apalachicola	Upper	10 to 90	Yes
	Middle	5 to 90	Yes
	Lower	10 to 85	Yes
Chipola	Lower	5 to 75	Yes
	North of Dead Lakes	39 to 52	Not used

We identified analysis unit with small (≤ 35 mm) individuals as exhibiting strong evidence of recent recruitment, and also examined the size range of individuals (Table 4-3) for our assessment of recruitment condition categories (Table 4-4). We considered evidence of recruitment within the last 10 years (≥ 2010). There is no instance of a hydraulic dredge having been used in an analysis unit and having failed to detect small individuals within that unit.

Table 4-4. Condition ranks for Fat Threeridge recruitment.

Condition Category	Recruitment
High	Presence of multiple age classes (individuals > and < 50 mm); small individuals (≤ 35 mm) detected using hydraulic dredge methods
Moderate	Presence of multiple age classes (individuals > and < 50 mm); but no small individuals (≤ 35 mm) detected using hydraulic dredge methods
Low	Only one size class ≥ 50 mm; no small individuals (≤ 35 mm) detected using hydraulic dredge methods
Ø	None

Fat Threeridge recruitment in all analysis units is characterized as **High.**

4.2.3 Demographic Factor – Occupancy

Fat Threeridge viability is likely limited where there is minimal habitat or what is available is not occupied. Occupancy (in this context) indicates the presence of suitable conditions and successful establishment. Though habitat may be available, variation in characteristics such as coarse woody debris and/or stabilization of fine sediment may limit occupation by providing conditions that are not optimal for Fat Threeridge, particularly during larval settlement or juvenile pedal feeding (Kaesar et al. 2019, p. 668).

We assessed the proportion of habitat occupied, which is derived from available habitat for most analysis units. We included the amount of habitat available for Fat Threeridge to grow or shift into in Table 4-6. The amount and proportion of available habitat is the sum of suitable mesohabitats divided by the area of all mesohabitat in the reach (Kaeser et al. 2019, p. 661). The area occupied by Fat Threeridge was also determined for most analysis units (Kaeser et al. 2019, p. 667). Habitat availability and area currently occupied were used to determine the percent occupied habitat in Table 4-5.

For analysis units where percent occupation is uncertain (Upper Flint, Chipola NDL), we relied on historical data, expert opinion, and literature when available to infer occupation. Both van der Schalie (1940, entire) and recent survey work (USFWS 2020) have found live Fat Threeridge predominantly at two locations in the Chipola NDL, with other reports containing uncertain locations or shells that may have been displaced (See Section 3.2.2.3). A similar situation occurs in the Lower Flint (Section 3.2.2.1) where Fat Threeridge is considered to occupy the extent of the currently suitable habitat in the sub-basin (Wisniewski pers. comm. 2020*a*). It would appear that given limits to available habitat in these analysis units, that the Chipola NDL and Lower Flint are maximally occupied (Table 4-5).

Table 4-5. Fat Threeridge occupation, including reach length (km), dredging history, and 2019 habitat metrics (occupied and available habitat) summarized by sub-basin (HUC 8) and reach. Habitat data is from Kaeser et al. 2019.

Sub-basin	**Reach**	**Length (km)**	**Dredging History (Section 5.3.3.1)**	**Available Habitat (ha)***	**Occupied Habitat (ha)****
Lower Flint	-	3	Never	~ 6*	likely maximal
Apalachicola	Upper	66.1	Not since 2001	186.3 (16.8%)	36 (19.3%)
	Middle	46.4	Not since 2001	148.4 (21.1%)	120 (80.9%)
	Lower	25.8	Not since 2001	67.9 (24.1%)	35.4 (52.1%)
Chipola	Lower	27.4	Not since 1990	64.6 (67%)	59 (91.3%)
	NDL	15	Never	~ 30*	likely maximal

* percent of reach ** percent of available

Dredging was a widespread, intensive, and frequent disturbance within the Apalachicola River that was likely detrimental to the species. However, dredging has either not occurred at all or at least within the last twenty years in Fat Threeridge analysis units, and recent signs of habitat recovery have been observed. The history of dredging is discussed in Section 5.1.3.3, and summarized in Table 4-5. Some habitat instability may remain in the Upper Apalachicola for other reasons such as an upstream impoundment which limits occupancy in what appears to be otherwise suitable habitat. We believe the effects of damming and dredging on occupancy may be reflected by a simple assessment of occupancy as presented in Table 4-6.

Table 4-6. Condition ranks for Fat Threeridge occupancy based on available habitat.

Habitat Occupancy		
100 -71% or maximal occupancy	31 – 70% or intermediate occupancy	< 30 % or minimal occupancy
High	Moderate	Low

We categorized analysis units into four condition classes based on occupancy. We rank occupancy as maximal (100 -71%), intermediate (31- 70%), or low (<30%) by partitioning percent occupancy into thirds (Table 4-6). Currently, Fat Threeridge occupancy in the Middle Apalachicola, Lower Chipola, Chipola NDL and Lower Flint is characterized as **High,** with the Lower Apalachicola as **Moderate,** and the Upper Apalachicola as **Low**.

4.2.4 Habitat Factor – Water Quality

There is no current data for the tolerance levels of Fat Threeridge to specific pollutants, but there is some general information available on the relationships and importance of these parameters to freshwater mussels and aquatic life in general. As a group, mussels are among the most sensitive organisms to many contaminants and are often the first organisms to respond to water quality impacts (Haag 2012, p. 355). Several features of mussel life history lead to vulnerability to contaminants: juveniles and adults are exposed to toxic material in sediment, surface water, and pore water, and through the filtration of contaminants bound to food particles (Augspurger et al. 2007, p. 2025), with mussel early life stages (e.g., glochidia) frequently showing the highest sensitivity to many chemical compounds (Augspurger et al. 2007, p. 2025–2026). Adult mussels have some ability to avoid acute exposure to pollutants by closing their valves and ceasing respiration, but earlier research suggesting that adult mussels are generally more tolerant of contaminants may have been overstated for methodological reasons (Cope et al. 2008, p. 453). Agricultural and developed lands are associated with high loadings of nutrients and silt and sediments in streams. The importance of appropriate water quality to complete all life cycles was presented in Section 2.5.3, and effects of contaminants or pollutants to freshwater mussels will be presented in detail in Chapter 5.

Contaminants enter streams through both point and nonpoint sources, including spills, industrial sources, municipal effluents, and runoff from agricultural and developed areas. Our ability to quantify effects of point source pollution within each analysis unit is limited. The designation of Outstanding Florida Water (OFW) status along the majority of the Chipola and Appalachicola rivers prevents the permitted discharge of pollutants that would lower existing water quality of, or significantly degrade the waterbody within Florida (See Section 5.3.3). However, pollutants may be contributed upstream in either the Chattahoochee or Flint Rivers with uncertain downstream effects both in regards to water quality impacts and Fat Threeridge response. To assess the presence of point source pollution in the Lower Flint subwatershed analysis unit, we used the EPA Water Pollutant Loading Tool (*https://echo.epa.gov/trends/loading-tool/get-data/watershed-statistics*, accessed Nov. 3, 2020) to compile information from Discharge Monitoring Report (DMR) and Toxics Release Inventory (TRI) records about facilities permitted to discharge pollutants into streams from all available records (2007 to 2020). No DMR or TRI records were found in the analysis subwatershed.

Nonpoint source impacts to water quality are dependent on landscape features that influence the sources and distribution of pollutants. Landcover can be used as a surrogate for potential water quality impacts on the Fat Threeridge. The amount of land that is developed and/or in agricultural use is of particular relevance for nonpoint source pollution, and specifics of land use to water quality will be discussed in Chapter 5. In general, urban land cover increases runoff into streams, increasing loads of sediments, nutrients, metals, pesticides, and other nonpoint source pollutants. Agricultural land cover can impact water quality and aquatic organisms via increased exposure to chemical fertilizers, pesticides, livestock waste, sedimentation, and potentially decreasing flows through irrigation. Maintaining forest on a large proportion of a watershed can help protect water quality and maintain high quality aquatic habitat. We assess water quality by using landcover surrogates of potential non-point source pollution and relating these to thresholds for aquatic species impacts. Therefore our water quality assessment is an indicator of conditions that may be present used as a relative assessment of risk to Fat Threeridge and not a direct measure of water quality.

To assess non-point source pollution, we summarized the current land use within each of the Fat Threeridge analysis units using spatial land cover data from the 2016 National Land Cover Database (NLCD) (Jin et al. 2019, entire), available at a 30 x 30-m resolution (98 x 98 ft). We collapsed the land use classes in the original data set that appeared within the range of Fat Threeridge down to five classes: three natural classes (‘forest’ [including woody wetland, and deciduous, evergreen, and mixed forest], ‘other’ [including shrubs, barren, herbaceous, and emergent wetland]) and open water, as well as two anthropogenic (‘urbanized’ [including various intensity of development and roads], and ‘agricultural’ [including cropland, and hay/pasture]). Open water was not assessed within riparian buffers, but was included in subwatershed analysis.

For each analysis unit, we examined landuse at two spatial scales; the entire analysis subwatershed, and a 100-m (330-ft) riparian buffer around analysis units (Figure 4-1). One hundred meters was chosen as the riparian buffer according to the suggested approach for conceptualizing threats to larger rivers in the Southeastern USA. A smaller 30-m buffer consistent with management objectives often led to ≥10 % open water within the riparian buffer, given 30-m is also the resolution of the NLCD data and the buffer may be classified as water on average. A 60 or 100-m buffer was suggested as a method to combat this error (Kaeser and Watson 2011, p. 13). The 100-m buffer used in this SSA provided a low occurrence of open water (maximum 12%), and also aligns with the buffer width used in similar peer-reviewed models (e.g., SPARROW model; Hoos and Roland 2019, p. 1; Figure 5-4).

We used the high resolution National Hydrography Dataset (NHD) to create the analysis unit buffer. The analysis units were depicted as polygons in the NHD (e.g., representing channels ≥15 m wide). The polygons identify the main channel of water for each analysis unit. Any area classified as water remaining in the buffer (12 to 5% of the area) was removed. All water was retained for the more holistic subwatershed analysis. The Apalachicola River contains wide floodplains of woody wetland, so we also used the subwatershed to represent the land uses adjacent to these wetlands; a similar subwatershed-scale approach was used to assess relationships between land use characteristics and mussel presence in the Lower Flint sub-basin (Shea et al. 2013, p. 385).

The proportion of each analysis subwatershed in each land use is displayed in Figure 4-3 (See Appendix A for table of values). Watersheds with over 80 percent forested landcover generally have streams with a high IBI and maintain aquatic habitat (Wang et al. 1997, p. 9). Stream stability can be maintained at lower levels of forest cover (60-80%) when combined with low levels of impervious surfaces (<10 %) and/or high levels of riparian forest cover (Brabec et al. 2002, p. 508). A review of the effect of impervious surfaces on stream quality found that, in general, the impact threshold for biotic health ranges from 3.6 – 15% watershed impervious surface (Brabec and Richards 2002, p. 505- 507). Sensitive fish species can decline in abundance when as little as 1-2% of the watershed is impervious surfaces (urbanized), and at ≥ 10 - 12% fish richness drastically declines (Chen and Olden 2020, pp. 4956-4967). Connected imperviousness between 8 and 12% is a threshold zone in which minor increases in urbanization are associated with sharp declines in biotic measurements of stream quality (Wang et al 2001 p. 264). Similar thresholds are seen at the subwatershed scale regarding the effects of agriculture on fish community composition and species richness; a drastic decline occurs between 25 to 31% (Chen and Olden 2020, p. 4956). Habitat suitability at the catchment scale for dwarf wedgemussel (*Alasmidonta heterodon*) within the Coastal Plain of Maryland declined steeply with low intensity development between 3% to 7.6%, and agricultural (pasture/hay) land cover > 13%. However, no decline in habitat suitability was predicted between 0 and 3.4% agricultural land cover (Campbell and Hildebrand 2017, p. 469-470). A description of how thresholds are expected to relate to Fat Threeridge condition is included in Table 4-7. The land use type with the greatest potential impact on condition was used to categorize the subwatershed score (e.g., 13% urban and 13% agricultural cover would fall under low rank, given the greater threat from urban development).

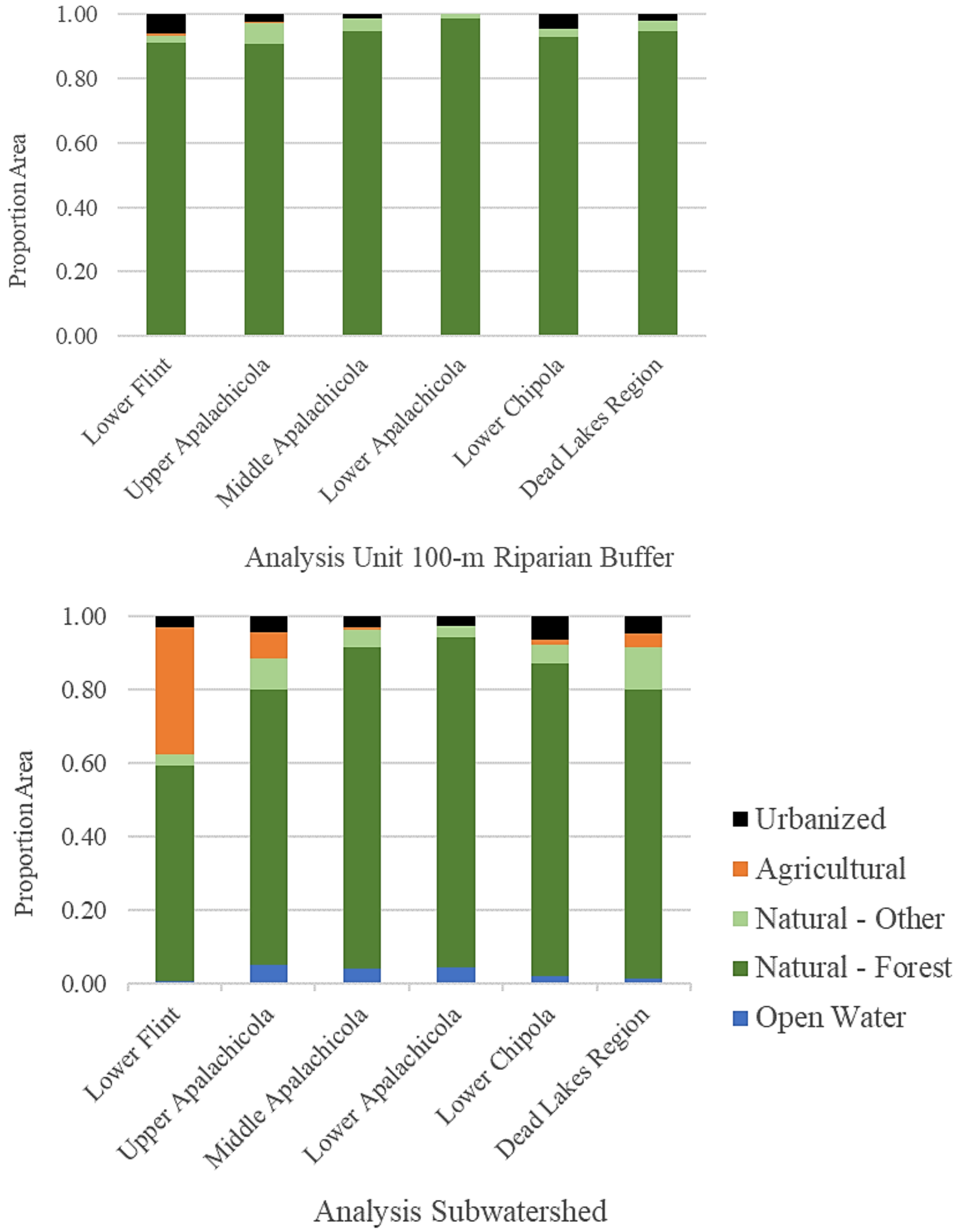


Figure 4-3. Current land use derived from NLCD 2016 landcover within HUC 12 subwatersheds and riparian buffers of Fat Threeridge analysis units. Natural classes are displayed on the bottom, and anthropogenic on the top.

The proportion of each analysis unit 100-m buffer in each land use is displayed in Figure 4-3 (See Appendix A for table of values). Although watershed-wide landcover is associated with water quality, the influence of riparian forest has a disproportionate effect on habitat and biological factors (Richards et al. 1996, entire; Wang et al. 2001, p. 263). In predominately non-forested watersheds, riparian buffer zones reduce sedimentation through streambank stabilization and erosion control, filter nutrients, shade and cool streams, and provide organic material for in-stream habitat and food resources (Wang et al. 2001, p. 263). Percent impervious or forested area within the riparian buffer zone has a higher influence on stream quality than the same amount spread across a watershed (Wang et al. 2001, p. 264; Rios and Bailey 2006, 158-159). Agricultural lands contribute more nutrients to watersheds than any other land use, but nutrient levels seem less critical to IBI scores than runoff volume and high temperatures found in urban environments (Brabec and Richards 2002, p. 508). More than 50% agricultural land was required to reduce IBI scores, and implementation of riparian buffer zones and other best management practices (BMPs) allowed for relatively healthy stream communities even in watersheds that are mostly agricultural (Wang et al. 1997, entire). Given the negative influences associated with predominantly agricultural riparian areas, > 60 % forested area with limited fragmentation within riparian buffers is recommended for the conservation of mussels and fish in Ohio (Hopkins and Wiles 2011, p. 207); sites where the Rabbitsfoot mussel occurs typically have 100-m reach buffers with > 70% forest cover (Hopkins 2009, p. 952). Stream reaches with less than 50% riparian forest were susceptible to losses in mussel diversity and only when forest percentages approached 80% were mussel communities relatively stable through time (Poole and Downing 2004, p. 121). The Southeast Aquatic Resources Partnership (SARP) has identified a goal of retaining adequate non-urban/non-agricultural riparian buffer habitats on at least 85% of lands within 30 meters of rivers and streams in the Southeast by 2022 (Kaeser and Watson 2011, p. 6). We used the SARP estimate of adequate cover as our upper riparian forest cover threshold, given that the natural communities surrounding analysis units are typically forests or woody wetlands. It is assumed that the proportion of forested area that is ideal for a 30-m riparian buffer as recommended by SARP is also suitable for determining thresholds for our 100-m buffer. A description of how these thresholds are related to water quality condition Fat Threeridge is included in Table 4-7.

Table 4-7. Condition categories for two Fat Threeridge water quality land cover surrogates.

Water Quality			
Condition Category	**% Subwatershed Urban or Agriculture Cover**	**% Riparian Forest Cover**	**Description**
High	0-3% urban and/or agriculture [1,2]	Primarily forested (>85%)[3]	No known or anticipated contaminant or sediment problems given the landcover
Moderate	4-7% urban and/or 4-13% agriculture [2]	60-85% forested [4, 5, 6]	Associated contaminant or sediment issues are likely in some areas
Low	8-14% urban and/or 14 - 30% agriculture [1, 2, 7]	50-60% forested riparian zone [6]	Associated contaminant or sediment issues increases the risk of negative impacts throughout Fat Threeridge habitat
Very Low	≥ 15 urban and/or > 30% agriculture [1, 7, 8]	< 50% forested/habitat is no longer present [6]	Associated contaminant or sediment levels pose the highest relative risk to Fat Threeridge habitat; Significant, widespread, or prolonged impacts likely occurring

[1] Chen and Olden 2020 [2] Campbell and Hildebrand 2017 [3] Kaeser and Watson 2011 [4] Hopkins and Wiles 2011
[5] Hopkins 2009 [6] Poole and Downing 2004 [7] Wang et al 2001 [8] Brabec and Richards 2002

We combined water quality condition surrogates in Table 4-8. An intact and protected riparian zone may not be adequate to maintain stream ecosystem integrity or species at risk if development throughout a watershed (e.g., agriculture or urbanization) significantly alters hydrology or water quality (Richardson et al. 2010, p. 1201). Condition ranks were converted to a numeric scale (e.g., high [4], moderate [3], low [2], very low [1]) and averaged. If a rank was intermediate it was rounded down as a conservative measure (e.g., 2.5 recorded as low). Water quality condition was then recorded as high, medium, low, or very low based on the percentage of the total subwatershed and riparian buffer that was developed and forested, respectively. The ranking may be considered a surrogate or indicator approach as well as a relative assessment of water quality to identify potential problem areas, and not an absolute assessment of water quality condition. Species are not always found in suitable habitat and may sometimes occur in sites deemed unsuitable.

Table 4-8. Combined condition ranks for Fat Threeridge water quality.

	Riparian Forest Cover (%)			
Subwatershed Land Use (%)	≥85	60-85	50-60	< 50
0-3 urban and/or agricultural	**High**	**Moderate**	**Moderate**	**Low**
4-7 urban and/or 4-13 agricultural	**Moderate**	**Moderate**	**Low**	**Low**
8-14 urban and/or 14-30 agricultural	**Moderate**	**Low**	**Low**	**Very Low**
≥ 15 urban and/or > 30 agricultural	**Low**	**Low**	**Very Low**	**Very Low**

Though riparian buffers are well forested, anthropogenic land use at the subwatershed scale suggests variable water quality throughout the Fat Threeridge range. All analysis units contain a riparian buffer that is > 85% forested. Within riparian buffers, over 90 percent of the area is in natural land uses, primarily woody wetland (a component of forested landcover; Figure 4-3). Regardless of ownership, wetlands are protected by the Environmental Protection Agency; additional protections are provided within the majority of Fat Threeridge range by The Florida Environmental Resources Permit (ERP) (See Section 5.3.3).

The relative water quality of the Lower Flint analysis unit is considered **Low** for Fat Threeridge given the large extent (~35%) of agricultural lands in the subwatershed that may be a limiting factor for the species. The Chipola NDL, Lower Chipola, and Upper Apalachicola analysis units were considered **Moderate,** given the presence of subwatershed urban and/or agricultural development > 3%. The Middle and Lower Apalachicola are considered to be in **High** condition. In general, land use patterns have stayed fairly stable since 2000, with the greatest increase in anthropogenic cover occurring in the Lower Flint Basin (Section 5.1.1, Table 5-1). Some analysis units are protected under public lands or easements, while others lack these protections and may contain less natural landcover in the future (See Table 5-3 in Section 5.3.1).

4.2.5 Habitat Factor – Water Quantity

Mussel survival and recruitment is likely influenced by both low and high flows. Species exhibiting equilibrium life history traits such as Fat Threeridge are favored by stable environmental conditions. Low flow conditions most often occur in the summer with high flows often occurring in the spring. The combination of consumptive water use, periodic drought, and water regulation has made ensuring sufficient water quantity for Fat Threeridge a priority. Groundwater withdrawals exacerbate drought conditions during dry years, which affects both tributaries and main river channels in the summer. During high spring flows, the erosive capacity of a stream is increased and streambed sediment and mussels can be dislodged causing injury and death, but this is more typical in tributary streams. Given that Fat Threeridge occurs primarily in mainstream habitats, it may be primarily impacted by extreme low flows and so we focus on these for our analysis.

Knowledge of precise sublethal and lethal effects on Fat Threeridge from flow extremes is lacking. Research about surface water temperature tolerances has been limited to 22 species, approximately 10 percent of the species known to occur in North America (Dimock and Wright 1993, entire; Pandolfo et al. 2010, entire; Archambault et al. 2014, entire; Ganser et al. 2015, entire; Khan et al. 2019, entire). There is some data available to describe the sensitivity of the Fat Threeridge to environmental stressors such as temperature (See Section 2.5.3), but in general the tolerance to these stressors can be inferred from thermal tolerance or drought research conducted on other, similar mussel species. Less is known about high-flow impacts. In general, flow conditions that decrease adult Fat Threeridge health and survival are also unlikely to be beneficial for recruitment; weak recruitment for the congener *A. plicata* occurred with extreme low summer flow (see Section 2.3.4). A discussion of extreme drought and low flow effects is provided in Section 5.1.5.2 and 5.1.4.1.

Given the unknowns about how the Fat Threeridge specifically responds to the direct and indirect impacts of low-flow events, we sought to characterize stream flows in terms of the relative risk of impacts between analysis units by describing qualitative thresholds. We compiled streamflow modeling outputs generated by LaFontaine et al. (2019, entire) for the historical time frame from 1952 to 2005 and the future time frame from 2045-2075, with results combined across 13 different climate models (LaFontaine et al. 2019, p. 15). We will revisit the future time frame predictions in the future condition section of the SSA; for the present section we investigated the 1952-2005 inputs developed from observation-based historical climate data. We split these historical outputs into two equally sized time periods to represent more historical conditions (Historical: 1952-1978) and more current conditions (Current: 1979-2005). The hydrologic simulation model, called the Precipitation-Runoff Modeling System (PRMS), used to produce water quantity outputs incorporated physical processes including precipitation, evaporation, transpiration, soil infiltration, and runoff. A limitation of the model is that it only included physical processes and did not include effects of anthropogenic water withdrawal for industrial, municipal, or agricultural use. Future models that incorporate both physical and anthropogenic mechanisms could provide more accurate predictions of future water quantity and should be investigated if/when they are developed. However, these impacts are somewhat characterized within the water quality resiliency factor.

We examined the mean minimum monthly flows over the summer (July-September) produced by the PRMS hydrologic simulation models (LaFontaine et al. 2019, pp. 21). We used data from the PRMS reaches that corresponded with our analysis units, with some overlap within the Apalachicola River. These flows are divided by the drainage area (cubic feet per second/ square mile) for comparisons between analysis units. We used minimum summer flow to characterize the relative risk from low flow conditions for the analysis units occupied by Fat Threeridge. The rate at which flows change during these events is also an important metric that influences whether mussels have time to move to more suitable conditions, but data was not available in a format allowing for meaningful comparisons between populations. Where conditions are particularly extreme within the range of Fat Threeridge (e.g., lower summer minimums), the risk of impacts is greater. The results illustrate some differences in hydrology between larger and smaller rivers within the range of the Fat Threeridge. While the comparison of flow (cfs) by drainage area (miles squared) helps to standardize the assessment, the Lower Flint, Lower Chipola, and Chipola NDL analysis units occur within smaller rivers than the larger Apalachicola River and small rivers may be more susceptible to high or low flows (Table 4-2).

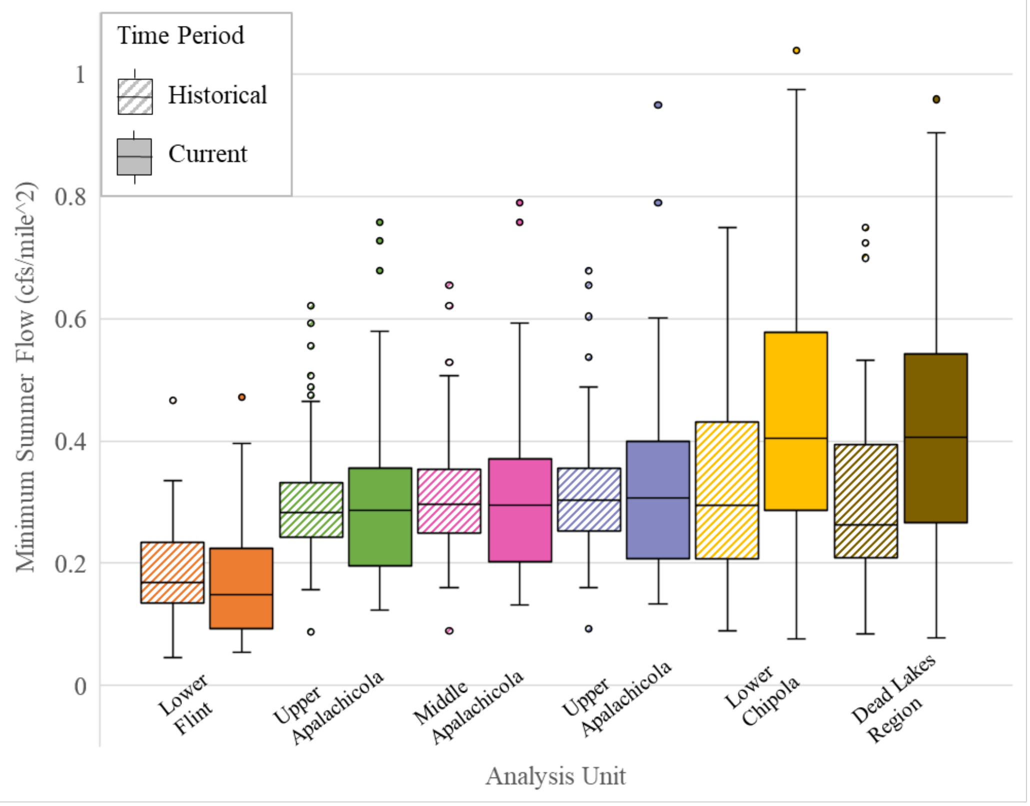


Figure 4-4. Current and historical minimum summer (July-September) mean monthly flows within Fat Threeridge analysis units.

The low summer flows of the Lower Flint analysis unit may increase its susceptibility to low-flow conditions compared to other analysis units. While other units appear to have become more variable or to have increased their minimum summer flows from the historic time period to the current, the Lower Flint appears to have experienced a slight decline. Historically, the Lower Chipola and Chipola NDL exhibited similar median values as the analysis units of the Apalachicola River; within the current timeframe, the minimum summer flows appear to have increased, reducing the risk of significant mortalities and potentially supporting strong recruitment years. The water quantity condition for each analysis unit was classified based on relative comparisons among populations (i.e., not based on empirical quantitative thresholds) in Table 4-9. No streams currently containing Fat Threeridge exhibit intermittent flow.

Table 4-9. Condition ranks for Fat Threeridge water quantity based on relative risk from the occurrence of high or low flows.

Condition Category	Water Quantity
High	Lower relative risk of direct and indirect impacts to the survival, health, or recruitment of Fat Threeridge from low flow events
Low	Higher relative risk of direct and indirect impacts to the survival, health, or recruitment of Fat Threeridge from low flow events
Ø	Intermittent flow; survival of Fat Threeridge is precluded

We consider the Lower Flint, Lower Chipola, and Chipola NDL analysis units to also have high water quantity condition, though potential impacts compared to other analysis units were noted. We acknowledge that these analysis units within smaller rivers are a part of the historical range of the species and it is likely that the species has adapted behaviorally or physiologically to the local conditions. Based on the relatively consistency in median low flows during the summer and high flows in the spring within both the historical and current time period, we considered all analysis units to be in **High** condition with few water quantity issues.

4.2.6 Current Resiliency

To summarize the current condition of Fat Threeridge analysis units, we combined all of the resiliency factors to generate an overall resiliency score. The current condition category is a qualitative estimate based on the analysis of the three population factors (abundance, evidence of recruitment, occupation) and two habitat factors (water quality and water quantity). Each analysis units was ranked as currently being in high, moderate, low or very low condition for each of the resiliency factors. These categories were then converted to the numerical ranks of 4,3,2, and 1, respectively. The presence of a null (Ø) condition would carry over as the overall resiliency score given the lack of a population; however no analysis units analyzed are currently extirpated. The average of the factor ranks was then used to generate an overall resiliency; we considered using a weighted average with population factors valued twice as much as habitat factors, but this did not result in different resiliency score for any analysis unit. Resiliency ranks were rounded down for values < 0.5, as a conservative measure. Resiliency was converted from the weighted average condition rank as follows:

- Very Low (1);
- Low Resiliency (2);
- Moderate Resilience (3);
- and High Resilience (4).

The gradient from low to high resiliency represents an increasing ability to persist in the face of stochastic natural and man-made conditions and events. Generally speaking, analysis units with high resiliency were considered to have resiliency, with moderate resiliency analysis units exhibiting some impairments but appearing resilient at present. Low or very low resiliency analysis units do not display resiliency.

The Middle Apalachicola, Lower Apalachicola, and Lower Chipola have **High Resiliency**, while the Lower Flint, Upper Apalachicola and Chipola NDL have **Moderate Resiliency**. Summaries of the six analysis units and their overall resiliency are provided in Table 4-10.

Table 4-10. Fat Threeridge resiliency factors and overall resiliency.

		Population	**Factors**	**Habitat**	**Factors**	
Analysis Unit	**Abundance**	**Evidence of Recruitment**	**Occupation**	**Water Quality**	**Water Quantity**	**Overall Resiliency**
Lower Flint	Low	High	High	Low	High	Moderate
Upper Apalachicola	Moderate	High	Low	Moderate	High	Moderate
Middle Apalachicola	High	High	High	High	High	High
Lower Apalachicola	Moderate	High	Moderate	High	High	High
Lower Chipola	High	High	High	Moderate	High	High
Chipola NDL	Low	High	High	Moderate	High	Moderate

Three analysis units for the Fat Threeridge exhibit resiliency at this time, and three analysis units (Lower Flint, Upper Apalachicola, and Chipola NDL) have moderate resiliency. The Chipola and Flint are at the outer margins of the species range, which may explain low abundance and density as habitat here is inherently is limited or marginal. Urban development and agricultural land use may also be limiting abundance in the Chipola NDL and Lower Flint, respectively. Continued surveying would provide more confidence in the abundance of mussels in these units as well as population trends. Both the Upper and Lower Apalachicola exhibited similar abundance and density estimates, however the occupation of suitable habitat within the Upper Apalachicola is low. Low occupancy in the Upper Apalachicola may be caused by the downstream effects of JWLD on substrate stability, as well as inherent substrate instability associated with the fairly straight channel compared to more sinuous reaches downstream (Kaeser et al. 2019, p. 667). The establishment of Fat Threeridge may be hindered by the relative risks to water quality derived from agricultural land use in some analysis units.

The construction of JWLD and maintenance of navigation channel through dredging and snagging over a 40-year period (1957-1998) may have significantly impacted Fat Threeridge viability. However, since that time, which saw both a reduction in dredging and an increase in survey efforts and techniques, current information supports that the species has persisted through local landscape modifications (predominantly agricultural), as well as through historical and contemporary droughts and floods.

4.3 Redundancy

For the species to be viable, there must be adequate redundancy (suitable number, distribution, and connectivity of populations to allow the species to withstand catastrophic events). Redundancy improves with increasing numbers of populations distributed across the species range, and connectivity (either natural or human-facilitated) that allows connected populations to "rescue" each other after catastrophes. We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. High redundancy for Fat Threeridge could occur when all analysis units display resiliency and these are spread across the species range, moderate as the majority but not all units are resilient, low as two to three resilient analysis units are present, with very low redundancy occurring if these two-three resilient units are not present within the species core range (Middle Apalachicola and Lower Chipola units) or only one unit in the core is resilient.

Our historical reference condition for the species is one of high connectivity. The core of the range within the Middle Apalachicola and Lower Chipola analysis units remains well connected, but linearly distributed (Figure 4-5). Between the four well-studied analysis units (Upper, Middle, and Lower Apalachicola, and Lower Chipola), an estimated 93.5% of the Fat threeridge population is located in the Middle Apalachicola and Lower Chipola analysis units (Kaeser et al. 2019, p. 667). Given their moderate resiliency largely driven by low abundance, the peripheral analysis units (E.g. Chipola NDL, Lower Flint) are unlikely to serve well as refugia or source populations for recolonization should the species experience one or more catastrophic events resulting in extirpation of the core range. In general, it is more likely that the peripheral analysis units would require immigration from the core range following a catastrophic event. The creation of Lake Seminole inundated historical records in the Lower Flint sub-basin. There are no longer Fat Threeridge located upstream of the Lower Flint that could act as a source population, and the Lower Flint is isolated from the core by an impoundment. The Chipola NDL is less isolated by distance from the core range and an impoundment no longer restricts the potential for recolonization or demographic rescue from the highly populated core of the species range, though the traversal of Dead Lakes may still present a higher risk of predation or low dissolved oxygen for host fishes.

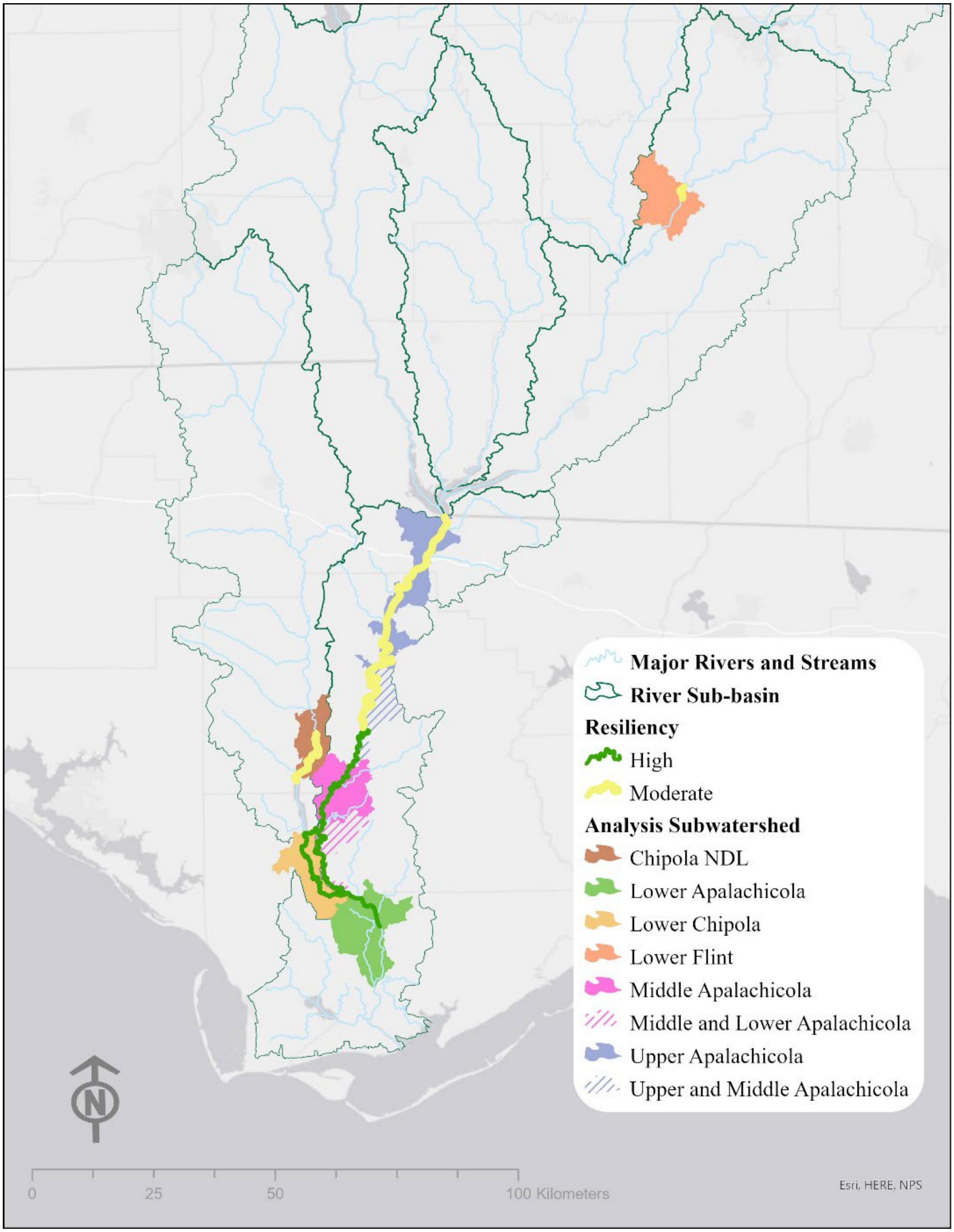


Figure 4-5. Current resiliency of Fat Threeridge analysis units, with subwatershed units for context.

Localized upstream catastrophic impacts like chemical spills in one analysis unit are unlikely to cause the extinction of the entire species. An extensive linear path provides dilution for toxic effects or the flows and sedimentation from a dam failure, lessoning impacts further from the source. Fat Threeridge in the four linearly connected analysis units are widespread and abundant and unlikely to be extirpated by such events (Kaeser pers. comm. 2020). The small, and more isolated analysis units existing at Newton GA in the Flint River, and Chipola River above Dead Lakes might be susceptible to a catastrophic event like a contaminants spill based on their low abundance and limited distribution. Extreme drought in the ACF Basin is unlikely to result in species decline independently, but could function in concert with other factors such as agricultural water use to reduce redundancy in areas such as the Lower Flint.

Redundancy for the Fat Threeridge can be described as moderate to high. All units in the species range displaying resiliency at present, meaning they are meaningfully contributing to redundancy for the species. Redundancy for Fat Threeridge is limited by its relatively narrow-range and linear arrangement of populations; however the species has largely maintained its historical distribution (~75%; USFWS 2016, p. 119) and connectivity. It has not experienced substantial contraction or disruption of connectivity within of the range, and the range has a relatively well-connected core that corresponds to relatively low risk of extirpation from catastrophic events.

4.4 Representation

Representation refers to the genetic and environmental diversity within and among populations that contributes to the ability of the species to respond and adapt to changing environmental conditions over time. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. 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. The available genetic data for Fat Threeridge suggests little variation (e.g., one representative unit). This is supported by the absence of notable behavioral, morphological or life history variation. This would suggest variation within the species is low and by extension so is representation.

However, it is possible that genetic differences exist among the analysis units for Fat Threeridge, and we can examine this possibility through a discussion of the degree of ecological diversity occupied by Fat Threeridge. Traits that allow persistence in a range of geographic or environmental conditions make long term persistence more likely. Maintaining populations (or analysis units) that display resiliency across the range of variation within the species will increase the amount of variation within the species on which natural selection can act, increasing representation and the chance that the species will persist in a changing world. In this context, representation for the Fat Threeridge can be described as moderate and is discussed below.

4.3.1 Rivers

It is possible that the Chipola and Flint River represent a small river “type” for the species. Fat Threeridge was documented present in all three major rivers during 2000-2019 in which it was present historically (Flint, Apalachicola, and Chipola; see Chapter 3). It was last collected in the Flint River in 2011 (but observed in 2019); in the Apalachicola River in 2019; and in the Chipola River in 2018. The analysis units in these rivers are resilient at present. In this context, Fat Threeridge representation could be considered moderate (e.g., more than one representative unit).

4.3.2 Longitudinal

Longitudinal variation in the ACF Basin occurs along the entirety of the basin, and represents changes that may be important to freshwater mussels including changes in local climate and weather, and changes in geology and hydrology which we represent in this SSA by looking at ecoregions (and corresponding aquifers) (Figure 4-6). There are two level three ecoregions occupied by the species, and both of these contain resilient analysis units. Representation in the Southeastern Plains and the Southern Coastal Plain is intact. In this context, Fat Threeridge representation could be considered moderate (e.g., more than one representative unit).

The Lower Flint analysis unit occurs at Newton, Georgia in the Flint Basin within the Dougherty Plain of the Southeastern Plains ecoregion, which is an area where the Floridan aquifer is accessible and used heavily for irrigation. The Upper Apalachicola is also located within the same ecoregion, but only partially within the same aquifer where agricultural pressures are not as great. Both the Lower Flint and Upper Apalachicola analysis units are resilient, providing representation for the Southeastern Plains. The ecological and hydrological setting of areas occupied by Fat Threeridge within the Chipola and Apalachicola rivers are similar, both occurring within the Floodplains and Low Terraces of the Southern Coastal Plain and underlain by surficial aquifers.

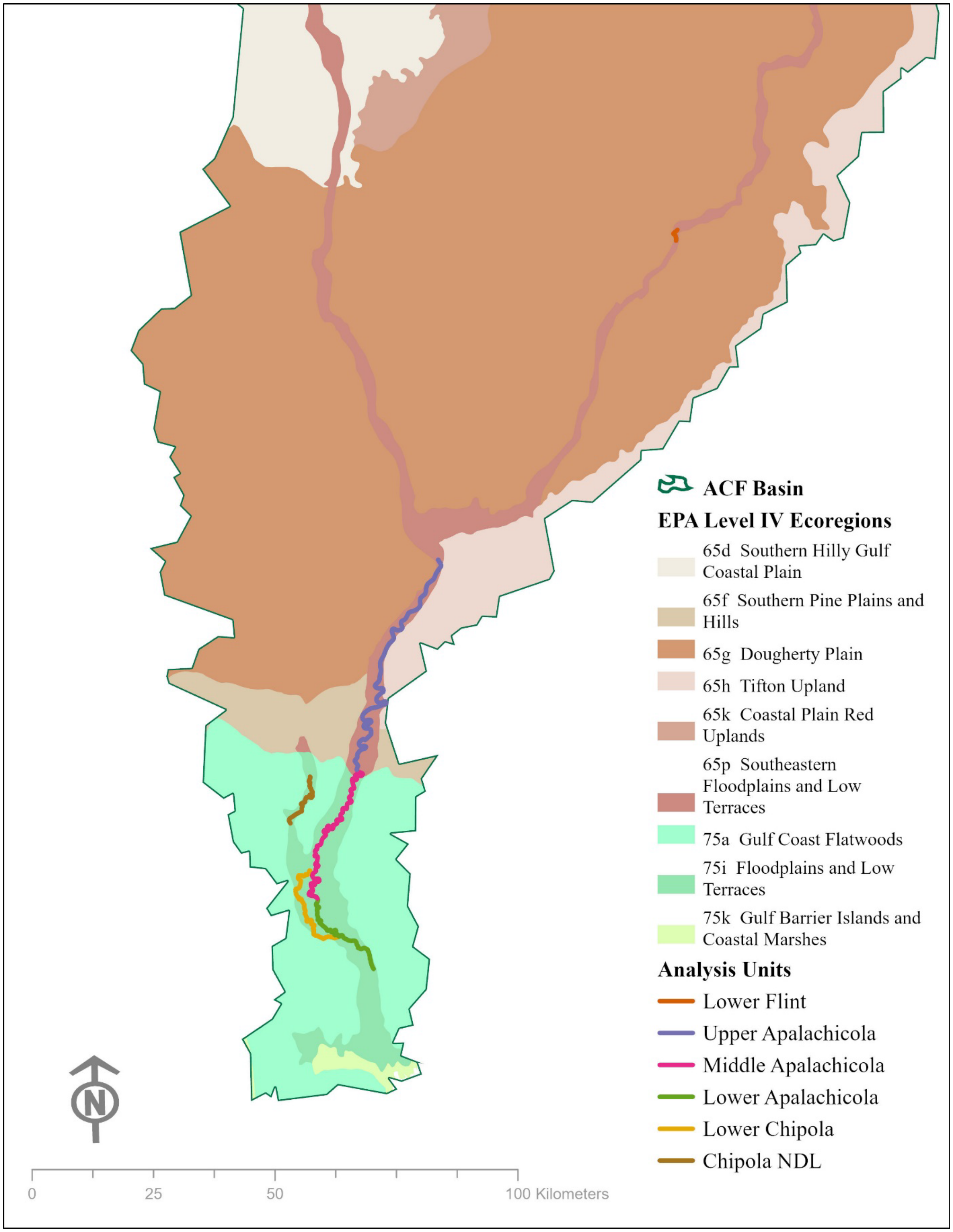


Figure 4-6. Ecoregions of the ACF Basin for consideration of Fat Threeridge representation. Ecoregions influence both hydrology and land/water uses.

4.5 Summary

We describe the species viability based on our analysis of the “three Rs” (Resiliency, Redundancy and Representation) in this section. Fat Threeridge exhibits resiliency throughout its limited range. The moderate resiliency among three (Lower Flint, Chipola NDL, Upper Apalachicola) of the six analysis units suggests some variation in resiliency though all units are considered to display resiliency in general. Abundance is a limiting factor for the Lower Flint River and Chipola NDL. While the Upper Apalachicola Unit contains many more individuals, they are spread over a much greater proportion of suitable habitat resulting in low occupation. Our water quality assessment using the landcover surrogates of agricultural and urban land cover indicated the highest relative risk to Fat Threeridge occurs in watersheds of these analysis units, presenting challenges for resiliency regardless of well vegetated riparian buffer zones.

Redundancy is moderate to high, and representation is moderate to low. The species has not experienced substantial contraction or disruption of connectivity within of the range, and the range has a relatively well-connected core that corresponds to relatively low risk of extirpation from catastrophic events conferring moderate to high redundancy. The abundance of the species in the core of its range helps offset concerns related to linear distribution. Representation may be low according to genetic variation, but ecological diversity (presence in differing river “types” and ecoregions) may indicate representation is moderate. Given the importance of the Lower Flint for River analysis unit is for redundancy and representation, updated surveying to verify the condition of this population as well as any other potentially occupied habitat within the Flint River (e.g., Upper Flint) would be needed to verify the resiliency of this analysis unit and how that relates to redundancy and representation for the species.

CHAPTER 5 – FACTORS INFLUENCING VIABILITY

In this chapter, we provide information on the negative and positive influences on viability of Fat Threeridge that may have influenced current condition of the species, and/or affect the species viability into the future. We define “threat” as any action or condition that is known to or is reasonably likely to negatively affect individuals of a species. This includes those actions or conditions that have a direct impact on individuals, as well as those that affect individuals through alteration of their habitat or required resources.

Depending on the context, we will use the term “threat” as a general term to describe —either together or separately—the source of the action or condition that negatively affects the species (e.g., agricultural activities, urbanization) or the action or condition itself, which includes direct impacts (e.g., exploitation) and stressors (e.g., water quality or quantity decreases). Generally, we define the term stressor as any physical, chemical, or biological alteration of the environment that can lead to an adverse individual response, and the term direct impacts as those things that directly negatively affect individuals of the species (e.g., harm or death).

Features identified as important habitat components for the listed ACF mussels include: geomorphically stable stream channels; predominantly sand, gravel, or cobble stream substrate; permanently flowing water; water quality that meets or exceeds aquatic life criteria established under the Clean Water Act (33 U.S.C §§ 1251 et seq.), and; presence of appropriate fish hosts. Factors affecting these features can limit the potential viability of Fat Threeridge. These features are, in many cases linked, so although they are described as individual factors, it is important to note that they often act synergistically in the aquatic environment. For example, development (urban or agricultural) can impact multiple ecological needs, and these needs can also influence each other (natural flow influences stable habitat, which influences suitable substrate). We present a simplified influence diagram in Figure 5-1.

Current threats to Fat Threeridge include the destruction, modification, or curtailment of the species habitat or range. Exploitation was also considered a threat at the time of listing (63 FR 12664). We summarize primary threats within a discussion of habitat degradation or loss, river regulation, water quality impacts, changing climate, and non-native species. Habitat degradation or loss has occurred from river regulation including altered flow regimes, dams and impoundments, and navigational dredging. While these habitat alterations may have significant, they predominantly occurred in the past; we discuss their residual effects and any abatement that has occurred. Water quality is also threatened by the pollutants associated with agriculture and urbanization; these influences may become more pronounced into the future, with the addition of emerging threats such as sea level rise.

Other potential negative influences considered during listing but not assessed to be threats to Fat Threeridge are mentioned below. Diseases, parasites and predation were not considred significant for this species (63 FR 12664; USFWS 2003, p. 84-85). Although considered at the time of listing, it was later thought that Fat Threeridge had likely never been exploited for pearling, pearl buttons, cultured pearls, or any other exploitative activity (USFWS 2003, p. 51-52) and this factor is not explored further here. As a host generalist, the availability of appropriate hosts is not likely to be a limiting factor for Fat Threeridge. We discuss the potential impacts of and competition with invasive species, but this factor is not considered a significant threat at present. Deadhead logging removes woody debris from a river channel, potentially disrupting stability in the project area and increasing sedimentation downstream (Kaeser and Litts 2008, entire). This activity has increased in Florida subsequent to the expiration of a moratorium in 2000. A discussion of the protection provided to mussels during deadhead logging is provided in Section 5.3.3, but this activity is regulated and not considered a significant threat to the species.

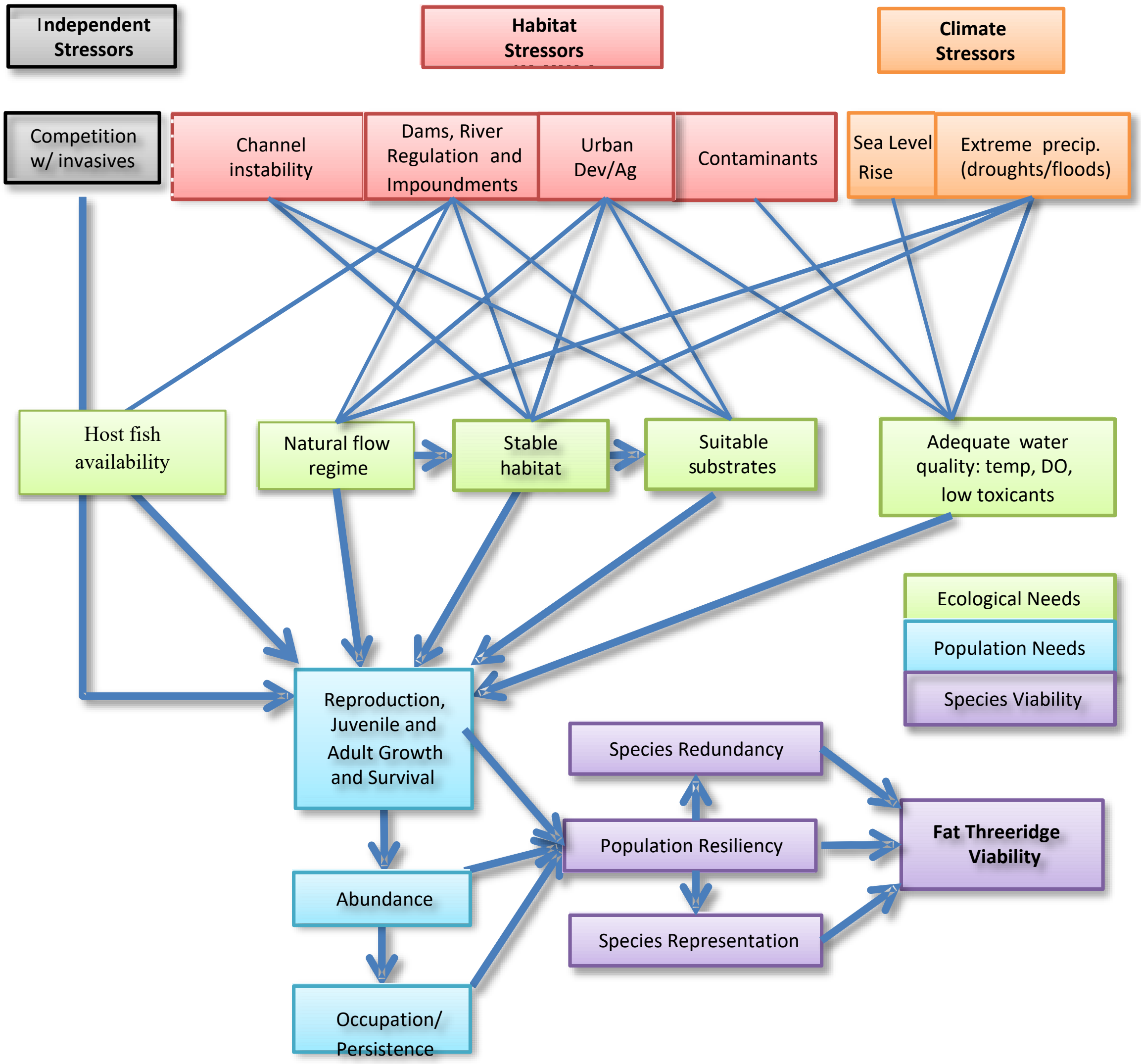


Figure 5-1. Influence diagram for Fat Threeridge, depicting threats, ecological needs, and demographic needs.

5.1 Habitat Degradation or Loss

The collapse of the mussel fauna, including Fat Threeridge, at the time of listing was the result of habitat loss from anthropogenic degradation (USFWS 2003, p. 52). Principle causes include dams and dredging that have altered habitat that are essential to the long-term viability of many riverine mussel populations. Agricultural and urban development and their impacts on water quality are also a factor in the decline (63 FR 12664).

5.1.1 River Regulation

Riverine ecologists have recognized that alterations in flow regime creates variable physical and chemical conditions that limit the distribution and abundance of riverine species. Altering natural long-term patterns of flow changes the structure, composition, and function of riverine communities; the accumulated research on the relationship between hydrologic variability and riverine ecological integrity overwhelmingly support a ‘‘natural flow paradigm,’’ that is, the patterns of variability in a river’s natural flow regime are critical in sustaining its ecological integrity (Poff et al. 1997, p. 770; Richter et al. 1997, p. 243). The paradigm has been useful for informing the recovery planning for freshwater mussels (Parasiewicz et al. 2017, entire). In this section we discuss various threats to Fat Threeridge that pertain to alterations of the natural flow regime as well as direct physical alterations to the aquatic environment. Some historical threats are persistent in some aspects (dams) or have ceased (dredging and snag removal). The alteration of the flow regime within the range of Fat threeridge and signs of recovery are discussed in light of these largely historical impacts.

5.1.1.1 Dams and Impoundments

Before construction of the dams, aquatic communities were structured by water quality and physical habitat conditions driven by the geography and climate described in the previous sections. The construction of the reservoir system significantly altered both the water quality and physical environment of the Apalachicola River. Protection of aquatic resources was generally not a consideration for many types of river projects at that time because flood control, navigation, and low-cost hydroelectric power for economic stimulation were more highly valued. Neves et al (1997, entire) reviewed the specific effects of impoundments on freshwater mussels and attributed the loss of diversity and abundance to habitat changes caused by impoundments. Upstream effects include changes from flowing water to still water habitats, increased depths and sedimentation, decreased dissolved oxygen, and changes in fish communities that can affect mussel reproductive success by separating host fish from mussel populations (Neves et al. 1997, p. 63). Downstream of dams there are alterations in flow regime, scouring, seasonal dissolved oxygen dips, reduced water temperatures, and changes in fish community structure (Neves et al. 1997, p. 63). Improperly constructed fish passages and road crossings can increase scouring or prevent fish migration within smaller streams. Habitat fragmentation and degradation of lotic (flowing water) habitats in the time period since widespread dam construction is a primary factor that has contributed to loss of mussel diversity and extinction of species (Haag and Williams 2014, p. 47-48).

There are 16 main stem impoundments in the ACF Basin that were constructed between 1834 and 1975 (Brim Box and Williams 2000, p. 4). Iterations of the River and Harbors Act (1874, 1945 and 1946) provided for navigation alterations and the construction of locks, dams, and reservoirs by USACE as part of a general plan to provide system-wide benefits for multiple purposes including navigation, flood control (flood risk management), hydropower generation, water supply, water quality, recreation, and fish and wildlife conservation. Approximately 177 km (110 mi) of main stem riverine habitat in the Flint River have been permanently altered by two reservoirs. The Jim Woodruff Lock and Dam (JWLD) at the confluence of the Flint and Chattahoochee Rivers creates Lake Seminole and affects the Apalachicola River. The lowermost portion of numerous other tributaries are also permanently flooded throughout these reservoirs. Smaller impoundments on other streams (e.g., Dead Lakes on the Chipola River) may have also been detrimental to mussels (Watters 1996, entire). Although the dam was removed in 1987, Dead Lakes continues to be highly sedimented and is limited to silt tolerant species.

Reservoir operations in the ACF Basin and water consumption demands described above likely resulted in the following impacts to the aquatic system (USFWS 2016*b*, p. 44). The consequences of some these alterations will be discussed in other sections of this SSA report (e.g., Water Quality):

- conversion of riverine habitat to reservoir pool habitat;
- loss of riverine habitat and associated species;
- conversion of floodplain to reservoir pool;
- loss of seasonal floodplain habitat and associated species;
- fragmentation of riverine sections;
- disruption of fish migrations;
- seasonal fluctuations of pool levels;
- seasonal drying of habitat which reduces abundance and diversity of species;
- strong stratification (layering) of temperature for certain dam types and change in thermal regime for the main channel rivers;
- stress or mortality of organisms or sensitive life stages;
- seasonal dissolved oxygen depletion in temperature stratified water;
- ammonia release created by presence of dissolved oxygen-depleted water;
- disruption of stream transport of sediment;
- trapping of sediment that would otherwise move as bed load through the system;
- altered channel morphology;
- capture of toxic substances associated with substrate;
- toxic substances release created by presence of dissolved oxygen-depleted water; and
- enrichment of nutrients (eutrophication) with consequent increases in productivity, plant and algae growth, and changes in habitat quality and associated species.

The most consequential direct effects to Fat Threeridge from impoundments include upstream and downstream flow effects as well as the loss of and fragmentation of riverine habitat. Disruption of sediment transport and trapping of sediment at JWLD has disproportionate effects on the Upper Apalachicola given its proximity to the dam, resulting in incision (see Section 5.1.1.3) and coarsening of the bed which would eliminate the preferred habitat for Fat Threeridge in the vicinity of the outflow. Two pre-dam collections in the Lower Flint River were inundated when Lake Seminole was impounded, and Lake Blackshear now marks the southern extent of suitable habitat for Fat Threeridge in the Upper Flint sub-basin but may have formerly also been occupied. Impoundments, as barriers to dispersal, contribute to losses of local subpopulations by blocking recolonization (Luttrell et al. 1999, p. 986). We are uncertain the extent to which these barriers may limit host fish movement or affect dispersal/colonization capabilities of Fat Threeridge, however, it is worth noting that the sub-basins that appear to contain the core of the species range (Apalachicola and Chipola rivers; Kaeser 2019, p. 669) are largely undammed. Suitable habitat is fragmented by both distance from other habitat and the dams on the Flint River. In the case of mussels, fragmentation can limit host fish movement which, in turn, may impact mussel distributions. Lee and DeAngelis (1997, pp. 176) modeled the dispersal of unionid mussels into unoccupied habitats as a traveling wave front with a velocity ranging from 0.87 to 2.47 km/year. Upstream dispersal of host fish could transport mussel larvae (glochidia) over long distances (e.g., > 10 km; NatureServe 2020) through unsuitable habitat, but it is unlikely that this occurs often.

More isolated units such as the Lower Flint may have relied on long distance dispersal by highly migratory host species, such as the striped bass to maintain viability. Possible impacts of genetic isolation from these barriers is unknown, but the immigration of nearby individuals can rescue a population from extinction by either increasing its size or increasing population fitness (Hufbauer et al., 2015, p. 10557). Provisions for conservation locking at JWLD during March-May are in place to promote fish passage (USACE 2017, p. 8-4); however migratory hosts are still limited in their ability to move throughout the system, and their numbers are probably much lower than they were historically, now maintained by hatchery stock fish. The restriction of long distance dispersal may be why current sampling has failed to detect the species in these tail regions of its historic distribution (e.g., Upper Flint). Fat Threeridge was historically patchy and isolated in the Flint River, perhaps as a result of the lack of available habitat and the mechanisms for dispersal leading to the development of satellite populations (i.e., migratory host seeding), and now with increased fragmentation we have observed what appears to be the fade out of satellite populations (e.g., Upper Flint).

River regulation can have direct impacts on freshwater mussels and their host fish. Reduced flows can lead to stranding, low dissolved oxygen, higher contaminant concentrations in pools, and reduced reproductive success. The timing and rates of discharges from dams may interrupt the ability of the host fish to become infected with glochidia, and the settlement of the juvenile mussels once released. Host fish may rely on the connection with the floodplain for spawning, rearing, foraging and sheltering (Walsh et al. 2006, p. 12-35). This floodplain connection may also have individual and population level effects for mussels via supply food sources (e.g., phytoplankton, fine particulate organic matter, bacteria) to the system. During low flow periods this connection can be diminished. The JWLD regulates the water draw-down rate and minimum flows in the Apalachicola river at 5,000 cfs, which benefits Fat Threeridge, except when drought operations are triggered that provide for minimum-flow support of 4,500 cfs. Water control at JWLD was deemed to have a negative, but not appreciable, impact on the survival and recovery of the Fat Threeridge due to mortality and other adverse effects if flows are reduced to 4,500 cfs, and if flows inundate the floodplain for less than 30 consecutive days between March and August thereby reducing recruitment (USFWS 2016, p. 188). An extensive review of potential flow effects to Fat Threeridge can be found in the Biological Opinion (USFWS 2016, pp. 179-182).

The effects of dam or impoundments can persist following their removal. The following description of the condition of Dead Lake following dam removal is from Hill et al. 1994 (p. 515, 518, 521 - 522). The immediate positive benefits of dam removal were associated with the return of periodic low water levels that facilitated habitat improvements for aquatic life (e.g., substrate compaction and stability, oxidation of bottom sediments). However, Dead Lakes currently provides habitat only for silt tolerant species (USFWS 2003, p. 32) and does not provide habitat for Fat Threeridge though collections have been made at the northern and southern boundaries of the lakes in both in the past and present.

While, Fat Threeridge has not been found to persist in impounded waters, and generally speaking, additional barriers and impoundments in areas where Fat Threeridge would alter connectivity and flow in ways likely to be detrimental to the species future dams in the system appear unlikely. The state of Georgia commissioned a report outlining the future water supply needs of the state, which identified several possible sites for potential development of water supply reservoirs in the upper Chattahoochee and Flint River systems (MACTEC Engineering and Consulting 2008, entire). However, no additional dams have been built since 1975, and additional dams are unlikely to be constructed given the presence of multiple federally protected species in the ACF Basin.

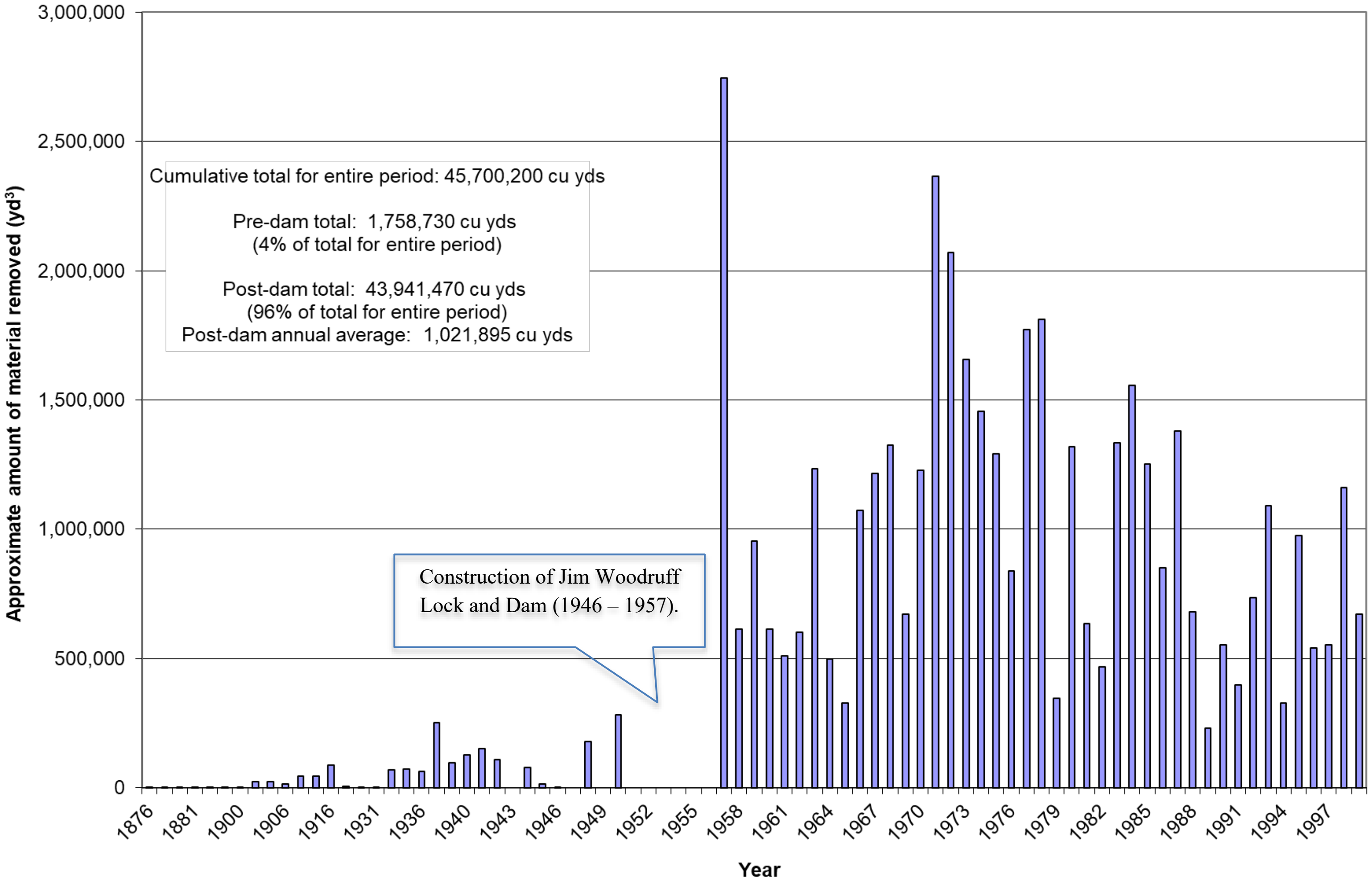
5.1.1.2 Dredging and Snag Removal

Channelization affects a stream's physical (e.g., erosion rates, depth, habitat diversity, geomorphic stability, riparian canopy) and biological (e.g., species composition and abundance, biomass, growth rates) characteristics. Channel maintenance may also result in downstream impacts, such as increases in turbidity and sedimentation, which may smother benthic organisms. Dredging occurred within the range of Fat Threeridge prior to 2001. A navigation channel exists on the Apalachicola River for 172 km (107 mi) between the Gulf Intracoastal Waterway and Jim

Woodruff Lock and Dam, however navigation is now maintained via flow releases and not through dredging. In the Flint River, a navigational channel is present 45 km (28 mi) up the Flint River to Bainbridge, Georgia, which is downriver of the Lower Flint River Fat Threeridge population. Dredging has occurred within the Lower Chipola mostly within the Chipola Cutoff, but not within the Chipola NDL or Flint River where Fat Threeridge occur.

Though some dredging and snag removal has occurred in the Lower Chipola River in the past, conditions appear highly suitable for Fat Threeridge. The last stream bottom disturbance and snag removal activities occurred in 1987 and 1990, respectively (Hoen and Leitman 2001). Fat Threeridge is highly abundant in the area, likely due to extensive submerged wood; aggregations over 100 m (328 ft) in length are common (Smit and Kaeser 2016, p. 11). However, depending on the density of wood, these areas can be difficult or impossible to safely and accurately sample during dive surveys.

A record of navigation improvements on the Apalachicola River from 1828 to 2000 was compiled by Hoehn and Leitman in 2001. Where information regarding dredging was available, it was compiled in to Figure 5-2. Early efforts at channel modification were not as intensive as those following the River and Harbors Act of 1945 and 1946 and completion of JWLD. A navigation project was initiated, which endeavored to maintain a 2.7 m (9 ft) deep and 30.5 m (100 ft) wide channel from the Gulf of Mexico to Columbus, Georgia, on the Chattahoochee River. Actions required to achieve this navigation depth required more dredging in some locations than others, which was ultimately untenable; ultimately, dredging, disposal, and snag removal was curtailed with the Restore the Apalachicola River Ecosystem (RARE) Act of 2002 (Mossa et al. 2017, p. 122). The navigation channel on the Apalachicola River was last dredged in 2001. The last complete cycle of dredging occurred in 1998; in 1999, dredging was discontinued. A 7.0 foot navigation channel is now maintained via water release from January to April, with possible extension into May (USACE 2017, p. 3-8). The project is not de-authorized, but dredging is deferred indefinitely because of the denial of a section 401 water quality certificate from the State of Florida. In addition, USACE designated the project as low use in 2005, which greatly reduces the likelihood of receiving funding for maintenance dredging (USACE 2017, p. 7-20). It is unlikely that dredging or snag removal will re-occur in a manner impacting Fat Threeridge viability presently or in the future.



Cumulative total for entire period: 45,700,200 cu yds

Pre-dam total: 1,758,730 cu yds
(4% of total for entire period)

Post-dam total: 43,941,470 cu yds
(96% of total for entire period)
Post-dam annual average: 1,021,895 cu yds

Construction of Jim Woodruff Lock and Dam (1946 – 1957).

Figure 5-2. Apalachicola River dredging, 1876 to 1999 (derived from Hoehn and Leitman 2001).

5.1.1.3 Altered Flow Regime

In the past, the morphology of the Apalachicola River was altered by upstream impoundments, channel alterations such as the construction of dike fields, meander cutoffs, and channel dredging and snagging operations, in addition to land use changes, consumptive use of water, and tectonic movement (Hupp 2000, p. 3, Light et al. 2006, p. entire, Price et al. 2006, p. x). The channel morphology has changed relative to the pre-dam period in the Apalachicola River. The Apalachicola River has not followed the normal pattern of lateral migration in which erosion and deposition are balanced so that the channel maintains a relatively constant width and bed elevation (Light et al. 2006, pp. 48-49). The probable cause of the channel morphology changes is sediment sequestration in the reservoirs and changes in flow regime (sediment transport patterns) following construction of dams (US FWS 2016, p. 45), and the removal of sediment and stabilizing features during dredging and snag removal (Mossa 2020, p. 3).

In the past 50 years during dredging, many portions of the Apalachicola have substantially declined in elevation (incised) and/or become substantially wider. However, the rate of change has slowed, and appears to have entered a somewhat dynamic equilibrium condition (USFWS 2012, p. 37), though an exact determination as to stability or degradation of the channel based upon discharge measurements cannot be made (USFWS 2016, p. 46). Mean bed elevation declined to some degree from 1960 to 2001 at 42 of 51 cross sections measured by the USACE throughout the nontidal portion of the Apalachicola River (Price et al. 2006, entire). This decline is greatest in the upper river (> RM 77.5) directly downstream of JWLD, and where the proportion of habitat occupied by Fat Threeridge is lowest. During the period 1954 to 2004, the stage equivalent to 10,000 cfs declined 4.8 ft. During the period 1960 to 2001, in the upper 41 miles of the river, mean bed elevation declined an average of 2.2 ft at 26 cross sections measured in this reach. Channel width, measured as the distance between the treeline of opposite banks on aerial photography, has significantly increased between 2004 and 1941. The mean increase in width of the Upper Apalachicola River has been 77 ft. Relative increases were greater going downstream, with widening increasing by 143 ft in the Middle Apalachicola and 171 feet in the Lower Apalachicola. Most of the widening occurred between 1959 and 1979, and appears to have stabilized between 1979 and 1999, with the exception of some minor widening in the Middle and Lower Apalachicola that continued between 1999 and 2004 and warrants continued monitoring (Price et al. 2006, entire; USFWS 2016, p. 45). The trend towards stabilization is a positive influence for Fat Threeridge viability, given the species is characterized as an equilibrium life history strategist best benefitted by stable environmental conditions.

Recent assessments of sandbar aerial extent suggests recovery from dredging has begun within the Apalachicola River. The Middle Apalachicola River contained small sand bars prior to dredging that enlarged during the navigation project. The small sand bar area prior to intensive dredging for navigational purposes reflected comparatively less disturbance and minimal bank erosion. The combination of dredging, within-channel (sandbar, bank) and floodplain spoil deposition, and snag removal created extensive disturbance in the system. Resulting from this legacy of disturbance, the total sand bar area became much larger through time. A prior comparison of the 27 largest sand bars on aerial photos from 1941 and 2004, acquired at ~380 m^3s-1 or the 40th flow percentile, found that dredging impacts caused sand bar areas to grow from 8.8 to 35.2 ha, a gain of 27.6 ha (Mossa et al., 2017, p. 128). Subsequently, Mossa et al. 2020 (pp. 9 – 10) completed a more recent 30th percentile comparison to examine sandbar extent during a period without the aforementioned disturbances. The period 2005–2015 exhibited a sandbar reduction from 37.4 to 32.7 ha, a 4.7 ha loss, while the paired 2007– 2016 comparison of sand bar area decreased from 76.3 to 71.0 ha, a net loss of 5.3 ha. While differing slightly due to starting and ending years and flow levels, both pairs confirm the decreasing area of bars attributed to vegetation growth. Mossa et al. 2020 (p. 11) caution that knowledge about the temporal extent of river ecosystem recovery from degradation is still limited, and that the ~10-year period of analysis post-dredging likely documents the early stages of recovery within the Middle Apalachicola River. While in some cases spoil piles are eroding back into the channel, many of the sand bars are expected to decrease in size through colonization by vegetation into the future (Mossa et al. 2017, p. 133). Sand bars are poor habitats for mussels in general, with willow a good indicator of the extent of IRZ and ORZ mesohabitats occupied by Fat Threeridge. A reduction in sand bar area and increases in vegetation, especially woody vegetation in the form of early successional willow stands, is likely a trend in the positive direction for Fat Threeridge viability.

Fat Threeridge within the Lower Flint occur far enough downstream of the Albany dam to be in habitat that is not influenced by scouring effects of the Albany dam. Sand constituted an increasing proportion of channel substrate with increasing distance from the dam (Kaeser et al. 2013, p. 642), limiting habitat suitability for Fat Threeridge directly downstream. Sandy banks are present where Fat Threeridge are encountered in the Lower Flint and are absent directly upstream and downstream given the presence of limestone bluffs and coarse shoals, respectively (Kaeser et al. 2013, p. 642). It is believed that suitable habitat for Fat Threeridge is naturally restricted within the Lower Flint, and Fat Threeridge was patchy and more isolated within the Flint River prior to the installation of dams.

5.1.2 Agricultural Activities

Agricultural activity can influence water quality, channel geomorphology, substrate suitability, and water quantity. While not all agricultural activities result in negative effects to freshwater mussels, the direct and secondary effects are well documented. Water pollutants associated with runoff from agricultural activity may adversely affect mussels. In the ACF Basin, agricultural contaminants include excess nutrients from poultry farms and livestock feedlots, and pesticides and fertilizers from row crop agriculture (Couch et al. 1996, p. 52; Frick et al. 1998, p. 2). Excess nitrogen and phosphorus from fertilizer and animal waste can result in harm to aquatic species through decreased dissolved oxygen levels from algal overgrowth (USEPA 2008, p. 1). Some pesticide components entering streams are highly toxic to juvenile and adult freshwater mussels (Bringolf et al. 2007*a*, p. 2092). Livestock grazing in riparian buffers can also increase runoff and erosion and alter stream hydrology (Agouridis 2005, p. 593). Light to moderate levels of siltation are common in many Apalachicolan Region streams, particularly in the Piedmont, which is known for its highly erodible soils (Couch et al. 1996, p. 7). Row-crop agriculture remains economically important in the Lower Flint basin, with the associated irrigation and sedimentation potentially impacting mussel fauna (Shea et al. 2013, p. 383, 384). However, the presence of forest buffers on unbuffered row-crop fields and pasture can reduce total stream bank soil loss by 72% and sediment from overland flow by up to 90% (Lee et al. 2003, p. 6-7; Zaimes et al. 2004, p. 26-27). Specific water quality effects on mussels are discussed in detail in Section 5.1.4.

Agriculture is the largest water user in the ACF Basin accounting for 35 percent of all water withdrawals in 2010 (Lawrence 2016, p. 29). Of the groundwater withdrawn in the ACF Basin, 89 percent was withdrawn in Georgia and about 11 percent was withdrawn in Alabama and Florida during 2010 for irrigation of approximately 736,200 acres (Lawrence 2016, p. 24). Extensive agricultural cropland areas, primarily planted in cotton, peanuts, corn, and soybeans, rely heavily on irrigation using groundwater, particularly in the Dougherty Plain. In the lower Flint River basin, an extensive conversion to center pivot irrigation systems increased groundwater withdrawals 100 percent between 1970 and 1976 (Rugel et al. 2011, p. 2). Studies in the lower Flint River suggest ~20 percent decrease in median flow levels because of irrigation during drought years (Singh et al. 2016, p. 279). As consumptive water use has steadily increased in the ACF Basin over the past several decades, reliance upon reservoirs during low-flow periods for maintaining water quality, navigation, municipal and industrial water supplies, and in-stream habitat also has increased. Effects of crop conversion to flows in agricultural areas of the ACF is unknown, but targeting future research to better understand those relationships would be beneficial. While this practice may not increase irrigated acres, commodity markets may drive changes to crops that will affect water usage nonetheless.

These groundwater withdrawals exacerbate drought conditions during dry years, which affects both tributaries and main river channels (Albertson and Torak 2002, p. 22; Mitra et al. 2016, entire). Studies in the lower Flint River suggest ~20 percent decrease in median flow levels because of irrigation during drought years (Singh et al. 2016, p. 279). The potential impacts to mussels, their host fishes, and their respective habitats from groundwater withdrawal may be profound. Lowering of the water table results in decreased stream flows, which is exacerbated by commonly aggraded stream channels. Declines in mussel populations from irrigation demands during drought were documented in tributaries of the Lower Flint River when flow became intermittent (Golladay et al. 2004, p. 494). It is unlikely that the mainstem would experience intermittent flows, but decreased flows could expose the limited habitat that is available in the Lower Flint River.

In Georgia, between 2010 and 2015 irrigators switched from surface water withdrawals to groundwater wells, which are seen as a more reliable source for irrigation. This contributed to the removal of 30,000 irrigated acres in the Flint and Chattahoochee Basins (Georgia Water Coalition 2017, p. 14). The greatest growth in irrigated acres is occurring in other parts of the state where producers are switching to groundwater wells (Georgia Water Coalition 2017, p. 14). However, the Upper and Lower Flint are expected to see a 22 percent and 16 percent increase in water use respectively by 2050 (Georgia Water Coalition 2017, p. 15). These are considered conservative estimates and reflect water used during very dry or drought conditions. The current and expected water demand for the Lower Flint-Ochlochonee water planning areas is 438 MGD (millions of gallons per day) in 2010 and 687 by 2050 (Georgia Water Coalition 2017, p.7, 16).

In Florida, Jackson County in the northern Chipola Basin is the largest agricultural region in the Northwest Florida Water Management District's (NWFWMD) area, which covers 16 counties in the Florida panhandle (NWFWMD 2018, p. 49). Currently, 60 percent of the water use in Jackson County is for agriculture (NWFMD 2018, p. 50). The total water demand for agricultural purposes within the water planning region that includes Jackson County and portions of the Chipola and Apalachicola Rivers is expected to increase by 2040, but not to exceed availability for all uses (NWFMD 2018, p. 50-51). We do not anticipate that water withdrawls within the range of Fat Threeridge will impact fat threeridge except for a relatively higher likelihood in the Lower Flint under drought conditions.

Land use in the sub-basins with Fat Threeridge present has remained relatively stable from 2000-2016 (Table 5-1). A large portion of each sub-basin is forested. The precipitation on forested lands is intercepted and prevented from quickly reaching surface water streams through infiltration and evapotranspiration processes. Forested ecosystems have high stream baseflows and low, lengthy storm peaks compared to other common land uses because of high infiltration and permeability rates. Forest cover (e.g., leaves and mulch) reduces raindrop velocities, allowing for higher infiltration, and soils have organic concentrations with higher porosities, allowing for higher permeability. During high storm flows, wetland forests, often streamside, can store large quantities of water and reduce downstream flooding impacts.

The amounts of cultivated crops and developed land have the most potential to negatively affect the water quality of Fat Threeridge in the Lower Flint where these land use types have increased most. Agricultural activity affects mussel populations through nutrient enrichment from farm fertilization and livestock production, contaminants from pesticide applications, channel instability from increased runoff, and decreased flows from water withdrawals (See Chapter 5). Agriculture is the largest water user in the ACF Basin through ground and surface water withdrawals (Lawrence 2016, p. 29). The type of withdrawal varies by region and is most detrimental in the lower Flint River basin during drought periods. Water used for crop irrigation is considered 100 percent consumptive because it is incorporated into crops or lost through evapotranspiration. Compared to forested land use, agricultural land uses produce larger storm flows during rain events because of the reduced soil cover. The runoff rates from agricultural areas are similar to the rates from low- and medium-density residential areas (USFWS 2016*b*, p. 42).

Models such as FORE-SCE (described further in Chapter 6) provide insight into potential future land use scenarios. The highest proportion and increase in anthropogenic land use has occurred in the Lower Flint Basin, during which Fat Threeridge was rediscovered in the Lower Flint, and has exhibited evidence of persistence and reproduction. However this area remains at the highest relative risk from agricultural land use.

Table 5-1. Land use categories as percent of total acres, from USGS National Land Cover Database (NLCD) 2001 and 2016, summarized by sub-basins with Fat Threeridge presence.

	2001			**2016**		
	Land Use Category (% of total)			**Land Use Category (% of total) (change from 2001)**		
Sub-basin	**Developed**	**Cultivated Crops**	**Forest Types**	**Developed**	**Cultivated Crop**	**Forest Types**
Upper Flint	8	13	50	10 (+2)	13	48 (-2)
Lower Flint	7	39	34	8 (+1)	46 (+7)	38 (+4)
Apalachicola	4	5	30	4	5	29 (-1)
Chipola	7	20	33	7	20	31 (-2)

5.1.3 Urbanization

One of the primary extinction drivers for endangered species is direct habitat losses and fragmentation from urban development. For Fat Threeridge, however, urbanization is indirectly driving many other water-related factors which are the primary threats currently, and will likely remain so in the future. The Atlanta metro region is outside of the mussel's range, but has a large ecological footprint and substantial downstream effects as the nexus of water demand in the region. The city holds substantially greater political and economic power than the rural areas to its south, where Fat Threeridge range occurs. Atlanta is considered the center of a hypothesized future "megaregion" in the Piedmont-Atlantic region extending from Birmingham, AL, to Raleigh, NC, based on expanding populations in the Southeast (
Figure 5-3; Regional Plan Association 2006, p. 11). The city of Albany, Georgia, is the most urbanized area located near a known Fat Threeridge population.

We assessed different models to evaluate how urbanization might progress in the future. Table 5-1 includes the general urbanization trend (development) within sub-basins occupied by Fat Threeridge from 2001 to 2016; urbanization has remained largely the same, with a slight increase in the Lower Flint which is occupied by Fat Threeridge currently and a greater increase in the Upper Flint where Fat Threeridge historically occurred. The SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model simulates patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks, including the sprawling, fragmented, "leapfrog" development that has been the dominant form of development in the Southeast (Terando et al. 2014, p.2). However, urbanization can be overestimated in rural landscapes with this model (e.g., areas that are not currently urbanized in 2020 are projected to have been). We also present urbanization and other land use projections from the USGS Forecasting Scenarios of land use (FORE-SCE) model. The FORE-SCE projections are spatially explicit and thematically more detailed than most comparable regional- or national-scale land-use and land-cover projections, resulting in an improved ability to inform ecological applications (Sohl, et al. 2014, p. 1033). We will utilize FORE-SCE projections in our assessment of future condition in Chapter 6.

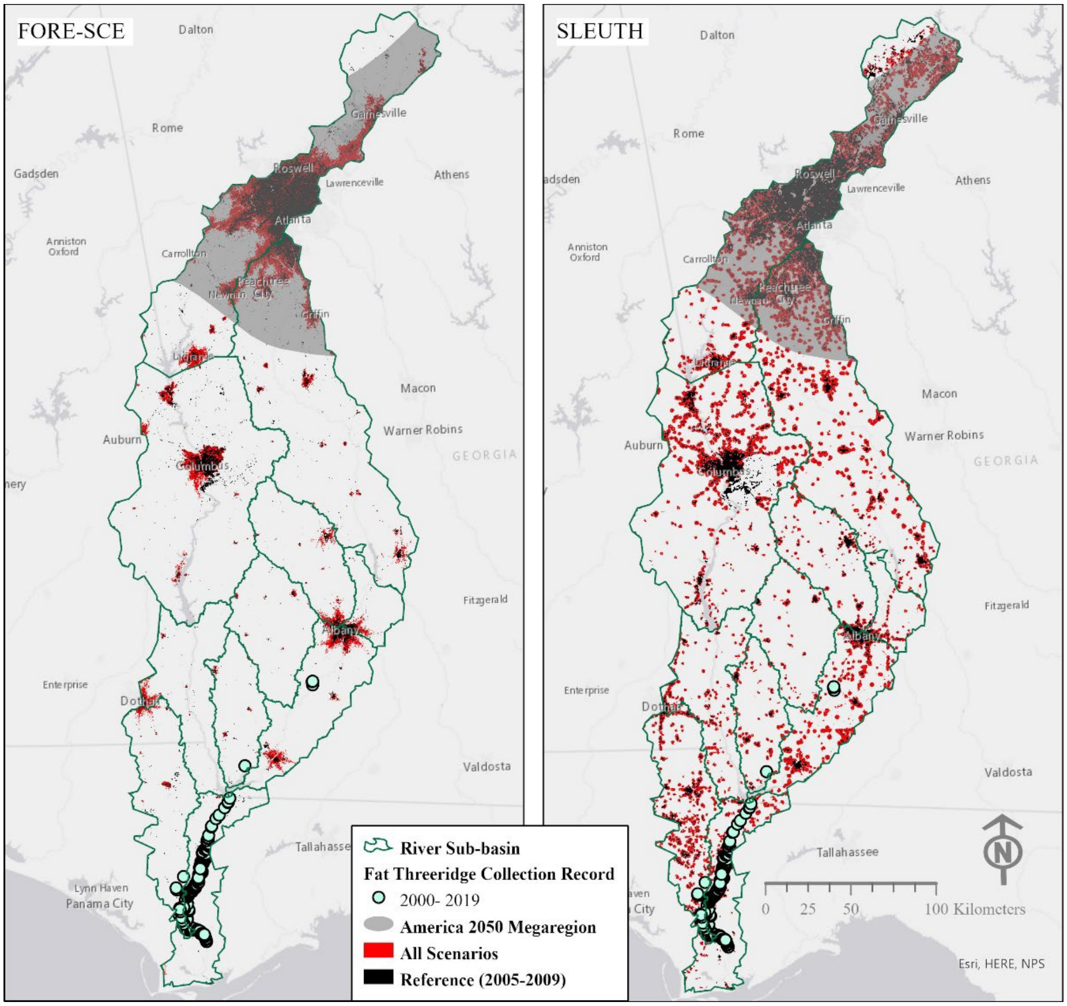


Figure 5-3. Projected future urban growth using the two models (FORE-SCE, SLEUTH) introduced in Chapter 4, which will be described in detail in Chapter 6, and the outline for the Atlanta "megaregion" by 2050. Fat Threeridge collection records since 2000 are also included.

Contamination of aquatic habitats by pesticides, excess nutrients, heavy metals, pharmaceuticals and organic pollutants is widespread in urban areas and associated with point (e.g., wastewater treatment plants) and nonpoint sources (Paul and Meyer 2001, pp. 341-346; Nobles and Zhang 2015, pp. 9 -10; 11). The widespread and pervasive extent of non-permitted, nonpoint discharges in urban systems has been posited as a key factor in the biological degradation frequently encountered in urban aquatic environments (Duda et al. 1982, pp. 1144-1145). See 5.1.4 for a discussion of the effect of specific contaminants on freshwater mussels, including ones commonly associated with urban development. Contaminants concentrations in urban areas can vary widely. For example, total nitrogen and phosphorus levels in the headwaters south of the Atlanta metro region are actually lower than some smaller urban areas to the north and rural sites near large poultry farms (Journey et al. 2018, p. 11). However, this study did not include sample sites in the agricultural areas farther south in the Fat Threeridge range, where levels of nutrient loading are likely to be quite high (e.g., Chipola NDR, Lower Flint).

Water quantity in urban areas is affected by water consumption and runoff from impervious surfaces. Impervious surfaces and other areas with reduced permeability, such as grass and barren land, can lead to high flow events from rainfall. This reduction in penetration leads to reduced groundwater recharge and thus reduced baseflows during dry periods (USACE 2016 pp. 2-13).). Most water removed from the basin for municipal and industrial water demands is returned to the basin as treated waste, but demands can alter natural channel flow.

Urban development changes sediment regimes by creating impervious surfaces and drainage system installations (Brim Box and Mossa 1999, p. 103). Stream channel erosion contributes up to two-thirds of the total sediment yield in urbanized watersheds (Trimble 1997, p. 1443). With development, watersheds become more impervious, resulting in increased storm-water runoff into streams. Impervious surfaces may reduce sediment input into streams but result in channel instability by accelerating storm-water runoff, which increases bank erosion and bed scouring (Brim Box and Mossa 1999, p. 103).

Stream channels become highly unstable as they respond to increased flows by incising, which increases shear stress and bed mobilization (Doyle et al. 2000, p. 177). Studies have indicated that high shear stress is associated with low mussel richness and abundance (Layzer and Madison 1995, p. 337; Allen & Vaughn 2010, p. 390). Impervious surfaces such as parking lots, roads, and roofs prevent water from soaking into the ground. Instead, water runs off of (during wet periods) and evaporates from (dry periods) impervious surfaces and can lead to dramatic fluctuations (more frequent and higher magnitude flooding) in water flow (Ferguson and Suckling 1990, entire; Wang et al. 2001, p. 255). Low impervious surface levels allow water to soak into the ground and be released over a longer period of time, leading to more stable base flows.

Channel instability has been reported in the Lower Chipola within the Chipola Cutoff from river mile (RM) 40 to 50. This instability may have been particularly pronounced during drought conditions in summer 2006 causing high local mussel mortality; the reach between RM 40 and 50 is also believed to be susceptible to a large amount of sediment redistribution following high flow events (USFWS 2007, p. 19). This area appears to be somewhat destabilized by riparian destruction by nearby development along the riverbank. Riparian wetland areas within the range of Fat Threeridge receive some legal protection that limits their conversion to other land uses (See Section 5.3.3), but development may still occur directly adjacent and upstream of the riparian zone that impact Fat Threeridge viability in the future.

5.1.4 Water Quality

5.1.4.1 Low Flow Conditions

The alteration of chemical and physical water quality properties such as dissolved oxygen, temperature, and suspended sediment are important water quality parameters for freshwater mussels. Their effects and general tolerance levels are discussed in Chapter 2. During summer drought, warm water temperatures and low dissolved oxygen levels are important secondary effects associated with flow reduction and cessation (Haag and Warren 2008, p. 1173), Along with other impacts such as riparian vegetation loss and urban stormwater inputs, presumably summer water temperatures and dissolved oxygen levels periodically exceed the tolerance range of sensitive mussel species.

Kaeser and Herrington (2011, entire) assessed the risk of Fat Threeridge exposure and mortality through fieldwork completed during low flow conditions. While conditions in mainstem streams may not deteriorate to the same degree as tributaries during low flows, the potential for poor water quality in pools or direct exposure in channel margins is high. Flows never went below 5000 cfs from 1939-2006 (a time period both prior to after dam installation), but did three times in the last 6 years of the record (USFWS 2016, p. 168). The majority of the Fat Threeridge range could be affected by low flows related to drought and river drawdowns to the minimum permitted flow (5,000 cfs) at JWLD, including the entire Apalachicola River, the Chipola Cutoff, and the Lower Chipola River; however, the drawdown rate is lower (0.25 feet/day; Kaeser and Herrington 2011, p. 9) than might be experienced in an unregulated, natural state and can be considered a protective measure for the species during low flows.

Two sites were selected for intensive study that were representative of known Fat Threeridge habitat in the main channel of the Apalachicola and Chipola rivers (Kaeser and Herrington 2011, p. 2). Locations at risk of low flow stranding resulting in $\geq$1 percent mortality were those with low sloped banks ($\leq$ 20 percent slope). The Lower Chipola does not contain gently sloped banks (20 - 60 percent slope; Kaeser and Herrington 2011, p. 28), and very few individuals were exposed and died during the low flow conditions (e.g., desiccation, increased water temperatures in pools) present over the course of the study. The mortality in the Lower Chipola River was likely even lower than the 0.2 to < 0.1 percent reported by Kaeser and Herrington 2011 (p. 22) given recent habitat mapping and population estimates (Kaeser et al. 2019, entire). The region of the Chipola River above Dead Lakes at the edge of the Fat Threeridge range where few individuals occur does not appear to be at high risk for drought-related mortalities from low flow conditions given similarity to sloping seen in the Lower Chipola.

The bulk of the species range containing the majority of individuals does not appear to be threatened by conditions that typically occur during drought and river drawdown. This conclusion is also supported by 50-year population viability analysis and empirical data collected by FWS and the Army Corps of Engineers. These works incorporated drawdown and drought effects between 4500 and 5000 cfs that suggested an isolated extreme low-flow event (e.g., once every 69 years) would not pose a major threat to Fat Threeridge, while low flow mortality events such as those observed in 2006 and 2010 occurring at greater frequency (e.g., once every 6 years) would be unlikely to singularly cause long-term population decline, unless population growth rates were decreased from other processes (Miller 2011, p. 21) Water control at JWLD was deemed to have a negative, but not appreciable, impact on the survival and recovery of the Fat Threeridge (USFWS 2016, p. 188) as detailed in Section 5.1.1.1.

5.1.4.2 Contaminants

Agricultural and developed lands are associated with high loadings of nutrients and silt and sediments in streams. Nitrogen, phosphorus, and suspended sediment loads by sub-watershed are shown in Figure 5-4 using the 2012 Spatially Referenced Regression On Watershed attributes (SPARROW) models (Hoos and Roland 2019, entire). Suspended sediment and TP (determined by parent-rock minerals, urban land, manure from livestock, municipal wastewater, agricultural fertilizer, and phosphate mining) are both highest toward the northern extent of the ACF Basin, and areas of higher concentrations within the range of Fat Threeridge occur in the Upper Flint sub-basin. Total Nitrogen (TN; derived from atmospheric deposition, agricultural fertilizer, municipal wastewater, manure from livestock, and urban land) has higher concentrations in the metro Atlanta area of the far Upper Flint, and then again in agricultural areas of the Lower Flint and Chipola River sub-basin.

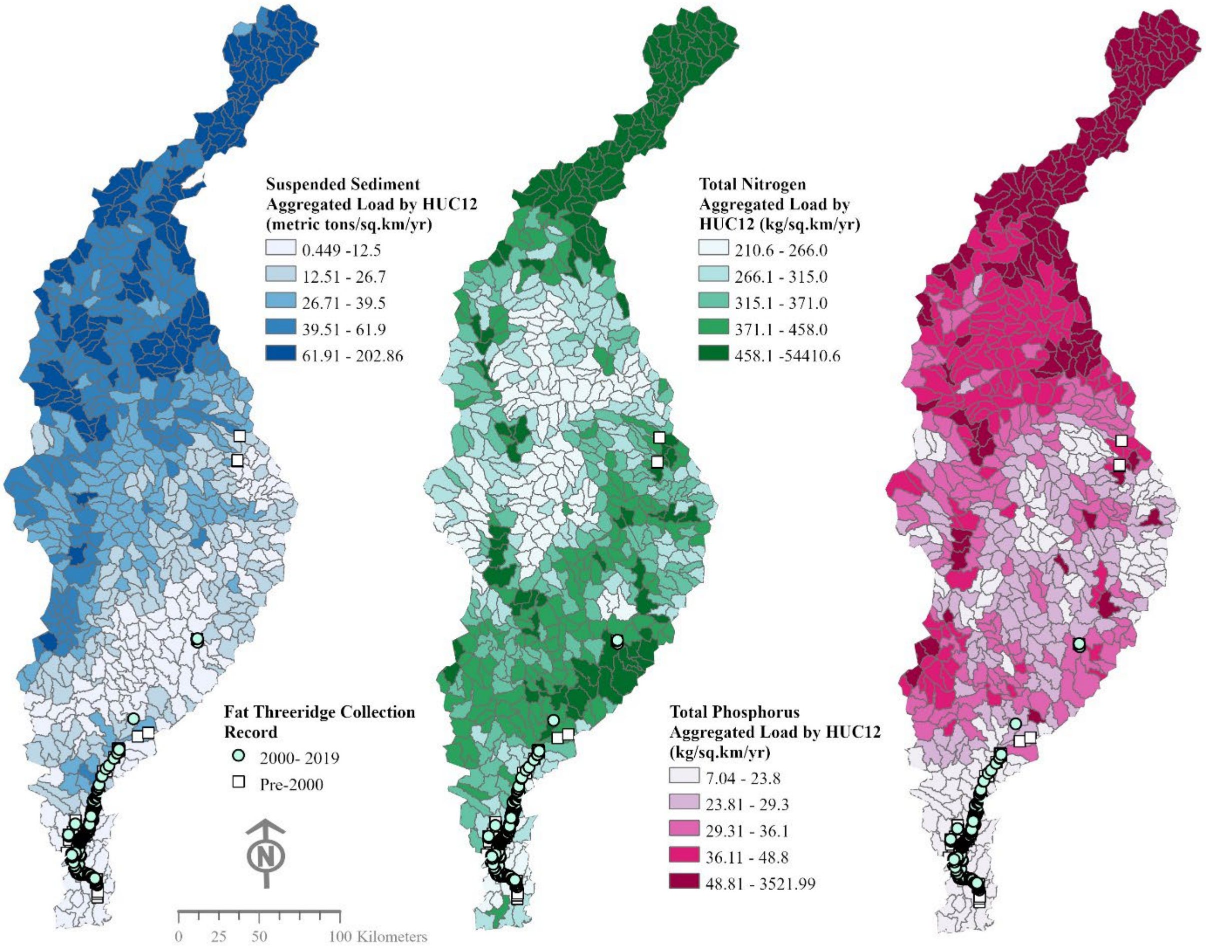


Figure 5-4. Sediment and nutrient loads within the basin at the HUC 12 sub-watershed scale using the 2012 Spatially Referenced Regression On Watershed attributes (SPARROW) models (Hoos and Roland 2019, entire).

Chemical contamination is another form of water quality impairment of particular importance to freshwater mussels. Contaminants enter streams through both point and nonpoint sources, including spills, industrial sources, municipal effluents, and runoff from agricultural and developed areas. These sources contribute organic compounds, heavy metals, pesticides and a wide variety of newly emerging contaminants to the aquatic environment. Several features of mussel life history lead to vulnerability to contaminants: juveniles and adults are exposed to toxic material in sediment, surface water, and pore water, and through the filtration of contaminants bound to food particles (Augspurger et al. 2007, p. 2025). Glochidia are likewise exposed to contaminants in the water column. As a group, mussels are among the most sensitive organisms to many contaminants and are often the first organisms to respond to water quality impacts (Haag 2012, p. 355) with mussel early life stages frequently showing the highest sensitivity to many chemical compounds (Augspurger et al. 2007, p. 2025–2026). Adult mussels have some ability to avoid acute exposure to pollutants by closing their valves and ceasing respiration, but earlier research suggesting that adult mussels are generally more tolerant of contaminants may have been overstated for methodological reasons (Cope et al. 2008, p. 453). There is no current data for the tolerance levels of Fat Threeridge to specific pollutants, but there is some general information available on the relationships and importance of these parameters to freshwater mussels and aquatic life in general.

Under the Clean Water Act, point source dischargers are required to obtain discharge permits as part of the National Pollutant Discharge Elimination System (NPDES). The pollutant loads permitted by discharge permits are based on approved water quality standards developed primarily through the results of laboratory-based toxicity testing. Currently, the available toxicity data for freshwater mussels is limited in comparison to other more common test species, including fish and benthic insects. The protectiveness of water quality standards for freshwater mussels is uncertain in instances where mussel toxicity data for a specific pollutant is lacking. As water quality standards are updated using additional data on freshwater mussel pollutant sensitivities, confidence in the protectiveness of water quality standards for freshwater mussels should increase. More details on the Clean Water Act and other regulations is discussed in Section 5.3.3.

Ammonia is among the most common and widespread pollutants found in freshwaters, with nitrogen-based fertilizers and industrial and domestic wastewater among the most significant sources of ammonia in streams. Streams carrying high nitrogen loads within the ACF basin correspond to sub-watersheds with high urban and row cropland uses (Figure 5-3, Figure 5-4). Freshwater mussels are among the most sensitive organisms to ammonia, especially its un-ionized form (Augspurger et al. 2003, pp. 2571-2574; Wang et al. 2007, pp. 2039–2046), and exposure to ammonia has been linked to mussel recruitment failure when present in sediments (Strayer and Malcom 2012, p. 1787). Higher levels of pH and temperature—conditions associated with low flows—increase the toxicity of ammonia to aquatic organisms by increasing the proportion of ammonia in its un-ionized form. The U.S. Environmental Protection Agency (EPA) revised its recommended criteria for ammonia in 2013. The new criteria recommendations take into account the latest freshwater toxicity information for ammonia, including toxicity studies for sensitive unionid mussels and gill–breathing snails (USEPA 2013*a*). We do not currently have information on specific tolerance levels for Fat Threeridge in regards to un-ionized ammonia, but EPA's new criteria represents the best general target for freshwater mussels. Still, recent work suggests that even low levels of ammonia (e.g., 1.5 mg N/L) which are below thresholds set in the 2013 criteria can be toxic to some mussel species (Wang et al. 2017, p. 791–792). The total Nitrogen aggregated load presented in Figure 5-4 suggests ammonia levels may be greatest in the Chipola NDL and Lower Flint within the current range of Fat Threeridge, though no exceedances for this metric are documented currently (Figure 5-5).

Heavy metal exposure can cause substantial harm to mussels. These inorganic pollutants enter aquatic systems via point and non-point sources and are frequently associated with urban land-use, mining, and industrial processes such as energy production. Many lab trials have demonstrated that mussels are among the most sensitive aquatic organisms to several metals, including nickel, copper, and zinc and lead (Wang et al. 2010, p. 2060-2062; Wang et al. 2017, p. 792, 795). Water quality criteria (WQC) for metals developed without accounting for the high sensitivity of mussels to inorganic compounds may leave many species unprotected. The current U.S. EPA WQC for lead appears to be adequate protection for freshwater mussels (Wang et al. 2010, p. 2062), but acute nickel exposure of juvenile mussels of two species was toxic at levels below the current EPA WQC for this metal (toxicity at median concentrations of <260 µg/L and 313 µg/L compared to WQC of 470 µg/L; Keller and Zam 1991, p. 542; Gibson et al. 2018, p. 249, respectively). Similarly, Wang et al. (2017, p. 793) demonstrated that several mussel species are intolerant of acute exposures to copper and zinc at concentrations near or below the EPA WQC for these metals. An important finding of this study was that sensitivity to inorganic chemicals was similar among mussels representing different tribes or families, even when the mode of toxic action differed (Wang et al. 2017, p. 792). An exceedance for lead occurs in the vicinity of Lake Seminole (Figure 5-5), but has not been directly linked to impacts on Fat Threeridge, and exposure to heavy metals is not known to be impacting Fat Threeridge at this time.

Pesticides are also widespread contaminants that have been implicated in mussel declines. Pesticides have been linked to freshwater mussel die–offs (Fleming et al. 1995, pp. 877–879), and lab studies show that sensitivity of mussel glochidia and juveniles to common pesticides can be high but is variable and difficult to predict (Conners and Black 2004, pp. 362–371; Bringolf et al. 2007*a*, pp. 2089–2093; Wang et al. 2017, p. 792). Whereas mussel species are frequently more sensitive to heavy metals than common aquatic invertebrate test organisms (e.g., *Daphnia*), some unionid mussels are more tolerant of acute exposure to common pesticides like chlorpyrifos, permethrin, and atrazine than these same test organisms (Bringolf *et al*. 2007b, pp. 2103-2105). However, studies have demonstrated high variability in mussel sensitivity to organic pollutants like pesticides (Wang et al. 2017, p. 792), which suggests that inferring the pesticide sensitivity of untested species like Fat Threeridge based on other mussels should be done cautiously. The risk of pesticide contamination is likely correlated with agricultural area (e.g., Lower Flint), especially if riparian buffers are not sufficiently limiting run-off. A complicating feature of pesticide contamination is that additional chemicals are often added to pesticides to increase their efficacy, and these auxiliary compounds can also be harmful to mussels. For example, while the active ingredient in the common herbicide Roundup® was found to be toxic to glochidia and juvenile mussels, one of its constituent elements, a surfactant (MON 0818) was found to be substantially more toxic to mussels than the active ingredient glyphosate (Bringolf *et al*. 2007c, pp. 2096–2097). Ultimately, while the potential role of pesticides in mussel declines has received more attention in recent years, the full range of long–term effects of pesticides, and their ingredients and metabolites, remains unknown (Haag 2012, pp. 374–379).

An emerging category of contaminants of concern to aquatic species is pharmaceuticals, including contraceptive medications, antidepressants, livestock growth hormones originating and microplastics from municipal, agricultural, and industrial wastewater sources. Pharmaceuticals have been shown to bioaccumulate in mussels downstream of wastewater treatment plants (De Solla et al. 2016, p. 489), and in lab studies, acute pharmaceutical exposure has caused mortality of glochidia (Gilroy et al. 2014, p. 543) and changes to mussel physiology (Bringolf et al. 2010, pp. 1315-1317) and behavior (Hazelton et al. 2014, p. 31-32). These chemicals may also act as endocrine disrupters and can affect mussel reproduction in a number of ways, including causing feminization of male mussels (Gagné et al. 2001, pp. 260–268; Gagné et al. 2011, pp. 99–106). Microplastics have been documented in freshwater mussels (Wardlaw and Prosser 2020, p. 12); though the consequences of ingestion are uncertain, the potential for the accumulation of other contaminants on microplastics would provide a pathway for increased chemical exposure in freshwater systems (Wagner et al. 2014, p. 6).

Although specific physical and chemical tolerance ranges are not known for the Fat Threeridge, we believe that numeric standards for most water quality criteria important to mussels (for example dissolved oxygen, temperature, ammonia) currently adopted by the States of Alabama, Florida, and Georgia under the Clean Water Act (See Section 5.3.3) represent levels that are adequate for the conservation of the species. However, some standards (such as those for chloride, potassium, nickel) are toxic to mussels at levels below the current criteria (Gibson et al 2018, p. 244–250; Wang et al. 2017, p. 795). In addition, standards do not exist for some mussel toxicants (for example, the surfactant sodium dodecyl sulfate; Gibson et al. 2016, p. 32), nor do any exist for any of the pharmaceuticals listed above. The relative risk of contamination and negative effects on Fat Threeridge viability would likely increase in the future with increasing anthropogenic land uses (e.g., urbanization, agriculture). The following section highlights areas within the species range with documented water quality impairments.

5.1.4.3 Impaired Waters

The CWA is a federal law that regulates the discharge of pollutants into surface waters, including lakes, rivers, streams, wetlands, and coastal areas. States are responsible for implementing standards that meet or exceed those established by EPA. Under Section 305(b) of the CWA, states provide designated uses for streams including: fish and aquatic life, livestock watering and wildlife, irrigation, navigation, domestic water supply, and industrial water supply, among others. Criteria to support the designated uses include numeric criteria for water quality parameters (e.g., ammonia, heavy metals, dissolved oxygen) and narrative criteria for biological parameters (e.g. benthic macroinvertebrates). Section 303(d) of the CWA requires States to identify waters that do not fully support their designated use classification. Streams that do not meet designated uses for criteria are placed on a Section 303(d) list of impaired waters and a total maximum daily load (TMDL) must be developed for the pollutant of concern. A TMDL is an estimate of the total load of pollutants that a segment of water can receive without exceeding applicable water quality criteria.

The Florida Department of Environmental Protection (FDEP), Alabama Department of Environmental Management (ADEM), and Georgia Environmental Protection Division (GEPD) completed the most recent assessments of impaired waters within the range of Fat Threeridge between 2018 and 2019. Impaired waterbodies within watersheds currently and historically occupied by Fat Threeridge are predominantly impacted by coliform bacteria (indicated as 'bacteria' or 'FC' in Figure 5-5). The Upper Flint River which contains historical species records is also impacted by FC. Although not necessarily harmful to mussels, coliform bacteria assays are useful as indicators of problems such as septic tank leaching, sewage spills or inadequate wastewater treatment, and stormwater runoff from livestock and poultry operations. These sources may also contribute nutrients, silt and sediment, and chemical pollutants. Other types of impairment include lead, nutrients, dissolved oxygen (DO) and impacts to the biological community in general (Biology) or the fish community specifically (Bio F) (ADEM 2018, entire; FDEP 2019, entire; GEPD 2019, entire). Elevated lead concentrations are often caused by stormwater input, and are associated with lake sediment in urbanized areas (FDEP 2019, p. 55). Sources contributing to FC and Bio F impairments in Cooleewahee Creek near Newton, GA (NE corner of inset, Figure 5-5) include limited or failing riparian buffer zones, livestock with direct access to the creek, and signs of illegal dumping (GEDP 2018, p. 9). These impairments suggest Fat Threeridge health may currently be impacted by water quality impairments and these effects may worsen (e.g., reduced recruitment) with decreasing riparian cover and/or increasing urban and agricultural development in the future, especially within the northern more heavily agricultural portion of the range with documented impairments (e.g., the Chipola NDL, Upper Apalachicola, and Lower Flint analysis units).

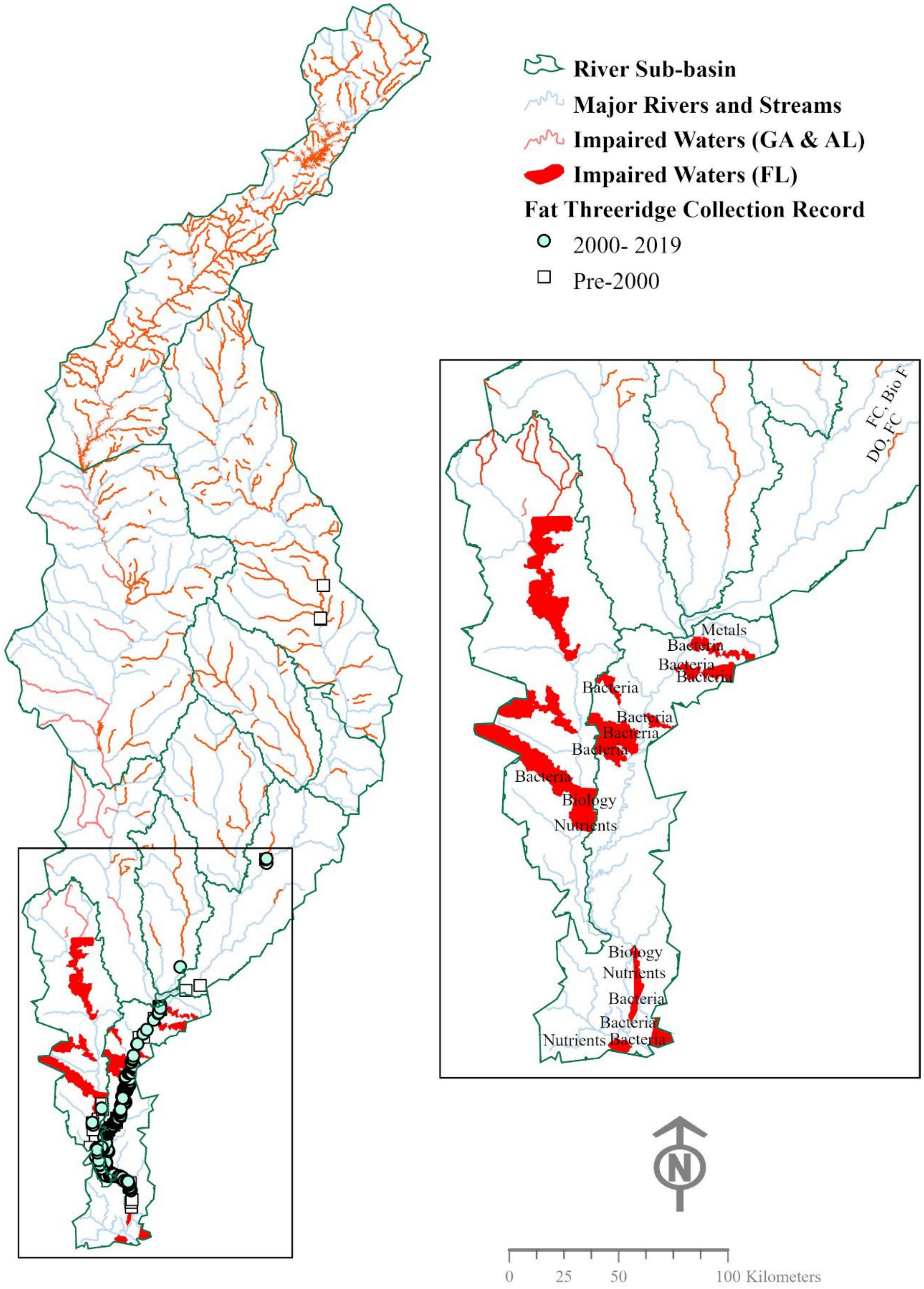


Figure 5-5. Stream reaches designated as impaired by Alabama, Florida, and Georgia within the ACF Basin as of 2020.An inset map of the current range of Fat Threeridge is included.

5.1.5 Changing Climate Conditions

In order to predict future changes in climate, scientists rely on climate model simulations that are driven by assumptions about future human population growth, changes in energy generation and land use, socio-economic development, and technology change. The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), published in 2014, presents the most recent climate findings based on a set of scenarios that use Representative Concentration Pathways (RCPs). The RCPs are representative of several different scenarios that have similar greenhouse gas emissions characteristics on a time-dependent trajectory to reach a certain projected outcome (Wayne 2013, p.1). There are four RCPs, identified by the amount of radiative forcing (i.e., the change in energy in the atmosphere due to greenhouse gases) reached by 2100: one high pathway (RCP 8.5); two intermediate stabilization pathways (RCP 6.0 and RCP 4.5); and one low trajectory pathway (RCP 2.6 or RCP 3PD) (Wayne 2013, p.11). RCP 8.5 assumes that emissions would be more or less unabated due to a lack of climate-change reversal policies; for RCP 4.5 and RCP 6.0, emissions are assumed to be relatively stable throughout the century, and RCP4.5 incorporates a number of climate policies into forecasts (Wayne 2013, p.15).

Despite the recognition of potential climate effects on ecosystem processes, there is uncertainty about what the exact climate future for the Southeastern US will be and how ecosystems and species in this region will respond. The greatest threat from climate change may come from synergistic effects. That is, factors associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats, especially for rivers in wide flood plains where stream channels have room to migrate (Elliot et al. 2014, p. 67 -68). As a result, impacts from land use change might be exacerbated under even a mild to moderate climate future. A suite of potential hydrological impacts to waters of the southeastern United States is possible under conditions of climate change, but climate models generally predict increases in extreme rainfall events and droughts of greater duration and intensity (Carter et al. 2018, pp. 745-746). Potential adaptation options to these hydrological impacts are included in Table 5-2, and their potential impacts on Fat Threeridge are detailed further, below.

Table 5-2. Potential adaptation options for managing hydrological impact and risks from climate change (Table reproduced from Sun et al. 2013, p. 229).

Hydrologic Impacts	Risks to Ecosystems	Adaptation Options
Water supply stress increase	Water shortage; drying up of drinking wells; Consequences to aquatic ecosystems, socioeconomics, and business	Reduce groundwater and surface water use for agriculture and lawns; enhance water conservation; increase water use efficiency and storage; recycle water; institute adaptive management.
Evapotranspiration increase	Hydrologic droughts; wildfires; insect, disease outbreaks	Use native tree species; reduce tree stocking; reduce water use by crops
Increase of peak flow, storm flow volume, floods	Flooding; increased soil erosion and sedimentation	Reduce impervious areas; increase stormwater retention ponds; increase evapotranspiration by increasing forest coverage; increase water storage capacity
Low flow decrease; drought	Water quality degradation; fish habitat loss; reduced transportation capacity	Increase water storage; reduce off-stream water withdrawal
Wetland hydroperiod change	Wildlife habitat loss; greenhouse gas (CO_2, CH_4, NO_x) emission	Plug ditches; adjust outflows from reservoirs
Stream water temperature increase	Water quality degradation, loss of cold fish habitat	Maintain riparian buffers and shading
Soil erosion, sedimentation increase	Water quality degradation, siltation of reservoirs; increase cost of water treatment	Enhance best management practices (BMPs); redesign riparian buffers; minimize direct discharge of runoff from roads to streams
Chemical loading increase	Water quality degradation; higher cost of water treatment	Maintain streamflow quantity; applications of BMPs

5.1.5.1 Sea Level Rise (SLR)

Fat Threeridge is believed to be intolerant of saline conditions. The ranges of tolerance levels for unionids is variable by species, exposure duration and salinity concentration, and life stage. The average chloride level in North American rivers is 0.007 parts per thousand (ppt) (Blackeslee et al. 2013, p. 2852), with the average salinity of the world's oceans approximately 35 ppt (NOAA 2021, n.p.). Salt exposure at 3 to 6 ppt can decrease the reproduction and survival of freshwater mussels (Blakeslee et al. 2013, p. 2849). The upper limit for exposure of most adult unionid mussels to long-term salinity stress is < 6 ppt, which may be consistent with Fat Threeridge tolerances. Freshwater species that occur in lower reaches of Coastal Plain rivers such as *Glebula rotundata* may survive at higher salt concentrations (6 and 12 ppt; Johnson et al. 2018, p. 61), but Fat Threeridge is not known to occur below the point of tidal influence in the Apalachicola River. An increase in salinity of fresh waters through the intrusion of seawater associated with sea level rise will likely modify community composition of unionids in affected areas, eliminating or at least reducing the abundance of species that are less adapted to increased salinity (Johnson et al. 2018, p. 67).

Climatic changes, including sea level rise (SLR) and shifts in seasonal precipitation, temperature, and storm cycles, are major threats to south Florida. Various studies (University of Florida Geoplan 2015, p. 13; The Nature Conservancy 2011, p. 4 – 6; Sweet et al. 2017, p. 22 - 23) have developed scenarios that range from less than 1 foot to 10.4 feet of SLR in the south Florida by 2100. Tidal gauges around Florida have shown 10 inches (25 cm) of SLR since 1913, with an increase in SLR of 2.56 mm/year from 1967 to 2019, equivalent to 25 cm in 100 years more locally (Relative Sea Level Trend at 8728690 Apalachicola, Florida; NOAA 2020, n.p.). This recent acceleration suggests that the intermediate to extreme sea level rise scenarios are more likely to occur than the low and intermediate-low scenarios (Sweet et al. 2017, p. 22- 23). SLR since 2000 has generally been within the trajectory of the Intermediate-High scenario, but it is important to note the trajectory could change throughout the century. Rapid ice sheet collapse in Antarctica could move SLR from the Intermediate to the Extreme scenario by the end of the century(Sweet et al. 2017, p. 35). Under the extreme scenario, some areas supporting Fat Threeridge (e.g., the Lower Apalachicola) will likely become partially inundated (i.e., under water) at some point during this century (Figure 5-6).

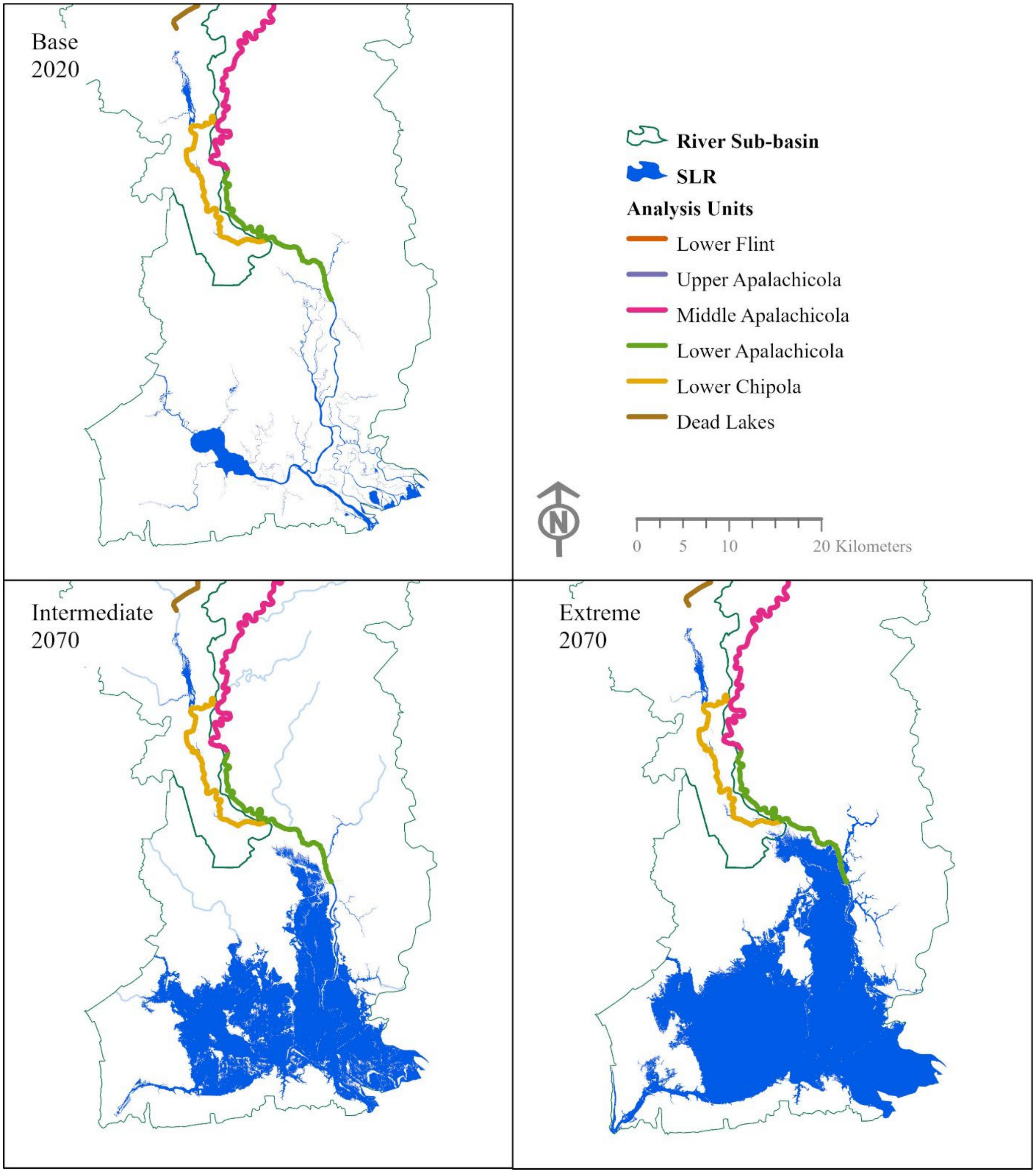


Figure 5-6. Sea Level Rise (SLR) projections for portions of the Chipola and Apalachicola sub-basins under the NOAA intermediate and extreme SLR scenarios, in the year 2070 (Sweet et al. 2017, p. 22- 23) with areas hydrologically connected to the ocean and the local mean higher high water datum (base 2020) included for context.

5.1.5.2 Extreme Drought

The intensity of drought and wet periods is exacerbated by changes in land use and population demand on resources. During the past eight decades, the ACF Basin has experienced numerous droughts, several of which are considered severe. In recent years, droughts have been experienced in 1980– 1982, 1985– 1989, 1998 – 2003, 2007 – 2008 and 2011 – 2012, with some variation in severity and duration around the Basin. Since 1999, six of the seven lowest-flow years (1999, 2000, 2002, 2007, 2011 and 2012) in terms of average annual flow in the period of record (1923 – present) for the Apalachicola River at the Chattahoochee, FL USGS gage have occurred. Fat Threeridge has persisted and arguably increased in abundance through this period.

An important question is whether the occurrence of multiple "rare events" in the past 30 years is an anomaly or should droughts of this magnitude be expected more regularly in the future with changing climate. Long-term climate records suggest that decade-long "mega-droughts" have occurred periodically during the past 1,000 years in the southeastern US, including in the ACF (Stahle et al. 2007, entire). This suggests that while the recently observed droughts in 2006-2008 and 2010-2012 were exceptional based on our recent <100-year period of record, they may not be exceptional compared to historic episodes (Pederson et al. 2012, p. 2) that the species has persisted through. Gibson et al. (2005, p. 855-862) used multiple future climate scenarios, combined with increasing water demand from human users, to predict that future river discharge conditions could include lower high discharge events and lower low flow events. Projections for the ACF watershed indicate that future droughts are likely to be more intense (Yao and Georgakakos 2011, entire). In Section 5.1.4.1, it was indicated that an isolated extreme low-flow event (e.g., once every 69 years) would not seem to pose a major threat to Fat Threeridge, while low flow mortality events such as those observed in 2006 and 2010 occurring at greater frequency (e.g., once every 6 years) would be unlikely to singularly cause long-term population decline, unless population growth rates were decreased from other processes (Miller 2011, p. 21)

From the 1940s to the 1990s (the majority of the period of record for gages in the ACF), the southeastern US was in a persistent, unusually wet period compared to the previous millennium (Seager et al., 2009, p. 5041-5043). This is the period of time during which most of the reservoir and human development occurred in the ACF and from which we derive flow assessments. The relative infrequency of severe drought events during this period may provide unrealistic expectations for future conditions. An analysis of conditions in the ACF Basin through 2050 under RCP 4.5 and 8.5 predicts increases in temperature (particularly summer and fall, Neupane et al. 2018, p 2232), surface water runoff, evapotranspiration, and decreases in soil moisture and groundwater discharge; all patterns were more pronounced under RCP 8.5 than RCP 4.5 (Neupane et al. 2018, p. 2236). Future projections of Fat Threeridge habitat availability under two disparate global climate models (one cool/wet, one hot/dry model) with emissions trajectories similar to RCP 8.5 (SRES A2) suggested there could be a large reduction in suitable habitat related to changes in average streamflow and average daily high temperatures (Barrett and Webber 2017, p. 69). However, the data used to model species distributions in this study were remotely sensed from within the species range, and likely do not represent the true tolerance range of Fat Threeridge or the protection of flows provided by JWLD.

Recent flow models in the ACF Basin provide predicted flows by river reach for a range of hydrologic variables, utilizing a variety of downscaled general circulation models. These data indicate that streams and rivers with Fat Threeridge could exhibit a range of changes in flow conditions under future climates (LaFontaine et al. 2019; Figure 5-7). Mainstem areas of the Flint River and Apalachicola River were estimated to maintain or increase flows with positive implications for Fat Threeridge viability. A study on flows in the Lower Flint River also found that variation in precipitation patterns among climate models adds to uncertainty with flow models, and that decreases in flow from climate conditions were often offset with increasing flows from increased runoff (Viger et al. 2011, p. 20). While PRMS models (Figure 5-7) may suggest low flows will increase in magnitude by up to 26% in the Chipola River in the future, the Lower Chipola and Chipola Cutoff are also protected by flow from the Apalachicola River and water release from JWLD.

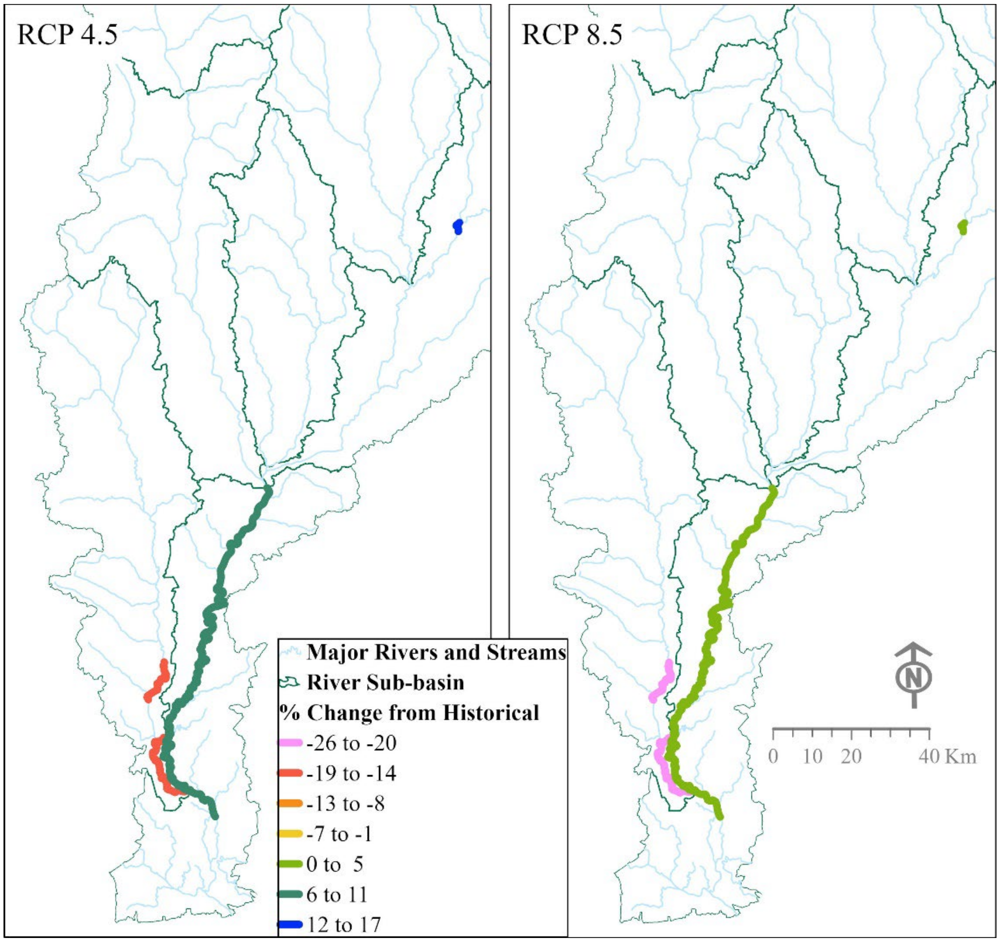


Figure 5-7. Future percent change from historical conditions for summer magnitude (i.e., mean minimum of the summer flows (July-September) divided by the drainage area (cubic feet per second/square mile)) within current and historically occupied stream segments. Future conditions were modelled for the period 2045-2075, and historical conditions are derived from the period 1952-2005 (LaFontaine 2019, entire). Values are expressed as the median modeled results for the RCP 4.5 and 8.5 pathways.

5.2 Nonnative Species

The invasive Asian Clam (*Corbicula fluminea*) was first detected in the eastern Gulf drainages in the early 1960s and was widespread within the ACF basin by the mid-1970s (Heard 1975, p. 3; Figure 5-8). Heard (1975, p. 3) considered *Corbicula* to be a factor in the decline of certain Apalachicola River mussels, noting that once common species have been replaced by "bottom-paving *Corbicula.*" *Corbicula* life history enables fast colonization; it is hermaphroditic and is able to self-fertilize, grows fast and reaches maturity in 3 to 6 months, and produces large numbers of juveniles (Strayer 1999, p. 81; Haag et al. 2012, p. 368). These traits allow the species to quickly reach densities of hundreds to thousands per square meter (Gardner et al. 1976, pp. 119-121), and to thrive in disturbed habitats (Haag 2012, p. 370). Although *Corbicula* can inhabit a wide-range of flow and substrate conditions, densities are highest in areas with low flow velocity and in substrates composed of sand or mixtures of mud, sand, and gravel (Gardner et al. 1976, p. 122; McDowell and Byers 2019, p. 6). Because the Fat Threeridge generally exhibits similar habitat preferences, *Corbicula* may reach high abundances in areas inhabited by Fat Threeridge (Gangloff 2012, p. 5).

Corbicula has one of the highest filtration rates per biomass, compared to native North American unionid mussels (McMahon 2002, p. 1238). Dense *Corbicula* populations can remove a substantial amount of suspended material from the water (Lauritsen 1986, pp. 168-170; Leff et al. 1990, p. 415). Corbicula were noted to be abundant at most sites surveyed for Fat Threeridge (Gangloff 2011, p. 17). *Corbicula* may negatively affect mussels by ingesting mussel sperm, glochidia, or newly metamorphosed juvenile mussels (Strayer 1999, p. 81-85; Modesto et al. 2019, pp. 159 - 162), and by elevating ammonia levels during die-offs (Cherry et al. 2005, p. 377), although the ambient concentrations of ammonia generated by *Corbicula* at high-density in a lab study were not considered elevated enough to cause mortality of glochidia (Modesto et al. 2019, pp. 159 – 162). Although the specific interaction between *Corbicula* and native mussels is not well understood, recent work has suggested *Corbicula* can negatively affect juvenile mussels (Haag 2019, p. 55 - 56). However, we have no direct evidence that this factor is influencing Fat Threeridge.

Figure 5-8. Asian Clams (*Corbicula fluminea*) in a sieved 0.25 m^2 (2.7 ft^2) sediment sample collected in the Apalachicola River, 2007. Photo credit: S. Pursifull

5.3 Conservation Measures and Protections

The following section details protection measures that benefit Fat Threeridge through the preservation of habitat of suitability quality and quantity to support the species. We begin with an overview of species-specific legal protections that are in place at the federal and state level. We then discuss various efforts to protect and conserve habitat in general, as well as specific water protections that benefit the species.

5.3.1 Critical Habitat and Protected Lands

Given the listing in 1998 and designated critical habitat since 2007, federal agencies have been required under the Act's Section 7 to coordinate with the US Fish and Wildlife Service to ensure actions that they carry out, fund, or authorize will not jeopardize species' persistence or adversely modify critical habitat. This requirement has protected Fat Threeridge throughout most of its historic range (Figure 5-9).

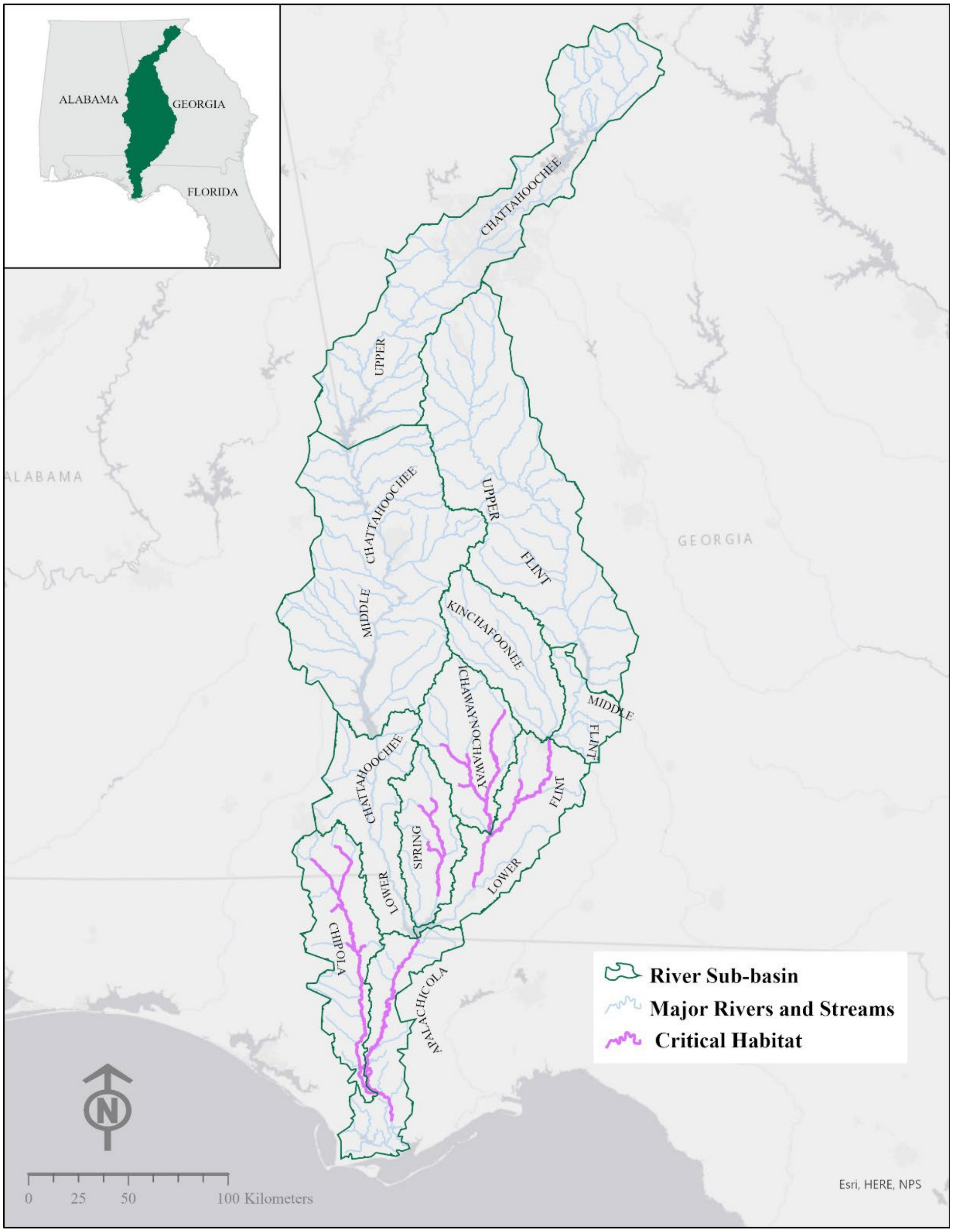


Figure 5-9. Existing critical habitat for Fat Threeridge within the ACF basin.

Some protected land exists in each river system of the ACF Basin, and locations within the watersheds occupied by Fat Threeridge are noted in figures within Section 3.2.2. Most relevant are the Apalachicola National Forest, Tates Hell State Forest, and the Apalachicola River water Management Area in the Apalachicola sub-basin, and the protection of spring habitats in the Chipola sub-basin. However, while protection of floodplains and upland areas within watersheds may offer some benefits to freshwater mussels, continued impacts to hydrology and water quality from unprotected areas upstream will persist in lotic habitats.

Over 40,000 hectares within the assessed analysis subwatersheds, including over 1,500 hectares within 100-m of the assessed analysis units for Fat Threeridge are in conservation, including federal, state, and county lands and/or private lands managed for conservation under an easement or covenant (Table 5-3). The most heavily-protected subwatershed and riparian area is within the Lower Apalachicola, followed by the Lower Chipola, the Middle Apalachicola, and the Upper Apalachicola. The Lower Flint and Chipola NDL contain little to no protected land. Conservation lands provide both current and future protection against land use changes that can increase water usage, the inputs of sediments, nutrients, and other nonpoint source pollutants into Fat Threeridge-occupied rivers.

Table 5-3. Conservation lands in analysis subwatersheds and within a 100-m buffer of analysis units (FNAI 2020, n.p; GADNR 2020).

Analysis Unit	Hectares in Conservation in Subwatersheds	Percent of Subwatersheds	Hectares in Conservation in 100-m buffer	Percent of Buffer
Lower Flint	1090.04	7.91	2.78	4.47
Upper Apalachicola	5180.26	17.75	272.20	19.76
Middle Apalachicola	12163.12	40.39	407.05	37.49
Lower Apalachicola	20524.30	78.94	501.22	95.12
Lower Chipola	4422.43	40.22	406.74	70.42
Chipola NDL	6.64	0.08	0.00	0.00

* some subwatersheds are shared between analysis units, and their land uses appear in both units

5.3.2 Conservation Measures of Water Management

In general, federal guidelines are in place to minimize alterations to flow regimes, and both state and federal permits may be required to alter wetlands and other surface waters. The Service and Department of Environmental Protection proposed instream flow guidelines for protecting riverine ecosystems under a possible interstate water allocation formula between Alabama, Florida, and Georgia for the ACF Basin. Although the three States failed to agree upon an allocation formula and the ACF Compact authorizing their negotiations expired, the Service has applied the instream flow guidelines in consultations with Federal agencies on actions affecting the species addressed in this rule. The Service-EPA guidelines are definitions of measures of flow magnitude, duration, frequency, and seasonality that may serve as thresholds for ‘‘may affect’’ determinations for proposed Federal actions that would alter a flow regime (for example, water withdrawals and dam operations). These measures include: monthly 1-day minima; annual low-flow duration; monthly average flow; annual 1-day maximum; annual high- flow duration.

Thresholds for these measures are computed from long-term flow records appropriate to the proposed action, such as daily flow records from a stream gage in the action area. The Environmental Resource Permit Program within the EPA regulates the construction, alteration, maintenance, removal, modification and operation of all activities in uplands, wetlands and all other surface waters that alter, divert and change the flow of surface waters.

More specifically in the regulated waters of the USACE's ACF project below Jim Woodruff Lock and Dam (JWD) in the Apalachicola River, several provisions are in place as part of the Master Water Control Manual (WCM, USACE 2017) for the benefit of the listed ACF mussels. These include: minimum flows of 5,000 cfs during drought conditions, or 4,500 cfs during extreme drought conditions, and specified fall rates when flows will decline below 10,000 cfs to slow the rate of declining flow in the river such that mussels have an opportunity to move down bank and reduce stranding rates (USACE 2017, p. 8-4). These minimum flow protections affect waters of the Apalachicola River and the Lower Chipola River. Provisions for conservation locking at the Dam during March-May are also included in the WCM to promote fish passage (USACE 2017, p. 8-4).

5.3.3 Water Quality Protections

Minimum water quality standards have been set by federal agencies through both the Clean Water Act and other initiatives. The Clean Water Act (CWA) is a federal law that regulates the discharge of pollutants into surface waters, including lakes, rivers, streams, wetlands, and coastal areas. The basis of the CWA was enacted in 1948, but was expanded and reorganized to form the VWA in 1972. The EPA, Service, and National Marine Fisheries Service agreed to a national consultation on the CWA Section 304(a) aquatic life criteria as part of a Memorandum of Agreement regarding interagency coordination under the CWA and the Endangered Species Act (66 FR 11202). In 2013, the EPA released new ammonia criteria that included acute and chronic toxicity testing for 13 freshwater mussels, thus leading to an improved understanding of ammonia toxicity and setting a more protective ammonia criteria value for freshwater mussels (USEPA 2013a). In 2016, Florida Department of Environmental Protection adopted the chronic criteria for ammonia as both the acute and chronic values, therefore improving the ammonia standard even further for the conservation of freshwater mussels statewide (USEPA 2016*b*). The Georgia Environmental Protection Division did not adopt the numeric ammonia criteria, but implemented it through the narrative toxicity criteria, the wasteload allocation process, and instream monitoring.

The Surface Water Improvement and Management (SWIM) Act was enacted in 1987 by the Florida Legislature to improve and manage the water quality and natural systems of Florida's surface waters, which include lakes, rivers, streams, estuaries, springs, and wetlands. The Florida Environmental Resources Permit (ERP) Program regulates activities involving the alteration of surface water flows, including new activities in uplands that generate stormwater runoff from upland construction, as well as dredging and filling in wetlands and other surface waters. Activities must not adversely impact water resources, including water quality, water quantity, and the value of functions provided to fish and wildlife and listed species by wetlands and other surface waters.

Florida has established water classifications that promote water quality standards that are more stringent than those of the Clean Water Act, designed to protect existing good water quality. The FDEP designates Outstanding Florida Waters (OFWs) under section 403.061(27), F.S. An OFW is defined by FDEP as a waterbody worthy of special protection because of its natural attributes, and the designation prevents the permitted discharge of pollutants that would lower existing water quality of, or significantly degrade the waterbody. The majority of waterbodies and segments in the Chipola and Apalachicola watersheds receive regulatory protection through designation as OFWs in addition to existing surface water. OFWs have even more restrictions on nitrogen contamination, which uses comparisons to a water quality baseline period set in February 1978 - March 1979. However, the effect of OFW designation on water quality parameters (e.g., nutrients) and parameters that are not currently established by rule is uncertain, and OFWs do not seem to receive special consideration for impaired waters restoration (Ankersen et al. 2009, p. 103). In addition, OFW rules do not consider riparian buffers, except within the context of silvicultural activities (Ankerson et al 2009, p. 102).

In Florida, “deadhead logging” has the potential to affect mussel communities by altering habitat and water quality. Timber cut approximately 100 years ago, then accidently sunk during log “drives,” is salvaged from stream bottoms. Because of their age and quality, these logs now have high commercial value, principally as flooring material. The removal of deadhead logs may result in localized damage to mussels by resuspending fines and disrupting stable substrates associated with partially buried logs. Deadhead logging is currently being conducted at several locations in northern Florida under permits from the State Department of Environmental Protection (USFWS 2003, p. 61). Permits cover a 20-mile river reach, several loggers may be permitted to work in the same segment of river, and permits are effective for one year. Deadhead logging permits all include several general conditions to avoid impacts to mussels and other aquatic life, such as prohibiting log removal from banks. Of note, deadhead logging is prohibited within state parks, and immediately downstream of JWLD. A deadhead logging project is to cease work immediately upon observation of a mussel bed at the work site and report the location to the Department of Environmental Protection district office, but there appears to be little oversight of logging activities.

5.3.4 Water Resource Planning and Policy

5.3.4.1 State of Georgia

The Georgia Water Council, a large group of organizations dedicated to protecting Georgia’s water resources, developed a report on the state of water and agriculture in Georgia in which they presented a history of regulations to manage the extensive water use from agricultural activities (Georgia Water Planning Council 2017, entire). In 1977, Georgia amended the Georgia Water Control Act of 1964 to regulate wastewater discharges and required permits for municipal and industrial users in excess of 100,000 gallons per day, but it did not limit the withdrawal's volume. Not until 1988 did farm withdrawals of surface and groundwater in the same amount require a permit when the Georgia Water Quality Control Act (1964) and the Groundwater Use Act (1972) were amended.

The Flint River Drought Protection Act (FRDPA) was passed in 2000 with the goal of reducing surface water withdrawals during dry periods, keeping more water in the ACF basin, and mitigating tri-state water war friction. The GEPD manages all water withdrawal permitting and compliance. The FRDPA allowed the GEPD director to declare a drought in the Flint River basin and the state could pay farmers not to irrigate. The process was used in 2001 and 2002; however, the GEPD concluded that the highest cropland users were not removed. The process has not been triggered again despite further droughts and the program has not been funded. In 2012 the GEPD issued a moratorium in response to the 2011 drought which continues to apply today to groundwater permit applications in a portion of the lower Flint and Chattahoochee River basins, in surface water withdrawal permits in the Kinchafoonee, Ichawaynochaway, and Spring Creek basins, and in a 24-county area of the Lower Flint River. The FRDPA was amended in 2014 to make the drought declaration process discretionary and included a requirement that all irrigation systems achieve efficiencies of 80 percent by January 1, 2020.

Regional Water Plans in Georgia are developed in accordance with the Georgia Comprehensive State-wide Water Management Plan (State Water Plan), which was adopted by the General Assembly in January 2008. The State Water Plan requires the preparation of regional water development and conservation plans (Regional Water Plans) to manage water resources in a sustainable manner through 2050. A Water Conservation Plan is required of all permit holders operating in the Flint River basin. The State Water Plan also guides regional water planning by the Metropolitan North Georgia Water Planning District (a 15 county area around Atlanta) which was created by the Metropolitan North Georgia Water Planning District Act of 2001. The Metropolitan North Georgia Water Planning District has implemented and expanded numerous conservation measures outlined in the 2017 Water Management Plan. The State has also enacted a number of laws related to water conservation, including but not limited to the Water Stewardship Act of 2010, which has decreased per capita water use in the District by 30 percent since 2000 (Metropolitan North Georgia Atlanta Water Planning District 2017, p. 5-44).

Despite the increased water management coordination and conservation focus in Georgia, the volume of withdrawal is not limited and few permits are conditioned in any way. Surface water permits and withdrawal amounts on Spring Creek and Ichawaynochaway Creek in the lower Flint River basin continue to be restricted based on evidence that irrigation use from the Floridan aquifer is at the maximum permittable capacity (GDEP 2006, p. 26). This may be protective of base flows in the Lower Flint, and a positive effect on Fat Threeridge. In general, permits have no expiration date except for those in specific parts of the lower Flint River basin where they must be renewed after 25 years.

5.3.4.2 State of Florida

The Florida Water Resources Act establishes that all water in Florida is a public resource managed by the Florida Department of Environmental Protection and five water management districts. Each district creates a Regional Water Supply Plan every five years. Florida establishes Minimum Flow Limits (MFLs) to identify the limit at which withdrawals would be significantly harmful to the water resources or ecology of an area. Water reservation is a legal mechanism in Florida that functions to set aside water from consumptive uses for the protection of fish and wildlife or public health and safety (F.S. 373.223). Water reservations and MFLs are both important tools to ensure an adequate supply of water for citizens and environment. Water reservations were established for the Chipola and Apalachicola rivers in 2006 (F.A.C. 40A-2.223). The magnitude, duration and frequency of observed flows are reserved, essentially in total, for the protection of fish and wildlife of the Chipola River, Apalachicola River, associated floodplains, and Apalachicola Bay. As the Chipola River is presently subject to a water reservation, it is not included in the Northwest Florida Water Management District (NFWMD) current MFL schedule. Jackson Blue Spring in Marianna, FL, is a first magnitude spring (>2.8 cms or >100 cfs) that flows into Spring Creek, a tributary to the Chipola River (Barrios and Chelette 2004, p. 3). Jackson Blue Spring is currently being evaluated for a MFL by the year 2022 and rule adoption in 2023 (NFWMD 2018, p.11). These flow protection mechanisms are considered protective for the Fat Threeridge.

5.3.4.3 State of Alabama

Alabama does not have a comprehensive water management plan. The Alabama Water Resources Act of 1993 created the Office of Water Resources but it does not provide for water protection planning. The headwater tributaries of the Chipola River occur in Alabama, but Fat Threeridge does not and has not historically occupied these areas.

5.4 Factors Most Important to Future Conditions

While we are uncertain about relative influence of all factors in contributing to current condition of Fat Threeridge, some landscape characteristics that have led to habitat degradation, such as dams that fragment and inundate habitat, and alter natural flow, are part of existing baseline conditions for Fat Threeridge and are unlikely to change substantially in the near future. Some threats, such as dredging and snagging, have been restricted through regulation and are unlikely to continue into the future, or if so, are likely to be limited. Based on our review of factors affecting viability of Fat Threeridge in this Chapter, we focus our evaluation of future condition on habitat degradation associated with stressors to water quality and water quantity. These stressors (or threats) largely originate from anthropogenic land uses and climate change, are well demonstrated in the literature, and are likely to increase through time.

CHAPTER 6 – FUTURE CONDITION

6.1 Approach

We have considered what Fat Threeridge needs for viability and the current condition of those needs (Chapters 2 and 4). We reviewed the factors that are driving the current, and future conditions of the species (Chapter 5). We now consider the species' resiliency, representation, and redundancy under feasible future scenarios to evaluate viability of Fat Threeridge.

The persistence of Fat Threeridge is most likely to be negatively impacted by habitat degradation associated with the following three major threats: 1) land use, 2) water quantity and 3) and interactions with climate change, including sea level rise. Based on our review of factors affecting viability of Fat Threeridge we focus our evaluation of future condition on habitat degradation associated with two prevalent land uses in the ACF Basin, agricultural and urban development and their associated stressors to water quality and quantity. We also assess the potential impacts of sea level rise (SLR), and the removal of suitable habitat from this saltwater inundation.

We modeled threats 50 years into the future to predict the condition of analysis units in 2070. We felt this timeframe was biologically appropriate (representing two or three generations) and within the available and reliable modelling timeframe for projecting future threats. Where possible, we present data from 2020 to 2100 to better describe the potential trend in threats within the future scenarios considered. Timeframes earlier than 2070 may be too short to observe a species response (based on a lifespan of at least 30 years) or change in threats, and beyond 2070 may be too far into the future to reliably account for either. The land and water use threat assessment was completed within the subwatersheds defined during the delineation process (Section 4.1). We then interpret the projected future resiliency as it relates to redundancy and representation (according to longitudinal gradient and habitat diversity) of Fat Threeridge in the future scenarios.

6.1.1 Climate Change

To project future changes in climate, scientists rely on climate model simulations that are driven by assumptions about future human population growth, changes in energy generation and land use, socio-economic development, and technology change. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), published in 2014, presents the most recent climate findings based on a set of scenarios that use Representative Concentration Pathways (RCPs). There are four RCPs, identified by the amount of radiative forcing (i.e., the change in energy in the atmosphere due to greenhouse gases) reached by 2100: one high pathway (RCP 8.5); two intermediate stabilization pathways (RCP 6.0 and RCP 4.5); and one low trajectory pathway (RCP 2.6) selected from the range of climate scenarios present in the climate literature (van Vuuren et al. 2011, pp. 11, 20).

Prior to the development of the RCP scenarios, the IPCC developed Special Report Emissions Scenarios (SRES). One of the main differences between RCP and SRES climate projections is that RCPs start with atmospheric concentrations of greenhouse gases and SRESs start with a narrative story about socioeconomic processes that lead to a given future (Nakićenović et al. 2000, p. 3). Although the SRES projections are not as used widely today, these two approaches (SRES or RCP) are not inconsistent. Rather, they both present plausible and consistent pictures of how future human activities may affect climate. The RCP 4.5 scenario is comparable to the SRES B1 scenario and the RCP 8.5 scenario is comparable to the SRES A2 scenario (van Vuuren et al. 2011, pp. 17, 20; Figure 6-1). The model that we used to forecast land use into the future was based upon SRES scenarios, while the water quantity projection models we used were based upon RCP scenarios. For both factors, land use change and water quantity change, we provided a high and low climate change impact projection based on the RCP 8.5/SRES A2 and RCP 4.5/SRES BI scenarios, respectively. In presenting this range, our purpose is to provide bounds on the range of plausible outcomes, and we do not imply that an outcome in the middle of the range is the most likely outcome.

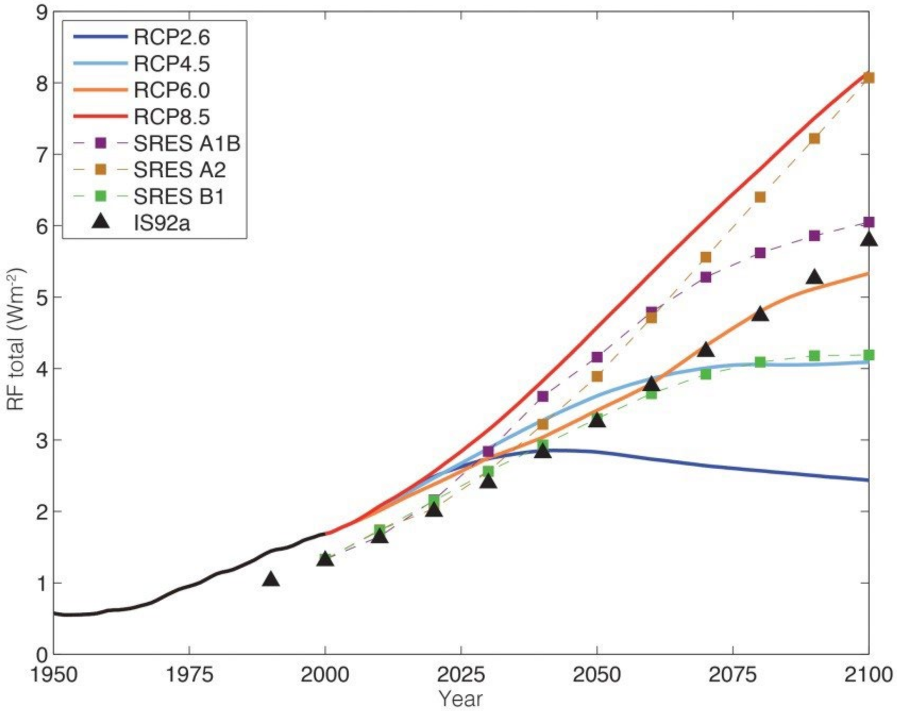


Figure 6-1. Historical and projected future anthropogenic radiative forcing (RF; the change in energy in the atmosphere due to greenhouse gases) under different scenarios, relative to the preindustrial period (about 1765; Cubasch et al. 2013, p. 146).

6.1.2 Land Use Change

To assess future changes in nonpoint source pollution, we summarized changes in land use within each of the Fat Threeridge analysis subwatersheds. We assessed both the change in the percent forested area in riparian buffers, and also the degree of urbanization and agricultural land use within subwatersheds as in the current condition (Section 4.2.4). Land cover data were compiled from the USGS FORE-SCE (FOREcasting SCEnarios of Land-use Change) model (Sohl et al. 2018, data release). This data set was selected because of the rural landscape in which Fat Threeridge occurs, and it provides future predictions of land use in annual time steps out to 2100 based on multiple future SRES scenarios (See Appendix B for more detail). We extracted results for SRES A2 and B1 to bound plausible future outcomes. The different land-use scenarios focused on socioeconomic impacts on anthropogenic land use (i.e., demographics, energy use, agricultural economics, and other socioeconomic considerations (Table 6-1). The SRES A2 projection assumes a continuously increasing global population where economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other land use projections. The SRES B1 projection describes a convergent world with global population that peaks in midcentury and declines thereafter, but with rapid changes in economic structures toward a service and information economy and the introduction of clean and resource-efficient technologies.

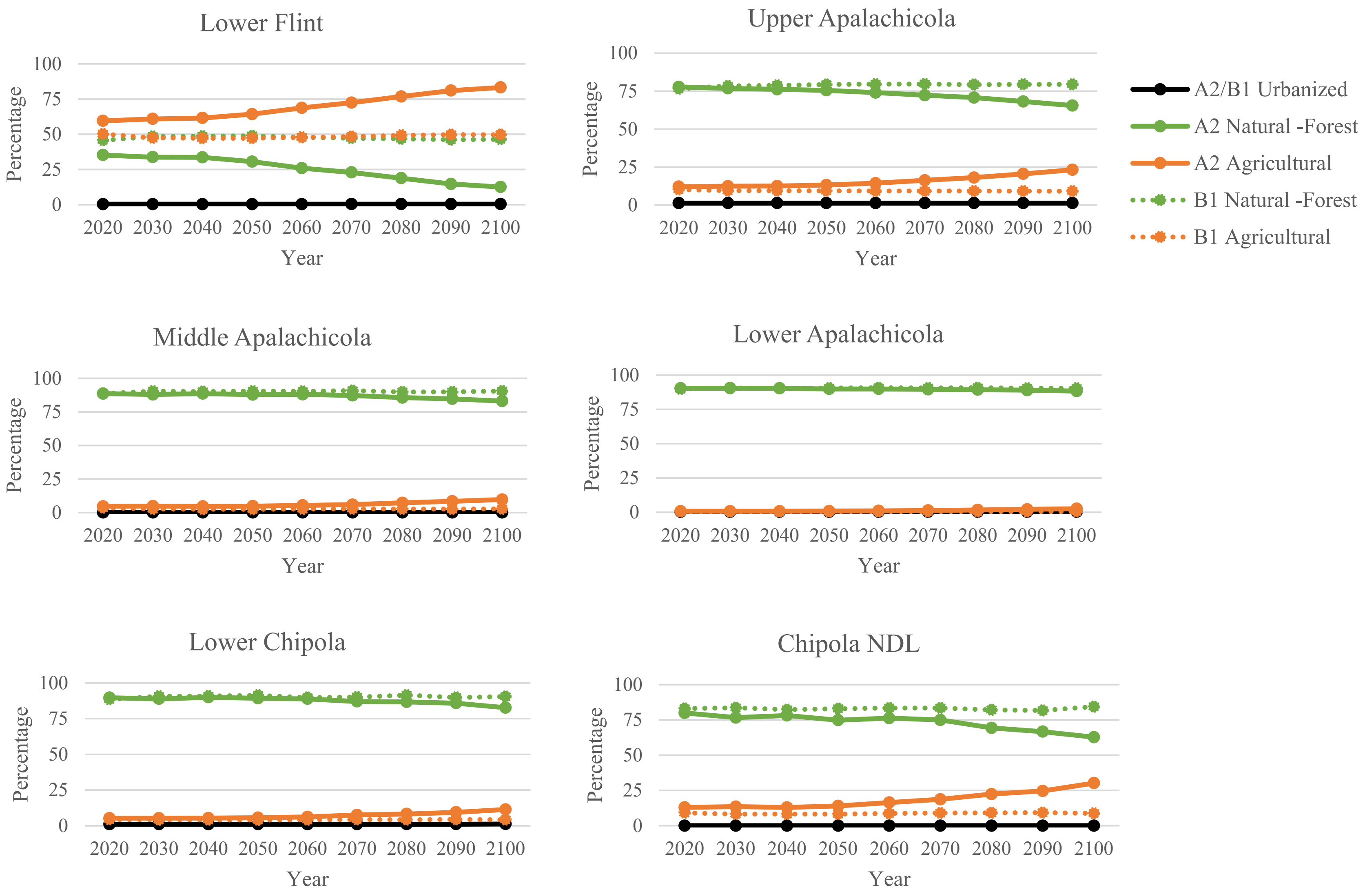
Table 6-1. Overview of characteristics of the SRES scenarios used in our future scenarios, adapted from Table 4-2 in IPCC (Nakićenović et al. 2000, p. 178).

Characteristics of Scenario Storylines	Scenario	
	A2	B1
Population Growth	high	low
GDP Growth	medium	high
Energy Use	high	low
Land Use Changes	medium/high	high
Resource Availability (oil and gas)	low	low
Pace of technological change	slow	medium
Technological change favoring	regional	efficiency and dematerialization

At the watershed scale, the amount of land in development is predicted to be low and stable across all populations and scenarios, while the amounts of natural lands and croplands are more variable (Figure 6-2). Under the B1 SRES, the amount of natural land and cropland are predicted to remain fairly stable or show a slight conversion of agricultural land back to natural land cover. Under the A2 SRES, natural lands are predicted to decrease in favor of cropland. The loss of natural land cover in the A2 SRES is predicted to be slight in the Lower and Middle Apalachicola as well as the Lower Chipola subwatershed, slightly more pronounced in the Upper Apalachicola and Chipola NDL watersheds, and most pronounced in the Lower Flint watershed where the amount of forested land (~23%) and agricultural use (~ 72%) are strongly diverging by 2070. While the Lower Flint currently contains more forested than agricultural cover, this is projected to change within the FORE-SCE A2 projection. All other subwatersheds are anticipated to retain a predominantly forested character.

Within the riparian buffer of analysis units, all populations are predicted to retain stable and high amounts of forested natural land cover and low amounts of anthropogenic land uses through time and between the A2 and B1 SRES. Forested riparian cover ranged from a low of 93.44% within the Lower Flint under A2 conditions in 2070, to 100%. The largest decrease in forested riparian cover occurs in the Lower Flint, with a corresponding increase in agricultural area under the A2 SRES (Appendix B).

Figure 6-2. Projected land use at the subwatershed scale for the A2 and B1 climate scenarios. The year of interest for our resiliency assessment is 2070, but all data is presented for an overview of trend.



Lower Flint

Upper Apalachicola

Middle Apalachicola

Lower Apalachicola

Lower Chipola

Chipola NDL

6.1.3 Water Quantity

To assess future water quantity, we used to same modeling outputs as in the current condition (LaFontaine et al. 2019, entire), which provided annual predictions for the time frame 2045-2075. We extracted results for two climate scenarios, RCP 4.5 and RCP 8.5 to bound plausible future outcomes and compared these against a historical simulated state (1950- 2005). Annual inputs of both historical and potential future land-cover type and percent impervious area were used to incorporate the effects of changing vegetation and impervious area (Lafontaine et al. 2019, p. 14). Historical simulations used observations of precipitation and air temperature presented in Section 4.2.6 and 13 historical simulations of precipitation and air temperature.

Results indicated that risk to the Fat Threeridge from low flow events will likely be lower than or similar to the current condition in the future for most analysis units (Figure 6-3; Appendix C, Table C1). There were few differences between the two climate scenarios. Mean minimum summer flows were projected to be comparatively lower under RCP 8.5 than RCP 4.

Under both modeled climate scenarios, minimum summer flow is predicted to increase or not change appreciably except for in the Chipola NDL and Lower Chipola. These units were noted to have both the highest minimum summer flow in Section 4.2.5. Future decreases in flow result in mean flows similar to modelled historical and future outputs for the Apalachicola River (Appendix C, Figure C1).

We assessed the current condition of this resiliency factor by classifying populations relative to each other as either high risk or low risk from low flow events. For the future condition, these classifications are not expected to change for any analysis unit. Low mean summer flows in the Lower Flint may increase under RCP 4.5, with minimal change under RCP 8.5. PRMS does not incorporate withdrawal of water for human uses, but this issue is considered somewhat within the land use change assessment.

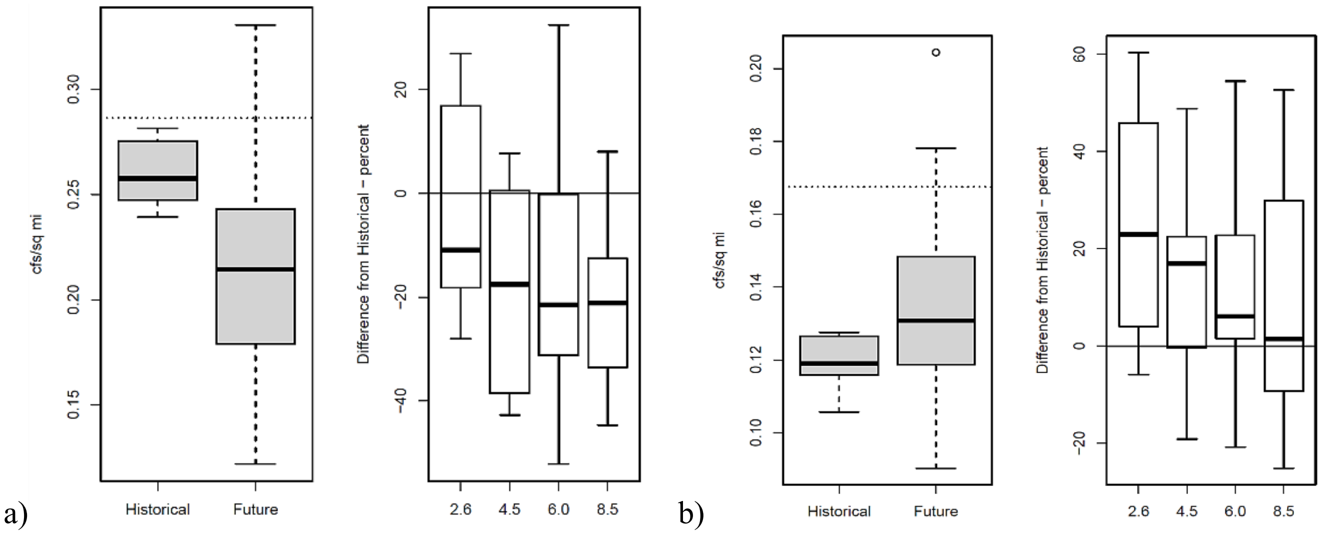


Figure 6-3. Future water quantity predictions under two climate scenarios (RCP 4.5 and RCP 8.5) compared to combined historical and current (1950 – 2005) simulated values for two Fat Threeridge subwatersheds. A comparison to observed historical values (horizontal dotted line) is provided. Boxplots depict mean summer minimum for the a) Chipola NDL and b) Lower Flint.

6.1.4 Sea Level Rise

As global temperatures increase, sea levels are expected to rise as a result of thermal expansion of ocean water and melting of ice sheets and glaciers, and already have risen about 0.19 meters between 1901 and 2010 (Church et al. 2013, p. 1139). The amount of SLR that will occur in the future will depend largely on the rate of anthropogenic greenhouse gas emissions and associated warming. To model SLR, we used four of the NOAA scenarios from Sweet et al. 2017 (pp. 21-22), projected out to 2070. Our possible future predictions of SLR include the intermediate, intermediate-high, high, and extreme scenarios, which are aligned with emissions-based, conditional probabilistic and global model projections of global mean sea level rise (Sweet et al. 2017, entire). We used the local scenario from at Apalachicola, FL, that best represents the range of Fat Threeridge (NOAA 2017, n.p.) for obtaining specific SLR values (Table 6-2). These SLR values were then rounded to the nearest foot to correspond to the resolution of the associated SLR shapefiles, which display SLR in one-foot increments.

Table 6-2. Actual and rounded values (in feet) used to estimate sea level rise (SLR) for four future sea level rise scenarios. The year of interest for our resiliency assessment is bolded. SLR values came from local scenarios for Apalachicola, FL.

	SLR Scenario	2040	**2070**	2100
Actual (ft)	Int	0.95	**2.10**	3.58
	Int-high	1.28	**3.12**	5.81
	High	1.64	**4.30**	8.14
	Extreme	1.9	**5.15**	10.14
Rounded (ft)	Int	1	**2**	4
	Int-high	1	**3**	6
	High	2	**4**	8
	Extreme	2	**5**	10

Rivers reaching the coast begin to feel the impact of tides. The NOAA SLR projections account for normal high tides (average high tide for a given local station), indicating areas that will be inundated or regularly flooded and affected by oceanic salts. While some degree of salt-water incursion may be expected in areas that are not inundated, the brackish zone would be difficult to define and the Fat Threeridge response uncertain. The upstream limit of tidal influence within the Apalachicola is an important consideration for defining Fat Threeridge habitat (Kaeser et al. 2019, p. 656). However, there is no precise boundary between the tidal and nontidal reaches; there is a transitional zone in which tidal influence is minimal at the upper end (occurring only at very low flows) and gradually increases downstream (Light et al. 2006, p. viii). Therefore, we focus on the observable upstream limit of inundation using the NOAA SLR models, with the understanding that a precise boundary cannot be delimited presently or in the future but relative comparisons should be insightful.

Saltwater inundation of Fat Threeridge habitat was determined through the presence of hydrological connectivity between inundated land and an analysis unit. Any tributaries projected to form between the analysis units and areas inundated by SLR, or existing tributaries flooded from tidal influences were indicators of salt water presence and/or tidal influence (Figure 6-4). The confluence of the affected tributary and the analysis unit was considered a conservative extent of salt-water inundation. Regions of an analysis unit downstream of these locations were projected to be inundated and no longer considered Fat Threeridge habitat. However, tidal influence may extend further upstream than what can be determined from tidal flooding and connectivity with inundated land; we believe it is unlikely that tidal influence is being overestimated using this approach.

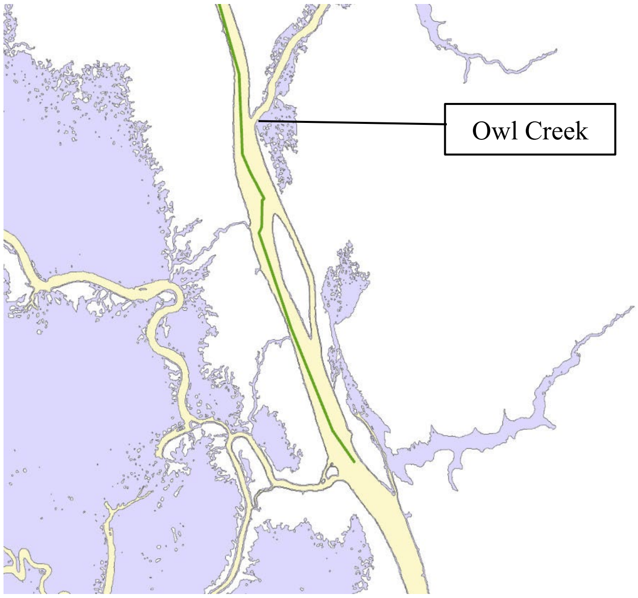


Figure 6-4. Seas level rise and salt-water inundation along the Lower Apalachicola River. Yellow areas indicate the current mean higher high water and existing surface water (NOAA 2017, n.p.). The green line indicates the approximate southern extent of the non-tidal zone of the Apalachicola River. Purple areas are inundated under 3-ft sea level rise (SLR). At this level of SLR, tributaries join inundated areas with the Apalachicola River. In addition, Owl Creek is enlarged, suggesting tidal flooding has moved norward at least this far within the Lower Apalachicola.

The Lower Apalachicola River contains many streams and lakes, such as Owl Creek and Lockey Lake, with bottom elevations below sea level and deep connections to the main channel at very low flows (Light et al. 1998, p. 53). This connectivity and minimal elevation helps to characterize the effects of SLR in the Apalachicola River. At 1 and 2-ft SLR low lying areas west of the Apalachicola River become inundated, but it is difficult to identify any effects to Fat Threeridge and the Apalachicola River. The extent of SLR anticipated under the intermediate NOAA projection would likely not affect Fat Threeridge until 2100, given a 2-ft rise is expected within our 2070 analysis timeframe. Similarly, intermediate-high projections are unlikely to impact Fat Threeridge by 2070. At 3-ft SLR new tributaries form between inundated areas and the Lower Apalachicola, and Owl Creek begins flooding; clear indicators that tidal influences and salt water intrusion are moving northward in connection with the Apalachicola River (Figure 6-4). However, this degree of inundation is minimal. At 4-ft SLR, tributaries form between inundated areas and the junction of the Lower Chipola and Lower Apalachicola rivers, with partial removal of habitat in the Lower Apalachicola. At 5-ft SLR, habitat is partially removed in both the Lower Apalachicola and Lower Chipola. These greater inundation extents occur within the high and extreme NOAA SLR projection by 2070. Estimates of the effects of various levels of SLR on Fat Threeridge habitat are included in Appendix D.

6.2 Future Scenarios

We assess resiliency, redundancy, and representation for Fat Threeridge under three sea level rise (SLR) threat levels (intermediate, high and extreme) and two multi-faceted scenarios largely based on potential variation in future land and water use . We used use these future threats and their effects on habitat as indicators of directional change in resiliency compared to the current condition. This assessment provides insight into how resiliency may change in the future. While we assign future resiliency estimates based on this ranking process, there is much uncertainty involved in doing so. For an analysis experiencing moderate resiliency at present, any of these downward changes in resiliency in the future might result in extirpation. We modeled threats 50 years into the future to predict the condition of analysis units in 2070.

Habitat was considered removed if it was projected to be inundated from SLR, and degraded if water quality or quantity condition were reduced from current condition (Table 6-3). Areas that are projected to be inundated by SLR in 2070 were categorized as "removed", as they are no longer considered habitat. If less than 10 percent of the analysis unit was removed through inundation, the unit was not considered impacted by SLR; if 10-90 percent of the analysis unit was removed through inundation, it was considered partially impacted; and if greater than 90 percent of the analysis unit was inundated, it was considered impacted (and extirpated). Habitat was considered partially degraded if water quality or quantity decreased condition in the future projection compared to the current condition rank, and degraded if both factors decreased one condition rank (or more); no degradation was expected if neither habitat factor changed condition.

Fat Threeridge could persist in degraded habitat, but salt water inundation is expected to preclude occupation. Partial habitat removal through SLR results in a greater loss of resiliency than partial degradation alone. We projected a similar drop in resiliency under partial and full habitat degradation, if partial habitat removal was also present, as we deemed the effects of partial habitat removal through SLR to be more impactful than the degree to which habitat degradation. If water flows were to cease, that level of degradation would result in extirpation, similar to completed habitat removal through inundation. No unit was expected to be fully inundated or lack flows by SLR by 2070, but our ranking system includes conditions that could lead to extirpation for context.

Table 6-3. Future change in resiliency based on threats to Fat Threeridge habitat.

Degraded (Water Quantity & Quality)	**Removed** (SLR)	**Resiliency Change**
no	no	no change
partial	no	↓
yes	no	↓↓
no	partial	↓↓
partial	partial	↓↓↓
yes	partial	↓↓↓
flows cease	yes	extirpated

As an upper bound of the potential effects of sea level rise (SLR) within both Scenarios, we examined SLR under the extreme NOAA projection of 5-ft SLR by 2070. The trends in sea level rise were introduced in Section 6.1.4 and assessed using data compiled in Appendix D. Extreme SLR projects **Partial** removal of habitat within the Lower Apalachicola and Lower Chipola by 2070. Only habitat within the Lower Apalachicola would be **Partially** removed under high SLR projections. If intermediate or intermediate-high SLR were to occur, **No Change** from SLR would be observed. We refer to these lower-range SLR projections together as "intermediate" in our discussion of future scenarios. Changes in water quality or quantity, and how that relates to habitat degradation and ultimately resiliency within analysis units is discussed below.

6.2.1 Scenario 1

This scenario assumes that conditions in the ACF Basin continue for the next 50 years along their present trajectory. Conservation actions that are already in place were assumed to continue, but were not increased or new projects initiated. Climate change trajectories presented in SRES A2 and RCP 8.5 projections were used to inform our consideration of the threats posed by land use to water quality and quantity (habitat degradation). Various sea level rise extents were considered in our assessment of habitat removal through inundation.

Water Quality

Changes in nonpoint source pollution were modeled as changes in land cover as described in Section 4.2.4 using the SRES land use projection data in Appendix B. SRES A2 represents high population growth and resource use, which is indicative of a continuation of current trends in the ACF Basin. The only analysis unit that decreases rank is the Middle Apalachicola which is considered to be in **Moderate** condition in 2070; agricultural area is expected to increase under the A2 scenario and this unit is expected to exceed 3% by 2070, or sooner; FORE-SCE projections suggest agricultural area would have surpassed 3% by 2020. All analysis units maintain high (> 85%) forested riparian cover, with no expected increase in urbanization.

Under SRES A2, water quality of the Lower Flint analysis unit remains in relatively **Low** condition given the large extent (~72%) of agricultural lands in the subwatershed and presence of a largely forested riparian area. The Chipola NDL, Lower Chipola, and Upper Apalachicola analysis units remain in **Moderate** condition, given the subwatershed urban and/or agricultural development > 3% but lower than cut-offs for a rank decrease. The Lower Apalachicola remains in **High** condition.

Water Quantity

Water quantity models from Section 6.1.3 were assessed as described in Section 4.2.5, resulting in **No Change** to this factor compared to the current condition.

Overall Resiliency

Compared to the current condition, resiliency is not predicted to change under this scenario for three out of six analysis units (Table 6-4). The Lower Flint, Upper Apalachicola and Chipola NDL will have no change in resiliency. While the Lower Flint is expected to have the greatest degree of agricultural land use of any analysis unit in the future, the intact riparian buffer mediates any further loss of condition given the maximal threshold for the subwatershed impacts of agricultural area (> 30%) has already been passed. There is generally no threshold change in water quality or quantity condition rank of analysis units; only the Middle Apalachicola is expected to decrease to moderate water quality due to the expansion of agricultural area, leading to partial habitat degradation compared to the current condition. The interpretation of a resiliency loss in the Middle Apalachicola from agricultural development is conservative, as the land use proportion is close to the threshold for change. The greatest potential impacts occur to the Lower Chipola and Apalachicola from SLR. These units decrease from high resiliency to low given the removal of habitat.

Table 6-4. Resiliency factors under future conditions. Changes in water quality or quantity inform the degree of habitat degradation, while NOAA sea level rise projections (extreme, high, and the grouped intermediate [labelled 'int']) influence habitat removal in 2070. Scenarios are denoted with (1) or (2). No change is denoted with (-).

Analysis Unit	**Current Resiliency**	**Water Quality**		**Water Quantity**	**Degradation**		**Removal (Int SLR)**	**Future Resiliency**		**Removal (High SLR)**	**Future Resiliency**		**Removal (Extreme SLR)**	**Future Resiliency**	
		1	**2**	**1&2**	**1**	**2**		**1**	**2**		**1**	**2**		**1**	**2**
Lower Flint	Mod	-	-	-	-	-	-	Mod	Mod	-	Mod	Mod	-	Mod	Mod
Upper Apalachicola	Mod	-	-	-	-	-	-	Mod	Mod	-	Mod	Mod	-	Mod	Mod
Middle Apalachicola	High	Mod*	-	-	Partial	-	-	Mod	High	-	Mod	High	-	Mod	High
Lower Apalachicola	High	-	-	-	-	-	-	High	High	Partial	Low	Low	Partial	Low	Low
Lower Chipola	High	-	-	-	-	-	-	High	High	-	High	High	Partial	Low	Low
Chipola NDL	Mod	-	-	-	-	-	-	Mod	Mod	-	Mod	Mod	-	Mod	Mod

*Mod = moderate condition or resiliency

6.2.2 Scenario 2

This scenario assumes that conditions in the ACF Basin continue for the next 50 years along a modified trajectory. Conservation actions that are already in place were assumed to continue, but were not increased or new projects initiated. Climate change trajectories presented in SRES B1 and RCP 4.5 projections were used to inform our consideration of the threats posed by land use to water quality and quantity (habitat degradation). Various sea level rise extents were considered in our assessment of habitat removal through inundation.

Water Quality

Changes in nonpoint source pollution were modeled as changes in land cover as described in Section 4.2.4 using the SRES land use projection data in Appendix B. We use SRES B1 in which conservation of water and other natural resources is improved from Scenario 1, and population growth is lower. **No Change** in condition is expected for any analysis unit. All analysis units maintain high (> 85%) forested riparian cover, with no expected increase in urbanization and slight increases or decreases in agricultural area.

Under SRES A2, water quality of the Lower Flint analysis unit remains in **Low** condition given the large extent (~48%) of agricultural lands in the subwatershed. The Chipola NDL, Lower Chipola, and Upper Apalachicola analysis units remain in **Moderate** condition, given the presence of subwatershed urban and/or agricultural development > 3% but lower than cut-offs for a rank decrease. The Lower Apalachicola remains in **High** condition.

Water Quantity

Water quantity models from Section 6.1.3 were assessed as described in Section 4.2.5, resulting in **No Change** to this factor compared to the current condition.

Overall Resiliency

Compared to the current condition, resiliency is not predicted to change under this scenario for any analysis unit in regards to water quality or quantity (Table 6-4). There is no threshold change in these resiliency factors and therefore no degradation compared to the current condition is anticipated from these sources. The greatest potential impacts may occur to the Lower Chipola and Apalachicola from SLR. Under intermediate SLR, It is likely the tidal zone will shift northward by 2070, but the extent of this is shift is difficult to depict and also may not modify resiliency to the point of reducing the current rank. However, under high and extreme SLR, two units transition from high to low resiliency.

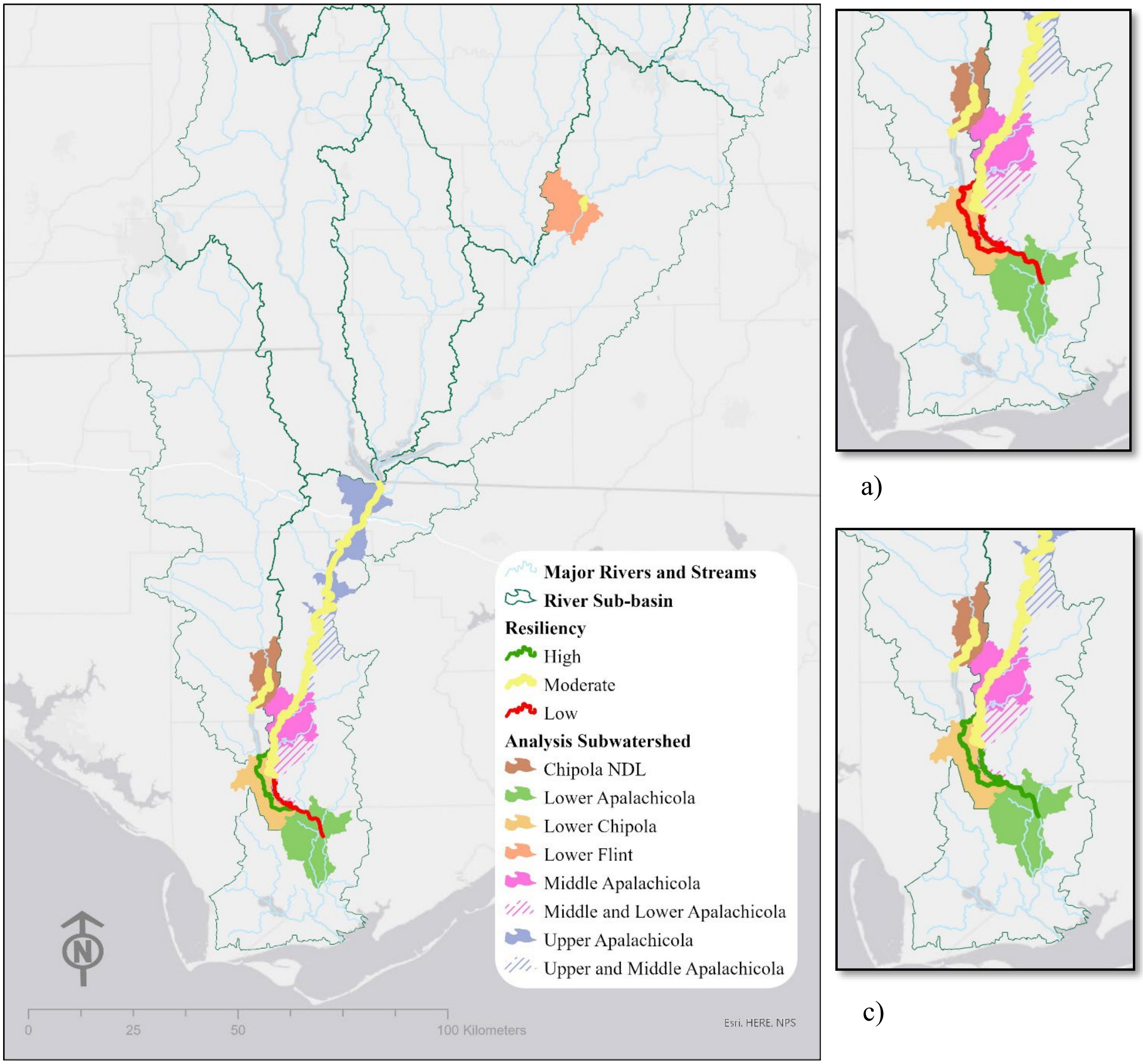
6.3 Future Resiliency

The largely climate and landuse-based future scenarios depict future conditions for Fat Threeridge which vary predominantly by the degree of sea level rise and its potential impacts. The greatest impacts from SLR occur to units that currently have high resiliency, resulting in two low resiliency and four moderate resiliency under extreme SLR within Scenario 1 (Figure 6-5). However, high or intermediate SLR within Scenario 2 would result in the retention of one or two high resiliency analysis units, respectively. Scenario 2 suggests resiliency can be maintained as in the current condition if SLR is similar to or less than the intermediate or intermediate-high NOAA projection. Otherwise, only one high resiliency may be maintained into the future under the highest SLR projections considered in Scenario 2.

While pathways to increasing resiliency were not incorporated within scenarios, it is evident that minimizing SLR is a key consideration for maintaining high resiliency in Fat Threeridge. Given our estimate of inundated area is likely conservative and the difficulty in describing the area of tidal influence, the effects of SLR may be beyond that described here. Therefore, we feel the greater degree of resiliency down-ranking for units affected by SLR, and the generous interpretation of partial habitat removal (> 10% of unit affected) is appropriate.

6.4 Future Redundancy and Representation

Fat Threeridge may experience a reduction in redundancy, largely depending on the extent of sea level rise. While moderate resiliency units contribute to redundancy and representation, low resiliency units do not. Redundancy is expected to be reduced when resiliency is lost in an analysis unit. No analysis units are expected to become extirpated, but two high resiliency units (Lower Apalachicola, Lower Chipola) may transition to low resiliency in the future regardless of changes in landuse. Redundancy under both scenarios could be described as moderate to high, as most (four of six) analysis units retain resiliency under the most severe projections (Figure 6-5), while no change from the current condition expected in Scenario 2 under intermediate SLR. Even under extreme SLR, ecoregion and river representation for Fat Threeridge is maintained at low to moderate. Under the greatest extent of sea level rise, representation in the Southern Coastal Plains is maintained by the Middle Apalachicola analysis unit (Figure 6-5). Representation is also maintained in all rivers (Apalachicola, Chipola, and Flint rivers).



a)

c)

Figure 6-5. Projected future change in resiliency for Fat Threeridge within Scenario 1 under a) extreme b) high and c) intermediate NOAA sea level rise projections. Scenario 2 is similar, however the Middle Apalachicola retains high resiliency. Analysis subwatersheds are depicted for context, with changes in resiliency occurring within the southern extent of the range.

CHAPTER 7 – FAT THREERIDGE VIABILITY SUMMARY

Based on best available data that we reviewed and synthesized in this SSA report, Fat Threeridge current condition is characterized by a restricted range. The species appears to exhibit redundancy and representation from the known historical distribution. Research and monitoring efforts for freshwater mussels in the ACF Basin since 2000 have provided empirical evidence that most Fat Threeridge analysis are exhibiting characteristics of resiliency, including the Lower Chipola, Lower Apalachicola, and Middle Apalachicola analysis units. Other units display moderate resiliency given some evidence of low occupation, abundance, or potential water quality issues regardless of possible positive or stable population trends and evidence of recruitment. However, we considered moderate and high resiliency units to exhibit resiliency in general, meaning all analysis units for the species were resilient at present given current knowledge. Continued efforts to monitor this species are necessary to determine if stable or increasing population trend is present in units such as Chipola NDL and the Lower Flint.

While we are uncertain about the precise mechanisms contributing to current condition of Fat Threeridge, some landscape characteristics that have contributed to habitat degradation, such as dams that fragment and inundate habitat, and alter natural flow, are part of existing baseline conditions for Fat Threeridge and are unlikely to change substantially in the time period until 2070. Dredging within the Apalachicola River may have significantly impacted habitat stability in the past, but this threat has been limited in frequency and extent to the degree that it has not occurred in the last 20 years, and is unlikely to occur in the future. Many of the threats are either largely in the past (dams, dredging), not as problematic as we expected (drought), or have only potential impacts given a limited understanding or extent in the range (deadhead logging, heavy metals, pesticides, pharmaceuticals). Based on our review of factors affecting viability of Fat Threeridge, the future condition of Fat Threeridge was assessed based on potential habitat degradation associated with two prevalent land uses in the ACF Basin, agricultural and urban development. The proportion of lands in these categories were surrogates for associated stressors to water quality and quantity. Potential variation in land use was assessed under differing SRES and RCP climate pathways, which formed the basis for two differing future scenarios. We also incorporated the potential effects of climate change through an assessment of various sea level rise (SLR) extents within the two scenarios.

Under both future scenarios, the predominant threat that may reduce viability for the species appears to be sea level rise. If SLR extent is high under Scenario 2, resiliency is lost in the Lower Apalachicola with the additional loss of resiliency in the Lower Chipola under extreme SLR. Under intermediate or intermediate-high SLR in Scenario 2, resiliency is maintained as in the current condition as land use change is minimal. Land use stressors will largely remain unchanged in Scenario 2 or increase in some analysis subwatersheds; the extent and scale of the increase is greater in Scenario 1. Agricultural land use is estimated to increase the most in the Lower Flint River, so impacts from stressors associated with that continuing land use could limit

Fat Threeridge such that resiliency transitions differently than projected. Fat Threeridge may be able to persist in larger river and mainstem habitats in the ACF Basin despite the potential for increasing land use stressors, and continue to exhibit resiliency in the Lower Flint if adequate water quality and quantity continue despite land use stressors, and all other needs are met in those areas.

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APPENDIX A

Table A1. Current land use in Fat Threeridge analysis unit subwatersheds and riparian buffer, derived from NLCD 2016 landcover.

Land Use	Analysis Unit	Combined Subwatershed		100-meter Riparian Buffer	
		Area (ha)	Percent	Area (ha)	Percent
Agricultural	Lower Flint	7509.78	**34.57**	0.36	**0.65**
	Upper Apalachicola	2433.87	**7.35**	5.22	**0.43**
	Middle Apalachicola	171.63	**0.80**	0.27	**0.03**
	Lower Apalachicola	11.61	**0.04**	0.00	**0.00**
	Lower Chipola	170.82	**1.47**	1.08	**0.20**
	Chipola NDL	376.56	**3.70**	0.00	**0.00**
Urbanized	Lower Flint	638.82	**2.94**	3.33	**5.98**
	Upper Apalachicola	1368.09	**4.13**	29.43	**2.40**
	Middle Apalachicola	606.24	**2.83**	13.32	**1.38**
	Lower Apalachicola	636.66	**2.44**	0.00	**0.00**
	Lower Chipola	735.75	**6.33**	24.30	**4.57**
	Chipola NDL	469.89	**4.62**	6.57	**2.02**
Natural - Forest	Lower Flint	12781.89	**58.83**	50.67	**90.95**
	Upper Apalachicola	24870.87	**75.14**	1113.93	**90.91**
	Middle Apalachicola	18759.15	**87.69**	915.84	**94.57**
	Lower Apalachicola	23529.06	**90.07**	462.06	**98.47**
	Lower Chipola	9871.74	**84.88**	493.47	**92.84**
	Chipola NDL	8021.61	**78.78**	307.89	**94.69**
Natural - Other	Lower Flint	658.53	**3.03**	1.35	**2.42**
	Upper Apalachicola	2784.33	**8.41**	76.77	**6.27**
	Middle Apalachicola	1017.54	**4.76**	38.97	**4.02**
	Lower Apalachicola	796.32	**3.05**	7.20	**1.53**
	Lower Chipola	595.98	**5.12**	12.69	**2.39**
	Chipola NDL	1186.83	**11.66**	10.71	**3.29**
Open Water	Lower Flint	136.89	**0.63**	n/a	**n/a**
	Upper Apalachicola	1640.34	**4.96**	n/a	**n/a**
	Middle Apalachicola	838.44	**3.92**	n/a	**n/a**
	Lower Apalachicola	1148.67	**4.40**	n/a	**n/a**
	Lower Chipola	255.33	**2.20**	n/a	**n/a**
	Chipola NDL	126.90	**1.25**	n/a	**n/a**

* some subwatersheds are shared between analysis units, and their land uses appear in both units

APPENDIX B

Table B1. Projected land use in Fat Threeridge analysis subwatersheds and river buffers in 2020 and 2070 under two climate scenarios within the FORE-SCE model.

Land Use	Analysis Unit	SRES	Year	Subwatersheds		100-meter Riparian Buffer	
				Area (ha)	Percent	Area (ha)	Percent
Agricultural	Lower Flint	A2	2020	8181.25	59.53	25.00	2.19
			2070	9950.00	72.46	56.25	4.92
		B1	2020	6893.75	50.20	25.00	2.19
			2070	6637.50	48.34	25.00	2.19
	Upper Apalachicola	A2	2020	3531.25	12.09	0.00	0.00
			2070	4712.50	16.25	0.00	0.00
		B1	2020	2975.00	10.18	0.00	0.00
			2070	2687.5	9.22	0.00	0.00
	Middle Apalachicola	A2	2020	956.25	4.67	12.50	3.28
			2070	1212.50	5.93	12.50	3.28
		B1	2020	750.00	3.67	6.25	1.64
			2070	568.75	2.78	6.25	1.64
	Lower Apalachicola	A2	2020	206.25	0.79	6.25	1.92
			2070	350.00	1.34	6.25	1.92
		B1	2020	162.50	0.62	0.00	0.00
			2070	150	0.57	0.00	0.00
	Lower Chipola	A2	2020	575.00	5.25	0.00	0.00
			2070	825.00	7.57	0.00	0.00
		B1	2020	481.25	4.39	0.00	0.00
			2070	481.25	4.39	0.00	0.00
	Chipola NDL	A2	2020	1118.75	12.92	6.25	0.70
			2070	1618.75	18.70	6.25	0.70
		B1	2020	787.50	9.10	6.25	0.70
			2070	775	8.95	6.25	0.70
Urbanized	Lower Flint	A2	2020	50.00	0.36	0.00	0.00
			2070	50.00	0.36	0.00	0.00
		B1	2020	50.00	0.36	0.00	0.00
			2070	50.00	0.36	0.00	0.00
	Upper Apalachicola	A2	2020	362.50	1.24	0.00	0.00
			2070	362.50	1.24	0.00	0.00
		B1	2020	362.50	1.24	0.00	0.00
			2070	362.50	1.24	0.00	0.00
	Middle Apalachicola	A2	2020	18.75	0.09	0.00	0.00
			2070	18.75	0.09	0.00	0.00
		B1	2020	18.75	0.09	0.00	0.00
			2070	18.75	0.09	0.00	0.00
	Lower Apalachicola	A2	2020	81.25	0.31	0.00	0.00
			2070	81.25	0.31	0.00	0.00

		B1	2020	81.25	0.31	0.00	0.00
			2070	81.25	0.31	0.00	0.00
	Lower Chipola	A2	2020	118.75	1.08	0.00	0.00
			2070	118.75	1.08	0.00	0.00
		B1	2020	118.75	1.08	0.00	0.00
			2070	118.75	1.08	0.00	0.00
	Chipola NDL	A2	2020	0.00	0.00	6.25	0.70
			2070	0.00	0.00	6.25	0.70
		B1	2020	0.00	0.00	6.25	0.70
			2070	0.00	0.00	6.25	0.70
Natural - Forest	Lower Flint	A2	2020	4843.75	35.24	1100.00	96.17
			2070	3143.75	22.89	1068.75	93.44
		B1	2020	6275.00	45.70	1093.75	95.63
			2070	6481.25	47.20	1112.50	97.27
	Upper Apalachicola	A2	2020	22731.25	77.81	356.25	100.00
			2070	20968.75	72.32	356.25	100.00
		B1	2020	22375.00	76.58	356.25	100.00
			2070	23218.75	79.67	350.00	98.25
	Middle Apalachicola	A2	2020	18131.25	88.63	368.75	96.72
			2070	17850.00	87.26	368.75	96.72
		B1	2020	18137.50	88.66	375.00	98.36
			2070	18581.25	90.86	375.00	98.36
	Lower Apalachicola	A2	2020	23593.75	90.38	318.75	98.08
			2070	23381.25	89.56	318.75	98.08
		B1	2020	23456.25	89.85	325.00	100.00
			2070	23650	90.59	325.00	100.00
	Lower Chipola	A2	2020	9818.75	89.67	481.25	98.72
			2070	9487.50	87.04	481.25	98.72
		B1	2020	9693.75	88.53	468.75	96.15
			2070	9868.75	90.13	487.50	100.00
	Chipola NDL	A2	2020	6918.75	79.93	862.50	96.50
			2070	6487.50	74.95	862.50	96.50
		B1	2020	7187.50	83.03	862.50	96.50
			2070	7218.75	83.39	856.25	95.80
Natural - Other	Lower Flint	A2	2020	206.25	1.50	6.25	0.55
			2070	200.00	1.46	6.25	0.55
		B1	2020	206.25	1.50	6.25	0.55
			2070	206.25	1.50	6.25	0.55
	Upper Apalachicola	A2	2020	156.25	0.54	0.00	0.00
			2070	156.25	0.54	0.00	0.00
		B1	2020	162.50	0.54	0.00	0.00
			2070	168.75	0.58	0.00	0.00
	Middle Apalachicola	A2	2020	100.00	0.49	0.00	0.00
			2070	100.00	0.49	0.00	0.00
		B1	2020	100.00	0.49	0.00	0.00

			2070	100	0.49	0.00	0.00
	Lower Apalachicola	A2	2020	43.75	0.17	0.00	0.00
			2070	43.75	0.17	0.00	0.00
		B1	2020	43.75	0.17	0.00	0.00
			2070	43.75	0.17	0.00	0.00
	Lower Chipola	A2	2020	12.50	0.11	0.00	0.00
			2070	12.50	0.11	0.00	0.00
		B1	2020	12.50	0.11	0.00	0.00
			2070	12.50	0.11	0.00	0.00
	Chipola NDL	A2	2020	12.50	0.14	12.50	1.40
			2070	12.50	0.14	12.50	1.40
		B1	2020	12.50	0.14	12.50	1.40
			2070	12.50	0.14	12.50	1.40
Open Water	Lower Flint	A2	2020	187.50	1.36	N/A	N/A
			2070	187.50	1.36	N/A	N/A
		B1	2020	187.50	1.36	N/A	N/A
			2070	187.5	1.36	N/A	N/A
	Upper Apalachicola	A2	2020	1831.25	6.27	N/A	N/A
			2070	1831.25	6.27	N/A	N/A
		B1	2020	1831.25	6.27	N/A	N/A
			2070	1831.25	6.27	N/A	N/A
	Middle Apalachicola	A2	2020	1025.00	5.01	N/A	N/A
			2070	1025.00	5.01	N/A	N/A
		B1	2020	1025.00	5.01	N/A	N/A
			2070	1025.00	5.01	N/A	N/A
	Lower Apalachicola	A2	2020	2068.75	7.92	N/A	N/A
			2070	2068.75	7.92	N/A	N/A
		B1	2020	2068.75	7.92	N/A	N/A
			2070	2068.75	7.92	N/A	N/A
	Lower Chipola	A2	2020	268.75	2.45	N/A	N/A
			2070	268.75	2.45	N/A	N/A
		B1	2020	268.75	2.45	N/A	N/A
			2070	268.75	2.45	N/A	N/A
	Chipola NDL	A2	2020	412.50	4.77	N/A	N/A
			2070	412.50	4.77	N/A	N/A
		B1	2020	412.50	4.77	N/A	N/A
			2070	412.50	4.77	N/A	N/A
Mechanically Disturbed	Lower Flint	A2	2020	275.00	2.00	12.50	1.09
			2070	200.00	1.46	12.50	1.09
		B1	2020	118.75	0.86	18.75	1.64
			2070	168.75	1.23	0.00	0.00
	Upper Apalachicola	A2	2020	600.00	2.05	0.00	0.00
			2070	962.50	3.32	0.00	0.00
		B1	2020	1512.50	5.18	0.00	0.00
			2070	875	3.00	6.25	1.75

	Middle Apalachicola	A2	2020	225.00	1.10	0.00	0.00
			2070	250.00	1.22	0.00	0.00
		B1	2020	425.00	2.08	0.00	0.00
			2070	156.25	0.76	0.00	0.00
	Lower Apalachicola	A2	2020	112.50	0.43	0.00	0.00
			2070	181.25	0.69	0.00	0.00
		B1	2020	293.75	1.13	0.00	0.00
			2070	112.5	0.43	0.00	0.00
	Lower Chipola	A2	2020	156.25	1.43	6.25	1.28
			2070	187.50	1.72	6.25	1.28
		B1	2020	375.00	3.42	18.75	3.85
			2070	200	1.83	0.00	0.00
	Chipola NDL	A2	2020	193.75	2.24	6.25	0.70
			2070	125.00	1.44	6.25	0.70
		B1	2020	256.25	2.96	6.25	0.70
			2070	237.5	2.74	12.50	1.40

*some subwatersheds are shared between analysis units, and their land uses appear in both units

The following is a description of the FORE-SCE model. The modeling time frame for this data set was 2006-2100, meaning that 2020 (current) results were modeled predictions also based on SRES scenarios as opposed to a common starting point. We used the FORESCE landcover for future projections though the degree of agricultural or urban development projected in 2020 differ slightly from NLCD 2016 landcover used to assess the current condition of the species.

Note that the FORE-SCE landcover data set is different from that used in the current condition assessment. We used NLCD data for the current condition because the resolution of the data (30 x 30 meters; 98 x 98 feet) was much smaller than the FORE-SCE data (250 x 250 meters; 820 x 820 feet), providing a direct interpretation and more spatially accurate picture of current land use. The FORE-SCE model, though it has a lower spatial resolution, offers annual predictions of land use into the future, which is not available with the NLCD data. Consequently, in presenting FORE-SCE land cover data for future assessments, we rely more heavily on the patterns of predicted land use change than the precise area of land predicted to be in each land cover class. To aid interpretation, we collapsed land cover classes down to five relevant categories similar to those used in Section 4.2.6: three natural classes ('forest' [including woody wetland, and deciduous, evergreen, and mixed forest], 'other' [including grassland, shrubland, barren, and emergent wetland]) and open water, as well as two anthropogenic ('urbanized' [development], and 'agricultural' [including cropland and hay/pasture]). Open water was not assessed within riparian buffers, but was included in subwatershed analysis. Extractive uses like forestry clearcuts were grouped into a 'mechanically disturbed' category and excluded from the following figures to aid interpretation and because values were low. Other low proportion cover types (e.g., natural-other, open water) were also omitted from figures for similar reasons. However, all cover types are provided in tabular form in Appendix B.

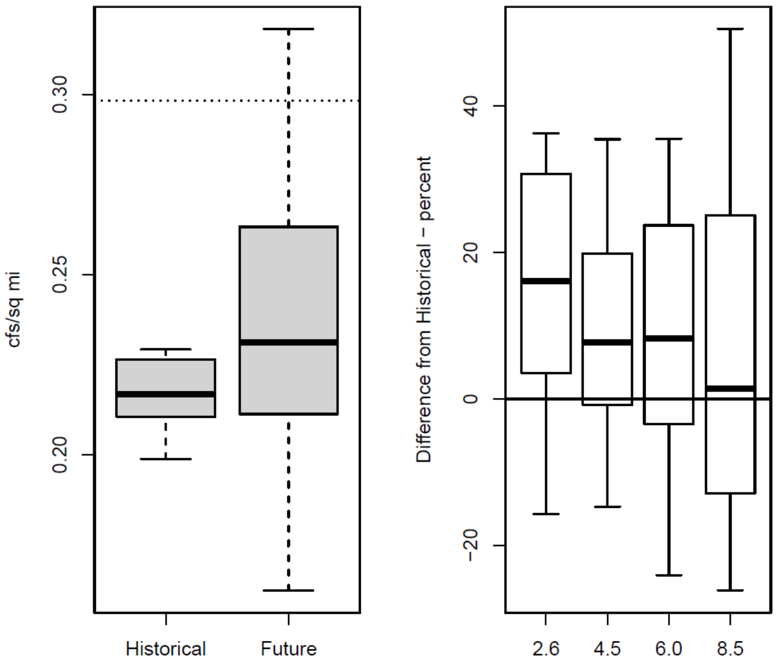
FORE-SCE incorporates effects of modeled future climate. The USGS's FORE-SCE model projections are used for a wide variety of purposes, including analyses of the effects of landscape change on biodiversity, water quality, and regional weather and climate. FORE-SCE scenarios were modeled for 2006 to 2100, corresponding to major scenario storylines from the IPCC Special Report on Emissions Scenarios (Nakićenović et al. 2000, entire). The 1992 to 2005 period was considered the historical baseline, with datasets such as the National Land Cover Database, USGS Land Cover Trends, and US Department of Agriculture's Census of Agriculture used to guide the recreation of historical land cover for this period. We focus on two of the downscaled SRES models, the A2 and B1 scenarios, used by FORE-SCE to produce landscape projections at decadal intervals consistent with the IPCC SRES.

APPENDIX C

Table C1. Simulated values for water quantity metrics over four time periods: Historical (1952-1978), Current (1979-2005), and Future (2045-2075) under two climate scenarios: RCP 4.5 and RCP 8.5.

Population	**Time Period**	**Mean Minimum Summer Flow** (cubic feet per second/ square mile)	
		Mean (SD) or % Change	**Median**
Lower Flint	Historical	0.19 (0.08)	0.17
	Current	0.18 (0.10)	0.15
	Future RCP 4.5	16.98%	N/A
	Future RCP 8.5	1.50%	N/A
Upper Apalachicola	Historical	0.30 (0.11)	0.28
	Current	0.30 (0.14)	0.29
	Future RCP 4.5	9.0%	N/A
	Future RCP 8.5	3.09%	N/A
Middle Apalachicola	Historical	0.31 (0.12)	0.30
	Current	0.31 (0.15)	0.29
	Future RCP 4.5	7.76%	N/A
	Future RCP 8.5	3.09%	N/A
Lower Apalachicola	Historical	0.32 (0.12)	0.30
	Current	0.33 (0.16)	0.31
	Future RCP 4.5	6.98%	N/A
	Future RCP 8.5	1.60%	N/A
Lower Chipola	Historical	0.34 (0.16)	0.30
	Current	0.43 (0.21)	0.41
	Future RCP 4.5	-18.48%	N/A
	Future RCP 8.5	-25.90%	N/A
Chipola NDL	Historical	0.31 (0.16)	0.26
	Current	0.40 (0.20)	0.41
	Future RCP 4.5	-18.02%	N/A
	Future RCP 8.5	-22.83%	N/A

Figure C1. Future water quantity predictions under two climate scenarios (RCP 4.5 and RCP 8.5) compared to combined historical and current (1950 – 2005) simulated values for the Apalachicola River. A comparison to observed historical values (horizontal dotted line) is provided for mean summer minimum flow. The segment presented here is representative of trends throughout the river.



APPENDIX D

Table D1. Projected impacts to Fat Threeridge habitat by sea level rise (SLR). No = < 10% impacted, Partial = 10-90%, Yes = > 90% impacted through habitat removal. The greatest extent of SLR considered for our future projection timeframe was 5 ft, but a range of SLR values are presented here for context as in Table 6-2. The exact percentage of inundation is included for reference.

Analysis Unit	**SLR 1 ft**	**SLR 2 ft**	**SLR 3 ft**	**SLR 4 ft**	**SLR 5 ft**	**SLR 6 ft**	**SLR 7 ft**	**SLR 8 ft**	**SLR 9 ft**	**SLR 10 ft**
Lower Flint	No	No	No	No	No	No	No	No	No	No
Upper Apalachicola	No	No	No	No	No	No	No	No	No	No
Middle Apalachicola	No	No	No	No	No	No	No	No	No	No
Lower Apalachicola	No	No	No (9.7%)	Partial (54.1%)	Partial (54.1%)	Partial (54.1%)	Partial (74.%)	Partial (74.%)	Partial (74.%)	Partial (75.4%)
Lower Chipola	No	No	No	No (1.8%)	Partial (19.3%)	Partial (19.3%)	Partial (19.3%)	Partial (38.3%)	Partial (53.3%)	Partial (53.3%)
Chipola NDL	No	No	No	No	No	No	No	No	No	No