

**U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT
AND LISTING PRIORITY ASSIGNMENT FORM**

SCIENTIFIC NAME: *Cambarus pristinus*

COMMON NAME: Pristine crayfish

LEAD REGION: Region 4

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DATE INFORMATION CURRENT AS OF: January 17, 2023

STATUS/ACTION

Species petitioned for listing which we have determined is not a listable entity

Species petitioned for listing which we have determined does not warrant listing (does not meet the definition of a threatened or endangered species)

Non-listed species for which we have not received a petition but for which we have undertaken a species status assessment on our own initiative and which we have determined does not warrant listing (does not meet the definition of a threatened or endangered species)

Listed species petitioned for delisting which we have determined does not warrant delisting

Listed species petitioned for downlisting which we have determined does not warrant downlisting

Listed species petitioned for uplisting for which we have made a warranted-but-precluded finding for uplisting (this is part of the annual resubmitted-petition finding)

Listed species petitioned for uplisting which we have determined does not warrant uplisting

New candidate

Continuing candidate

Date when the species first became a candidate (as currently defined):

Listing priority number change

Former LPN:

New LPN:

Candidate removal: Former LPN:

Taxon does not meet the Act's definition of "endangered species" or "threatened species" because it is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

Taxon does not meet the Act's definition of "endangered species" or "threatened species" because it is not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

Taxon does not meet the Act's definition of "species."

Taxon mistakenly included in past notice of review.

Taxon believed to be extinct.

Petition Information:

Non-petitioned

Petitioned; Date petition received: April 20, 2010

90-day "substantial" finding FR publication date; citation: September 27, 2011

PREVIOUS FEDERAL ACTIONS:

On April 20, 2010, we received a petition from the Center for Biological Diversity, Alabama Rivers Alliance, Clinch Coalition, Dogwood Alliance, Gulf Restoration Network, Tennessee Forests Council, and West Virginia Highlands Conservancy to list 404 aquatic, riparian, and wetland species, including the pristine crayfish, as an endangered or threatened species under the Act. On September 27, 2011, we published a 90-day finding in the *Federal Register* (76 FR 59836) concluding that the petition presented substantial scientific or commercial information indicating that listing may be warranted. This document constitutes our 12-month finding on the April 20, 2010, petition to list pristine crayfish under the Act.

ANIMAL GROUP AND FAMILY/PLANT GROUP, ORDER AND FAMILY:

Crustaceans, Cambaridae

ANALYTICAL FRAMEWORK

To assess the pristine crayfish's viability, we conducted a species status assessment (SSA) using the three conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 306–311). Briefly, resiliency supports the ability of the species to withstand environmental and demographic stochasticity (for example, wet or dry, warm or cold years, variation in demographic rates), redundancy supports the ability of the species to withstand catastrophic events (for example, droughts, large pollution events), and representation supports

the ability of the species to adapt to both near-term and long-term changes in its physical and biological environment (for example, climate change, disease). A species with a high degree of resiliency, representation, and redundancy 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). Using these principles, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing the species' viability.

We use the SSA framework to assemble the best scientific and commercial data available for this species. The SSA framework consists of three sequential stages. During the first stage, we evaluate the species' needs. The next stage involves an assessment of the historical and current condition of the species' demographics and habitat characteristics, including an explanation of how the species arrived at its current condition (i.e., how threats and conservation actions have influenced the species). The final stage of the SSA framework involves assessing the species' plausible range of future responses to positive and negative environmental and anthropogenic influences. The SSA framework uses the best available information to characterize viability as the ability of a species to sustain populations in the wild over time and is used to inform our regulatory decision.

The SSA report does not represent a decision by the Service on whether pristine crayfish should be listed as threatened or endangered under the Act. However, it does provide the scientific basis that informs our regulatory decisions, which involve the further application of standards within the Act and its implementing regulations and policies. The Species Status Assessment Report for the pristine crayfish (*Cambarus pristinus*) – October 2021, Version 1.1 (SSA report) is a summary of the information we have assembled and reviewed and incorporates the best scientific and commercial data available for this species. Excerpts of the SSA Report are provided in the sections below. For more detailed information, please refer to the SSA Report (Service 2021, entire).

Species Description

The pristine crayfish is a relatively small, freshwater crustacean distinguishable by its greenish-brown mottled pattern on the carapace and tail, as well as its markedly large eyes and delicate chela and a broad areola (Withers and McCoy 2005, p. 2; Rohrbach and Withers 2006, p. 2). A more detailed species description is provided in the SSA report in section 2.2 Species Description (Service 2021, pp. 16–17).



Figure 1. Dorsal view of a pristine crayfish male (Caney Creek form from West Fork Creek). Photo credit: Carl Williams, Tennessee Wildlife Resources Agency.

Taxonomy

The pristine crayfish was first described by Hobbs in 1965 based on individuals collected from Whiteoak Creek, a tributary to the Caney Fork of the Cumberland River, Tennessee (Hobbs 1965, p. 271). Intraspecific divergence within the species has been identified, and two morphologically and genetically identifiable forms are now recognized: the Caney Fork form and the Sequatchie form (Grubb 2019, p. 4; Johansen 2018, pp. 8–9). The Caney Fork form is restricted to the Caney Fork River system, while the Sequatchie form is found in the Sequatchie River system and streams within the Fall Creek Falls State Park in the Caney Fork River system (Grubb 2019, pp. 4–5, 31, 34; Simmons 2021, pers. comm.). The Caney Fork River is part of the Cumberland River drainage, whereas the Sequatchie River flows into the Tennessee River. There is no taxonomic uncertainty for pristine crayfish species at this time and both forms are recognized as the species *Cambarus pristinus*. In addition, we have carefully reviewed the available taxonomic information to reach the conclusion the species is a valid taxon. Additional

information regarding pristine crayfish taxonomy and phylogeny is available in section 2.1 Morphology and Taxonomy of the SSA report (Service 2021, pp. 14–16).

Habitat/Life History

Information regarding the life history and resource and habitat needs of pristine crayfish is available in the SSA report sections 2.3 Life History and 2.4 Resource Needs and Habitat (Service 2021, pp. 17–20) and summarized below and in Table 1, below.

The specific patterns and cycles of the pristine crayfish’s life history have not been determined. However, based on anecdotal information from field survey notes, we assume it follows a similar general pattern observed in other congenics. Male crayfish molt from form II (non-reproductive) to form I (reproductive) during spring, fall, and some summer months, while females likely bear eggs in the spring as typical of most crayfish species. The pristine crayfish lifespan appears to be four years with three to four age classes in healthy populations. Pristine crayfish typically naturally occur in low densities and population sizes are relatively small in the streams where they occur. The species abundance is similar to other rare crayfish in the southeastern United States, although distribution within occupied streams is patchy and related to the presence of flat rocks in shallow pools with appropriate flow Williams et al. 2004, p. 4; Johansen 2018, p. 56; Kilburn et al. 2014, p. 116; Grubb 2019, p. 4). Capture efficiency averages 32 percent; thus, pristine crayfish abundance may be underestimated in some studies or areas (Johansen 2018, p. 26).

The pristine crayfish occurs in shallow pools of low gradient first to fourth-order streams that have ample riparian cover, slow-to-moderate flow, and thalweg depths ranging from 4 to 55 centimeters (cm) (1.6–22 in) (Williams et al. 2004, pp. 4, 6; Withers and McCoy 2005, pp. 9–25; Johansen et al. 2016, p. 282; Simmons 2021, pers. comm.). Habitats occupied by the pristine crayfish are characterized by large slabs of rock resting on exposed bedrock, as well as small rocks, cobble, and sand interspersed throughout, but not consolidated by finer substrates such as silt (Hobbs 1965, p. 271; Withers and McCoy 2005, p. 2; Rohrbach and Withers 2006, p. 3; Dinkins 2009, p. 1-1; Johansen et al. 2016, p. 285). Pristine crayfish rely on suitable pool habitat featuring slab rocks to access prey and provide refuge from predation and competition, as well as cover during molting and egg extrusion. Pristine crayfish occur in streams with temperatures ranging from 4–17.8° Celsius (°C) (39–64° Fahrenheit (°F)), although temperatures as high as 30°C have been recorded at a pristine crayfish occurrence site (Flatrock Branch) (Williams 2021, pers. comm.).

Table 1. Pristine crayfish individual-level needs.

Type of Requirement	Description
Stream Permanence	Permanent
Stream Order	First- to fourth-order streams
Water Temperature	4–17.8°C (39–64°F)
Stream Flow Velocity	Shallow pools with slow to moderate flow

Stream Substrate	Slab substrate composed of large flat rocks with ample small rocks, cobble, and sand substrate
Embeddedness	Low embeddedness so that prey and refugia under rocks and in crevices remain accessible and interstitial spaces are available
Refugia	Cavities and crevices within large rocks
Diet	Precise diet unknown: likely smaller invertebrates, periphyton, and/or plant and animal detritus

Historical and Current Range/Distribution

The pristine crayfish is endemic to the Cumberland Plateau in Tennessee (Figure 2) (Grubb 2019, p. 4). The known range of pristine crayfish has expanded since the species’ description to include the Sequatchie River system in addition to the Caney Fork River system. Two distinct forms of pristine crayfish, the Caney Fork and Sequatchie forms, occupy the Caney Fork and Sequatchie river systems. The Caney Fork form is known only from the Caney Fork drainage where it occurs in 17 streams. The Sequatchie form is known to occur in 5 streams in Sequatchie drainage and 5 streams in the Caney Fork drainage (Table 2). The best available science indicates pristine crayfish occurs in 27 streams with most sites having multiple occurrence records over time, some sites with single survey information since 2004, and one site having no occurrences in a 2013 collection effort. Additional information regarding the historical and current range and distribution of pristine crayfish is found in the SSA report section 2.5 Range and Distribution (Service 2021, pp. 21–24).

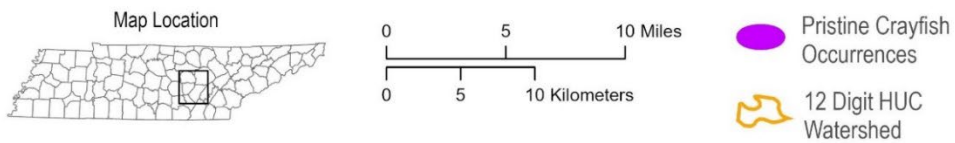
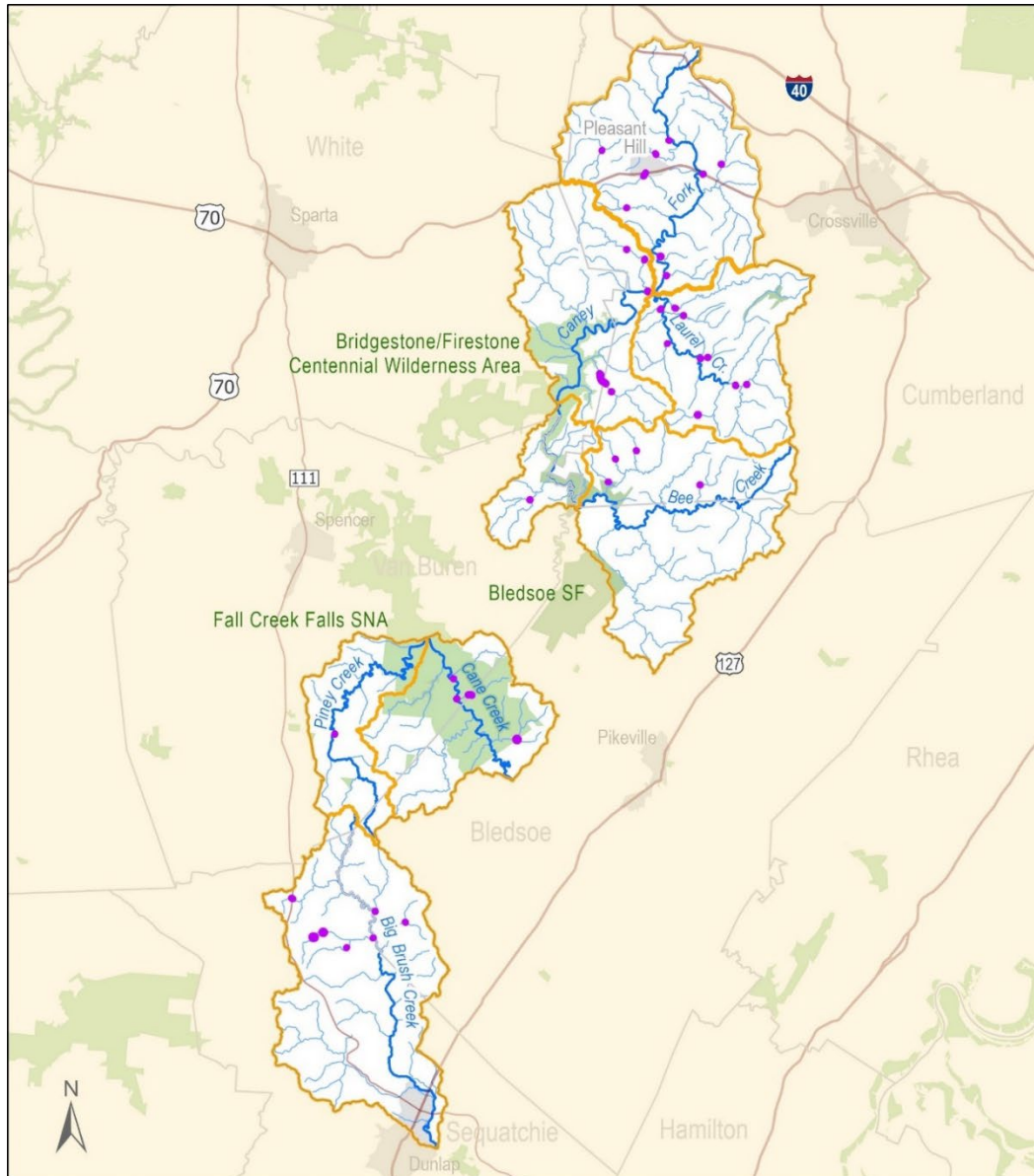


Figure 2. Range and distribution of pristine crayfish occurrences in eight HUC12 watersheds.

Table 2. Pristine crayfish (Caney Fork and Sequatchie form) current range and distribution and form in the Caney and Sequatchie river systems in Tennessee.

River System (HUC8)	Watershed (HUC10)	Subwatershed (HUC12)	Stream	Pristine Crayfish Form
Caney	Caney Fork River	Caney Fork River Headwaters	Wilkerson Creek	Caney Fork
			Pokepatch Creek	Caney Fork
			Whiteoak Creek	Caney Fork
			Maple Branch	Caney Fork
			Beam Creek	Caney Fork
			Caney Fork	Caney Fork
		Caney Fork River – Clifty Creek	West Fork Creek	Caney Fork
			Puncheoncamp Creek	Caney Fork
		Laurel Creek	Meadow Creek	Caney Fork
			Jumping Branch	Caney Fork
			Little Laurel Creek	Caney Fork
			Henderson Branch	Caney Fork
		Bee Creek	Bee Creek Lower	Spring Creek
	Miller Branch			Caney Fork
	Bee Creek Upper		Oldfield Branch	Caney Fork
			Little Cane Creek	Caney Fork
			Raccoon Creek	Caney Fork
Cane Creek	Cane Creek Upper	Flat Rock Branch	Sequatchie	
		Pineorchard Creek	Sequatchie	
		Piney Creek	Sequatchie	
		Camp Creek	Sequatchie	
	Piney Creek	Piney Creek	Sequatchie	
Sequatchie	Sequatchie River	Big Brush Creek	Glady Fork	Sequatchie
			Long Fork	Sequatchie
			Bird Fork	Sequatchie
			Flatrock Branch	Sequatchie
			Rattlesnake Branch	Sequatchie

Population Needs

As described in the SSA report section 2.4 Resource Needs and Habitat, pristine crayfish populations need the same key habitat-based resources as individuals (Table 1), as well as a sustainable population size and connectivity within and among populations (Service 2021, pp. 20). Crayfish populations also need relatively stable conditions within the stream ecosystem each year, especially during the spring when females are ovigerous. To maintain needed gene flow,

there needs to be connectivity between and among populations to facilitate genetic exchange.

For a detailed description of information sources and delineation methodology, see the SSA report (Service 2021, p. 46). We delineated eight pristine crayfish analysis units (AUs) at a subwatershed (HUC12) level across the range of the species to include 27 streams with pristine crayfish occurrence (Table 2).

Species Needs

For species viability, there must be adequate redundancy (suitable number of populations, distribution of populations, and connectivity between populations allow the species to withstand catastrophic events) and representation (suitable genetic and environmental diversity to allow the species to adapt to changing environmental conditions). Redundancy improves with increasing numbers of populations at moderate and high resiliency conditions and connectivity among those populations to allow populations to “rescue” each other after catastrophic events. Representation improves with increased genetic diversity and environmental conditions within and among populations. The species-level needs of pristine crayfish are further described in the SSA report (Service 2021, pp. 20).

BIOLOGICAL INFORMATION

The pristine crayfish is a small, freshwater crayfish endemic to the Cumberland Plateau in Tennessee. The species occurs in small to medium-sized streams and rivers in the Caney Fork and Sequatchie river systems in central Tennessee. Pristine crayfish are known to occur in 27 streams in 8 subwatersheds (HUC12) in the region. Two distinct forms of the pristine crayfish are recognized based on body characteristics and genetics: the Caney Fork form and the Sequatchie form. The Caney Fork form of pristine crayfish occurs in five northern subwatersheds (17 streams) and the Sequatchie form occurs in three southern subwatersheds (10 streams).

The pristine crayfish requires good water quality in first- to fourth-order perennial streams with ample riparian cover and cool water, shallow pools with slow to moderate flow, slab rock substrate with cobble and low levels of sedimentation. Pristine crayfish rely on suitable pool habitat featuring slab rocks to access prey and provide refuge from predation and competition, as well as cover during molting and egg extrusion. Stream temperatures range from 4–17.8° Celsius (°C) (39–64° Fahrenheit (°F)). The precise diet of pristine crayfish is unknown, but is likely smaller invertebrates, periphyton, or plant and animal detritus.

For additional information on the species description, taxonomy, habitat/life history, historical and current range/distribution please refer to pp. 14–24 of the SSA report. For additional information on population and species needs, please refer to pp. 20–21 of the SSA report.

FACTORS INFLUENCING THE STATUS

The Act directs us to determine whether any species is an endangered species or a threatened species because of any factors (or threats) affecting its continued existence (i.e., whether it meets the definition of a threatened species or an endangered species). We use the term “threat” to refer in general to actions or conditions that are known to or are reasonably likely to negatively affect individuals of a species. The term “threat” includes 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. The term “threat” may encompass—either together or separately—the source of the action or condition, or the action or condition itself.

However, the mere identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an “endangered species” or a “threatened species.” In determining whether a species meets either definition, we must evaluate all identified threats by considering the expected response by the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Secretary determines whether the species meets the definition of an “endangered species” or a “threatened species” only after conducting this cumulative analysis and describing the expected effect on the species now and (if evaluating whether a species is a threatened species) in the foreseeable future.

Threats

The following discussion provides a summary of the factors that are affecting, or could be affecting, the current and future condition of the pristine crayfish throughout some or all of its range. Of the threats, habitat destruction or modification, including the impacts of sedimentation, decreased water quality, and the effects of impoundments, is the primary threat affecting the pristine crayfish. We also evaluated the potential impacts of climate change, disease, isolation and small population size, which were not identified as primary threats to the species. For a full description of influences and the species’ response, see Chapter 3 of the SSA report (Service 2021, pp. 25–46).

Sedimentation

Sedimentation or siltation of substrate and filling of interstitial spaces is considered to be the primary influence on pristine crayfish viability. Crayfish occupy the substrate at the bottom of their associated stream or riverine habitat. Therefore, the availability of unembedded rocks, crevices, and woody debris microhabitats that provide access to prey, refuge from predation and competition, as well as cover during vulnerable periods such as molting or egg extrusion are essential to pristine crayfish. Under base flow conditions, the headwater streams where pristine crayfish occurs typically do not have adequate velocity to dislodge and transport excess sediment downstream. This results in sediment deposition that embeds resources (e.g., food, shelter, refugia) necessary to pristine crayfish (Withers and McCoy 2005, p. 5; Rohrbach and Withers

2006, p. 8). Therefore, additional sediment input from a variety of sources overwhelms the stream's capacity to remove it (except during heavy rainfall events) and negatively affects the pristine crayfish. Sources of sedimentation in the pristine crayfish range include silviculture activities that do not use best management practices (BMPs) or that improperly implement BMPs, agriculture, historical mining, and impoundments. We describe the effect of sedimentation related to historical mining and small stream impoundment in the Historical Coal Mining and Stream Impoundment sections below, respectively. Sedimentation is also a component of water quality and sediment may carry pollutants into the stream, which result in an increase in suspended solids and reduced light availability leading to a reduction or loss of aquatic plants.

Silviculture

Sedimentation resulting from timber harvest, road construction, and other silvicultural practices that do not employ appropriate silvicultural BMPs is the primary influence on pristine crayfish viability (Withers and McCoy 2005, p. 5; Rohrbach and Withers 2006, p. 8). Silvicultural activities, when implemented with appropriate and adequate best management practices (BMPs), can retain adequate conditions for aquatic ecosystems. However, we also note that, when BMPs are not implemented or inadequate implementation occurs, these forestry activities can also cause measurable impacts (NCASI 2015, p. 1) and contribute to the myriad of stressors facing aquatic systems in the Southeast (Service 2021, p. 28–29). In addition, we note that one major, albeit temporary, BMP failure, a harvest that is non-compliant with BMPs, or failure to maintain a BMP, can cause sedimentation that severely impacts pristine crayfish populations as described below. Tennessee's forestry BMPs, when properly implemented, protect water quality and help conserve aquatic species, including the pristine crayfish. Forest landowners who properly implement those BMPs are helping conserve the crayfish and those forest landowners who are third-party-certified to a credible forest management standard are providing audited certainty that BMP implementation is taking place across the landscape.

A forested landscape provides ideal conditions for aquatic ecosystems, including pristine crayfish. While forests with natural composition contribute to sediment in streams, pine plantations were shown to contribute to erosion and subsequent sediment deposition to a higher degree than natural deposition in a Southeast Coastal Plain study (Anderson and Lockaby 2011, p. 171). We expect a similar pattern in the pristine crayfish's range due to similar soils and slope gradients. Recently harvested forests with an exposed forest floor can increase runoff and erosion due to a lack of canopy cover (Anderson and Lockaby 2011, p. 171). In addition, roads and stream crossings associated with silvicultural practices may contribute a greater amount of runoff and subsequent sedimentation than timber harvest activities themselves (Anderson and Lockaby 2011, p. 171). In the Cumberland Plateau, established roads within forest plantations have been found to interrupt natural drainage patterns, increase soil exposure, concentrate runoff flow, alter soil structure and subsurface hydrology, steepen side slopes, compact soil that is repeatedly driven over, as well as continuously create disturbances by means of traffic, grading, and/or establishing new roads (McGrath et al. 2004, p. 16). Excess sedimentation is present at several pristine crayfish sites adjacent to forested areas where silvicultural activities are conducted with

improperly implemented or no BMPs in place (Johansen 2021, pers. comm.; Simmons 2021, pers. comm.; Williams 2021, pers. comm.). Land use in silviculture (evergreen forest land cover class) occurs within approximately 10 percent of the 30-m riparian area adjacent to streams with pristine crayfish occurrence.

Agriculture

Agricultural practices, including row crops and cattle grazing, can contribute to sedimentation in nearby streams and can negatively influence pristine crayfish viability. The tablelands of the Cumberland Plateau provide suitable land for certain farming practices. The region also features steep slopes and ravines, and heavy rain events have the potential to produce significant runoff that transports suspended sediments from agricultural lands to nearby streams within the catchments. Potential sources of sedimentation from agricultural practices include the exposure of loose soil following row crop harvest, the use of heavy machinery that disturbs soil composition and breaks down sediments into fine particles, as well as cattle trampling vegetation that would otherwise anchor the soil and stabilize nearby streambanks (Burskey and Simon 2009, p. 207). The pristine crayfish's range is not in an area of Tennessee with heavy agricultural use; however, the small headwater streams where the species occurs are more sensitive to sedimentation and water quality concerns than larger streams with a greater volume of water to dilute pollutants entering the stream (Simmons 2021, pers. comm; Williams 2021, pers. comm.).

Stream Impoundment

Sedimentation is considered to be the most significant influence on freshwater habitat quality caused by small stream impoundment (Arnwine et al. 2006, p. 3). Decreased flow velocity associated with stream impoundment results in increased fine sediment accumulation leading to subsequent substrate embeddedness, decreased woody debris availability, more severely entrenched stream channels, and increased water temperature, reducing or eliminating pristine crayfish food and shelter resources (Arnwine et al. 2006, p. 3; Adams 2013, p. 1328; Barnett and Adams 2021, p. 3; Williams 2021, pers. comm.). In Tennessee, eighty percent of small streams in headwater areas surveyed by the TDEC-Division of Water Pollution Control failed to meet regional habitat quality expectations as a result of sediment deposition below small dams (Arnwine et al. 2006, p. 3). In the Cumberland Plateau, impounded streams demonstrate more silt and sand substrate and less cobble and boulder substrate compared to unimpounded streams, resulting in habitat less suitable for pristine crayfish (Arnwine et al. 2006, p. 62). The density of small impoundments (less than 250 acres) in the Cumberland Plateau ecoregion and Caney Fork watershed is among the top 10 percent of areas in Tennessee. Therefore, we expect the high number of small stream impoundments in the pristine crayfish range influences habitat conditions in those streams and negatively impacts pristine crayfish viability (Arnwine et al. 2006, pp. 13–14). Conditions in several streams with pristine crayfish occurrences have been observed to be negatively impacted by small impoundments (Simmons 2021, pers. comm.; Williams 2021, pers. comm.).

Water Quality

Suitable water quality is a requirement for most freshwater species, including the pristine

crayfish. Although little is known regarding the pristine crayfish's specific water quality requirements, water quality parameters such as water temperature, nutrient load, pH, and conductivity influence crayfish biological processes such as osmoregulation, immunology, acid/base regulation, gas exchange, reproduction, molting, growth rate, and behavior (Romano and Zeng 2013, p. 17; Schorr et al. 2013, p. 340). Of these water quality parameters, conductivity has the greatest influence on the species with a negative correlation between higher conductivity waters and pristine crayfish site occupancy (Johansen 2018, pp. 21, 24). Current and historical surrounding land uses that affect conductivity in the pristine crayfish range include historical coal mining, silviculture, agriculture, and urbanization and development.

Historical Coal Mining

Within the species' range, the Cumberland Plateau's history of extensive coal mining has resulted in stream degradation due to sedimentation and acid mine drainage derived from historical coal mining sites (Etnier and Starnes 1993, p. 14; Grubb 2019, p. 23). Although little coal mining takes place in the species' range now, the effects of historical practices continue to affect streams in the region. Acid drainage from coal mining sites decreases the pH and increases the conductivity in receiving streams (Schorr and Backer 2006, pp. 19, 21; Schorr et al. 2013, pp. 339–353; Gangloff et al. 2015, pp. 702–712). Due to the underlying sandstone geology, streams draining the Cumberland Plateau naturally have low conductivity. Observed specific conductance values above the expected value for the region suggests that acid mine drainage may have been or may currently be an influence on pristine crayfish viability. Conductivity tolerances for the pristine crayfish are unknown; however, a negative relationship has been observed between conductivity and pristine crayfish site occupancy (Johansen 2018, pp. 21, 24). Furthermore, the abundance of fish, salamanders, and macroinvertebrates is consistently lower in streams influenced by acidic mine drainage on the Cumberland Plateau (Schorr and Backer 2006, p. 19; Schorr et al. 2013, pp. 345, 347; Gangloff et al. 2015, pp. 702–712). Water quality changes related to mine drainage, including changes in conductivity and pH, may influence crayfish molting patterns and growth rates (Zanotto and Wheatly 1993, pp. 2, 5, 13). Although the specific pH tolerance of the pristine crayfish is unknown, a decrease in stream pH as a result of acid mine drainage could impair the pristine crayfish's ability to appropriately calcify its exoskeleton, influencing survival and reducing abundance. Information pertaining to the effects of acid mine drainage specific to crayfish abundance is limited; however, an overall decrease in aquatic species richness and abundance as a result of increased conductivity and decreased pH has been observed within the species' range (Schorr and Backer 2006, p. 20; Schorr et al. 2013, pp. 345–349).

Coal mining has also contributed to sedimentation in streams in the past and historical coal mine sites continue to contribute sediments in receiving stream reaches. Strip-mining practices, in particular, have left behind expansive swaths of exposed substrate that contribute to sedimentation in receiving streams as a result of stormwater runoff. Sedimentation in streams with pristine crayfish occurrences has been observed to embed refugia and food resources, making them inaccessible, and thereby decreasing pristine crayfish viability as described above.

Agriculture

Agricultural practices influence water quality by means of stormwater runoff that transports sediment and pollutants including pesticides, herbicides, fertilizers, and livestock waste into nearby streams. Stormwater runoff from agricultural fields during the planting season (spring and early summer) is considered to be the most significant source of water quality contamination (Sohn et al. 2018, pp. 900, 905). Corn, tobacco, and hay are grown in locations on the Cumberland Plateau and fertilizer, pesticides, and herbicides are typically applied to these crops. When exposed to pesticides commonly used on crops in the pristine crayfish range, crayfish in the genus *Orconectes* showed behavioral changes that increase the risk of predation or injury (Sohn et al. 2018, p. 905). We do not have information sufficient to allow us to estimate the amount and types of pesticides used within the pristine crayfish's range or the level of pesticides in streams with pristine crayfish occurrence.

Stormwater runoff from agricultural lands also contributes to increased nutrient loads within nearby streams as a result of fertilizers and livestock waste transported into the streams. Nitrogen loading has several deleterious effects on crustaceans: inhibition of growth rate, reduced osmoregulation, reduced immunological capacity, altered acid/base regulation, and reduced gas exchange (Romano and Zeng 2013, p. 17). The specific influence of nitrogen loading on the pristine crayfish is unknown, but we expect the species to experience negative effects as observed in other crustaceans. Pristine crayfish affected by stunted, inefficient biological processes would experience an overall decrease in fitness and would be less likely to successfully mature and reproduce, leading to decreased population abundance.

Agricultural practices can also influence changes in water quality through increased water temperature and availability in streams as a result of decreased canopy cover, increased water withdrawal, or stream impoundment for irrigation. Increased water withdrawal may reduce groundwater recharge, making lower order streams with pristine crayfish occurrences more susceptible to going dry in severe drought conditions. The effects of agriculture on water quality through the transport of pesticides, herbicides, fertilizers, livestock waste, and other substances into streams and on water quantity have not been quantified within streams with pristine crayfish occurrences. However, lands in agricultural use in the species' range are not extensive and the primary threat associated with agriculture is sedimentation.

Silviculture

Conversion of forests with natural composition to pine plantation managed through silvicultural practices may affect water quality in nearby receiving streams with pristine crayfish occurrence. The percent evergreen forest cover (as a surrogate measure of pine plantation silviculture) is negatively correlated with pristine crayfish site occupancy, with a similar negative relationship between site occupancy and conductivity (Johansen 2018, pp. 11–12, 20–21, and 24–25). Crayfish require the availability of certain elements, such as calcium, to successfully rebuild their chitinous exoskeleton during normal molting. The conversion of naturally occurring

hardwood forests to pine reduces calcium availability on the forest floor and in runoff, groundwater, and streams (McGrath et al. 2004, pp. 17–18, 21). Although measurements of calcium are not available for streams with pristine crayfish occurrence, we expect available calcium is reduced in streams with a high level of pine plantation silviculture in the catchment.

Urbanization and Development

An increase in impervious surfaces associated with urbanized land cover directly results in a higher volume of stormwater runoff with higher velocity flows discharged into receiving streams. Hydrological alterations due to increased high-velocity runoff can result in the scouring of streambeds and stream banks of lower order streams similar to the effects of flooding (Lockaby et al. 2013, p. 333). The temperature of receiving streams is increased as a result of stormwater runoff flowing over warm impervious surfaces. In addition, an increase in the volume and velocity of stormwater runoff due to urbanization can result in an increased amount of sediment and pollutants carried in the runoff and discharged into receiving streams (Lockaby et al. 2013, pp. 316–317). Areas of urbanization are limited in the pristine crayfish's range compared to silviculture and agricultural land uses; however, threats associated with urbanization and increased impervious surfaced may affect individuals or populations of pristine crayfish.

Climate Change

Changes in global precipitation patterns as a result of climate change are expected to result in decreased precipitation and higher temperatures in the Southeast (Nissenbaum 2016, p. 33). The combination of higher temperatures and decreased precipitation may result in more frequent and prolonged drought conditions. Since the 1970s, moderate to severe droughts in the Southeast have increased by 12 to 14 percent during spring and summer months (Jones et al. 2015, p. 126). During drought, stream flow is reduced, or streams may run dry if not replenished by rainfall and groundwater recharge (Lockaby et al. 2013, p. 310). Lower order (typically shallower) streams are particularly vulnerable to low flow and subsequent drying that could influence the pristine crayfish by decreasing the amount of available habitat, in turn increasing predation and competition and reducing prey items and shelter and refugia sites. Pristine crayfish do not burrow into the substrate or stream banks during dry periods and, as a result, rely on remaining isolated pools and stream segments during periods of drought (Simmons 2021, pers. comm.). These factors, along with potential desiccation of individuals, would result in decreased abundance and reproduction, leading to reduced population resiliency.

Higher precipitation or extreme weather events may also affect the pristine crayfish.

Cumberland, Sequatchie, and Van Buren counties, Tennessee, experienced above average annual rainfall from 2015 to 2020, and each county received more than 20 inches of precipitation above the annual average in 2018 (Climate Explorer 2021). An increase in the frequency, duration, and/or severity of rain events may influence pristine crayfish habitat through increased sedimentation and degraded water quality as a result of increased sediment, pollutants, and nutrients carried in higher volume stormwater runoff (Poff et al. 2002, p. 12). Additionally, more frequent and heavier rain events would result in more frequent and intense flooding (Lockaby et

al. 2013, p. 310). Flooding has the potential to modify the stream channel as higher volumes of water with increased velocity scour the streambed and stream banks, altering the depth, width, and substrate composition of the stream (Poff et al. 2002, p. 12). Changes in depth and velocity influence pristine crayfish site occupancy by changing conditions in the shallow pools with slow to moderate flow where the pristine crayfish occurs (Williams et al. 2004, p. 4; Withers and McCoy 2005, p. 2; Rohrbach and Withers 2006, p. 3; Dinkins 2009, p. 1-1; Johansen et al. 2016, p. 285). Severe flooding events could also potentially result in direct mortality, with increased negative effects expected if severe flooding becomes more frequent as a result of heavier and more frequent rain events due to climate change (Furse et al. 2012).

The best available information does not indicate that the effects of climate change are currently affecting pristine crayfish resiliency or viability through decreased precipitation, higher temperatures, and increased extreme weather events (flooding). As the effects of climate change become more intense, the resiliency of pristine crayfish populations may be affected to a greater degree by the threat of climate change.

Disease

Evidence of porcelain disease (thelohaniasis) has been observed in the Caney Fork form of pristine crayfish populations (Grubb 2019, p. 29). Porcelain disease is caused by *Thelohania*, a microsporidian parasite that invades crayfish muscle tissue giving the underside an opaque, porcelain-like appearance (Grubb 2019, p. 29). Infected crayfish become increasingly lethargic as infection persists until individuals become incapable of performing the tail-flick escape reaction (El-Matbouli and Soliman 2006, p. 206). The prevalence of disease within a population is associated with increased stress as a result of habitat degradation (Grubb 2019, p. 29). We do not consider porcelain disease a threat to the species' viability on its own, but it may affect individuals or populations of pristine crayfish.

Isolation and Small Population Size

The pristine crayfish's naturally limited range and inherently fragmented distribution and small population size are factors that may exacerbate other threats to the species. Small population size along with population isolation often leads to reduced genetic diversity and associated negative consequences including reduced fitness (Frankham 1995, p. 309; Frankham 2005, pp. 132–135). The deleterious effects associated with small population size can exacerbate the negative influences of habitat degradation caused by other threats. The Caney Fork form's small, fragmented populations exhibit considerably lower heterozygosity and allelic richness than that of non-imperiled species, suggesting the occurrence of inbreeding (Grubb 2019, pp. 23–24). Similar information is not available for the Sequatchie form. Evidence of a recent bottleneck event suggests that population isolation is not the result of long isolation over time, but rather is the result of a relatively contemporary disruption of connectivity due to human influence (Grubb 2019, pp. 19, 26, 28–29). Small and isolated pristine crayfish populations may exhibit reduced resiliency to withstand future stochastic events compared to species with larger populations and greater connectivity (Johansen 2018, pp. 1, 34, 56; Grubb 2019, p. 29).

Conservation Measures and Existing Regulatory Mechanisms

A summary of existing regulatory mechanisms and conservation measures provided to the pristine crayfish are summarized here. A more detailed description of these protections is found in the SSA report section 3.8 Conservation Efforts (Service 2021, pp. 43–44).

Protection Through Regulation

The pristine crayfish is listed as endangered by the State of Tennessee under the provisions of the state’s wildlife code. The Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated, Section 70-8-101-112) states that “it is unlawful for any person to take, attempt to take, possess, transport, export, process, sell or offer for sale, or ship nongame wildlife, or for any common or contract carrier knowingly to transport or receive for shipment nongame wildlife.” Additional protections are provided to all State-listed crayfish by the Tennessee Wildlife Resources Commission Proclamation 21-08 stating that the species cannot be used as bait or moved between identified watersheds. In addition to State protections by regulations, the pristine crayfish is included as a Species of Greatest Conservation Need (SGCN) in Tennessee’s State Wildlife Action Plan (TN-SWAP 2015, Appendix C, p. 255). Key goals of the TN-SWAP are to develop and implement conservation strategies and prioritize funding for conservation projects to protect SGCN species and their habitats.

The Clean Water Act of 1972 (33 U.S.C. §1251) provides some protections to the habitat where pristine crayfish occurs. Section 404 of the Clean Water Act requires a Department of the Army permit to discharge dredge or fill material in “waters of the United States” including jurisdictional wetlands and areas below the ordinary high water mark in streams and rivers. Most higher order streams (and some lower order streams) where pristine crayfish occur are jurisdictional under the final rule announced on December 30, 2022, in which the Environmental Protection Agency and Department of the Army Navigable Waters Protection Rule finalized the revised definition of “waters of the United States” under the Clean Water Act, effective March 20, 2023. On April 12, 2023, the 2023 rule was enjoined in 24 states, including Tennessee. The headwater streams where the species occurs are consistent with the pre-2015 operative definition of “waters of the United States” under which Tennessee currently operates. Applicants for a section 404 permit must show that steps have been taken to avoid and minimize impacts to wetlands, streams, and other aquatic resources, and that compensation will be provided for all remaining unavoidable impacts. State regulation of water quality occurs through the TDEC, including enforcement of the Tennessee Water Quality Control Act of 1977 (T.C.A. 69–3–101). TDEC monitors surface water quality throughout the state, including watersheds within the pristine crayfish’s range.

Protected Lands

Three streams with pristine crayfish occurrences are on public lands in the Fall Creek Falls State Park near Spencer, Tennessee (Simmons 2021, pers. comm.). These streams include Camp Creek, Piney Creek, and Flatrock Branch. Pristine crayfish occurrences on State-owned public

lands are more buffered from the effects of urbanization and development compared to private lands and Fall Creek Falls State Park is typically managed in a way that is not detrimental to the species.

Cumulative Effects

We note that, by using the SSA framework to guide our analysis of the scientific information documented in the SSA report, we have analyzed the cumulative effects of identified threats and conservation actions on the species. To assess the current and future condition of the species, we evaluate the effects of all the relevant factors that may be influencing the species, including threats and conservation efforts. Because the SSA framework considers not just the presence of the factors, but to what degree they collectively influence risk to the entire species, our assessment integrates the cumulative effects of the factors and replaces a standalone cumulative-effects analysis.

When potential stressors occur together, one factor may exacerbate the effects of another, causing effects not accounted for when factors are analyzed individually (Brook et al. 2008, entire). For example, in regions that were historically mined for coal, the influences of acidic mine drainage may be intensified by silvicultural practices and urbanization (i.e., road establishment, soil compaction, grading, clear cutting, impervious surfaces, etc.) that contribute to increased stormwater runoff carrying pollutants associated with coal mining (i.e., solutes, dissolved metals, etc.) into nearby streams (Gangloff et al. 2015, p. 712), resulting in degraded water quality and negatively impacting pristine crayfish biological processes. Agriculture may be associated with subsequent stream impoundment to create reservoirs for livestock or crop irrigation, leading to increased sedimentation and reduction in interstitial spaces required by pristine crayfish for feeding, breeding, and sheltering. Similarly, urban growth may also lead to subsequent stream impoundment to establish drinking water or wastewater treatment infrastructure with comparable impacts to the species. Warmer temperatures and more frequent and/or severe drought associated with the effects of climate change could lead to decreased water availability, reducing available suitable habitat for pristine crayfish as streams with species' occurrence have reduced flows or run dry. As a result of limited water availability, water withdrawal from nearby streams could increase in order to support agricultural and/or municipal water supply demands, resulting in reduced flows in pristine crayfish streams and impacting the species requirement for cool, clean, flowing water. Urbanization can exacerbate drought conditions by channeling stormwater runoff from impervious surfaces into ditches and drains that directly flow into sewer lines and/or larger order streams, thereby decreasing the amount of water available for groundwater recharge to headwater streams. Without adequate groundwater recharge, lower order streams where pristine crayfish occurs are especially susceptible to going dry in the event of severe drought with impacts to pristine crayfish and its habitat requirements as described above. Lastly, the pristine crayfish's small population size and isolation of populations exacerbates the effects of other threats to the species. Therefore, we consider the cumulative impact of all the potential influences on pristine crayfish viability when assessing conditions of the species.

CURRENT CONDITION

In the following discussion, we provide a summary of our analysis of and key findings about the pristine crayfish's current condition including our evaluation of current resiliency, representation and redundancy. For the full description of the methodology, analysis, and results, see Chapter 4 of the SSA report (Service 2021, pp. 46–63).

Based on pristine crayfish individual and population needs, we developed an approach using key habitat and demographic parameters to assess the current resiliency for each analytical unit (AU) as either high, moderate, low or very low. These included four habitat parameters (percent riparian canopy cover, percent evergreen forest cover, drought, and headwater impoundments) and three demographic parameters (extent of occurrence, abundance, and age class distribution) (Table 3). We scored each stream catchment, named stream, or AU parameter in the species' range and then summed the habitat and demographic parameter scores. Stream catchments are the smallest area assessed and represent individual stream segments in the mid-resolution National Hydrology Dataset with data to inform our habitat condition analysis. The 27 named streams are larger areas used to assess demographic parameters and the analysis units are used to assess overall resiliency. For the stream catchment and named stream parameters, we determined an AU score by averaging the values across the AU. The parameters of drought and extent of occurrence were scored at the AU level directly.

Finally, we summed the habitat and demographic parameter scores to obtain an overall AU condition score with a total possible score of 28 (Service 2021, pp. 47–48).. Each AU was assigned an overall resiliency condition class from high to very low using the following scale: high=>21, moderate=14.1–21, low=7.1-14, very low=1-7. An AU resiliency class may not be characterized by all parameters that fall in the same parameter condition category (Table 3), but most parameters fall into the same resiliency category or an adjacent category. For example, an AU that exhibits low resiliency (total score of 7.1–14) may have scores for riparian canopy cover, evergreen forest, and impoundments that are low. The same AU may have low abundance with very low (assumed due to no information) age class distribution and moderate extent. The averaged overall AU resiliency may reflect habitat and demographic parameter scores of more than one category (very low, low, moderate, or high).

Table 3. Habitat and demographic parameters and parameter condition categories used in determining current pristine crayfish resiliency. Parameters were assessed at the catchment level or names stream level and averaged over the analysis unit, except drought and extent of occurrence that were assessed at the analysis unit level. This table does not indicate future parameter metrics used to assess future pristine crayfish viability (described below).

Demographic Parameter	High (4)	Moderate (3)	Low (2)	Very Low (1)
Extent of	50 percent	30–50 percent	10–30 percent	less than 10

Occurrence				percent
Abundance	Quantitative estimate average greater than 50 individuals/100 m; or qualitative average greater than 20 crayfish/person hour or site visit	Quantitative estimate average 20–50 individuals/100 m; or qualitative abundance average 10–19 crayfish/person hour or site visit	Quantitative estimate 10–19 individuals/100 m; or qualitative abundance average 1–9 crayfish/person hour or site visit	Quantitative estimate less than 10 individuals/100 m; or qualitative abundance average less than 1 crayfish/person hour or site visit
Age Class Distribution	3 distinct age classes including hatchlings or juveniles	2 distinct age classes including hatchlings or juveniles	2 distinct age classes, but no hatchlings or juveniles	1 age class of any type
Habitat Parameter				
Mean percent canopy cover within 30 meters of stream	greater than 75 percent	50–75 percent	25–50 percent	less than 25 percent
Percent evergreen forest	less than 10 percent	10–30 percent	30–50 percent	greater than 50 percent
Drought (D3 or D4 in the last 20 years)	D3 or D4 drought never exceeds 4 consecutive weeks in any season in a calendar year	D3 or D4 drought exceeds 4 consecutive weeks in any non-reproductive season in a calendar year	D3 or D4 drought exceeds 4 consecutive weeks during reproductive season in one calendar year	D3 or D4 drought exceeds 4 consecutive weeks during reproductive season in two or more calendar years
Headwater impoundments or small reservoirs (small and low head dams)	0	1	2	more than 2

Of the 8 delineated pristine crayfish AUs, we determined that 7 AUs exhibit moderate current

resiliency and 1 exhibits low current resiliency. The pristine crayfish AUs with moderate resiliency include Caney Fork River Headwaters, Caney Fork River – Clifty Creek, Laurel Creek, Bee Creek Upper, Bee Creek Lower, Cane Creek Upper, and Big Brush Creek; the Piney Creek AU exhibits low resiliency (Figure 3). No pristine crayfish AUs were assessed to have either high or very low resiliency, although at a finer scale, some individual stream catchments or named streams within AUs have high habitat and demographic parameter scores. This level of detail on catchment condition is averaged across the AU and not represented individually in the AU resiliency scores.

Within the overall AU resiliency analysis, we assessed 27 named streams to determine demographic parameters for pristine crayfish. Of these, 5 named streams (18 percent) in 4 AUs have high scores for the demographic parameter of abundance. Given the pristine crayfish low densities and rarity, streams with lower abundance scores may not accurately reflect species occurrences as survey methodology is not standardized and most survey efforts do not sample to depletion (count all crayfish through repeated searches in the same area). Age class distribution information is available for 15 of the 27 streams in the species’ range. For the purpose of the SSA analysis, we assumed streams with occurrence records, but lacking additional information, to have only one age class. In our current condition analysis, 12 of the 27 named streams (44 percent) have either 2 or 3 distinct age classes including hatchlings or juveniles (high or moderate condition for the age class distribution current condition parameter). We have no specific information regarding reproduction in 12 of the remaining 15 named streams, thus, the best available information indicates reproduction is occurring in 80 percent of named streams with age class information. The named streams characterized by demographic parameters in high condition are distributed in 7 of 8 AUs across the species’ range (Table 4).

Within the overall resiliency analysis, we assessed parameters in 414 catchments across the species range to determine habitat condition. Of these, over half of the assessed catchments have high scores for either the unadjusted habitat parameters of percent canopy cover (60 percent), evergreen forest (58 percent), and impoundments (68 percent). Catchments characterized by all three habitat parameters in high condition occur in all AUs across the range of the species (Caney Fork River Headwaters 28%, Caney Fork – Clifty Creek 14%, Laurel Creek 18%, Bee Creek Lower 19%, Bee Creek Upper 14%, Cane Creek Upper 36%, Piney Creek 21%, Big Brush Creek 19%).

Table 4: The distribution of high and moderate abundance and age class parameters in 27 named streams in analysis units across the pristine crayfish’s range.

Analysis Unit	High or Moderate Abundance	High or Moderate Age Class Distribution (Reproduction)
Caney Fork River Headwaters	2 streams	4 streams
Caney Fork River – Clifty	2 streams	2 streams

Creek		
Laurel Creek	2 streams	2 streams
Bee Creek Lower	1 stream	
Bee Creek Upper	2 streams	3 streams
Cane Creek Upper	1 stream	1 stream
Big Brush Creek	1 stream	

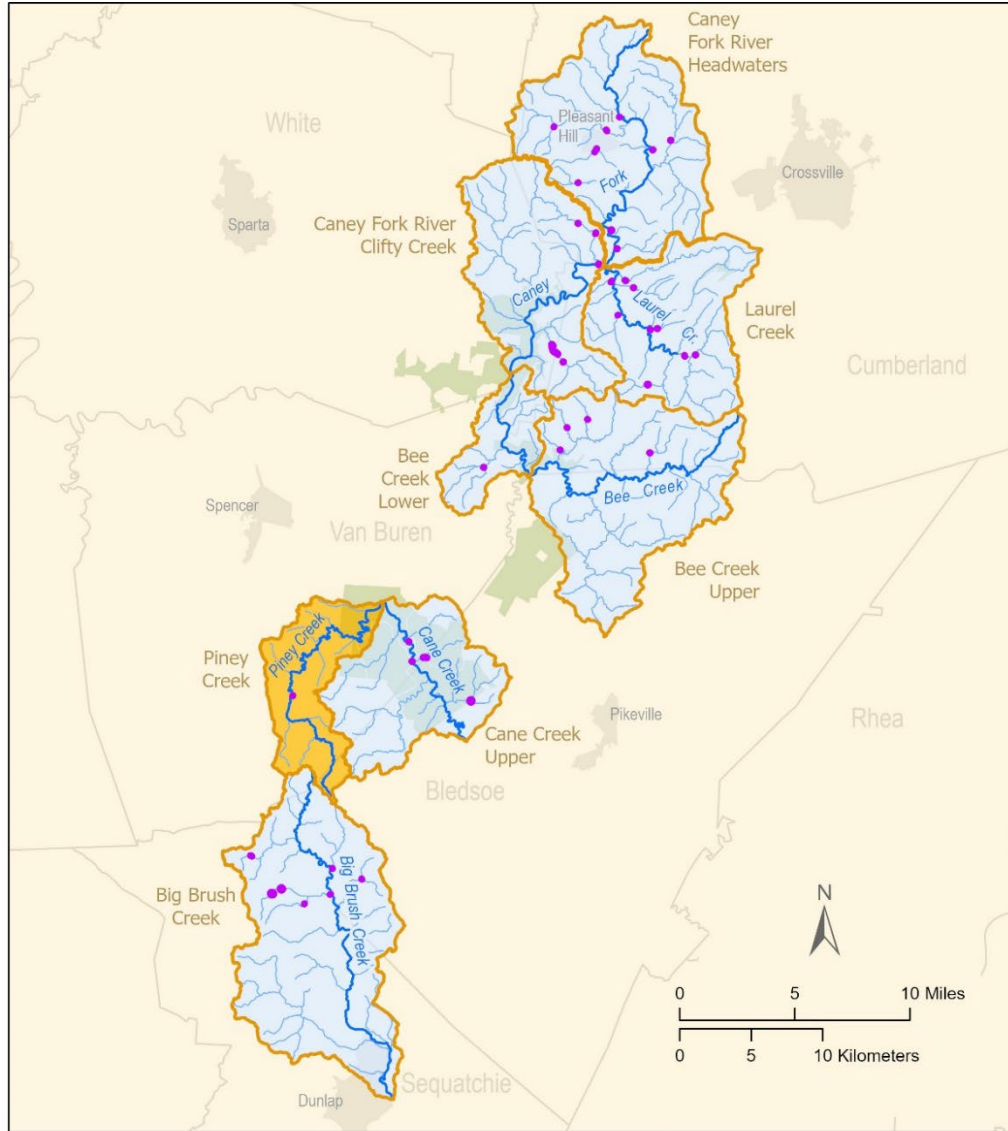


Figure 3: Current resiliency of eight pristine crayfish analysis units. The Sequatchie form of pristine crayfish occurs in three analysis units (AUs): Big Brush Creek AU in the Sequatchie River system and Piney Creek and Cane Creek Upper AUs in the Caney Fork River system. The Caney Fork form occurs in the remaining five AUs.

We determined pristine crayfish to have moderate redundancy with 7 of 8 pristine crayfish AUs exhibiting moderate resiliency and distributed across the range of the species. The current range and distribution of the species is not reduced from the known historical range and distribution has expanded to include streams in the Sequatchie River system in 2018.

To determine species' representation, we assessed available genetic information and core species' attributes related to distribution and demographics. Information pertaining to genetic diversity, effective population size, presence of inbreeding, and habitat structure is limited and available for eight Caney Fork form streams in five AUs (Grubb 2019, pp. 23–31); similar information is not available for Sequatchie form populations. The species occurs in first- to fourth-order streams, representing a range of ecological and habitat conditions. The two forms of pristine crayfish occur within two separate river systems (the Caney Fork and the Sequatchie river systems) and we expect that these morphological and distributional differences provide the species with adaptive capacity. The current representation of the species is not substantially reduced from the historical levels, and we determined that pristine crayfish exhibits moderate current representation.

FUTURE CONDITION

In the following discussion, we summarize the future scenarios, future condition analysis, and projected future condition including resiliency, representation, and redundancy for pristine crayfish. See Chapter 5 in the SSA report for a full discussion of our future analysis (Service 2021, pp. 63–81).

To evaluate the future condition of the species, we developed three plausible future scenarios that encompass varying levels of key threats to pristine crayfish to capture the uncertainty associated with the future threats. We assessed the future resiliency, redundancy, and representation in 2036 and 2051 (15 and 30 year from the SSA analysis, respectively). We selected these time steps based on pristine crayfish's lifespan of approximately 4 years and the reliability of the data (including the species' response to future threats) and models used in the future threat projections and analyses. Although the models used in the SSA to assess varying levels of future threats to the species project conditions further into the future than 30 years, the best available information on the species response to those threats does not allow us to project the effect of the threats on the species in longer time steps. Therefore, we determined 15 years and 30 years to be time steps at that we can reasonably predict the threats to pristine crayfish and the species' response to those threats. To assess the potential future condition of pristine crayfish, we selected four key habitat-based threats (urbanization, land use change, climate change, and impoundments) based on the influences these factors have on pristine crayfish viability. We quantitatively assessed expected levels of urbanization (SLEUTH model), land use change (FORE-SCE model), and climate change (USGS NCCV model), and we qualitatively assessed the threat of impoundment (State parcel data). The threats of urbanization, land use change, and impoundments are expected to negatively impact pristine crayfish habitat through increased sedimentation water quality degradation and climate change is expected to affect the species

through higher temperatures and increased drought conditions. We also considered the cumulative effect of these threats. Information was not available to allow us to directly project the current condition demographic parameters into the future, although we do expect changes to pristine crayfish habitat that decrease availability of species' needs may have an impact to species' demographics.

The three scenarios incorporate different levels of impoundments and reflect land use change, urbanization, and temperature change under two different climate change scenarios (RCP4.5 and 8.5) (Table 5). Three plausible scenarios were considered when predicting future condition: (1) status quo with lower development; (2) status quo with higher development; and (3) increased impacts. For the increased impact scenario, we reviewed population growth records, rate of small impoundment construction, and projected populations growth and determined that an increased rate of impoundment construction was not plausible in AUs other than those that occur in Cumberland County since very limited population growth is projected in all other areas, therefore the current rate of impoundment construction was used in the other 6 AUs. We estimated a future resiliency score for each AU by adjusting each unit's current condition score based on impacts from projected changes in the four habitat parameters (Service 2021, p. 71). The resulting overall resiliency score was categorized as a resiliency class using the same scale as for current condition to allow comparison. However, we note that the individual habitat and demographic parameter metrics used in our current condition analysis (Table 3) are not intended to be applied to the resulting future resiliency class. For example, an AU in projected low future resiliency is expected to exhibit decreased resiliency from moderate current resiliency, but we do not predict demographic values or habitat values that fall in the low condition category as defined in Table 3 and our current condition analysis.

Table 5. Comparison of parameters assessed in three plausible future scenarios for the pristine crayfish.

Scenario		Parameter			
		Urbanization	Impoundments	Land Use	Climate Change
1	Status Quo/ Lower Development	Percentage of area with an 80 percent or greater probability of urbanization	Constructed at less than the current rate	Change in evergreen forest (FORE-SCE model SRES B1)	Temperature change (RCP 4.5)
2	Status Quo/ Higher Development	Percentage of area with a 50 percent or greater probability of urbanization	Constructed at the current rate	Change in evergreen forest (FORE-SCE model SRES B1)	Temperature change (RCP 4.5)

3	Increased Impacts	Percentage of area with a 20 percent or greater probability of urbanization	Constructed at the current rate and increased in Cumberland County	Change in evergreen forest (FORE-SCE model SRES A2)	Temperature projections under RCP 8.5
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The future resiliency under scenarios 1 and 2 (status quo/lower development and status quo/higher development, respectively) is projected to be the same in both time steps (2036 and 2051). Under Scenario 1, 6 of 8 pristine crayfish AUs are predicted to exhibit low resiliency in the future with an additional AU expected to decline to low resiliency under Scenario 2. All pristine crayfish AUs are projected to remain on the landscape in 15 and 30 years under both scenarios. Although projected AU resiliency reflects the negative impacts to the habitat that are expected to occur, the stream reaches with species' occurrences will not be affected uniformly. As described above, we developed a habitat condition score for each catchment with species occurrence. Catchments in all AUs have habitat parameter values in the highest condition category (e.g., canopy cover, percent evergreen cover, and impoundments). These catchments within the AUs are expected to maintain higher values for habitat parameters in the future compared to the remainder of catchments with lower habitat condition parameter scores. However, habitat parameter scores in other stream catchments within the AU are lower, bringing down the average AU resiliency. We expect that the species will maintain viability within these high condition stream catchments in the future. Although the threats and the species responses will decrease AU resiliency and the species' condition at 15 and 30 years in the future under the status quo/lower development and status quo/higher development scenarios.

Under the increased impact scenario, the resiliency of all AUs is projected to decline over time. In the first time step (2036) under Scenario 3, the projected resiliency is the same as the Scenario 2 projection in 2051 with 7 of 8 AUs declining in resiliency. In 2051 under Scenario 3, AU resiliency is projected to further decline compared to resiliency projections under the same scenario in 2036. The threats and species responses to the threats increase in severity at 2051 under Scenario 3, primarily in the effects of urbanization and climate change (temperature increase). Under Scenario 3 in 2051, four AUs are projected to exhibit low resiliency and four are projected to exhibit very low resiliency. However, all pristine crayfish AUs are expected to remain on the landscape in 2036 and 2051 under the increased impacts in Scenario 3.

Table 6: Pristine crayfish AU future resiliency under three plausible scenarios and two time steps.

		Scenario 1 (Status Quo/Lower Development)		Scenario 2 (Status Quo/Higher Development)		Scenario 3 (Increased Impact)	
Analysis Unit	Current Resiliency Class	2036	2051	2036	2051	2036	2051

Caney Fork River Headwaters	Moderate	Low	Low	Low	Low	Low	Very Low
Caney Fork River – Clifty Creek	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Laurel Creek	Moderate	Low	Low	Low	Low	Low	Very Low
Bee Creek Upper	Moderate	Low	Low	Low	Low	Low	Low
Bee Creek Lower	Moderate	Low	Low	Low	Low	Low	Very Low
Cane Creek Upper	Moderate	Low	Low	Low	Low	Low	Low
Piney Creek	Low	Low	Low	Very Low	Very Low	Very Low	Very Low
Big Brush Creek	Moderate	Low	Low	Low	Low	Low	Low

Although our calculation methodology averages projected parameter declines across an AU, resulting in overall low resiliency, we note that catchments within each AU with current high demographic and/or habitat conditions are expected to remain in better condition than the overall resiliency for the AU. We did not have future threat information available at the fine scale resolution needed to project habitat condition at the catchment level. For example, between 14 and 28 percent of catchments in each AU are currently characterized by high riparian canopy cover, low evergreen land cover, and a low level of impoundments, and over half of all catchments are characterized by one of these parameters. These catchments in higher habitat condition are expected to be impacted to a lesser extent by projected threats and the species’ response to those threats and exhibit future habitat conditions sufficient to support pristine crayfish resiliency. We expect that pristine crayfish individuals or populations may be impacted by threats and the species’ response to those threats, resulting in somewhat more isolated populations. However, we expect that localized pristine crayfish populations that currently occur in habitat with high condition parameter values will remain on the landscape in higher resiliency than populations in lower quality habitat.

As a result of projected declines in resiliency, pristine crayfish redundancy is projected to decline to varying degrees under all future scenarios. Although the number of AUs exhibiting moderate resiliency declines under all scenarios; at least one AU with moderate resiliency is maintained in all but the increased impact scenario in 2051. No AUs of either the Caney Fork or Sequatchie forms are predicted to become extirpated under any future scenario in 2036 or 2051 (Table 6). Therefore, the distribution of pristine crayfish is projected to remain the same at the AU level in our future scenarios, although specific occurrences within AUs may die out or shift in location.

Pristine crayfish representation is expected to remain in moderate condition in the projected

future scenarios. Although pristine crayfish AU resiliency, including abundance, is expected to decrease in the future, no AUs are predicted to become extirpated. Each AU is present on the landscape in all three scenarios and both time steps.

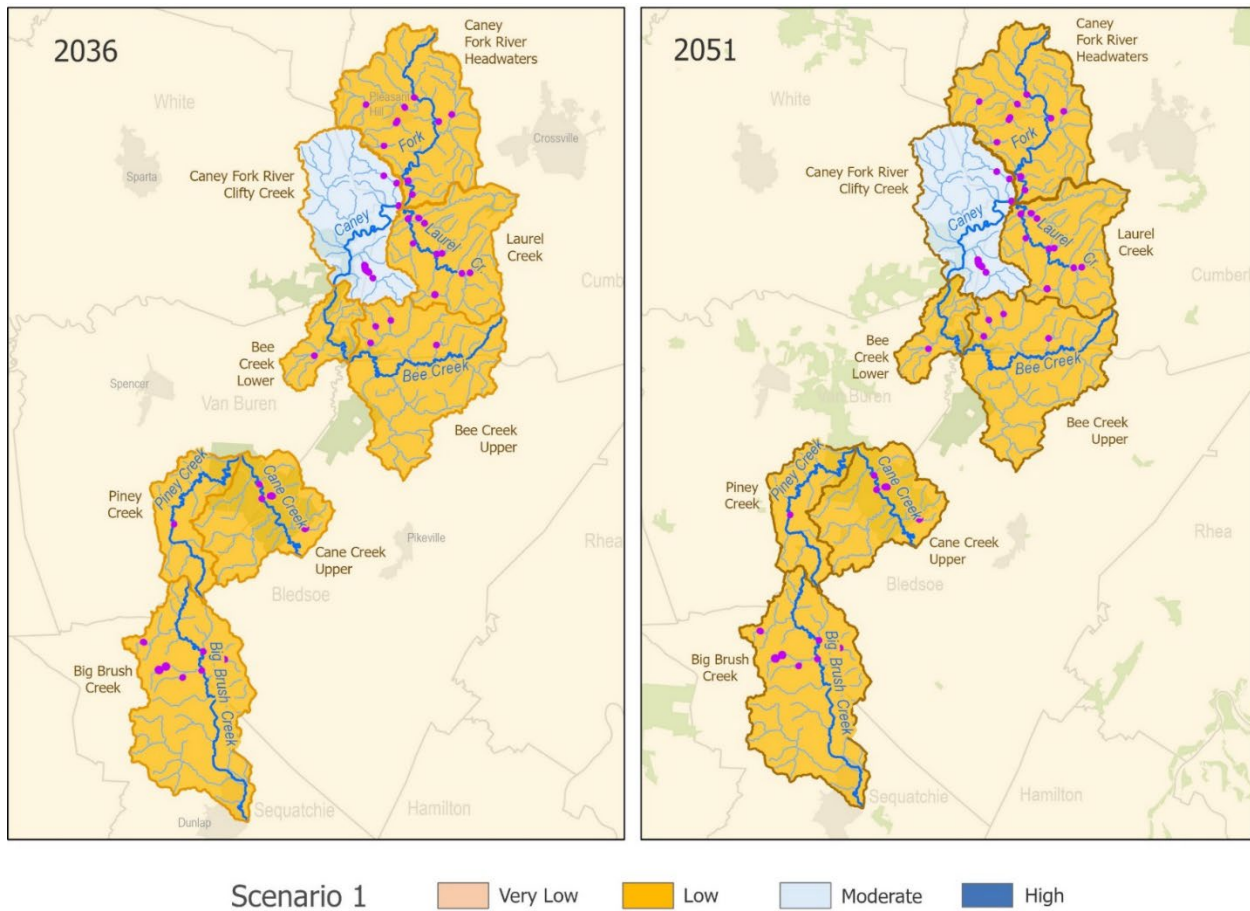


Figure 4. Future resiliency class for pristine crayfish AUs in 2036 and 2051 under Scenario 1.

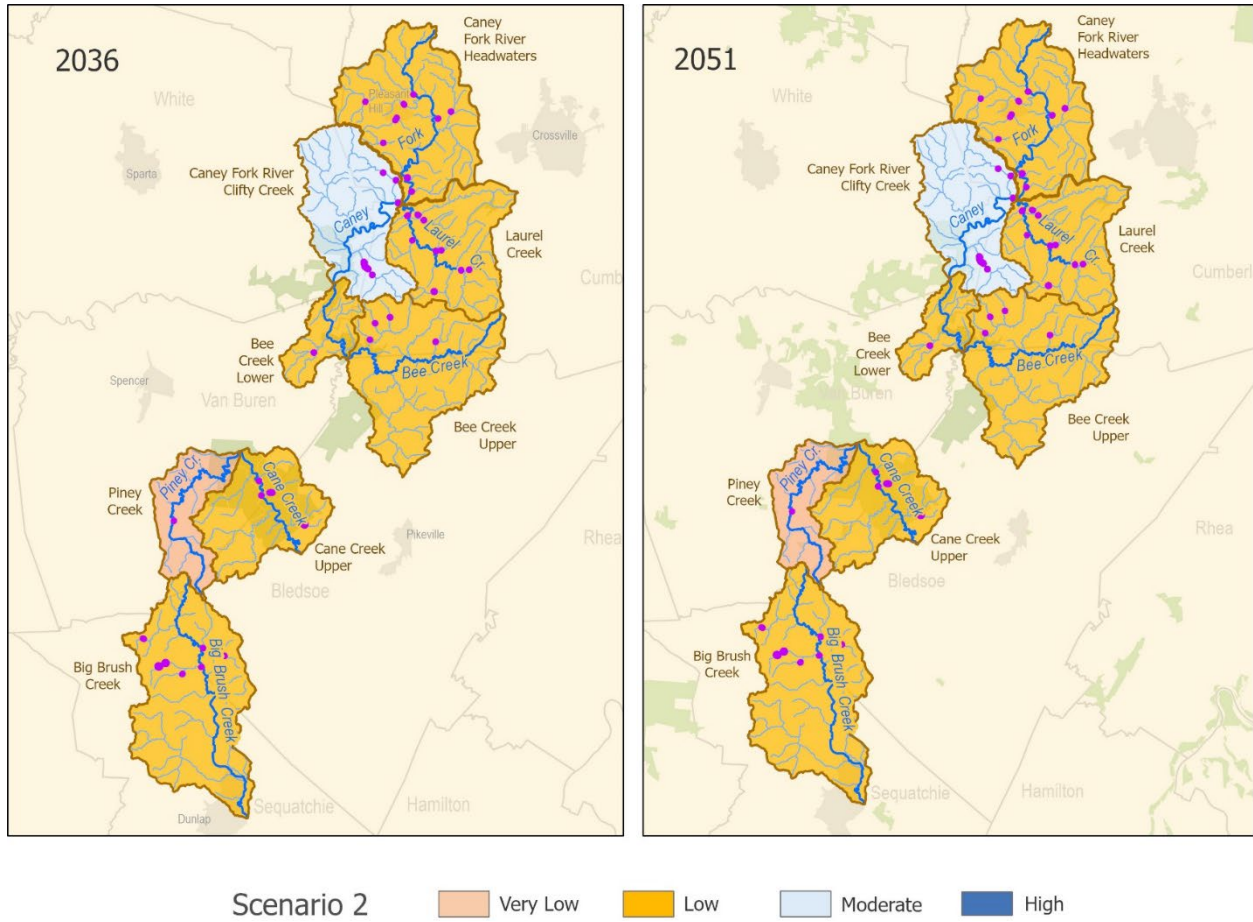


Figure 5. Future resiliency class for pristine crayfish AUs in 2036 and 2051 under Scenario 2.

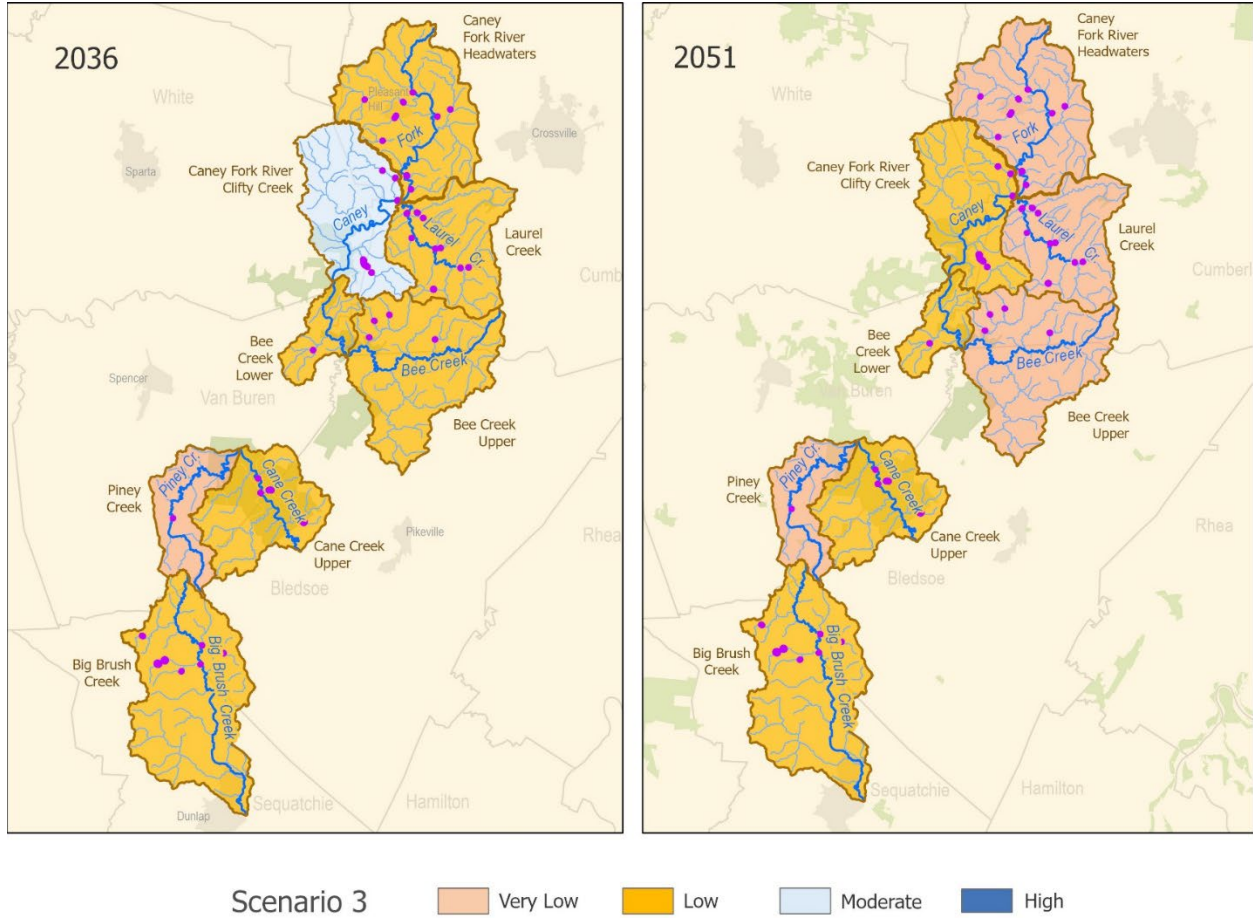


Figure 6. Future resiliency class for pristine crayfish AUs in 2036 and 2051 under Scenario 3.

FINDING

Regulatory Framework

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species is an “endangered species” or a “threatened species.” The Act defines an endangered species as a species that is “in danger of extinction throughout all or a significant portion of its range,” and a threatened species as a species that is “likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” The Act requires that we determine whether any species is an “endangered species” or a “threatened species” because of any one or a combination of the following factors:

- (A) The present or threatened destruction, modification, or curtailment of its habitat or range;
- (B) Overutilization for commercial, recreational, scientific, or educational purposes;

- (C) Disease or predation;
- (D) The inadequacy of existing regulatory mechanisms; or
- (E) Other natural or manmade factors affecting its continued existence.

These factors represent broad categories of natural or human-caused actions or conditions that could have an effect on a species' continued existence. In evaluating these actions and conditions, we look for those that may have a negative effect on individuals of the species, as well as other actions or conditions that may ameliorate any negative effects or may have positive effects.

The Act does not define the term "foreseeable future, which appears in the statutory definition of "threatened species." Our implementing regulations at 50 CFR 424.11(d), as revised in 2019, set forth a framework for evaluating the foreseeable future on a case-by-case basis. The term "foreseeable future" extends only so far into the future as we can reasonably determine that both the future threats and the species' responses to those threats are likely. In other words, the foreseeable future is the period of time in which we can make reliable predictions. "Reliable" does not mean "certain"; it means sufficient to provide a reasonable degree of confidence in the prediction. Thus, a prediction is reliable if it is reasonable to depend on it when making decisions.

It is not always possible or necessary to define the foreseeable future as a particular number of years. Analysis of the foreseeable future uses the best scientific and commercial data available and should consider the timeframes applicable to the relevant threats and to the species' likely responses to those threats in view of its life-history characteristics. Data that are typically relevant to assessing the species' biological response include species-specific factors such as lifespan, reproductive rates or productivity, certain behaviors, and other demographic factors.

Status Assessment

Status Throughout All of Its Range

After evaluating threats to the species and assessing the cumulative effect of the threats under the section 4(a)(1) factors, we found that the pristine crayfish does not meet the definition of an endangered species throughout all of its range. In our assessments of current and future viability for the pristine crayfish, we considered the impacts of habitat destruction or modification (Factor A), climate change (Factor E), disease (Factor C), and the effect of small, isolated populations (Factor E), as well as the cumulative effects of the various threats on the landscape. Of the threats, habitat destruction or modification and climate change were identified as threats that may be acting at the species level. Habitat destruction or modification is currently the primary threat to current and future pristine crayfish viability. Impacts to the pristine crayfish's habitat rangewide are caused by sedimentation, decreased water quality, and the effects of impoundments. These impacts occur at the individual and population level across the species distribution, but the best available information indicates that these localized impacts have not affected pristine crayfish at the species level. Climate change has the potential to impact the

species through increased frequency and severity of drought and increased temperature, and this threat is ongoing and projected to increase in the future. Although drought and increased temperatures may result in a decrease or lack of recruitment in some portions of the range during some years, there have been no documented species-level declines as a result of consecutive years of drought. The threats of disease and small, isolated populations may exacerbate the effects of the primary threats, but are not expected to affect population resiliency, or species' representation and redundancy alone.

The best available information indicates that the range of the pristine crayfish has not contracted since first described and, in fact, the range was recently expanded into an additional river system. The species is naturally patchily distributed within its range, and is known to occur in 27 streams across 8 HUC12 AUs. Seven of the 8 AUs exhibit moderate current resiliency. Although we identified habitat destruction or modification as the key driver of species' viability, the species' current condition does not indicate species-level impacts from this or cumulative factors that have led to reductions in AU resiliency. Species' representation and redundancy are moderate, and the species occurs in multiple analysis units with sufficient resiliency across the historical and current range of the species. Overall, no threat is acting at an extent or severity such that the pristine crayfish is at risk of extinction throughout its range. Thus, after assessing the best available information, we conclude that pristine crayfish is not in danger of extinction throughout all of its range.

Therefore, we proceed with determining whether pristine crayfish is likely to become an endangered species within the foreseeable future throughout all of its range. To evaluate the future viability of the pristine crayfish, we considered the relevant threats currently acting on the species, those threats expected to act on the species in the future, and the species' response to those threats. The primary threats to the pristine crayfish in the future are habitat destruction or modification and climate change. The key drivers of habitat destruction or modification with available future models relevant to the species include urbanization or development, change in land cover/land use, and the rate of construction of small impoundments. The three plausible future scenarios we examined included projections of urbanization, land use change (evergreen forest cover), impoundments, the effects of climate change, and the cumulative effect of these threats. Our analysis of the species condition under future scenarios at two time steps (2036 and 2051) encompasses the best available information for future projections of modeled parameters under a range of plausible threat levels. In addition, these time steps encompass the period in which we can predict the species' response to expected threats. We selected these time steps based on pristine crayfish's lifespan of approximately 4 years and the reliability of the data and models used in the future threat projections and analyses. Therefore, we determined 15 years and 30 years to be the foreseeable future for which we can reasonably predict the threats to pristine crayfish and the species' response to those threats.

The pristine crayfish is distributed across 8 AUs (HUC12 subwatersheds) and is expected to remain extant in all future scenarios across all AUs. There are minor projected increases in some

threats that may affect the availability of suitable habitat across the species' range. Urbanization is projected to increase an average of 6–11 percent and evergreen forest cover (land use change) is projected to decrease up to 1 percent. Based on our analysis, the projected effects of climate change and impoundments may have a greater effect on species' resiliency compared to current impacts, but the magnitude and imminence of the threats and the species response are more uncertain. Our future condition analysis projected declines in resiliency in 6 or 7 AUs in all scenarios except the increased impact scenario in 2051, where all 8 AUs are projected to decline in resiliency.

Although declines in AU resiliency are projected, we expect that named streams with current high or moderate abundance (11 of 24 streams with information or 46 percent) and evidence of reproduction (moderate or high age class distribution; 80 percent of streams with information) within these AUs will be more resilient to projected threats. We expect that the 14 to 28 percent of catchments with current high habitat condition as described above may also be less affected by threats, although we did not have fine scale information that allowed projection of catchment-level future habitat condition. In addition, the patchy distribution of pristine crayfish within occupied streams means not all areas within a stream or within an AU will exhibit the same demographic and habitat parameters that characterize resiliency.

We project species' representation and redundancy will decline slightly but are expected to remain sufficient to support the pristine crayfish's future viability with all AUs remaining on the landscape in all scenarios. Although no AUs are projected to be extirpated and the distribution of the species across the range is projected to remain at the current level, only one AU is projected to exhibit moderate resiliency in the future. Likewise, representation is expected to be maintained to a lower degree via extant populations of the Caney and Sequatchie, although some parameters used to assess representation are projected to decline as AU resiliency declines. Impacts from current and ongoing threats will reduce population resiliency as a result of declines in habitat condition and resultant demographic impacts in some catchments within AUs. These declines will also affect species' representation and redundancy in the foreseeable future, but the reductions in some catchments within AUs are not projected to lead to the species decline in condition such that it is likely to become in danger of extinction in the modeled scenarios.

The best available information does not indicate that the pristine crayfish's viability will decline within the foreseeable future so much that the species is likely to become in danger of extinction. After assessing the best available information, we conclude that pristine crayfish is not likely to become an endangered species within the foreseeable future throughout all of its range.

Status Throughout a Significant Portion of Its Range

Under the Act and our implementing regulations, a species may warrant listing if it is in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range. Having determined that the pristine crayfish is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we now consider

whether it may be in danger of extinction or likely to become so in the foreseeable future in a significant portion of its range—that is, whether there is any portion of the species’ range for which it is true that both (1) the portion is significant; and (2) the species is in danger of extinction now or likely to become so in the foreseeable future in that portion. Depending on the case, it might be more efficient for us to address the “significance” question or the “status” question first. We can choose to address either question first. Regardless of which question we address first, if we reach a negative answer with respect to the first question that we address, we do not need to evaluate the other question for that portion of the species’ range.

In undertaking this analysis for pristine crayfish, we chose to address the status question first. We began by identifying portions of the range where the biological status of the species may be different from its biological status elsewhere in its range such that it may warrant listing under the Act. For this purpose, we considered information pertaining to the geographic distribution of (a) individuals of the species, (b) the threats that the species faces, and (c) the resiliency condition of populations.

We evaluated the range of the pristine crayfish to determine if the species is in danger of extinction now or likely to become so in the foreseeable future in any portion of its range. The range of a species can theoretically be divided into portions in an infinite number of ways. We focused our analysis on portions of the species’ range that may meet the definition of an endangered species or a threatened species.

We first considered whether the species may be in danger of extinction in a significant portion of its range. We examined the following threats and the species response to these threats throughout the range: habitat destruction or modification (sedimentation, water quality, impoundments), disease, and the effect of small, isolated populations, including cumulative effects. Although threats are similar throughout the range of the species, the species’ response is more pronounced in the Piney Creek AU. Due to lower current resiliency, threats are currently having a greater impact in the Piney Creek AU than elsewhere in the range. The Piney Creek AU exhibits low current resiliency driven primarily by a low extent of occupancy (few sites known within the stream) and lack of information regarding reproduction. Given the species’ condition within the Piney Creek AU, we have identified the unit as an area that may be in danger of extinction due to the low extent of occupancy and low reproduction/recruitment. We then proceeded to the significance question, asking whether this portion of the range is significant. Although the Piney Creek AU contributes to the overall species-level representation and redundancy, it does not contain any high quality or high value habitat or any habitat or resources unique to that area and necessary to pristine crayfish’s life history. In addition, only 1 of the 27 known streams with species occurrence is located in the Piney Creek AU so it does not contribute substantively to the species viability. The Piney Creek AU makes up 4.2 percent of the area of catchments with pristine crayfish occurrences and does not make up a large geographic area of the range or contain a high proportion of species habitat or populations. Accordingly, we do not find this portion to be a significant portion of the range. Therefore, we find the pristine crayfish is not

currently in danger of extinction in a significant portion of its range.

We next considered whether the pristine crayfish may be likely to become an endangered species within the foreseeable future in a significant portion of its range. As discussed in *Status Throughout All Its Range*, we analyzed the species' condition under future scenarios at two time steps (2036 and 2051), encompassing the best available information for future projections of modeled parameters under a range of plausible threat levels. We selected these time steps based on pristine crayfish's lifespan of approximately 4 years and the reliability of the data and models used in the future threat projections and analyses. Therefore, we determined 30 years to be the foreseeable future for which we can reasonably predict the threats to pristine crayfish and the species' response to those threats.

As also discussed in *Status Throughout All Its Range* habitat destruction or modification and climate change are the primary factors currently acting on or expected to act on the species in the future at a rangewide scale. The species currently exhibits moderate resiliency in 7 of 8 AUs. Although threats are projected to impact the species similarly across the range, the species' response is more pronounced in some AUs due to lower resiliency where threats are expected to have a greater impact in the future than elsewhere in the range. One AU (Caney Fork River – Clifty Creek) is projected to remain in moderate resiliency in all but the increased impact scenario in 2051. The remaining 7 AUs are projected to exhibit low or very low (with respect to 1 AU) resiliency under scenarios 2 and 3 in 2036 and 2051. We considered whether the 7 AUs that are projected to exhibit low or very low resiliency in future scenarios may be a portion of the range that could become in danger of extinction within the foreseeable future.

Although the future condition analyses projects overall AU resiliency declines within each of the 7 AUs, stream catchments with species' occurrences are projected to remain in good condition within each AU. Our future condition analysis did not spatially project the impacts of expected threats at the catchment level (fine resolution). However, we expect that threats to the species will generally occur rangewide and the species' response will be similar rangewide. Areas within a stream currently characterized by high habitat condition will be proportionately impacted by threats and the species' response to those threats. Within the catchments with high current condition habitat scores, we expect that habitat conditions will continue to support sufficient pristine crayfish abundance and reproduction in the future and that pristine crayfish resiliency is sufficient to withstand the impact of threats in these smaller areas within AUs. Although projections indicate low or very low (for 1 AU) future resiliency in 7 AUs, the remaining stream catchments in current high condition indicate that pristine crayfish in these AUs will remain on the landscape with sufficient viability. In addition, though some declines in representation and redundancy are projected in the future, we expect that pristine crayfish will have sufficient adaptive capacity and ability to withstand catastrophic change in the foreseeable future. We found no portion of the pristine crayfish's range where the biological condition of the species differs from its condition elsewhere in its range such that the status of the species in that portion warrants listing under the Act.

Therefore, we find that the species is not in danger of extinction now or likely to become so in the foreseeable future in any significant portion of its range. This does not conflict with the courts' holdings in *Desert Survivors v. Department of the Interior*, 321 F. Supp. 3d 1011, 1070-74 (N.D. Cal. 2018), and *Center for Biological Diversity v. Jewell*, 248 F. Supp. 3d 946, 959 (D. Ariz. 2017) because, in reaching this conclusion, we did not apply the aspects of the Final Policy on Interpretation of the Phrase "Significant Portion of Its Range" in the Endangered Species Act's Definitions of "Endangered Species" and "Threatened Species" (79 FR 37578; July 1, 2014), including the definition of "significant" that those court decisions held to be invalid.

Determination of Status

Our review of the best available scientific and commercial information indicates that the pristine crayfish does not meet the definition of an endangered species or a threatened species in accordance with sections 3(6) and 3(20) of the Act. Therefore, we find that listing the pristine crayfish is not warranted at this time.

COORDINATION WITH STATES

In preparing the finding for the pristine crayfish, we closely coordinated with State agencies in Tennessee throughout the SSA process. Specifically, we contacted all relevant State and Federal agencies (Tennessee Wildlife Resources Agency, Tennessee Department of Environment and Conservation (Tennessee Natural Heritage Program), and Tennessee Valley Authority) to request information, provide technical review of the threats assessment and analytical framework. We also include biologists with expertise in the species, its habitat, and relevant threats, in our partner review of the draft SSA report. The information, feedback, and comments received through these coordination efforts were incorporated into the SSA report, where appropriate. We continue to coordinate with State agencies on conservation of pristine crayfish.

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All SAFs supporting 12-month findings or candidate notices of review will be signed by the Director. SAFs should continue to be surnamed by Regional and Headquarters staff and leadership.

Date:
Wendi Weber,
Acting Director,
U.S. Fish and Wildlife Service

Date of annual review:
Conducted by: