Species Status Assessment (SSA) Report

for the

Elk River Crayfish

(*Cambarus elkensis*)

Version 1.1

Elk River Crayfish (Photo credit: John Schmidt, U.S. Fish and Wildlife Service)

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U.S. Fish and Wildlife Service
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EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the Elk River crayfish (*Cambarus elkensis*), a species petitioned in 2010 for listing under the Endangered Species Act of 1973, as amended (Act). The SSA assesses (*see chapter 1*) the species' viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (together, the 3Rs). For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in natural ecosystems within a biologically meaningful timeframe, in this case 50 years. In conducting the SSA, we compiled the best available scientific information regarding the Elk River crayfish's biology; individual-, population-, and species-level needs (*see chapter 2*); and factors that influence the species' viability (*see chapter 3*). We use this information to evaluate and describe the species' current (*see chapter 4*) and projected future conditions (*see chapter 5*) in terms of the 3Rs and describe the uncertainty in these projections (*see chapter 6*). This SSA report does not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the Elk River crayfish. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and a decision will be announced in the *Federal Register*.

Species Information (chapter 2): The Elk River crayfish is a relatively small, freshwater, tertiary burrowing crustacean from West Virginia that can be differentiated from other crayfishes through rostral (a stiff beaklike projection on the head) and claw morphology. While total body length measurements are not available, one study noted the species' carapace length (the upper portion of the main body covered by a hard shell) ranged from 26.2 to 39.9 millimeters (1.0 to 1.6 inches). While first documented in West Virginia in 1899, the species was not described and formally named as a separate species until 1993. There are no genetics data currently available for the Elk River crayfish, and the species' uncontested taxonomy is based solely on morphology.

Like most crayfish, the Elk River crayfish begins its life as a fertilized egg attached to the underside of a female's abdomen. Elk River crayfish clutch sizes of between 100 and 216 eggs have been reported, but the number of eggs can vary by size, age, and environmental factors that dislodge or cause egg losses. In approximately 35 days, the egg hatches but the hatchling remains physically attached to the female as it undergoes a series of four to five molts that allows it to grow and its shell to harden. The juvenile then leaves the female to begin life as a free-living individual. Individual Elk River crayfish become reproductive in 2.5 to 3 years, have one reproductive event per year once mature, and may live up to 5 years.

The Elk River crayfish reaches reproductive age later than other *Cambarus* species and grows larger, through a continuous series of molts, before reaching maturity. Molting is a vulnerable life stage for crayfish because during molting crayfish are soft and unable to move effectively, making them susceptible to predation. They are also more sensitive to contaminants and water quality degradation when molting, which may be due to physiological, metabolic, and other factors. Both male and female Elk River crayfish alternate between two morphological forms depending on whether or not they are reproductively active. It is not known when Elk River crayfish mate. For many species of *Cambarus,* mating occurs in the fall (September to

November), although it is possible, given the seasonal observations of young of the year and relative abundance of reproductively active individuals, that the Elk River crayfish may be able to mate at any time of the year.

Crayfish are most active between dusk and dawn when they abandon cover to forage for food. The species is assumed to be an opportunistic omnivore feeding on a wide variety of items, including aquatic and terrestrial vegetation, plant detritus, insects, snails, and small aquatic vertebrates. Therefore, healthy populations of stream macroinvertebrates and the presence of healthy riparian and instream vegetation may be important components of Elk River crayfish habitats.

Similar to other species in the genus, Elk River crayfish habitat requirements consist of permanently flowing, moderately sized streams with riffles, runs, or pools that have some current. However, there may be times of year when flow is limited in some suitable streams. The species has not been found in small headwater streams and is not typically found in larger streams such as the lower Elk River mainstem where stream gradients and velocities become more moderate. Substrate composition is an important component of crayfish habitat because they depend on larger particle size (e.g., gravel, cobble, or boulder) substrates, woody debris, and vegetation to provide shelter and cover from predators. Stream substrates where Elk River crayfish have been found include small to medium boulders, large cobble, coarse gravel, fissured bedrock, and sand with little to no sedimentation.

The historical and current range of the Elk River crayfish is restricted to areas of the Elk River U.S. Geological Survey's Hydrologic Unit Code (HUC) 8 watershed in Pocahontas, Randolph, Webster, Braxton, Nicolas, and Clay Counties, West Virginia. The range includes the upper and middle sections of the Elk River mainstem and/or tributaries to the Elk River located in the following HUC 10 watersheds: Upper Elk River, Holly River, Middle Elk River, Laurel Creek, Birch River, and Lower Elk River. The best available data suggest that the species' range has not changed significantly. This is based on: a series of targeted survey efforts in 1988, 1989, 1995, and from 2007 to 2013; an examination of museum specimens; and a personal observation. Given the species' longevity, evidence of reproduction, and lack of information to the contrary, we assume the streams occupied in 2009 to be currently occupied for the purposes of this SSA.

Historically, all Elk River crayfish were likely part of one metapopulation that had some limited connectivity. There is little information available regarding the demographic or genetic processes that define the spatial structure of Elk River crayfish populations, thereby precluding our ability to make reliable groupings of biological populations. Therefore, we used the aforementioned HUC 10 watersheds as a surrogate to define analytical units for the purpose of evaluating the species' status in this SSA report.

Habitat elements that are important to the Elk River crayfish include moderately sized, stable stream channels with riffles, runs, or pools that have some current and low levels of sedimentation; unembedded stream substrates that have larger particle sizes and provide instream cover; and, healthy riparian and instream characteristics (e.g., adequate riparian cover to moderate temperature and sedimentation, appropriate prey resources, and sufficient water chemistry). These elements allow for individuals to have sufficient food and shelter resources to grow, reach maturity, and reproduce. For populations to be resilient, they need healthy demography (i.e., stable or positive growth rates), dispersal habitat that provides connectivity to allow for gene flow among subpopulations, and sufficient habitat quality and quantity to support healthy individuals.

Species-level resiliency is a function of the number of healthy populations and the distribution of these populations relative to the degree and spatial extent of environmental stochasticity. For the Elk River crayfish, we expect that environmental stochasticity primarily includes differences in prey availability and habitat conditions (disturbance, embeddedness, water quality) throughout its range. We consider the HUC 10 subwatershed to be equivalent to an Elk River crayfish's population, and that a healthy population comprises multiple, healthy, interconnected subpopulations (streams). The greater the number (redundancy) of healthy populations and the greater the distribution (representation) of those populations relative to the diversity of prey and other habitat quality conditions, the greater resiliency the species will possess.

Redundancy reflects the ability of a species to withstand catastrophic events and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events. For the purposes of this SSA, we define a catastrophic event as a biotic or abiotic event that causes significant impacts at the population level such that the population cannot rebound from the effects or the population becomes highly vulnerable to normal population fluctuations or stochastic events. For the Elk River crayfish, we considered extreme flooding, spills, and discharges to be events potentially resulting in catastrophic impacts to one or more populations (see chapter 3 for details). We consider multiple occupied sites (e.g., survey locations) within a stream, multiple occupied streams within each watershed, and multiple occupied watersheds within the species' range to be important for the species' redundancy.

Representation is a function of both genetic and adaptive diversity. We do not have specific genetic, morphological, or ecological niche information to inform where there may be differences in the species within the Elk River watershed. However, because the species occurs in both headwater streams and in the Elk River mainstem, and because there may be temperature or other differences of which we are as yet unaware, we are using the species' east to west distribution within the Elk River watershed as a surrogate for representation. Therefore, we infer that the species' representation needs would be best met by retaining its distribution within the watershed.

Influencing Factors (chapter 3): The primary influences to the Elk River crayfish's viability currently and in the future are: (1) population demographics (i.e., distribution and abundance); (2) the quality of instream breeding, feeding, and sheltering features; (3) water quality; and (4) riparian conditions. Connectivity influences the Elk River crayfish's population demographics and is itself influenced by the quality of instream features, water quality, and riparian conditions. The main stressor to the quality of instream features is sedimentation, which can result from point sources and non-point sources. Depending on the source, sedimentation can be managed through properly implemented and enforced best management practices (BMPs) and forest management plans. While it is unknown to what extent climate change is currently affecting the species, it may have synergistic, deleterious effects in the future through increased water temperature compounding the effects of competition from other crayfish species, as well as increasing sedimentation from extreme flooding events brought on by increased precipitation. All four of the primary influences will be considered in the future conditions analysis.

Disease is not currently, or expected to be, having a major effect on the species. Other factors (e.g., predation and competition) may be affecting individuals, but are not currently rising to the level of affecting subwatershed populations or the species as a whole. However, if the quality of instream features or water quality, or both, become too degraded, the magnitude and severity to which disease and competition may affect the species is likely to change.

Current condition (chapter 4): We assessed the current condition of the Elk River crayfish using six metrics: (1) habitat quality via the Rapid Bioassessment Protocol Visual Based Habitat Assessment Protocol (VBHA), (2) prey condition via the West Virginia Stream Condition Index (WVSCI), (3) water quality (silt score), (4) demographics; (5) distribution, and (6) invasive crayfish. These are derived from a combination of GIS analyses, survey data, and WVDEP water and habitat quality data. Each of these metrics correlate to one of the Elk River crayfish's needs, specifically for breeding (abundance, number of sites), feeding (WVSCI), and sheltering (VBHA and silt score).

The Elk River crayfish currently occurs in six HUC 10 watersheds (Redundancy) where it has been documented, consisting of five historical locations (Birch River, Holly River, Laurel Creek, Middle Elk River, and Upper Elk River) and an additional watershed (Lower Elk) where it was not previously documented (2009 - new). Five out of the six HUCs are in moderate to high conditions and one is in moderate-low condition (Resiliency). The moderate-low reduced resiliency is due to reduced habitat and prey conditions, as well as lower demographics.

Future conditions (chapter 5): We used the demographic and habitat information to predict how the six watersheds will respond to the primary factors likely to influence the species' condition in the future. These influencing factors include population demographics (i.e., distribution and abundance); the quality of instream breeding, feeding, and sheltering structures; water quality; and riparian conditions. Our analysis projected three future scenarios, which are representative examples from the potential range of plausible scenarios, and that describe how these stressors to the species may drive changes from current conditions. Projections of the Elk River crayfish's 3Rs were forecast in 10-year increments out to 50 years. This timeframe is supported by approximately 20 years of Elk River crayfish persistence data, which we deem biologically reasonable to use as a surrogate to project forward a similar amount of time; available water quality (20 years), published projections of energy development (50 years), and reasonably reliable climate data (50 years) to reasonably predict potential significant effects of stressors (up to 50 years); the current forest management plan, which has been in place since 2006 and is anticipated to be reevaluated approximately every 10 years; and other potential, but plausible, conservation actions (see chapters 2, 3, and 5). A summary of the three scenarios are presented in the table (ES-1), below.

Table ES-1. Summary of Future Scenario Primary Influencing Factors as Compared to Current Condition.

Influencing Factor	Scenario 1	Scenario 2	Scenario 3
Quality of Instream Conditions			
Habitat Condition (VBHA)	↓[a]	↓↓[a]	↓[a]
Prey Availability (WVSCI)	↓[a]	↓↓[a]	↓[a]
Water Quality (Sedimentation)	↓[a]	↓↓[a]	↓[a]
Climate Projection[b]	Representative Concentration Pathway (RCP) 8.5	RCP 8.5	RCP 4.5
Climate Effects	↑[a] air temperature and variation in precipitation and flooding	↑↑[a] air temperature and variation in precipitation and flooding	↑[a] air temperature and variation in precipitation and flooding
Riparian Conditions			
Conservation Actions (habitat restoration, Japanese knotweed control, etc.)	Same	Same	↑[a]
Population Demographics			
Demography (Abundance)	Same	↓[a]	Same
Distribution (# sites)	Same	↓[a]	Same
Nonnative crayfish	Same	↑	Same
Connectivity	Same	Same	Same

[a] Influencing Factor Rate of Change Compared to Current Condition: some increase (↑), greater increase (↑↑), some decrease (↓), greater decrease (↓↓), no change in rate (Same). b Climate projections are from the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2014, entire). See Chapter 3 for additional information.

The Elk River crayfish is narrow endemic whose range is restricted to one HUC 8 watershed; therefore, it has inherently limited *representation*. While we do not have information on the species' genetic, morphological, or ecological niche information, we use the species' east-west distribution as a surrogate for representation. The species retains its representation through maintaining populations across its range. The species currently occurs in six HUC 10 watersheds throughout the Elk River HUC 8 watershed. In all of the future scenarios, the species is predicted to become extirpated in the Middle and Lower Elk watersheds, which are two western watersheds in the species' range. With these watersheds extirpated, the range primarily shifts towards the eastern watersheds. Therefore, the species' representation is reduced as the range contracts, and as a result, the Elk River crayfish may not be as adaptive to changing conditions over the next 50 years.

Species *redundancy* for the Elk River crayfish is achieved through multiple, widely distributed populations throughout its range. The species is currently known from 18 streams (i.e., subpopulations) in 6 HUC 10 watersheds, distributed throughout the Elk River HUC 8 watershed. While individual subpopulations are not modeled to change in condition, the species is predicted to become extirpated in two watersheds in each scenario (Middle and Lower Elk watersheds) based on overall habitat conditions in the watershed. Under all scenarios through 50 years, the species persists in the two HUC 10 watersheds with a higher number of subpopulations (Holly and Upper Elk) as well as in the two others (Birch River and Laurel Creek), albeit at a lower condition under Scenario 2. Therefore, there will be redundancy both at the subpopulation and species' levels, but we acknowledge that the two low condition HUCs in Scenario 2 likely do not contribute equivalent value to the species' redundancy as the higher condition HUCS (see *Resiliency*). This redundancy will help the species persist in the event of catastrophic events such as flooding, spills (i.e., oil, brine and other wastewater, chemical, sewer), or disease.

Species-level *resiliency* for the Elk River crayfish is evaluated through the number and condition of healthy populations through the species' range. The species currently has subpopulations in six HUC 10 watersheds within its range. These watersheds are currently in various conditions (i.e., not all are high or low condition), which provide resiliency to environmental stochasticity. The species is predicted to become extirpated in two watersheds (Lower Elk River and Middle Elk River) in all scenarios. However, in all scenarios, the Upper Elk watershed retains its high condition to 50 years, and the Holly River watershed remains in moderate condition at 50 years. Therefore, while the species loses resiliency through the extirpation of some populations, these watersheds, where the species is currently predominantly found, in combination with the Birch River (below Sutton Dam) and Laurel Creek HUCs at moderate to low (depending on the Scenario) condition, maintain most, if not all, of their resiliency and provide a buffer against environmental stochasticity.

Uncertainty: Inherently, projecting future scenarios and predicting the species' response to those scenarios requires us to make plausible assumptions. Our analyses are predicated on multiple assumptions, which could lead to over and underestimates of the Elk River crayfish's viability (see chapter 6 for additional details).

CHAPTER 1 BACKGROUND

1.1 Background

This report summarizes the results of a species status assessment (SSA) conducted for the Elk River crayfish (*Cambarus elkensis*). In 2010, we, the U.S. Fish and Wildlife Service (Service), received a petition to list 404 aquatic, riparian, and wetland species, including the Elk River crayfish, as endangered or threatened under the Endangered Species Act of 1973, as amended (Act) (Center for Biological Diversity (CBD) 2010, pp. 1–66, 192–193). In September of 2011, the Service found that the petition presented substantial scientific or commercial information indicating that the listing of 374 species, including the Elk River crayfish, may be warranted. Thus, we conducted an SSA to compile the best scientific and commercial information available regarding the species' biology and factors that influence the species' viability.

1.2 Analytical Framework

The SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, the SSA report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, will be based if the species warrants listing under the Act.

This SSA report for the Elk River crayfish will provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered and if so, whether or not to propose designating critical habitat. The process and this SSA report do not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the Elk River crayfish. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and a decision will be announced in the *Federal Register*.

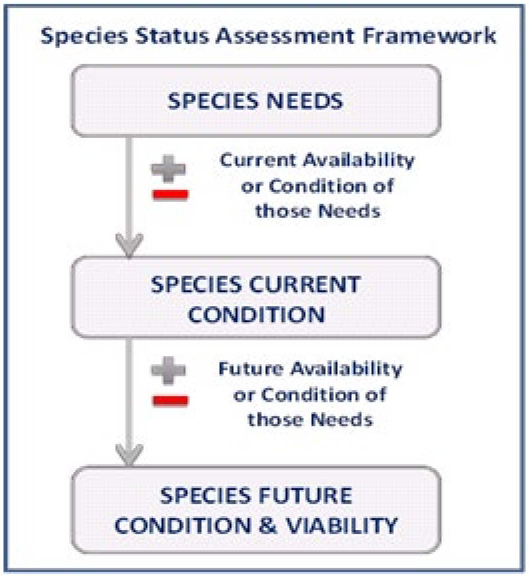

Figure 1. Species Status Assessment Framework

Using the SSA framework (figure 1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Smith *et al*. 2018, entire). For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in natural stream ecosystems within a biologically meaningful timeframe: in this case, 50 years. The 50-year timeframe is projected in 10-year increments in our future scenarios. This timeframe is supported byapproximately 20 years of Elk River crayfish persistence data, which we deem biologically reasonable to use as a surrogate to project forward a similar amount of time; available water quality data (20 years), published projections of energy development (50 years), and reasonably reliable climate data (50 years) to reasonably predict potential significant effects of stressors (up to 50 years); the current Monongahela National Forest management plan, which has been in place since 2006 and is anticipated to be reevaluated approximately every 10 years; and other potential, but plausible conservation actions (see chapters 2, 3, and 5).

Resiliency, redundancy, and representation are defined as follows:

Resiliency describes the ability of the species to withstand stochastic events (arising from random factors), which is associated with population size, growth rate, and habitat quality. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of human activities.

Redundancy describes the ability of the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations), which is related to the number, distribution, and resiliency of populations. Redundancy is about spreading the risk. Generally, the greater the number of populations that a species has distributed over a larger landscape, the better it can withstand catastrophic events.

Representation describes the ability of the species to adapt to changing environmental conditions, which is related to distribution within the species' ecological settings. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic information, we evaluate representation based on the extent and variability of habitat characteristics within the geographical range.

The 3Rs, and their core autecological parameters of abundance, distribution and diversity, are the key characteristics that contribute to a species' ability to sustain populations in the wild over time. When combined across populations, they measure the health of the species as a whole.

The decision whether to list a species is based *not* on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the species by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of resiliency, redundancy, and representation (together, the 3Rs). We then evaluate the future biological status by describing a range of plausible future scenarios representing a range of conditions for the primary factors affecting the species and forecasting the most likely future condition for each scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to individually describe and analyze. These scenarios do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures. This future scenario analysis is intended to inform the determination of the risk that extinction will be the future experienced by the species within each timeframe analyzed.

CHAPTER 2 SPECIES DESCRIPTION AND INDIVIDUAL NEEDS

The Elk River crayfish is a freshwater, tertiary burrowing crustacean of the Cambaridae family (Loughman and Welsh 2010, pp. 68). Tertiary burrowing crayfish inhabit permanent flowing rivers and creeks where they shelter in shallow excavations under loose cobbles and boulders on the stream bottom (Simon 2016, pp. 181).

2.1. Morphological Description

The Elk River crayfish (see figure 2) can be differentiated from other crayfishes through rostral (a stiff beaklike projection on the head) and claw morphology (Loughman (2017a, entire). Its rostrum is broad at the base, converges to a distinct pointy tip, and is lancelike in appearance. Elk River crayfish claws lack tubercles (raised bumps) on the palm, are large and robust, and possess an opening between the movable and immovable finger when the chelae (the two fingers on the claw) are closed. The carapace (hard outer shell covering the back portion of the animal), abdomen, and chelae are all various shades of brown and occasionally can be orange or pink in coloration. There is very little morphological variation in this species. While total body length measurements are not available, in one study, the species' carapace length (the upper portion of the main body covered by a hard shell) ranged from 26.2 to 39.9 millimeters (mm) (1.0 to 1.6 inches (in) (Jezerinac *et al*. 1995, p. 109). More detailed descriptions of the species are found in Jezerinac and Stocker (1993, entire) and Jezerinac *et al*. (1995, p. 107–112).

Figure 2. Elk River crayfish.

2.2 Taxonomy

We have no information to suggest there is scientific disagreement about the Elk River crayfish's taxonomy. Taxonomic treatment is based solely on morphology. The first recorded capture of this species was in 1899 in the Elk River near Cogar's Mill, in Randolph County, West Virginia (Faxon 1914, pp. 387; Newcombe 1929, p. 278[1]; Douglas 2017, p. 1). In 1914, this specimen was identified as *Cambarus bartonii veteranus*, although some differences in morphology

[1] Original information included with the museum specimen listed the collection location only as Elk River near Cogar's Mill. Subsequent records erroneously listed this location as being in Kanawha County (Newcombe 1929, pp. 278). Byrne (1940, pp. 36–44) and Johnson (2005, pp. 61–71, 279) provide more detailed descriptions of the location of Cogar's Mill (also spelled Cowgar's Mill), which allowed for the correct county and more precise location to be determined (Douglas 2017, p. 1).

between other specimens were noted (Faxon 1914, p. 387). Further inspections of the preserved specimen have confirmed the species as an Elk River crayfish (Jezerinac *et al.* 1995, pp. 2, 107).

The next recorded captures are from 1988 and 1989 at various locations within the Elk River watershed. At the time, these were identified as the New River crayfish (*Cambarus chasmodactylus*), but it was noted that these specimens differed in several key aspects from the New River crayfish (Jezerinac and Stocker 1993, p. 346). After comparisons of these specimens to other specimens from throughout West Virginia, the Elk River crayfish was described and formally named as a separate species in Jezerinac and Stocker (1993, entire). The Elk River crayfish is recognized as a valid taxon in subsequent studies and crayfish atlases (Loughman *et al.* 2009, pp. 225–238; Jones and Eversole 2011, entire; Loughman and Welsh 2013, pp. 63–78,). The Service has accepted the species' taxonomy as described by Jezerinac and Stocker (1993, entire).

2.3. Life History

Elk River crayfish begin life as fertilized eggs attached to the underside of a female's abdomen (Taylor *et al.* 1996, pp. 26–27). Elk River crayfish clutch sizes of between 100 and 216 eggs have been reported (Jones and Eversole 2011, p. 647; McLay and van den Brink 2016, p. 101). The number of eggs produced by individual crayfish is affected by size, age (with older, larger females having greater reproductive capacity), and environmental factors that dislodge or cause egg losses (Jones 2012, p. 105). Once the eggs hatch, the young remain attached to the female by a "telson thread," a ropelike structure attached to the telson (the last segment in the abdomen) of the female and connected to the abdomen of the hatchling (Vogt and Tolley 2004, pp. 569–571; Jones and Eversole 2011, pp. 649–650). Young crayfish undergo a series of at least four molts (a process of shedding, or molting, their old exoskeleton, and growing and hardening the new exoskeleton) while still remaining attached to the female (Jezerinac *et al.* 1995, p. 17; Taylor *et al.* 1996, pp. 26–27). During this time period the females will care for and protect their young (Vogt and Tolley 2004, p. 573). The juveniles then leave the female to begin life as free-living individuals. It is not known how long it takes for Elk River crayfish eggs to mature into independent young; however, 35 days has been reported for other crayfish in this genus (Smart 1962 *In* Jones 2012, pp. 104–105). Eggs and young have been found attached to Elk River crayfish females from June through October (Jones and Eversole 2011, p. 647). Jones and Eversole (2011, p. 647) did not find free-living young-of-year Elk River crayfish from August through November, but did find young of the year starting in March (no sampling was conducted December through February).

Molting is one of the critical life history stages of the Elk River crayfish. Starting from the time that crayfish eggs hatch and continuing until death, crayfish go through a continuous series of molts (Taylor *et al.* 1996, pp. 26–27; Jones and Eversole 2011, p. 648; Jones 2012, p. 99). This allows crayfish to increase in size. Molting is a vulnerable life stage for crayfish because during molting crayfish are soft and unable to move effectively, making them susceptible to predation (University of Kentucky 2016, p. 1). They are also more sensitive to contaminants and water quality degradation when molting, which may be due to physiological, metabolic, and other factors (Taylor *et al.* 2007, p. 374; Wigginton and Birge 2007, p. 548; Loughman and Welsh

2010, p. 74). Elk River crayfish can molt at any time of year, but molting may be most prevalent in July and August (Jones and Eversole 2011, p. 648; Jones 2012, p. 99).

In addition to increasing in size, when male *Cambarus* crayfish molt they may alternate between reproductively active (Form I) and nonreproductive (Form II) states (Jezerinac *et al.* 1995, pp. 17; Taylor *et al.* 1996, pp. 26–27). There are distinct morphological differences between Form I and Form II male Elk River crayfish (Jones 2012, pp. 103–104). Form I males have significantly longer and wider chelae than Form II males of similar carapace length (Jones 2012, pp. 106–107). Males molt from Form II to Form I in the fall (August and October) and back to Form II in the spring/summer; however, these molts are not synchronized between individuals (Jones and Eversole 2011, pp. 650–651). Unlike other species in the genus, female Elk River crayfish also undergo reproductive form alternation. Form I females have longer chelae and wider abdomens and are heavier than Form II females of the same carapace length (Jones 2012, pp. 106–107). These morphological differences may give Form I females advantages in social encounters over other similarly sized Form II females and possibly over Form II males. These differences are relevant because it is probable that inter and intraspecific competition occurs for limited space, food, and mate resources (Jones and Eversole 2011, p. 650; Jones 2012, p. 110).

It is not known when Elk River crayfish mate; however, for many species of *Cambarus,* mating occurs in the fall (September to November) (Jezerinac *et al.* 1995, p. 16). In one study specifically on Elk River crayfish, individuals of each sex and reproductive form were found throughout the year, but the highest percentages of Form I (reproductively active) females were found in March and April, and the lowest percentages were found in October and November (Jones and Eversole 2011, pp. 647–651). This is earlier and later in the year, respectively, than the big water crayfish (*C. robustus*) (Jones and Eversole 2011, p. 651). Therefore, timing of mating may be different for Elk River crayfish when compared to other *Cambarus* species, and it is possible that the species may be able to mate at any time of the year.

Individual Elk River crayfish become reproductive in 2.5 to 3 years, have one reproductive event per year once mature, and may live up to 5 years (Jones and Eversole 2011, p. 650; Jones 2012, p. 110). The Elk River crayfish reaches reproductive age later than other *Cambarus* species and grows larger before reaching maturity (Jones and Eversole 2011, p. 650).

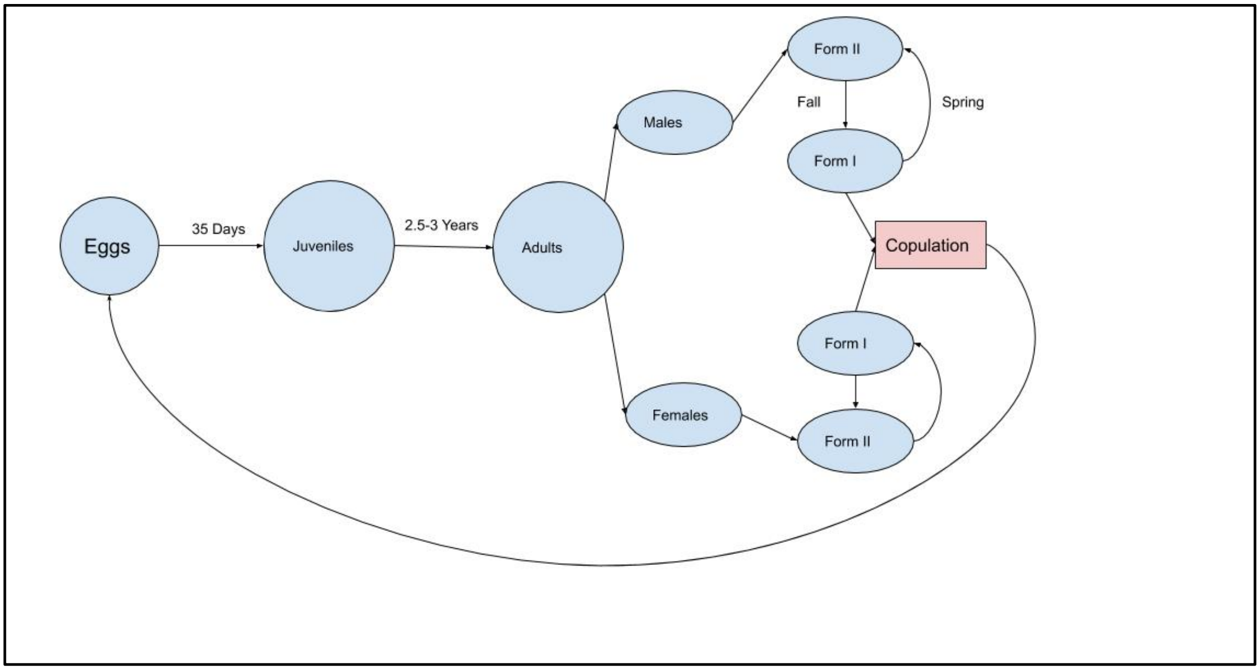

Figure 3. Conceptual model of the Elk River crayfish's life history.

2.4 Foraging Behavior and Requirements

Crayfish are most active between dusk and dawn when they abandon cover to forage for food (Taylor *et al.* 1996, pp. 26–27). The species is assumed to be an opportunistic omnivore feeding on a wide variety of items, including aquatic and terrestrial vegetation, plant detritus, insects, snails, and small aquatic vertebrates (Jezerinac *et al.* 1995, p. 113). Therefore, healthy populations of stream macroinvertebrates and the presence of healthy riparian and instream vegetation may also be important components of Elk River crayfish habitats. This assumption is consistent with other Cambarus crayfish, such as the Big Sandy crayfish (*Cambarus callainus*) and the Guyandotte River crayfish (*C. veteranus*) (Service 2015, entire (80 FR 18710); Service 2016, entire (81 FR 20450)).

2.5 Habitat

Similar to other species in the genus, Elk River crayfish habitat requirements consist of moderately sized streams with riffles, runs, or pools that have some current (Jezerinac *et al.* 1995, p. 113). However, there may be times of year when flow is limited in some suitable streams (see figure 4). The species has not been found in small headwater streams and is not typically found in larger streams such as the lower Elk River mainstem where stream gradients and velocities become more moderate (Jezerinac and Stocker 1993, p. 351; Loughman *et al.* 2009, p. 231; Loughman and Welsh 2013, p. 38).

Figure 4. Elk River crayfish habitat in the Elk River near Elk Springs, Randolph County, WV.

Substrate composition is an important component of crayfish habitat because they depend on larger particle size (e.g., gravel, cobble, or boulder) substrates, woody debris, and vegetation to provide shelter and cover from predators (Taylor *et al.* 2007, p. 374). Stream substrates where Elk River crayfish have been found include small to medium boulders, large cobble, coarse gravel, fissured bedrock, and sand (Jezerinac and Stocker 1993 pp. 350; Jones 2012 pp. 96–97; Jones and Eversole 2011, p. 648). In a life history study of the Elk River crayfish conducted on the Left Fork of Holly River (the type locality used to describe the species), the researcher observed there was little to no sedimentation in areas that supported the species (Jones and Eversole 2011, p. 648; Jones 2012, pp. 96–97). At the time of the study (2003 to 2004), riparian areas of this stream were dominated by eastern hemlock (*Tsuga canadensis*), birch (*Betula* sp.), alder (*Alnus* sp.), and rhododendron (*Rhododendron maximum*), and the surrounding land-use was "relatively undisturbed," consisting of forest or pasture (Jezerinac and Stocker 1993, p. 350; Jones and Eversole 2011, p. 648).

2.6 Historical and Current Range and Distribution

The historical and current range of the Elk River crayfish is restricted to areas of the Elk River watershed in Pocahontas, Randolph, Webster, Braxton, Nicolas, and Clay counties, West Virginia (Jezerinac and Stocker 1993, pp. 350–351; Loughman and Welsh 2013, p. 38). See figure 5. The Elk River watershed was and is one of the most ecologically diverse rivers in the State (Green 1999, p. 2), supporting more than 100 species of fish and 30 species of mussels, including 5 federally endangered mussels and 1 federally endangered darter (Welsh 2009a, p. 1; Service 2013, p. 45083). The Elk River has been renowned for its excellent fishery since the early 1800s (Byrne 1940, entire; Johnson 2005, entire), with records of large native and nonnative fish such as northern pike (*Esox lucius*) and channel catfish (*Ictalurus punctatus*) reported (WVDEP 1997, pp. 14–16).

The Elk River watershed begins near Snowshoe Mountain Resort above the town of Linwood in Pocahontas County and extends generally west to the confluence of the Elk River with the Kanawha River at Charleston (West Virginia Department of Environmental Protection (WVDEP) 1997, pp. 14–16) (see figure 5). The Elk River watershed drains approximately 1,530 square miles (mi^2) (3,962 square kilometers (km^2)) (979,724 acres (396,480 hectares (ha))) and covers parts of nine counties in West Virginia: Braxton, Calhoun, Clay, Kanawha, Nicholas, Pocahontas, Randolph, Roane, and Webster (U.S. Environmental Protection Agency (USEPA) 2001, p. 1-1). The elevation in the watershed ranges from over 4,300 feet (ft) (1,310 meters (m)) near the headwaters to 566 ft (172 meters) at Charleston (WVDEP 1997, pp. 14–16). The Elk River itself is formed by the junction of Big Spring Fork and Old Field Fork at the town of Slaty Fork (WVDEP 1997, pp. 14–16). From there, the river flows about 186 mi (299 km) and drops about 2,070 ft (631 m) in this distance (WVDEP 1997, pp. 14–16). Major tributaries of the Elk River include Birch River, Big Sandy Creek, and Buffalo Creek (USEPA 2001, pp. 1-1).

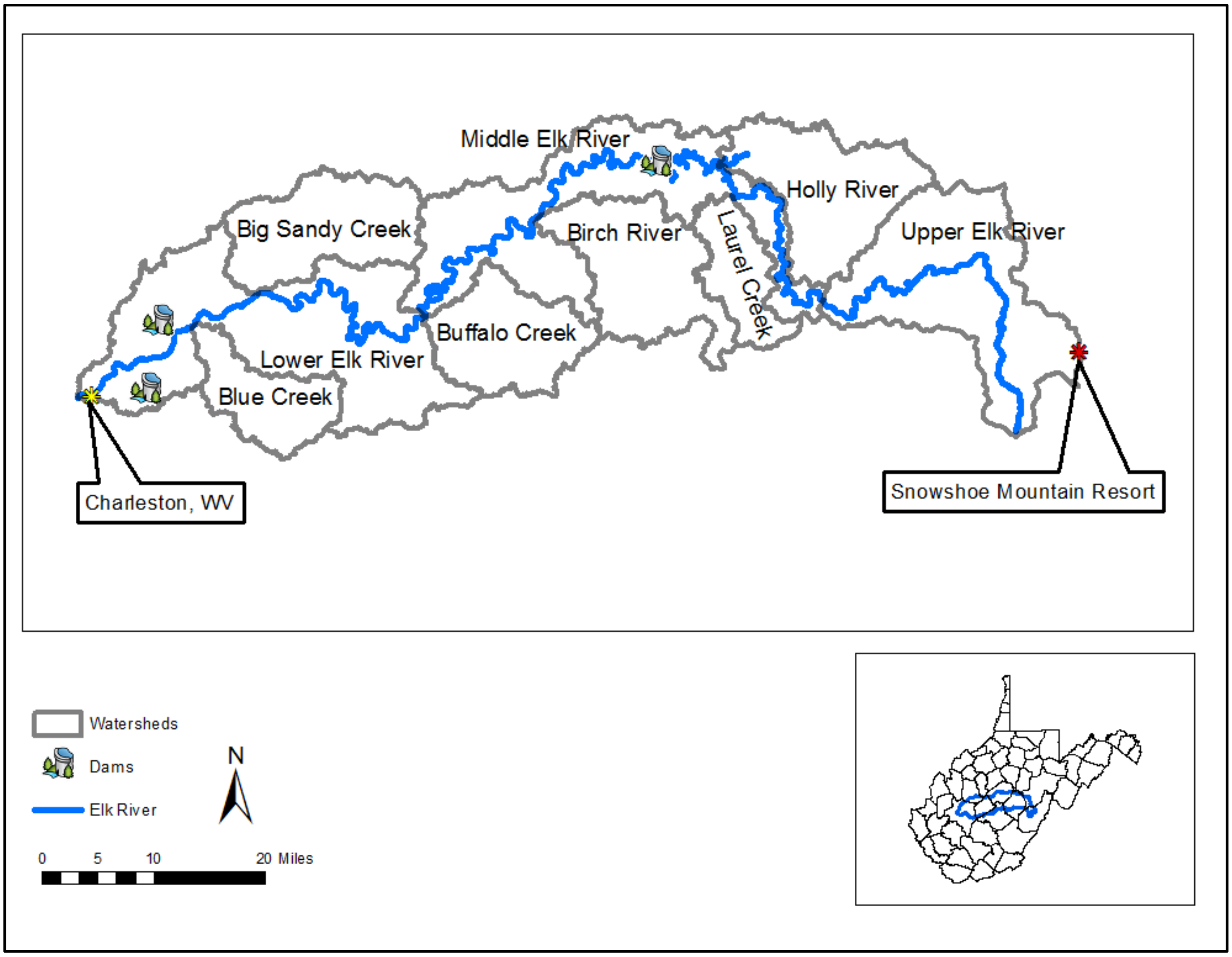

Figure 5. Extent of the Elk River watershed and inclusive of the Elk River crayfish's historical and current range.

As shown below in figure 6, the range includes the upper and middle sections of the Elk River mainstem and/or tributaries to the Elk River located in the following subwatersheds (as defined by U.S. Geological Survey (USGS) 10-digit Hydrologic Units (HUCs)): Upper Elk River, Holly River, Middle Elk River, Laurel Creek, Birch River, and Lower Elk River (Jezerinac and Stocker 1993, pp. 350; Loughman and Welsh 2013, p. 38). The species is not found in the areas of the Elk River watershed in Kanawha or Roane counties, or in any other watersheds or streams throughout the State (Jones and Eversole 2011, p. 647).

The range of the species was first established during surveys conducted by Jezerinac and Stocker (1993, entire) in 1988 and 1989. This survey effort was designed to determine the distribution of this species (Jezerinac *et al.* 1995, p.5). Surveyors documented Elk River crayfish presence in 10 streams in the Elk River watershed (WVDNR 2017a, entire). "Special effort" was then made to search adjacent watersheds including the Greenbrier, Gauley, Cherry, and Cranberry River, but no Elk River crayfish were found (Jezerinac *et al.* 1995, pp. 5, 112). Jezerinac *et al.* (1995, p. 2, 4) also examined crayfish (1,040 lots and 7,055 specimens) from museum collections at the Smithsonian Institution, Marshall University, and Ohio State University.

The range was further refined as part of a Statewide crayfish survey effort, when additional crayfish surveys within the Elk River and surrounding watersheds were conducted by Loughman and Welsh (2013, entire) between 2007 and 2013, with the Elk River watershed sampled in 2009. Within each watershed, they conducted systematic sampling at random sites and at sites previously sampled by Jezerinac *et al.* (Loughman and Welsh 2013 pp. 5, 6). Collection methods used were similar to those used in the previous survey effort. However, unlike Jezerinac *et al.* (1995, entire), Loughman and Welsh's (2013, entire) level of effort at each site was standardized. This Statewide-effort added only one new distribution record for the Elk River crayfish in Middle Creek, a tributary of the lower Elk River in Clay County (Jones 2012, p. 95, Loughman and Welsh 2013, p. 38). This is the furthest west and most downstream location in the watershed that the species has been collected (Loughman and Welsh 2013, pp. 38). See figure 6. The Middle Creek area was previously surveyed during the 1988–89 effort and no Elk River crayfish were found (Jezerinac *et al.* 1995 p. 4; WVDNR 2017a, entire). It is unclear whether Middle Creek is a native population that was not detected in the previous sampling or a more recent localized introduction since the species was not located from any neighboring streams (Loughman and Welsh 2013, p. 38).

With the exception of the potential expansion of the current range into Clay County, the data suggest that the range of the species has not changed significantly between 1988–89 and 2009. All sites where the Elk River crayfish were found in 1988–89 were either: 1) revisited in 2009 and found to be positive for the species; or 2) had sites surveyed in 2009 that were positive for the species and were located in the same stream in close proximity to the 1988–89 site. Surveys were not conducted in the Elk River at Cogar's Mill during either the 1989 or 2009 effort, potentially because the exact location of this historical site was not known at the time (WVDNR 2017a, pp. 41). However, surveys in 2009 found the species in the Elk River both upstream and downstream of Cogar's Mill. No surveys have been completed since 2009, but a Service employee located a single Elk River crayfish while on the mainstem Elk River near Elk Springs Resort in 2017 (Schmidt 2017, p. 1).

The Elk River crayfish is not present within the Elk River mainstem below Sutton Dam. The species appears to be replaced by the big water crayfish in the middle and lower Elk River mainstem where stream gradients and velocities become more moderate (Loughman and Welsh 2010, p. 68; Loughman and Welsh 2013, p. 38); see *chapter 3 Factors Influencing the Species—Competition*).

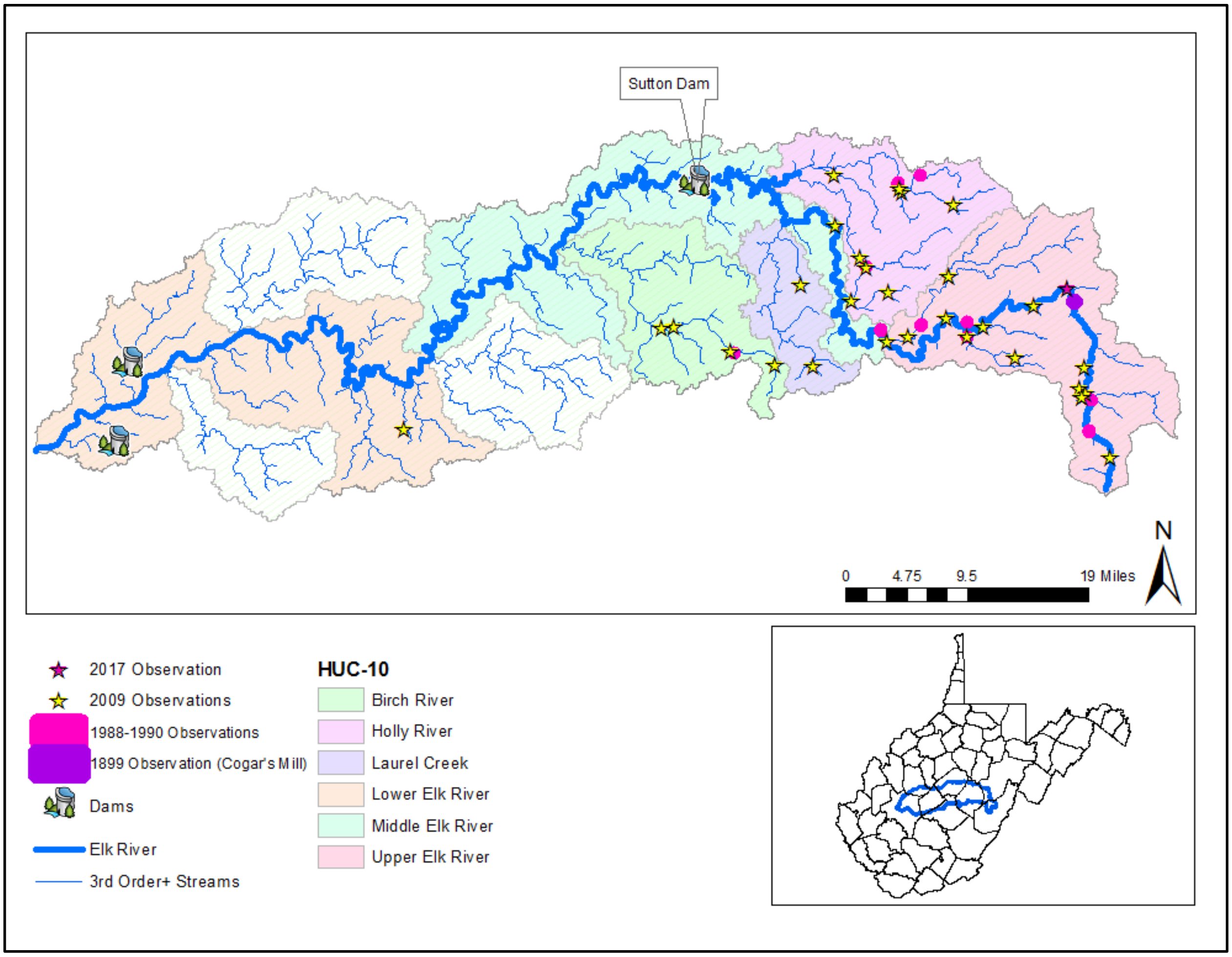

Figure 6: Range of the Elk River crayfish.

Historically, all Elk River crayfish were likely part of one metapopulation that had some limited connectivity. There is little information available regarding the demographic or genetic processes that define the spatial structure of Elk River crayfish populations, thereby precluding our ability to make reliable groupings of biological populations. Therefore, we used USGS HUC 10 watersheds as a surrogate to define analytical units for the purpose of evaluating the species' status in this SSA report. The USGS uses a national standard hierarchical system based on surface hydrologic features to delineate watershed boundaries at various scales. The entire U.S. has been divided and subdivided into successively smaller hydrologic units. The HUC 8 watersheds, like the Elk River, are analogous to medium-sized river basins, whereas HUC 10 watersheds represent tributaries or smaller units within the overall HUC 8 watershed boundary. This established structure for evaluating physical, chemical, and biological factors affecting streams and their ecosystems provides a logical framework for evaluating factors affecting the status of the Elk River crayfish. From here forward, we use the terms HUC 10 and population interchangeably.

There are nine HUC 10 units within the Elk River watershed. Three of these (Buffalo Creek, Big Sandy, and Blue Creek) have no current or previous records of Elk River crayfish occurrence, and are therefore not considered in our analysis. Table 1 lists each of HUC 10 units (populations) and the individual streams (subpopulations) within each unit where Elk River crayfish have been found.

Table 1. HUC 10 units (populations) and their corresponding streams (subpopulations).

HUC 10 Number	HUC 10 Name	Streams with ERC
0505000709	Lower Elk River	Middle Creek
0505000706	Middle Elk River	Elk River mainstem
0505000704	Birch River	Birch River
		Poplar Creek
0505000702	Laurel Creek	Given Run
		Camp Creek
0505000703	Holly River	Left Fork Holly River
		Old Lick Creek
		Grassy Creek
0505000701	Upper Elk River	Elk River mainstem
		Old Field Fork
		Laurel Run
		Props Run
		Big Run
		Leatherwood Creek
		Back Fork Elk River

The 2009 survey data, and the one individual sited in 2017, is the most recent occurrence information for the species and represents the best available data. Given the species' longevity, evidence of reproduction, and lack of information to the contrary, we assume the streams occupied in 2009 to be currently occupied for the purposes of this SSA.

2.7 Needs of the Elk River Crayfish

For the purpose of this assessment, we define viability as the ability of the species to sustain populations in natural stream ecosystems within a biologically meaningful timeframe. Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs). Using various timeframes and the current and projected levels of the 3Rs, we thereby describe the species' level of viability over time.

2.7.1 Individual and 'Population' Needs

Habitat elements that are important to the Elk River crayfish include moderate-sized, stable stream channels with riffles, runs, or pools that have some current and low levels of sedimentation; unembedded stream substrates that have larger particle sizes and provide instream cover; and, healthy riparian and instream characteristics (e.g., adequate riparian cover to moderate temperature and sedimentation, appropriate prey resources, and sufficient water quality (chemistry and siltation parameters). A stable stream is defined as a stream that has the ability in the present climate to support the streamflows and sediment of its watershed in such a manner that the channel and banks maintain their lateral dimensions, longitudinal profiles, and sinuosity patterns over time without an aggrading or degrading (Rosgen 2011, p. 71). These elements allow for individuals to have sufficient food and shelter resources to grow, reach maturity, and reproduce. For populations to be resilient, they need healthy demography (i.e., stable or positive growth rates), dispersal habitat that provides connectivity to allow for gene flow among subpopulations, and sufficient habitat quality and quantity to support healthy individuals. See table 2.

Table 2. Summary of Elk River Crayfish Needs

Requirement	**Description**
Healthy Demography	Sufficient number of individuals of both sexes to allow for reproduction.
Gene Flow Among Subpopulations	Sufficient connectivity to allow for movement of individuals.
Space	Sufficient abundance of individuals and populations to remain competitive against intra and interspecies completion including invasive crayfish.
Substrates	Small to medium boulders, large cobble, coarse gravel, fissured bedrock, and sand (feeding, breeding, and sheltering) with low levels of siltation.
Prey resources	Vegetation, detritus, insects, snails, small aquatic vertebrates (feeding).
Water Quantity	Adequate stream flow in permanent streams to retain water quality and unembedded substrates.
Water Quality	Adequate water quality (e.g., temperature, water chemistry, silt) at levels that promote healthy prey resources and resistance to invasive species and disease.
Healthy riparian corridors and stable stream channels	These features support healthy instream feeding, breeding, sheltering requirements.

2.7.2 Species Needs

Resiliency

Species-level resiliency is a function of the number of healthy populations and the distribution of these populations relative to the degree and spatial extent of environmental stochasticity. Environmental stochasticity acts at local and regional scales; thus, the health of populations in any one year can vary over geographical areas (Hanski 1999, p. 372). For this reason, having populations distributed across a diversity of environmental conditions reduces the likelihood of concurrent losses of populations at local and regional scales.

As described in *section 2.7.1—Individual and 'Population' Needs*, an Elk River crayfish healthy population is comprised of multiple, healthy, interconnected subpopulations. The greater the number of healthy populations and the greater the distribution of those populations relative to the diversity of prey and other habitat quality conditions, the greater resiliency the species will possess. For the Elk River Crayfish, we expect that environmental stochasticity primarily includes differences in prey availability and habitat conditions (disturbance, embeddedness, water quality) throughout its range. Given the relatively narrow range of the Elk River crayfish, these and other environmental differences could affect the species throughout its range in any one year. Thus, the species is inherently vulnerable to environmental stochasticity.

Redundancy

Redundancy reflects the ability of a species to withstand catastrophic events and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events. In addition to guarding against a single or a series of catastrophic events extirpating the entire species, redundancy is important to protect against losing irreplaceable sources of adaptive diversity. To determine what the Elk River Crayfish requires to guard against catastrophic events, we first considered what catastrophic events to which the species may be subjected (see chapter 3). For the purposes of this SSA, we define a catastrophic event as a biotic or abiotic event that causes significant impacts at the population level such that the population cannot rebound from the effects or the population becomes highly vulnerable to normal population fluctuations or stochastic events.

For the Elk River crayfish, we considered extreme flooding, spills, and discharges to be events potentially resulting in catastrophic impacts to one or more populations (see chapter 3 for details). Floods have the potential to displace or cause mortality of individuals or populations (Rizzo *et al*. 2018, p. 115), as well as to either degrade habitat or replenish habitat, depending on the scope and severity of the flood event. Some species may be adapted to periodic flooding events or not immediately show an effect but may experience an effect in the longer term. In June of 2016, there was a significant flood event that affected the majority of the Elk River watershed (NOAA 2019; USGS 2019) and which generated scouring and sedimentation and potentially introduced contaminants into the river. The long term effects to aquatic species from that flooding event are still being assessed (Rizzo *et al*. 2018, p. 116). We did not consider drought to be a potentially catastrophic event because the best available climate modeling information for the Elk River indicates that there will be an increase in precipitation, not a decrease. See chapter 3 for additional details.

We consider multiple occupied sites (e.g., survey locations) within a stream, multiple occupied streams within each watershed, and multiple occupied watersheds within the species' range to be important for the species' redundancy.

Representation

Representation is a function of both genetic and adaptive diversity. As described in chapter 1, genetic diversity is important because it can delineate evolutionary lineages that may harbor unique genetic variation, including adaptive traits. It can also indicate gene flow, migration, and dispersal. Ecological diversity is important because it provides the variation in phenotypes and ecological settings on which natural selection acts. In addition, the processes that drive evolution (gene flow, natural selection, mutations, and genetic drift) are required to maintain species-level representation (Crandall 2000, p. 291). We do not have specific genetic, morphological, or ecological niche information to inform where there may be differences in the species within the

Elk River watershed. However, because the species occurs in both headwater streams and in the Elk River mainstem and there may be temperature or other differences that we are as yet aware, we are using the species' east to west distribution within the Elk River watershed as a surrogate for representation. Therefore, we infer that the species' representation needs would be best met by retaining its distribution within the watershed.

2.8 Summary of Description, Life History, Habitat, Distribution, and Needs

The Elk River crayfish is a relatively small, freshwater, tertiary burrowing crustacean, that can be differentiated from other crayfishes through rostral (a stiff beaklike projection on the head) and claw morphology (Loughman (2017a, entire). While total body length measurements are not available, Jezerinac *et al*. (1995, p. 109) noted the species' carapace length (the upper portion of the main body covered by a hard shell) ranged from 26.2 to 39.9 mm (1.0 to 1.6 in). While first documented in West Virginia in 1899, the species was not described and formally named as a separate species until 1993 (Jezerinac and Stocker 1993, entire). There are no genetics data currently available for the Elk River crayfish, and the species' uncontested taxonomy is based solely on morphology.

Like most crayfish, an Elk River crayfish begins its life as a fertilized egg attached to the underside of a female's abdomen (Taylor *et al.* 1996, pp. 26–27). Elk River crayfish clutch sizes of between 100 and 216 eggs have been reported (Jones and Eversole 2011, p. 647; McLay and van den Brink 2016, p. 101), but the number of eggs can vary by size, age, and environmental factors that dislodge or cause egg losses (Jones 2012, p. 105). In approximately 35 days, the egg hatches but the hatchling remains physically attached to the female (Vogt and Tolley 2004, pp. 569–571; Jones and Eversole 2011, pp. 649–650) as it undergoes a series of four to five molts (Jezerinac *et al.* 1995, p. 17; Taylor *et al.* 1996, pp. 26–27) that allow it to grow and its shell to harden. The juvenile then leaves the female to begin life as a free-living individual. Individual Elk River crayfish become reproductive in 2.5 to 3 years, have one reproductive event per year once mature, and may live up to 5 years (Jones and Eversole 2011, p. 650; Jones 2012, p. 110).

The Elk River crayfish reaches reproductive age later than other *Cambarus* species and grows larger, through a continuous series of molts, before reaching maturity (Jones and Eversole 2011, p. 650). Molting is a vulnerable life stage for crayfish because during molting crayfish are soft and unable to move, effectively making them susceptible to predation (University of Kentucky 2016, p. 1). They are also more sensitive to contaminants and water quality degradation when molting, which may be due to physiological, metabolic, and other factors (Taylor *et al.* 2007, p. 374; Wigginton and Birge 2007, p. 548; Loughman and Welsh 2010, p. 74). Both male and female Elk River crayfish alternate between two different morphological forms depending on whether or not they are reproductively active. It is not known when Elk River crayfish mate. For many species of *Cambarus,* mating occurs in the fall (September to November) (Jezerinac *et al.* 1995, p. 16), although it is possible, given the seasonal observations of young of the year and relative abundance of reproductively active individuals, that the Elk River crayfish may be able to mate at any time of the year.

Crayfish are most active between dusk and dawn when they abandon cover to forage for food (Taylor *et al.* 1996, pp. 26–27). The species is assumed to be an opportunistic omnivore feeding on a wide variety of items, including aquatic and terrestrial vegetation, plant detritus, insects, snails, and small aquatic vertebrates (Jezerinac *et al.* 1995, p. 113). Therefore, healthy populations of stream macroinvertebrates and the presence of healthy riparian and instream vegetation may also be important components of Elk River crayfish habitats.

The habitat requirements of the Elk River crayfish, like those of other species in the genus, consist of permanently flowing, moderately sized streams with riffles, runs, or pools that have some current (Jezerinac *et al.* 1995, p. 113). However, there may be times of year when flow is limited in some suitable streams (see figure 4). The species has not been found in small headwater streams and is not typically found in larger streams such as the lower Elk River mainstem where stream gradients and velocities become more moderate (Jezerinac and Stocker 1993, p. 351; Loughman *et al.* 2009, p. 231; Loughman and Welsh 2013, p. 38).

Substrate composition is an important component of crayfish habitat because they depend on larger particle size (e.g., gravel, cobble, or boulder) substrates, woody debris, and vegetation to provide shelter and cover from predators (Taylor *et al.* 2007, p. 374). Stream substrates where Elk River crayfish have been found include small to medium boulders, large cobble, coarse gravel, fissured bedrock, and sand with little to no sedimentation (Jezerinac and Stocker 1993 pp. 350; Jones 2012 pp. 96–97; Jones and Eversole 2011, p. 648).

The historical and current range of the Elk River crayfish is restricted to areas of the Elk River watershed in Pocahontas, Randolph, Webster, Braxton, Nicolas, and Clay Counties, West Virginia (Jezerinac and Stocker 1993, pp. 350–351; Loughman and Welsh 2013, p. 38). See figure 5. The range includes the upper and middle sections of the Elk River mainstem and/or tributaries to the Elk River located in the following HUC 10 subwatersheds: Upper Elk River, Holly River, Middle Elk River, Laurel Creek, Birch River, and Lower Elk River (Jezerinac and Stocker 1993, pp. 350; Loughman and Welsh 2013, p. 38). The species is not found in the areas of the Elk River watershed in Kanawha or Roane Counties, or in any other watersheds or streams throughout the State (Jones and Eversole 2011, p. 647). The best available data suggest that the species' range has not changed significantly. This is based on: a series of targeted survey efforts in 1988 and 1989 (Jezerinac and Stocker 1993, entire), in 1995 (Jezerinac *et al.* 1995, pp. 5, 112), and from 2007 to 2013 (Loughman and Welsh 2013, entire); an examination of museum specimens (Jezerinac *et al.*1995, p. 2, 4); and a personal observation (Schmidt 2017, p. 1). Given the species' longevity, evidence of reproduction, and lack of information to the contrary, we assume the streams occupied in 2009 to be currently occupied for the purposes of this SSA.

Historically, all Elk River crayfish were likely part of one metapopulation that had some limited connectivity. There is little information available regarding the demographic or genetic processes that define the spatial structure of Elk River crayfish populations, thereby precluding our ability to make reliable groupings of biological populations. Therefore, we used the aforementioned USGS HUC 10 watersheds as a surrogate to define analytical units for the purpose of evaluating the species' status in this SSA report.

Habitat elements that are important to the Elk River crayfish include moderately sized, stable stream channels with riffles, runs, or pools that have some current and low levels of sedimentation; unembedded stream substrates that have larger particle sizes and provide instream cover; and, healthy riparian and instream characteristics (e.g., adequate riparian cover to moderate temperature and sedimentation, appropriate prey resources, and sufficient water chemistry and siltation parameters). These elements allow for individuals to have sufficient food and shelter resources to grow, reach maturity, and reproduce. For populations to be resilient, they need healthy demography (i.e., stable or positive growth rates), dispersal habitat that provides connectivity to allow for gene flow among subpopulations, and sufficient habitat quality and quantity to support healthy individuals (see table 2).

Species-level resiliency is a function of the number of healthy populations and the distribution of these populations relative to the degree and spatial extent of environmental stochasticity. For the Elk River crayfish, we expect that environmental stochasticity primarily includes differences in prey availability and habitat conditions (disturbance, embeddedness, water quality) throughout its range. We consider the HUC 10 watershed to be equivalent to an Elk River crayfish's population, and a healthy population comprises multiple, healthy, interconnected subpopulations (streams). The greater the number (redundancy) of healthy populations and the greater the distribution (representation) of those populations relative to the diversity of prey and other habitat quality conditions, the greater resiliency the species will possess.

Redundancy reflects the ability of a species to withstand catastrophic events and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events. For the purposes of this SSA, we define a catastrophic event as a biotic or abiotic event that causes significant impacts at the population level such that the population cannot rebound from the effects or the population becomes highly vulnerable to normal population fluctuations or stochastic events. For the Elk River crayfish, we considered extreme flooding, spills, and discharges to be events potentially resulting in catastrophic impacts to one or more populations (see chapter 3 for details). We consider multiple occupied sites (e.g., survey locations) within a stream, multiple occupied streams within each watershed, and multiple occupied watersheds within the species' range to be important for the species' redundancy.

Representation is a function of both genetic and adaptive diversity. We do not have specific genetic, morphological, or ecological niche information to inform where there may be differences in the species within the Elk River watershed. However, because the species occurs in both headwater streams and in the Elk River mainstem and because there may be temperature or other differences of which we are currently unaware, we are using the species' east to west distribution within the Elk River watershed as a surrogate for representation. Therefore, we infer that the species' representation needs would be best met by retaining its distribution within the watershed.

CHAPTER 3 FACTORS INFLUENCING THE SPECIES

In this chapter, we evaluate the past, current, and future influences that are affecting or could be affecting the current and future conditions of the Elk River crayfish. These influences are summarized in a conceptual model (figure 7) and discussed in more detail in the section below. The factors primarily affecting the species' needs are population demographics (e.g., connectivity), effects to the quality of instream conditions (e.g., level of sedimentation), water quality, and riparian conditions.

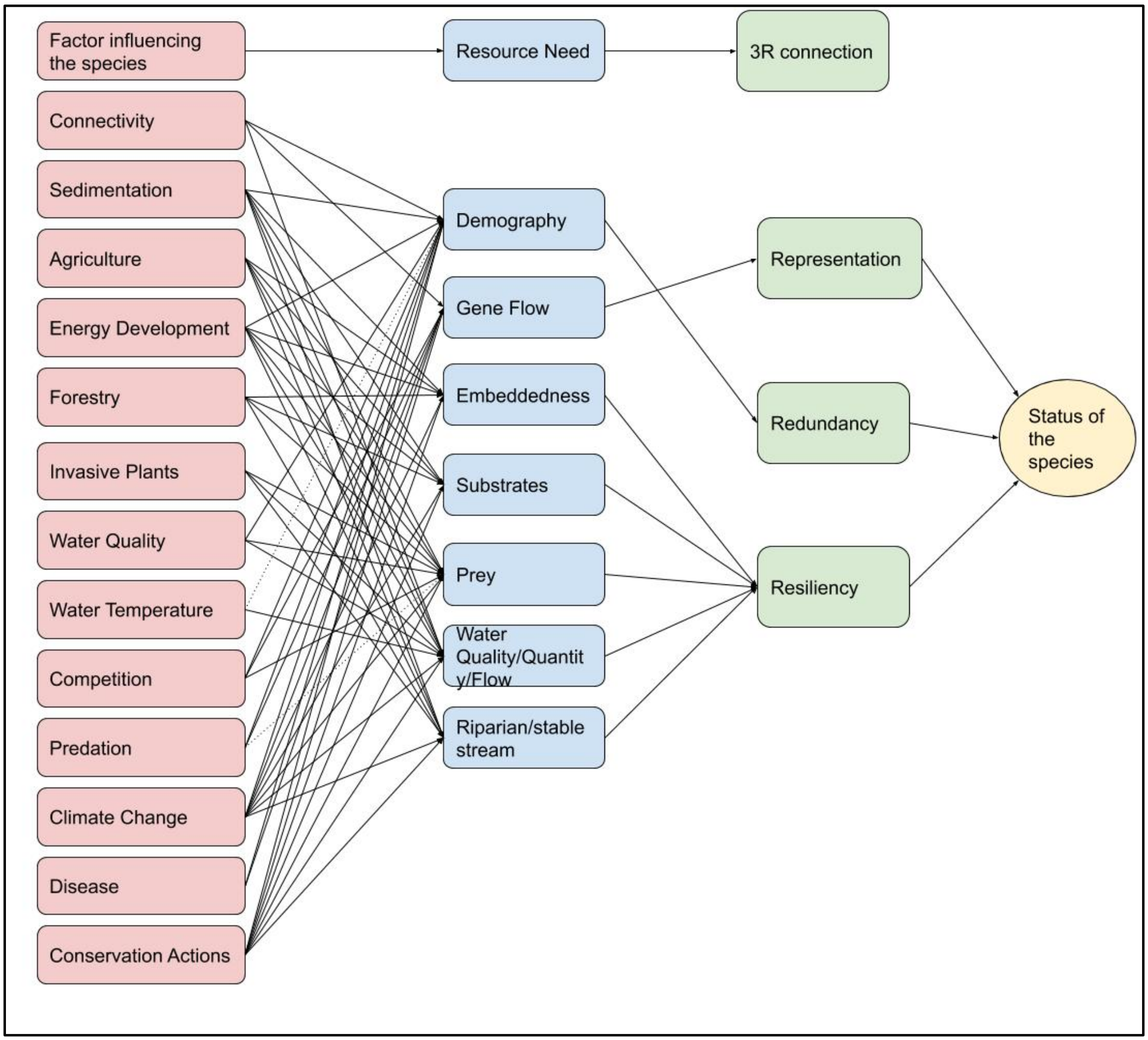

Figure 7. Presumed influence diagram for the Elk River crayfish. Red shaded boxes represent influencing factors, blue shaded boxes represent the species' resource needs, and green shaded boxes represent the corresponding 3R (representation, redundancy, or resiliency), which all have an effect on the species' status.

3.1 Connectivity

The species' range includes anthropogenic and natural barriers to connectivity. There is one major dam, Sutton Dam, which is fragmenting populations of the Elk River crayfish. Sutton Dam is located on the mainstem Elk River within the Middle Elk River watershed, 101 mi (163 km) above the mouth of the Elk River and 90 mi (145 km) downstream from the headwaters. The 210ft (64-m) high dam was built by the U.S. Army Corps of Engineers in 1961 for the purpose of flood control. Approximately 14 mi (23 km) of the Elk River has been impounded by the dam creating a 1,440-acre (583-ha), 125ft (38-m) deep lake (U.S. Army Corps of Engineers 2018). This portion of the Elk River and its impounded tributaries are no longer suitable habitat for the crayfish because it no longer consists of moderately sized streams with riffles, runs, or pools that have some current.

In addition to dams, some culvert designs (e.g., perched) associated with roads and bridges can form barriers to aquatic species' movements. We lacked information with which to quantify how many perched culverts may be within the Elk River crayfish's range. However, other crayfish have been documented to move upstream over small barriers and have been seen climbing up rock faces around waterfalls or moving overland (Kerby *et al*. 2005, p. 407). Therefore, while we acknowledge that there may be some unquantifiable number of culverts within the species' range, we are unaware of the specific effects that such culverts may have on the Elk River crayfish.

Some natural barriers to movement are also present within the range of the Elk River crayfish. These include Whitaker Falls on the mainstem Elk River and Bergoo Falls on Leatherwood Creek, (both are within the Upper Elk River watershed). While these barriers may limit the distribution and connectivity of crayfish populations within the watershed, it is likely that they are not absolute barriers to movement. Although not documented for the Elk River crayfish, other crayfish species have occasionally been transported downstream over these features during floods or high waters (Kerby *et al*. 2005, p. 407). In addition, crayfish have been documented to move upstream over small barriers and have been seen climbing up rock faces around waterfalls or moving overland (Kerby *et al*. 2005, p. 407). These barriers are geologic in origin, the species likely evolved with these barriers in place, and they are likely to remain in place for the duration of the analysis period. Therefore, we are focusing on anthropogenic barriers to movement in this analysis.

Summary of Connectivity: Dams and natural barriers have historically impeded connectivity and will continue to do so in the future. In addition, invasive crayfish (see *section 3.4.1* below) may decrease connectivity in the future; therefore, we are carrying connectivity forward in our analysis.

3.2 Sedimentation

Streams that support the Elk River crayfish have little to no sedimentation (Jones and Eversole 2011, p. 648; Jones 2012, pp. 96–97). Therefore, increases in sedimentation within Elk River crayfish habitat degrades habitat quality and may make some areas unsuitable for the species. This conclusion is consistent with the effects to other *Cambarus* species ((Service 2015, entire (80 FR 18710); Service 2016, entire (81 FR 20450)).

Sedimentation can result from both anthropogenic activities (e.g., land use) and natural causes (i.e., floods). Major stressors associated with land use change include loss or degradation of physical habitat attributes and water quality. The Elk River watershed is affected by land use changes relating to agriculture, timber harvest, coal mining, natural gas production and transportation, and urban development. The dominant land cover type in the Elk River watershed is forest, ranging from 88 to 95 percent forested, depending on watershed, with developed landcover ranging from 3 to 8 percent, and agriculture or barren landcover summing below 5 percent of total landcover (Homer *et al.* 2015, entire). Typical activities within the watershed that increase sedimentation include forestry, surface coal extraction and related infrastructure, natural gas well pads and related infrastructure, construction or maintenance of roads and highways, and agriculture (WVDEP 2012, p. 33–35). Pipelines and wells constructed on slopes can result in landslides and slips that release large amounts of sediment into waterways, which can affect water quality during transport, as well as streambeds via deposition. Some of these activities also result in an increase of contaminants within the watershed, resulting from point sources (i.e., sewage treatment plant discharge) or non-point sources (i.e., surface runoff from a mining refuse pile) (WVDEP 2012, p. 26–32). Increases in sedimentation can reduce species' richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (Larsen *et al*. 2011, entire), which are prey species for the Elk River crayfish.

Excessive stream sedimentation results from soil erosion associated with upland activities (e.g., agriculture, forestry, mining, unpaved roads, road or pipeline construction, and general urbanization) as well as activities that can destabilize stream channels themselves (e.g., dredging or channelization, construction of dams, culverts, pipeline crossings, or other instream structures) (WVDEP 2012, p.12). Excessive sediments can cover the stream bottom and fill the interstitial spaces between bottom substrate particles (i.e., sand, gravel, and cobbles) and in severe cases also cause stream bottoms to become "embedded." Embeddedness occurs when substrate features including larger cobbles, rocks, and boulders are surrounded by, or buried in, sediment. Sedimentation alters aquatic habitats by reducing light penetration, changing heat radiation, increasing turbidity, and covering the stream bottom (Ellis 1936 *In* Grandmaison *et al.* 2003, p. 17). Increased sedimentation has also been shown to abrade and suffocate bottom-dwelling organisms and reduce aquatic insect diversity and abundance, which can affect a species' growth, survival, and reproduction (Berkman and Rabeni 1987, p. 285).

Since enactment of various state and Federal regulations (e.g., Federal Clean Water Act of 1977 (33 U.S.C. 1251 *et seq*.), Surface Mining Control and Reclamation Act of 1977 (30 U.S.C. 1234–1328), West Virginia Water Pollution Control Act (WVSC § 22–11)) and the increased implementation of forestry and construction "best management practices" (BMPs) designed to reduce erosion and sedimentation, levels of stream sedimentation have generally improved over historical conditions. However, based on the most recent state water quality reports, sedimentation remains a problem in many streams within the range of the Elk River crayfish. In the Central Appalachian physiographic province of West Virginia, which includes the Elk River watershed, an estimated 15.3 percent of the total stream miles were rated as "poor" with respect to sedimentation, 60.3 percent were rated "fair," and 16.8 percent were rated as "good" (WVDEP 2019a, p. 37).

3.2.1 Resource Extraction

The Elk River watershed has been affected by historical and ongoing coal, oil and gas, and timbering activities. This section describes each extraction industry and its influence on sedimentation within the Elk River watershed, which affects the condition of Elk River crayfish habitat.

Energy associated development has increased in the time since the Elk River crayfish population surveys. The Nature Conservancy's Appalachian Energy Development Final Report assessed the probability of energy development across the Appalachian Landscape Conservation Cooperative (LCC). This report projects that nearly 1.6 million acres (647,497 ha) within West Virginia have a high probability of energy development from one or more sources based on projections of energy development to 2040 (Dunscomb *et al*. 2015, p. 19). The majority of the area with a high probability of energy development occurs within forested areas (Dunscomb *et al*. 2015, p. 27). Based on the LCC's geographic information system (GIS) data, 29.4 percent of the Elk River watershed has a high probability (greater than 0.66) of being developed by shale gas, 47.8 percent of the Elk River watershed has moderate probability (between 0.33 and 0.66) of being developed by shale gas, and 22.8 percent of the Elk River watershed has low probability (less than 0.33) of being developed by shale gas within the next 30 years (Dunscomb *et al*. 2015, entire).

3.2.1.1 Coal Mining

Coal mining began in the mid-1800s and was limited at first, but expanded over time. In the 1850s, large shipments of coal were reported to be coming from lands adjacent to and transported on the Elk River, and a coal processing facility was built 7 mi (11 km) upstream from Charleston, WV (Laing 1966, pp. 144–155). Coal production increased and spread further upstream after the Civil War as a result of the construction of railroads throughout the watershed (Laing 1966, pp. 144–155; WVDEP 1997, pp.14–19). West Virginia's coal production has been declining since 2008 (Lego and Deskins 2017, p. 1). West Virginia University's (WVU) Coal Production Forecast projects that coal production in West Virginia will remain steady through 2022 and trend downward after 2022 (Lego and Deskins 2017, p. 17). Surface mining results in the elimination of surface vegetation, change in topography, and loss of topsoil or compaction of soil, all of which increase runoff and downstream flooding (Palmer *et al*. 2010, p. 148). Primary contaminants associated with surface mine runoff include increased pH, conductivity, and total suspended solids, which results in disruptions to aquatic life downstream of mined areas (Palmer *et al*. 2010, p. 148; Pond *et al*. 2008, p. 724)

Coal mining permits are distributed throughout the Elk River basin. As of 2019, 489 permits have been issued since 1972 and cover 29,065 acres (11,762 ha): 90 permits are considered active; 129 are in reclamation or have been reclaimed; and the remainder are either inactive, forfeited, not started, or of unknown status. In watersheds where Elk River crayfish are present, there are eight active underground mines, four active surface mines (with three actively moving coal), and three active quarries (WVDEP 2019b, entire).

3.2.1.2 Oil and Natural Gas Extraction

Limited oil and gas development was present before 1910. However in 1911, the "Blue Creek field" was discovered along a tributary of the Elk River, which led to a boom in development in the lower sections of the watershed (Allen and Matchen 2017, p. 1). Natural gas development poses a risk to surface waters because installation of well pads and infrastructure often requires the clearing of land, which can then increase sedimentation in streams (Entrekin *et al*. 2011, p 507), especially in areas with steep slopes like the topography adjacent to the Elk River. Sedimentation is increased 49 times higher than reference sites following the construction of well pads and decreases over time as vegetation reestablishes in the area (Williams *et al.* 2008, p. 1470). There is a moderate to high probability (77.2 percent) of shale gas development within the Elk River watershed (Dunscomb *et al*. 2015, entire). The associated impacts on surface waters demonstrate that shale development poses a risk to the Elk River crayfish's habitat and, therefore, viability of the Elk River crayfish.

Oil and gas development currently focuses on the extraction of oil and natural gas liquids from the Marcellus shale formation (King 2019, entire). Drilling wells within Marcellus shale formation has increased since 2010 due to the development of the horizontal drilling technique, which creates more permeability in the formation and produces more gas from the well. The Utica shale formation is deeper, and it could provide a profitable resource for oil and natural gas extraction. The Elk River crayfish's range is entirely underlain by the Marcellus shale formation, and only partially underlain by the Utica shale formation (see figure 8). The large transmission pipelines in development, as described below, could allow for increased development of new Utica wells. The watershed may see an increase in pipeline development as new Utica or Marcellus wells are drilled and connect to the transmission pipelines.

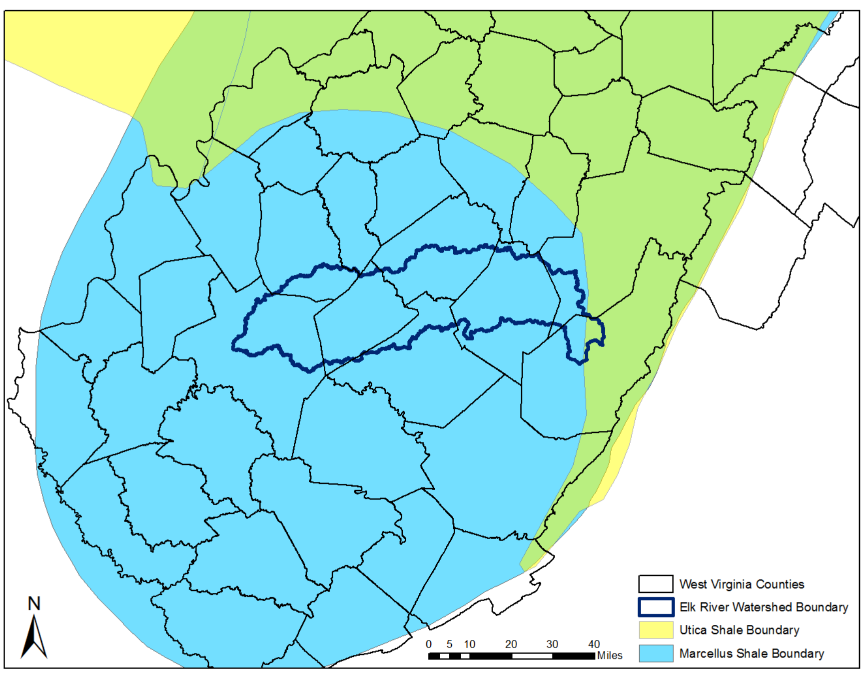

Figure 8. Utica and Marcellus shale fields overlain with the Elk River crayfish's range.

Overall, natural gas production, through the Marcellus and Utica Shale formations, is predicted to increase through 2020, with production continuing to increase but at a slower rate through 2050 (USEIA 2019, p. 72).

In addition to the Utica and Marcellus shale fields, the Rodgersville Shale play underlays parts of the lower Elk watershed in Kanawha, Clay, Roane, Calhoun counties (Whitman 2019). However, the Rodgersville play intersects only small portion of the Elk River basin in an area where the Elk River crayfish has not been observed. This shale play is much deeper than Marcellus and Utica and may not be as economically viable. The best available information precludes our ability to project the potential for the Rodgersville Shale play to be developed within the timeframe of our analysis.

Two major pipelines, the Atlantic Coast Pipeline (ACP) and the Mountain Valley Pipeline (MVP), propose to cross through the upper portion of this watershed. The Federal Energy Regulatory Commission (FERC) issued the certificates to proceed for both pipelines on October 13, 2017 (161 FERC 61,042; 161 FERC 61,043).

About 16 mi (26 km) of the ACP traverse the Upper Elk River watershed in Randolph County, WV. The pipeline traverses the upper portion of the watershed and does not propose to cross any streams that contain Elk River crayfish. As of August 2018, roughly half of the pipeline right-of-way has been felled of trees (Stout 2018, entire). As of March 2019, pipe has not been laid nor have stream crossings been completed for this section of the pipeline. The pipeline has experienced numerous permitting and legal challenges and is slated to be fully in service by 2021, pending results of litigation (*Defenders of Wildlife* v. *United States Department of the Interior* 2019, entire).

Approximately 29 mi (47 km) of the MVP traverse the Birch River, Laurel Creek, Middle Elk, and Holly River watersheds, and the pipeline proposes to cross four streams that contain Elk River crayfish. As of May 2019, tree felling has been completed for 99.6 percent of the pipeline right-of-way (Eggerding 2019, entire). Due to continued permitting and legal challenges (*Sierra Club* v. *U.S. Army Corps of Engineers* 2018, entire; CBD 2019, entire), no stream crossings have been completed as of June 2019.

The stream crossings and forest clearing associated with the permanent rights-of-way are likely to increase sediment loading in Elk River crayfish watersheds, possibly degrading the habitat in streams and affecting the viability of the Elk River crayfish. This is based on the conclusions of similar pipeline projects and their effects on aquatic species and their habitat (Service 2017, entire; Service 2018, entire).

Based on the energy predictions of Dunscomb *et al*. 2015 and the presence of FERC-regulated pipelines, the watersheds of the Elk River subbasin are anticipated to experience a low, moderate, or high effect from oil and gas development (see appendix B for a detailed watershed analysis).

3.2.1.4 Timber Harvest

The timber industry has been an important economic sector in the Elk River watershed for over 140 years. There were steam powered sawmills in the lower Elk River as early as 1860, and much of the watershed was extensively harvested since that time. The rivers and streams in the watershed were used to "raft" timber downstream to ports and sawmills. This practice caused extensive erosion and scour of the streambeds (Clarkson 1964, pp. 45–54). By the 1920s, most of the virgin timber had been clear cut and the watershed was negatively affected by poor logging practices (e.g., lack of erosion control), which lead to heavy sedimentation, flooding, and fires (Hennen 1991, pp. 46–62). Currently, the watershed is mostly forested with second growth timber (WVDEP 1997, pp. 14–16).

In 2011, approximately 90.6 percent of the Elk River subbasin is forested (Homer *et al*. 2015, entire) compared to 91.1 percent in 2001. The forested landscape is a mix of private, Federal, and State ownership, and 33,764 acres (13,664 ha) or 3.4 percent of the subbasin, is federally protected as part of the Monongahela National Forest. Five percent of the subbasin or 48,927 acres (19,800 ha) is State-protected land (Holly River State Park, wildlife management areas, and a small portion of Kumbrabow State Forest). As described in the Forest's 2006, updated in 2011, Land and Resource Management Plan (U.S. Forest Service 2011, entire), the Monongahela National Forest is managed for multiple use objectives, including timber harvest and wildlife management. With respect to wildlife management, the plan states:

> "The amount, distribution, and characteristics of habitat are present at levels necessary to maintain viable populations of native and desired non-native wildlife and fish species. For Regional Forester Sensitive Species (RFSS), management actions do not contribute to a trend toward federal listing. Human activities do not prevent populations from sustaining desired distribution and abundance, especially during critical life stages. Habitat conditions support populations of species of ecological, socio-economic, cultural, and recreational significance. The Forest works with the West Virginia Division of Natural Resources (WVDNR) to achieve agreed-upon wildlife management objectives. Distribution of native and desired non-native fish and other aquatic species is maintained or is expanding into previously occupied habitat, with inter-connectivity between and within metapopulations. Efforts are in place to prevent new introductions of undesirable non-native fish species and to reduce degrading effects from past introductions. Restoration activities have resulted in maintaining necessary water temperatures, reducing pollutants such as sediment, and removing human-caused barriers to fish passage to restore populations and habitat connectivity where genetic contamination to native fish species from exotic species is not an issue" (U.S. Forest Service (USFS) 2011, p. II-29).

While this does not specifically apply to the Elk River crayfish, the species may benefit through this approach to other covered aquatic species. The Monongahela National Forest also manages timber harvest (i.e., "The Forest provides a dependable source of large-diameter, high-quality sawtimber. Commercial timber harvest is a viable tool for accomplishing vegetation management objectives.") through the use of prescriptions, including, but not limited to, Timber Resource (TR) goal TR02 "Use appropriate harvest technologies to ensure cost efficiency and demonstrate prudent forest management, while addressing environmental concerns and preserving ecosystem integrity" (USFS 2011, pp. II-40–II-42). These prescriptions are akin to BMPs. As indicated during discussion with USFS staff about other species, the Monongahela National Forest may be increasing the production of its timber harvest (Landress 2018, entire).

Some forestry practices contribute sedimentation through surface runoff (WVDEP 2012, p. 35). Forestry operations do not have permitting requirements under the Clean Water Act because there is a silvicultural exemption as long as BMPs are used to help control non-point source pollution (Ryder and Edwards 2006, p. 272). The West Virginia Logging Sediment Control Act was developed to protect aquatic resources, such as the Elk River crayfish's habitat, in response to the requirements of the Clean Water Act and mandates the use of BMPs to reduce the amount of sediment from logging operations that enters nearby waterways (West Virginia Division of Forestry (WVDOF) undated, p. 1). When properly used and enforced, BMPs can be effective at reducing or eliminating the amount of sedimentation entering streams. However, illicit logging operations represent 2.5 percent of forestry operations, and they do not have proper BMPs to reduce sedimentation to streams (WVDEP 2012, p. 34).

3.2.2 Agriculture

Agriculture is present within the Elk River watershed and was cited in the listing petition (CBD 2010, p.192) as one of the factors that should be evaluated as a stressor for this species. Agricultural activities close to streams can be linked to impacts on instream sediment, iron, and fecal coliform levels (see *section 3.3—Water Quality*), as well as streambank erosion (WVDEP 2012, pp. 34–35). While 2.1 percent of the total land within the watershed is agriculture, the amount of agricultural land cover within the watershed has decreased since 2001 (Homer *et al.* 2015, entire). In West Virginia, animal products exceed crop sales (West Virginia Department of Agriculture (WVDA) 2019, p. 24), which may indicate that factors influencing the Elk River watershed are those commonly associated with livestock production. Of the land within 0.5 mi (0.8 km) of the 2009 Elk River crayfish observations, 2.4 percent is used as pasture or hay production, and 0.1 percent is used as cropland (Homer *et al.* 2015, entire). Agriculture consisting of livestock production can remove the riparian vegetation, resulting in increased sedimentation (WVDEP 2012, pp. 34–35).

3.2.3 Commercial Development

Other types of development occurring within the Elk River watershed include commercial and residential development, especially those associated with tourism and outdoor recreation. Infrastructure to support tourism includes lodging, restaurants, trails, and roads, all of which have the potential to alter a watershed's hydrology and contribute to sedimentation and contamination to adjacent rivers or streams. These impacts result from a loss of forest cover prior to construction, additional point source discharges from stormwater permits for construction, NPDES permits for operation of sewage treatment plants, runoff from roads and trails, and permanent conversion of forest to impermeable surfaces (e.g., roads, parking lots, sidewalks). As of 2011, approximately 51,835 acres (20,977 ha) or 5.3 percent of the Elk River subbasin was categorized as developed based on landcover data (Homer *et al.* 2015, entire).

One example of development within the range of the Elk River crayfish is Snowshoe Mountain Resort. The resort encompasses 244 acres (99 ha) in the Upper Elk watershed and is approximately 5 mi (8 km) from the closest Elk River crayfish observation. This resort provides lodging and restaurants, as well as opportunities for recreation, including skiing, hiking, biking, off-road vehicle trails, and guided fishing. Any development or expansion of Snowshoe

Mountain Resort could result in increased sedimentation downstream of the resort if the development activities do not implement sufficient BMPs.

3.2.4 Invasive Plants

Invasive, nonnative plants associated with riparian areas, such as Japanese knotweed (*Reynoutria japonica*), have the potential to adversely affect habitat conditions within the Elk River watershed. Japanese knotweed is a species native to eastern Asia that was introduced in the United States as an ornamental landscape plant (Barney 2006, p. 704). The species forms dense, monotypic stands that exclude native vegetation (Urgenson 2006, p. 6). Once introduced into an area, it spreads rapidly through riparian areas as flood waters carry root and stem fragments downstream, and these fragments then regenerate to form new populations (Urgenson 2006, p. 1). In addition, spread of Japanese knotweed upstream is possible when road crews remove vegetation during ditch and bridge or culvert cleanouts and then leave the debris in headwater areas (Pond 2019, p. 1).

Healthy, functioning, riparian forests are an essential component of maintaining water and habitat quality in streams, and streams are adversely affected when riparian areas are invaded by species such as Japanese knotweed (Urgenson 2006, p. 35). Streambanks dominated by Japanese knotweed populations are less stable and more prone to erosion because Japanese knotweed has shallower roots compared to native riparian trees and woody shrubs. Because Japanese knotweed dies back in winter, it also leaves streambanks more exposed to erosive forces (Urgenson 2006, pp. 35–36). Thus, knotweed can increase streambank erosion, increase sedimentation in streams, and alter channel morphology. In addition, riparian areas dominated by Japanese knotweed change the natural composition of leaf litter entering the stream. This change affects nutrient cycling and organic matter inputs into the aquatic food web, and can have long-lasting effects on microhabitat conditions and aquatic life of affected stream systems (Urgenson 2006, pp. i, 31). Because leaf litter from Japanese knotweed is of lower nutritional quality than native vegetation, it can negatively impact the productivity of aquatic macroinvertebrates, which are a food source for crayfish (Urgenson 2006, p. 32).

The best available information (Schmidt 2013, p. 1; EDDMapS 2019; Whitman 2019) indicates that Japanese knotweed has been documented throughout the Elk River watershed, both above and below Sutton Dam). In 2012, Service biologists and their partner organizations documented and initiated control measures on 27 Japanese knotweed populations on the mainstem Elk River and its tributaries. These populations were located within the Upper Elk subwatershed (see figure 9). Some of these populations were over 0.25 ac (0.1 ha) in size and had doubled in size in the 2 years since first documented (Schmidt 2013, p. 1). Japanese knotweed is difficult to control and eradicate. Effective eradication requires many years of focused efforts, and often populations are discovered downstream before 100-percent mortality is achieved in the treated area (Urgenson 2006, p. 37).

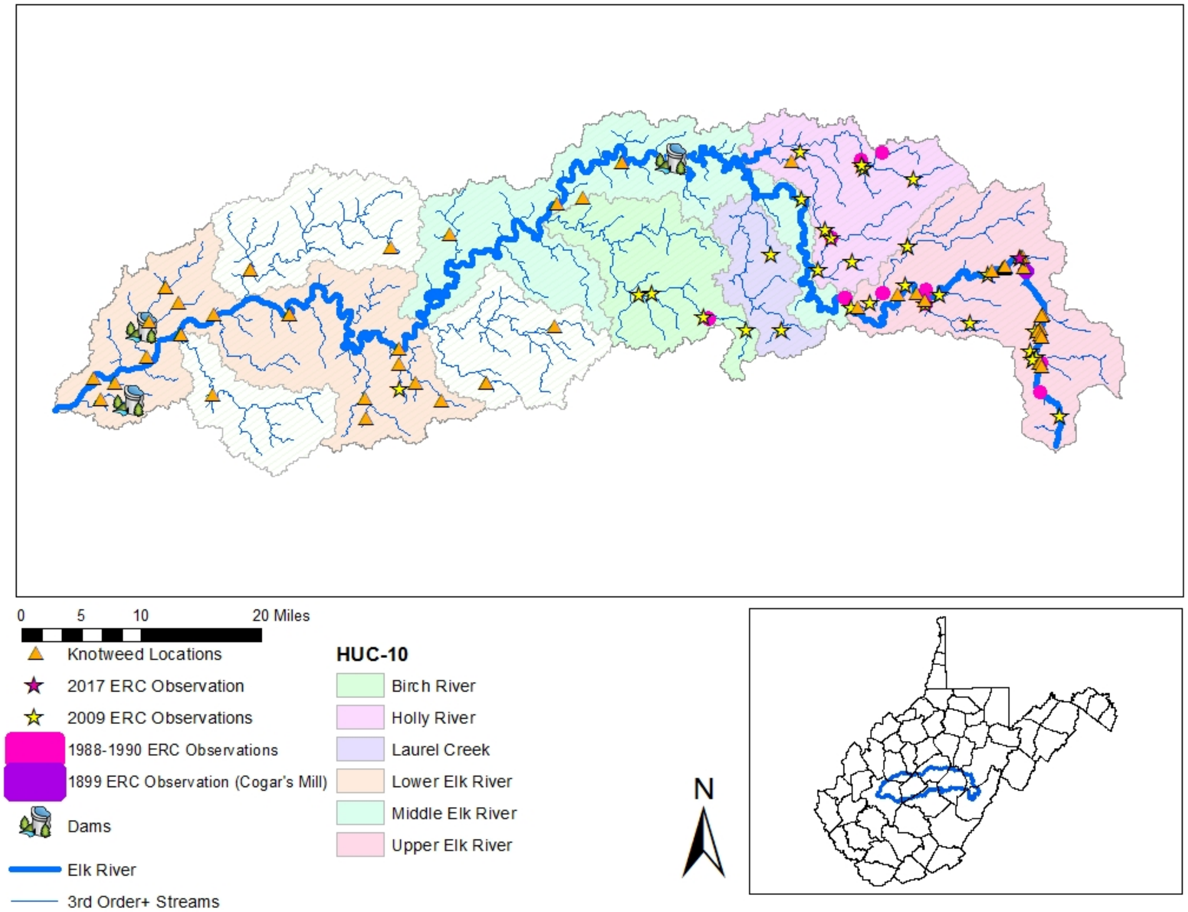

Figure 9. Locations of Japanese knotweed observations (orange triangles) within the Elk River crayfish's range.

3.2.5 Summary of Sedimentation

Excessive sedimentation, regardless of source, is a major influencing factor for the Elk River crayfish because it directly disrupts the species' breeding, feeding, and sheltering needs during transport (see water quality, below) and deposition, and therefore indirectly affects the species' demography. While land use associated with agriculture has decreased in the Elk River watershed, resource extraction, especially oil and gas, has increased. In addition, timber harvest and the spread of invasive plants may increase in the future. Therefore, we are carrying the effects of sedimentation forward in our current and future conditions analysis.

3.3 Water Quality

The upper reaches of the Elk River watershed are formed over limestone, and conditions here are heavily influenced by this karst topography. For example, during the summer, the water of Big Spring Fork flows through and out of the 6 springs and over 60 caves found in this vicinity. This scenario of surface water flowing underground via a network of limestone solution cavities or faults and then resurging at a down-gradient spring is common in the upper Elk River watershed

(WVDEP 1997, pp. 14–16). In addition to the transport and deposition of silt/sediment discussed above, water resources are especially sensitive to contamination and pollution in these types of karst regions (Baker and Groves 2008, pp.103–104). Normally in non-karst areas, when precipitation and overland flows pick up contaminants, they can be filtered through soils before entering groundwater or streams. However in karst areas, the water flows quickly through fissures in the bedrock and then into concentrated subsurface flows in the rock; this provides for less contact with soils and their ameliorating reactions (Baker and Groves 2008, pp. 103–104). Down river from Elk River Springs, the river predominantly flows through sandstone, shales, and siltstones on its way to Charleston (WVDEP 1997, pp. 14–16).

3.3.1 Source and Non-point Source Pollution

Although water quality has generally improved since 1977 when the Clean Water Act (33 U.S.C. 1251 *et seq*.) and Surface Mining Control and Reclamation Act (30 U.S.C. 1234–1328) were enacted or amended in 1977, there is continuing, ongoing degradation of water quality within the range of the Elk River crayfish. The WVDEP monitors the water quality of State waters to determine whether the waters are impaired. Impaired waters violate water quality standards and do not support designated uses, (e.g., recreation, propagation and maintenance of aquatic life), and these waters are placed on the 303(d) list (WVDEP 2019a, p. 2–3). The WVDEP used the West Virginia Stream Condition Index (WVSCI) scores to determine which streams to add to the 303(d) list for 2016, which is the source of the most recent data that have been compiled (WVDEP 2019a, p. 16). The WVDEP continues to gather water quality data in impaired streams to determine total maximum daily loads (TMDLs), which establish limits for discharge of pollutants authorized by National Pollution Discharge Elimination System (NPDES) permits. For water bodies on the 303(d) list, States are required under the Clean Water Act to establish a TMDL for the pollutants of concern that will improve water quality to meet the applicable standards. The WVDEP has established TMDLs for total iron, dissolved aluminum, total selenium, pH, and fecal coliform bacteria. The total iron TMDL is used by the agency as a surrogate to address impacts associated with excess sediments (WVDEP 2012, p. 47). We do not yet know the long-term effectiveness of TMDLs to reduce the levels of these pollutants, or how long streams within the Elk River watershed will remain impaired. In addition, there are sources of sedimentation that are not regulated by the WVDEP NPDES system; therefore, the application of TMDLs alone may not be sufficient to reduce overall sedimentation in the watershed.

The Elk River mainstem below the confluence with Big Sandy Creek was listed on the 303(d) list as impaired for Aquatic Life starting in 1998, due to aluminum, lead, iron, and zinc (USEPA 2001, p 1.3). Most of the streams within the Elk River watershed have either been added to the 303(d) list or have TMDLs developed. Causes of impairment of streams that contain Elk River crayfish observations are biological impairment, fecal coliform/bacteria, iron, and selenium (WVDEP 2017, entire). In developing TMDLs for these streams, the WVDEP determined that sources of pollutants were both point and non-point. Sources include active mining, abandoned mine lands, stormwater permits, municipal stormwater, forestry, oil and gas, agriculture, roads, streambank erosion, sewage permits, sewage treatment facilities, failing septic systems, and urban/residential runoff (WVDEP 2012, p. 27–47). The data are not available to determine the contribution of each point and non-point source category. According to the 2016 Water Quality Report (WVDEP 2019a, Appendix F, p. 6), 31 mi (50 km) of streams in the watershed were added to the 303(d) list.

3.3.2 Water Temperature

An analysis of historical water temperature data indicates a general increase in river and stream temperatures throughout the United States over the last 90 years. These temperature increases are attributed primarily to, where they occur, changes in land use (e.g., urbanization and deforestation), thermal inputs (e.g., power plant discharges), and changes in climatic conditions (Kaushal *et al*. 2010, entire). Other studies demonstrate that changes in water temperatures can lead to shifts in the range and distribution, and in some cases to local extirpations, of aquatic species (Hossain *et al*. 2018, entire; Wiens 2016, entire).

Empirical data on the effects of warm water temperatures on Elk River crayfish physiology or reproductive success are lacking; therefore, we are uncertain about the significance of increased water temperatures on the species' viability. However, the Elk River crayfish occurs in headwater streams, which tend to have lower water temperatures than mainstem rivers, depending on adjacent land use and riparian canopy cover (Rayne *et al*. 2008, p.566); therefore, we infer that the species may prefer lower water temperatures (*see chapter 2 for additional information*). Additionally, based on other *Cambarus* species, the Elk River crayfish likely has an upper tolerance and preferred water temperature; thus, an increase in water temperature may affect the species' survival and reproductive capability (Westhoff and Rosenberger 2016, entire; Mirenda and Dimock 1985, p. 258). The results of the "Climate Change Vulnerability Assessment" of more than 700 species in the Appalachian region ranking the Elk River crayfish as "moderately vulnerable" to the effects of climate change support the assumption that the species is likely to be affected by the changes, but may not pinpoint the exact pathway for the change (Byers and Norris 2011, p.13). See *section 3.6 Effects of Climate Change* below for more information.

3.3.3 Spills and Discharges

There is a potential for spills and discharges to occur as a result of many of the activities discussed above such as resource extraction and commercial development. For example, pipelines and ponds used to handle brine and wastewaters from fracking operations can rupture, fail, or overflow and discharge into nearby streams and waterways. In Pennsylvania, accidental discharges of brine water from a well site have killed fish, invertebrates, and amphibians up to 0.4 mi (0.64 km) downstream of the discharge even though the company immediately took measures to control and respond to the spill (PADEP 2009, pp. 4–22). In 2011, the WVDEP cited a company for a spill at a well site in Elkview, West Virginia (Lower Elk River watershed). Up to 50 barrels of oil leaked from a faulty line on the oil well site. The spill entered a tributary of Indian Creek, traveled into Indian Creek, and then flowed into the Elk River (Charleston Gazette 2011, p. 1). In 2014, over 10,000 gallons of chemicals used in coal processing were discharged into the Elk River near Charleston when an above-ground storage tank ruptured, affecting the quality of the drinking water for over 300,000 people (Bahadur and Samuels 2015, p.1). In 2010, a section of stream bank along the Elk River near Clendenin failed and fell into the river, damaging a sewer line when it fell. The line then discharged raw sewage into the river (Marks 2010, p. 1). While these spills did not affect the Elk River crayfish because the spills occurred outside of the species' known range, the potential exists for these types of events, and resulting effects to the species, to happen in all six of the Elk River crayfish's watersheds (i.e., populations). We are not able to predict where future spills may occur or the extent of potential effects, but the presence of other activities in the watershed (resource development or other sources of sedimentation listed above) are an indicator of areas that have higher potential for spills to occur.

3.3.4 Summary of Water Quality

In addition to siltation/sedimentation, we consider three components to water quality: point source and non-point source contamination, temperature, and spills and discharges. Based on the previous 20 years of data, we anticipate water quality impairments from point sources and non-point sources to continue in the future. We do not know if the continuation will occur at the same, increasing, or decreasing rates. We do not know the specific thermal tolerances of the Elk River crayfish, but do know based on information regarding other *Cambarus* species that increasing water temperature may affect reproduction. We also do not know where future spills and discharges will occur, but there is a history of spills occurring within the Elk River watershed. The presence of other development activities within the area (resource extraction, commercial development) are an indicator of areas that have a higher threat for future spills to occur. Because water quality affects the Elk River crayfish's food and breeding resources, we are carrying it forward in our current and future conditions analysis.

3.4 Competition and Predation

3.4.1 Invasive Crayfish

Elk River crayfish could be affected by the introduction and spread of nonnative invasive crayfish species. Biological degradation of streams by invasive crayfish has been identified as the second most significant threat to native crayfishes, with only stream degradation through land-use changes being more important (Loughman 2013, p. 1). Invasive crayfish can dominate and outcompete native species, and have resulted in the elimination of local crayfish populations in some watersheds, or caused reductions in the ranges of native crayfish species (Taylor *et al.* 2007 p. 374; Loughman and Welsh 2013, pp. 24–25, 72). Examples of sites where native species have been reduced or eliminated are in Fourpole Creek in West Virginia, as well as in three Midwestern states and one Canadian province (Taylor *et al*. 2007, p. 374; Loughman and Welsh 2013, pp. 24–25, 72).

Two invasive crayfish species are known to occur in West Virginia, the virile crayfish (*Orconectes virilis*) and the rusty crayfish (*O. rusticus*) (Loughman and Welsh 2013, pp. 1, 20, 54–56). Bait bucket releases are a likely source of introductions and movement of nonnative crayfish (Loughman 2013, p. 2; Loughman and Welsh 2010, pp. 66, 71). The virile crayfish has been widely cultured for use as fish bait, and aquaculture facilities sell live specimens of this species (Swecker 2012, p. 7). Anglers in West Virginia have been observed with virile crayfish in their bait buckets and interviews with these individuals indicated that they planned to travel into other watersheds to use the species as bait (Swecker 2012, p. 59). West Virginia does not have any fishing regulations regarding the use of crayfish as bait (WVDNR 2019a).

The virile crayfish was first recorded in West Virginia in 1970 from an impoundment in the New River in Summers County. It is now distributed throughout the State and has been found in a variety of impoundments and large rivers, as well as in smaller tributaries (Swecker 2012, pp. 31–32), including the Elk River (Loughman and Welsh 2013, pp. 54–56).

The rusty crayfish was first documented in West Virginia in 1979 in Fourpole Creek, a relatively low gradient tributary of the Ohio River (Loughman and Welsh 2013 pp. 56). Since that time, rusty crayfish have also been found in the Little Kanawha River basin, the Kanawha River mainstem, the Ohio River backwaters in Marshall and Wetzel Counties, several impoundments throughout Twelve Pole Creek (Loughman 2013, p. 2), and the Elk River (Loughman and Welsh 2013, pp. 54–56).

Although neither invasive species was documented during surveys in the Elk River watershed in 1988-1989, both species were documented in the watershed in 2009 (Loughman and Welsh 2013, pp. 54–56). One rusty crayfish hybrid was found at a location in the mainstem Elk River near its confluence with the Kanawha River (Lower Elk River watershed) (Loughman and Welsh 2013, p. 56). The virile crayfish is abundant and widespread within Sutton Lake (Middle Elk River watershed) (Loughman 2013, p. 6). In addition, one virile crayfish was found in the Lower Elk River watershed in the mainstem Elk River at a location slightly upstream from the rusty crayfish, and the other was found at a location in the upper portion of the Birch River watershed (Loughman and Welsh 2013, p. 56; Loughman 2017b, entire).

Impoundments are noted to be important source populations for the virile crayfish (Loughman and Welsh 2010, p. 54). In contrast, high-gradient streams may impede dispersal of the virile crayfish because it lacks the ability to hold position in high velocity habitats (Loughman and Welsh 2010, p. 73). The virile crayfish selects habitats with low velocity water and with depositional substrates that are made of compressed silt and detritus beds (Loughman 2013, pp. 63–66). The species avoided habitats comprising boulders or slabs that are preferred by the Elk River crayfish. West Virginia streams with large invasive crayfish populations tend to have anthropogenic disturbances leading to elevated siltation and high nutrient loads (Loughman 2013, pp. 65–66). Therefore, streams in West Virginia that are most susceptible to invasive crayfish are those that are affected by impoundments, degraded by other anthropogenic disturbances, or at lower elevations and have naturally high silt loads (Loughman 2013, pp. 63–66). In contrast, native crayfish have been able to maintain populations even when nonnative crayfish are present in streams. For example, the native New River crayfish (*Cambarus chasmodactylus*) has maintained populations within Anthony Creek, West Virginia, despite the presence of the virile crayfish. This is likely because Anthony Creek has naturally low nutrient levels and low levels of sedimentation and has a high enough gradient that preferred habitats for the virile crayfish (depositional, sediment laden habitats with low flow conditions) are limited within the watershed (Loughman 2013, entire).

Given these factors and the presence of both invasive crayfish species in the lower Elk River mainstem, it is likely that the Elk River mainstem and tributaries around Sutton Lake (Lower Elk River and Middle Elk River watersheds) are at highest risk of invasion from invasive crayfish species. In addition, many streams in the Upper Elk River watershed are extremely popular fishing locations, which could increase the likelihood of bait transfer and range expansion into that watershed (Swecker 2012, p. 58).

3.4.2 Nonnative Fish

Nonnative fish species may stress crayfish populations via increased predation. Nonnative rainbow trout (*Oncorhynchus mykiss*) or brown trout (*Salmo trutta*), or both, are regularly stocked in the following Elk River crayfish streams (see figure 10): the Elk River, Laurel Fork, Left Fork Holly River, and Backfork of Elk River (WVDNR 2018, p. 19). In addition, smallmouth bass (*Micropterus dolomieu*) was previously introduced throughout the eastern United States, and is now naturally reproducing within the range of the Elk River crayfish, although it is more abundant below Sutton Dam. An evaluation of the diet of smallmouth bass and stocked trout was conducted in Logan County, West Virginia. Although the study area did not include any Elk River crayfish streams, the study streams do support a suite of crayfish species that are similar to those found within the range of the Elk River crayfish. No *Cambarus* species were found within any brook and rainbow trout stomach contents evaluated, and 99 percent of the diet of these fishes consisted of mayfly nymphs and adults, terrestrial insect orders, hellgrammites, and unidentifiable materials (WVDNR 2017b, p. 2). Over 18 percent of brown trout stomach contents consisted of *Cambarus theepiensis*, and over 60 percent of the diet of smallmouth bass consisted of crayfish including *Orconecte*s and *Cambarus* species (WVDNR 2017b, p. 2). This suggests that brown trout and smallmouth bass could routinely eat the Elk River crayfish. The impact of fish predation is related to the size and distribution of both the prey and predator. Adult crayfish may reach a size at which they are no longer able to be consumed by gape-limited predators; therefore, smaller or young crayfish may be more susceptible to predation (Jones *et al*. 2016, p. 275). Though the exact effects of nonnative fish on Elk River crayfish populations are unclear, the potential for negative interactions has been documented in other crayfish species. In New Zealand, the native crayfish *Paranephrops zealandicus*, was negatively associated with the presence of introduced brown trout. In addition, introductions of smallmouth bass have been associated with severe and widespread declines of native *Cambarus* and *Orconectes* species in Canada (Edwards *et al*. 2009, pp. 722–730). However, any effects from nonnative fish predation are continuing and ongoing. Smallmouth bass introductions began in the mid-1800s and trout stocking in the Elk River watershed has been ongoing since at least before the early 1980s (WVDNR 2019b, entire). We anticipate that predation, where it occurs, is having an individual effect not a watershed- or species-level effect; therefore, we will not be carrying predation forward in our analysis. We acknowledge, however, that as populations decline, the effects of predation can increase.

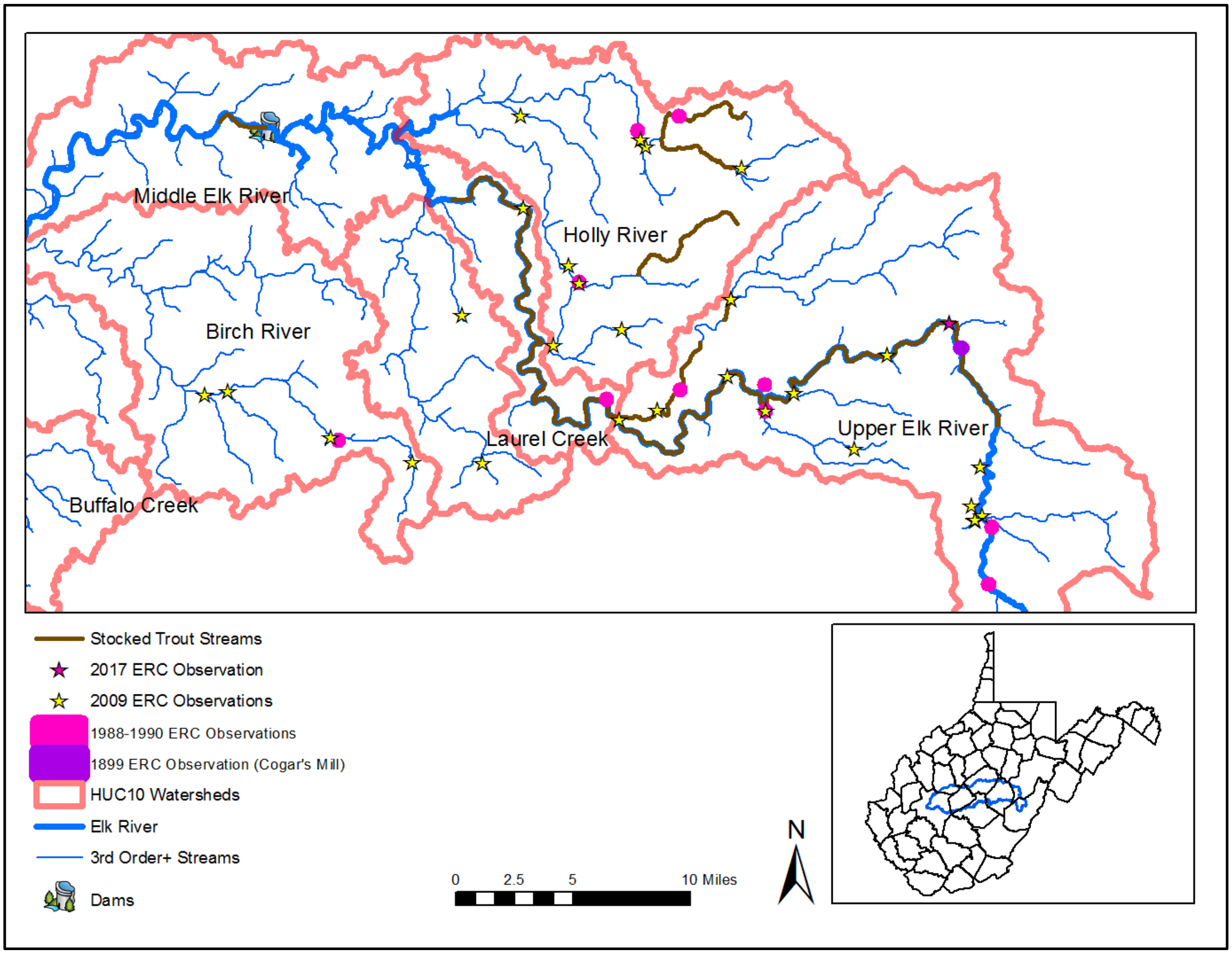

Figure 10. Streams within the Elk River crayfish's range that are regularly stocked with rainbow trout, brook trout, or both.

3.4.3 Summary of Competition and Predation

Nonnative fauna can compete with native fauna for feeding, breeding, and sheltering resources. The rusty and virile crayfishes have been documented within the Elk River crayfish's range. While currently not a significant threat, further spread of these nonnative invaders is a concern for the Elk River crayfish's resiliency, and we are carrying the effects of competition with nonnative species forward in our analysis. Conversely, predation of Elk River crayfish by stocked trout species may be affecting individuals, but is not likely having a population- or species-level effect, and we will not be carrying the effects of predation by nonnative trout forward in our analysis.

3.5 Direct Mortality

Direct mortality can be caused by instream work or bait collection. Any instream work could directly affect individual crayfish. Pipeline crossings (*see section 3.2.1.2 Oil and Natural Gas Extraction*) using an open trench method would impact the stream bottom or banks and could also crush individuals, resulting in direct mortality to adults or juveniles of aquatic species (Service 2018a, p. 14). Bridge repair or replacement projects that use causeways, temporary bridges, or cofferdams for access could also result in direct mortality to adults or juveniles (Service 2019, p. 14). Other prominent instream activities include post-flood channel alterations or channel modifications that are intended to promote ecological uplift for aquatic environments (Owen 2019). These activities are normally subjected to regulatory procedures intended to manage individual projects for levels of acceptable risk (Owen 2019). However, deleterious impacts to stream ecosystems can and do occur when standard regulatory procedures are not followed or properly implemented (Owen 2019). Further, as noted above under section *3.4.1 Invasive Crayfish*, crayfish are used as bait by anglers. We have no information to indicate that Elk River crayfish specifically are used for bait, but it is possible individuals of the species may be collected for that use. Direct mortality can result in local reductions in numbers to the species, so we anticipate that direct mortality, where it occurs, is having an individual effect not a watershed- or species-level effect. Therefore, we will not be carrying the effects of direct mortality forward in our analysis.

3.6 Effects of Climate Change

The Intergovernmental Panel on Climate Change (IPCC) concluded that the evidence for warming of the global climate system is unequivocal (IPCC 2014, p. 2). Numerous long-term climate changes have been observed including changes in arctic temperatures and ice and widespread changes in precipitation amounts, ocean salinity, wind patterns, and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones (IPCC 2014, pp. 2–4). The terms "climate" and "climate change" are defined by the IPCC. "Climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014, p. 557). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014, p. 557). Various types of changes in climate can have direct or indirect effects on species. These effects may be positive, neutral, or negative and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation).

The likely impacts of climate change on aquatic systems include increases in water temperatures that may alter fundamental ecological processes and the thermal suitability of aquatic habitats for prey species, as well as the geographic distribution of species (Poff *et al*. 2002, entire). Changes and shifts in seasonal patterns of precipitation and runoff will alter the hydrology of stream systems, affecting species composition and ecosystem productivity. Aquatic organisms are sensitive to changes in frequency, duration, and timing of extreme precipitation events such as floods or droughts. Climate change is an additional stressor to sensitive freshwater systems, which are already adversely affected by a variety of human impacts, such as altered hydrological regimes and deterioration of water quality.

Aquatic ecosystems have a limited ability to adapt to climate change. Reducing the likelihood of significant impacts will largely depend on human activities that reduce other sources of ecosystem stress to ultimately enhance adaptive capacity; these include maintaining riparian forests and forested wetlands, reducing nutrient loading, restoring damaged ecosystems, and minimizing groundwater and surface water withdrawal (Poff *et al*. 2002, pp. 32–35).

The general climate trend for North America includes increases in mean annual temperatures and precipitation and the increased likelihood of extreme weather events by the mid-21st century (IPCC 2014, pp. 1452–1456). The primary sources of climate data and predictions used in this assessment were the two most recent U.S. Global Change Research Program (USGCRP) reports: Third National Climate Assessment (NCA3; Melillo *et al*. 2014, entire report) and Fourth National Climate Assessment (NCA4, Volume I; Wuebbles *et al*. 2017, entire). The NCA4 used the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project (CMIP5) and primarily discussed two pathways: the highest radiative forcing pathway (Representative Climate Pathway (RCP 8.5) and the medium-low radiative forcing scenario (RCP 4.5). For detailed descriptions of these scenarios, see Hayhoe *et al*. (2017, pp. 135–149). As part of NCA4, state summaries were prepared by NOAA (Runkel *et al*. 2017, entire) with maps of the projections using the RCP 8.5 path.

We primarily use RCP 8.5 in our analysis based on current trend data in global emissions (Jackson *et al*. 2017, entire), the long-lasting influence of greenhouse gases already in the atmosphere (Collins *et al*. 2013, p. 1102–1105; Mauritsen and Pincus 2017, entire), and analysis of expected emissions through 2050 (U.S. Energy Information Agency 2017, entire). The USGCRP stated with very high confidence that the observed increase in global carbon emissions over the past 15 to 20 years has been consistent with higher scenarios such as RCP 8.5 (Wuebbles *et al*. 2017, p. 152–153; Carter *et al.* 2014, p. 751). It is therefore reasonable to conclude that changes from now through mid-century will also be closer to RCP 8.5 than to RCP 4.5. However, we did use RCP 4.5 in one of our future scenarios (see chapter 5) to incorporate the suite of plausible scenarios.

The WVDNR's Climate Vulnerability Assessment and the West Virginia state summary for climate predictions support a finding that conditions within the Elk River crayfish's range are expected to undergo significant temperature and precipitation changes by 2050, although the amount varies depending upon the higher or lower emissions pathway (Byers and Norris 2011, pp. 19–21; Runkle *et al*. 2017, entire). Byers and Norris's (2011, pp. 19–21) and Runkle *et al*.'s (2017, entire) findings are further supported by the NCA's Northeast region report findings (Dupigny-Giroux *et al*. 2018, entire). West Virginia, and thus the Elk River crayfish's range, is included within the Northeast report. The 2018 report indicates that climate models project increases in temperature and rainfall intensity with increases in total precipitation in the winter and spring (including up to 1 in (2.5 cm) in December to April under the higher emissions scenario), but not in the summer (Dupigny-Giroux *et al*. 2018, pp. 671, 682). The winter precipitation is shifting from snow to rain (Dupigny-Giroux *et al*. 2018, p. 680) under both the RCP 4.5 and RCP 8.5 scenarios. The habitat types at most risk of experiencing the effects of increasing precipitation and temperature are alpine, freshwater aquatic, and some forests (Dupigny-Giroux *et al*. 2018, p. 678).

> "The projected changes in precipitation intensity and temperature seasonality would also affect streams and the biological communities that live in them. Freshwater aquatic ecosystems are vulnerable to changes in streamflow, higher temperatures, and reduced water quality.[131] Such ecosystems are especially vulnerable to increases in high flows,

decreases in low flows, and the timing of snowmelt.[113,132,133] The impact of heavy precipitation on streamflows partly depends upon watershed conditions such as prior soil moisture and snowpack conditions, which vary throughout the year.[134,135,136,137] Although the annual minimum streamflows have increased during the last century,[138,139,140] late-summer warming[4,141] could lead to decreases in the minimum streamflows in the late summer and early fall by mid-century" (Dupigny-Giroux *et al*. 2018, p. 682).

As climate change alters freshwater ecosystems, aquatic species will either adapt to the new conditions, migrate to waters that maintain suitable conditions, or become locally extirpated. Species with small geographical ranges or those limited in their ability to disperse because of watershed boundaries and fragmented river networks (e.g., by dams and impoundments) may be particularly vulnerable to climate change (Eaton and Scheller 1996, p. 1113; Ficke *et al*. 2007, p. 602; Capinha *et al*. 2013, p. 732; Trumbo *et al*. 2014, pp. 182–185).

The Elk River crayfish has been assessed with moderate confidence to be "moderately vulnerable" to the effects of climate change based on generalized (across all crayfish species) barriers to movement and hydrological niche, but tempered by wider food selection across prey items (Byers and Norris 2011, pp. 12, 33, 49). The moderately vulnerable category means that a species' abundance or range is likely to decrease by 2050 (Byers and Norris 2011, p. 29). As ambient air temperatures increase, stream water temperatures are also expected to rise, although the precise relationship between air temperature and water temperature may vary based on a variety of factors, such as ground water inflow, riparian vegetation, or precipitation rates (Webb and Nobilis 2007, pp. 82–84; Kaushal *et al*. 2010, pp. 464–465; Trumbo *et al*. 2014, pp. 178–185). In chapter 2, we state that we do not know the exact thermal preferences of the Elk River crayfish, but we do know that the species occurs in higher elevation sections and tributaries of the Elk River, as compared to other crayfish species, and that the Sutton Dam is a barrier to movement. This indicates that the species is less likely to be able to move any further up in the watershed away from warmer stream temperatures that are projected to occur over time in response to the effects of climate change. In addition, individual crayfish may experience physiological stress, poor reproductive success, and increased mortality when exposed to elevated stream temperatures that approach a species' maximum temperature tolerances (Service 2016 (81 FR 20449, p. 20476)).

In addition to changes in water temperature, Elk River crayfish may be affected by climate change through alterations in its food or shelter resources. Stream invertebrates, like the Elk River crayfish and their prey, are particularly vulnerable to changes in temperature and flow regimes (Dupigny-Giroux *et al*. 2018, p. 682), and fine sediment loading (Jones *et al*. 2012, p. 1056). An increase in the number and intensity of precipitation events also means a likely increase in the risk of flooding (e.g., changing flow regime) events (Runkle *et al*. 2017, p. 3). West Virginia already has a history of extreme precipitation and resulting flooding events; 12 of the 16 FEMA disaster declarations for the State from 2005 to 2014 were the result of severe storms and floods (Runkle *et al*. 2017, p. 3). In addition, as mentioned in chapter 2, the Elk River watershed was affected by a severe flood on June 25, 2016. The lower Elk River at Queen Shoals reached the second highest ever recorded peak crest at that location, reaching over 33 feet (ft) (10 meters (m)) above flood stage (NOAA 2019). That equated to a greater than 200-year flood event (Rizzo *et al*. 2018, p. 111). Queen Shoals is approximately 26 miles (mi) (42 kilometers (km)) up-river from Charleston, WV. The federally listed diamond darter

(*Crystallaria cincotta*) occurs in the lower Elk River and was subjected to the 2016 flood event. Based on a limited dataset of pre- and post-flood sampling sites, Rizzo *et al*. (2018, pp. 113–116) found that, while the species' total estimated abundance declined after the flood, there was high variability in estimated abundances between the age classes at some of the sample sites. "While this variation is generally inconsequential to the persistence of most taxa, species with short life spans may experience local population extirpations when there are successive years for poor year-class strength" (Rizzo *et al*. 2018, p. 115). The authors conclude that the effects of the flood on other diamond darter life stages is unknown, including potential delayed effects (Rizzo *et al*. 2018, p. 116). Equally unknown is how significant flooding events affect the Elk River crayfish and how often a significant flooding event may occur.

Flood events increase stream flow and velocity that, in turn, increase erosion of stream banks, mobilize sediment, and then deposit it downstream, and result in degradation of suitable instream habitat. Degradation of suitable habitat may include indirect effects to the Elk River crayfish's food resources and direct effects to the species' shelter resources. As described in chapter 4, we use benthic invertebrate (a source of food for the crayfish) diversity indices as a surrogate to assess water quality within the Elk River crayfish's range. Sediment loading has variable changes to the stream's physical habitat suitability, quantity and quality of food, and the interrelationships of the stream community (Jones *et al*. 2012, pp. 1063–1064). Further, as explained above in *section 2.5—Habitat*, Elk River crayfish require shelter resources to protect them from predators, especially during vulnerable life stages (e.g., when molting). Excessive sedimentation is known to result in a loss of suitable burrow sites due to increased embeddedness (Service 2015, p. 18722). See *section 3.2—Sedimentation* above for more details.

3.6.1 Summary of the effects of climate change

While uncertainty exists, the best available scientific data indicate that by about 2050, climate change will alter the ambient air temperature and, via a lag effect, water temperature, precipitation, and flooding regimes within the Elk River crayfish's range. Because the species likely has little ability to migrate in response to increasing stream temperatures or other climate change-induced perturbations (flooding-induced sedimentation), we conclude that the effects of climate change will more likely than not act as an ongoing stressor to the Elk River crayfish. Therefore, we are carrying the effects of climate change forward in our analysis.

3.7 Other Possible Stressors

3.7.1 Disease

Crayfishes are subject to a range of infectious and non-infectious agents that can cause mortalities in individuals and affect populations. Described below are the primary pathogens that have been documented in North American crayfish populations and have the potential to affect the Elk River crayfish.

The crayfish plague is a water mold caused by *Aphanomyces astaci* (World Organization for Animal Health 2009, p. 2). The fungus has led to widespread mortality of crayfish populations in Europe (Longshaw 2011, p. 55). Crayfish plague is not expected to be a significant threat to the Elk River crayfish. There is no documentation of crayfish within the Elk River watershed being affected by crayfish plague. All species of *Cambarus* (*acuminatus, bartonii, latimanus,* and *longulus*) that have been tested were determined to have low susceptibility to the disease (Svoboda *et al*. 2017, p. 28), and although two species of *Cambarus* (*fasciatus* and *manningi*) have been found to be carriers or have been infected by crayfish plague (Panteleit *et al*. 2017, p. 4), North American species of crayfish that have been infected appear to succumb to crayfish plague only when under stress (Cerenius and Söderhäll 1992 *In* Holdich *et al*. 2009, p. 11). Therefore, the crayfish plague is unlikely to affect the Elk River crayfish unless their resiliency is already reduced.

Porcelain Disease, caused by the microsporidian *Thelohania contejeani,* is an infectious pathogen documented in North American crayfish populations. The pathogen causes whitening of the skeletal muscle and reduced locomotor activity (Quilter 1976, pp. 226, 228), eventually resulting in the death of infected individuals (Pretto *et al*. 2018, p. 60). The disease is not well studied in North America, but evidence suggests that it occurs at a low rate in wild North American crayfish populations (Imhoff 2018, p.9). It may occur at higher rates in waterways with poor water quality or altered habitat and hydrology (Imhoff 2018, p. 9). The disease has been confirmed in diverse locations across the continent including Ontario, Canada, and U.S. states California, Missouri, Ohio, and Washington (Imhoff 2018, p. 9). Although systematic studies have not been conducted in West Virginia, evidence of the disease has been noted in the Monongahela National Forest in the Cheat River watershed (Loughman 2019, entire). The Cheat River watershed abuts the Upper Elk River watershed; therefore, there is the potential that this disease could occur in the range of the Elk River crayfish.

Summary of Disease: Disease has not been previously documented in Elk River crayfish. However, when water mold or porcelain disease has occurred in other *Cambarus* species the disease appears to have an individual rather than a watershed- or species-level effect, and only when the crayfish are already stressed. Therefore, we are not carrying disease forward in our current or future conditions analysis.

3.8 Synergistic Effects

In addition to stressors having singular effects on the Elk River crayfish, some stressors can become exacerbated when in combination. For example, cool to cold water crayfish become more susceptible to disease when subjected to prolonged exposure to warmer water temperatures. Water temperatures are likely to increase, although the rate is unknown, as a result of increasing air temperatures due to changing climate conditions. In addition, climate change reports indicate that West Virginia is likely to experience increased precipitation and flooding events, which will reduce water quality through increased sedimentation. Reduced water quality can also lead to increases in invasive crayfish, which outcompete native crayfish such as the Elk River crayfish when the latter are at reduced resiliency. Native crayfish populations may be able to withstand the presence of invasive crayfish in high gradient streams that have low levels of siltation and nutrient inputs. However, invasive crayfish have also extirpated populations of other native crayfish, particularly in streams that are already degraded by anthropogenic nutrient inputs or high levels of sedimentation (Loughman 2013, pp. 66–67). Further, removal of native riparian vegetation increases the amount of sedimentation. Invasive species such as Japanese knotweed can replace riparian vegetation; Japanese knotweed also contributes to sedimentation because occupied areas are prone to erosion due to the knotweed's shallow root system. Nonnative riparian vegetation can also change the nutrient inputs into an aquatic system, disrupting the benthic community, and thus the Elk River crayfish's prey resource.

3.9 Conservation Actions

The Elk River crayfish is identified as a priority 1 species in the West Virginia State Wildlife Action Plan (SWAP) (WVDNR 2015, p. 42). Priority 1 species are the primary focus for conservation action (WVDNR 2015, p. 2). In addition, the range of the Elk River crayfish is encompassed within two Conservation Focus Areas (CFA). Although the SWAP does not list any specific conservation actions for the Elk River crayfish, it does identify the development of natural gas, climate change, and invasive nonnative crayfish as threats to the species, and acid mine drainage, water pollution from industrial and sewage discharges and spills, and forest fragmentation as CFA-level stressors (WVDNR 2015, pp. 44, 361–369). The SWAP also identifies the following conservation actions to be implemented relevant to the Elk River crayfish and the associated CFAs (WVDNR 2015, pp. 242, 361–369):

- Continue to improve and maintain water quality of significant streams.
- Engage with the public and especially local watershed and environmental groups, to instill awareness and concern for the aquatic resources.
- Partner with local watershed groups, and local governments to elevate efforts to reduce water pollution and avoid future spills.
- Incorporate steps to reduce forest habitat loss and fragmentation in planning for gas well development, as well as associated infrastructure.
- Collaborate with others to implement control and management strategies of the "West Virginia Invasive Species Strategic Plan and Voluntary Guidelines."

Conservation actions also include the aforementioned Japanese knotweed control (see section *3.2.4 Invasive Plants*) by Service biologists.

3.10 Summary of Influencing Factors

The primary influences to the Elk River crayfish's viability currently and in the future are: (1) population demographics (i.e., distribution and abundance); (2) the quality of instream breeding, feeding, and sheltering features; (3) water quality; and (4) riparian conditions. Connectivity influences the Elk River crayfish's population demographics and is itself influenced by the quality of instream features, water quality, and riparian conditions. The main stressor to the quality of instream features is sedimentation, which can result from point sources and non-point sources. Sedimentation also effects water quality during transport. Depending on the source, sedimentation can be managed through properly implemented and enforced BMPs and forest management plans. While it is unknown to what extent the effects of climate change is currently affecting the species, it may have synergistic, deleterious effects in the future through increased water temperature compounding the effects of competition from other crayfish species, as well as increasing sedimentation from extreme flooding events brought on by increased precipitation. All four of the primary influences will be considered in the future conditions analysis.

Disease is not currently, or expected to be, having a major effect on the species. Other factors (e.g., predation and competition) may be having an individual effect, but are not currently rising to the level of affecting subwatersheds or the species as a whole. However, if the quality of instream features or water quality, or both, becomes too degraded, the magnitude and severity to which disease, predation, and competition may affect the species is likely to change.

CHAPTER 4 ANALYSIS OF CURRENT CONDITION

4.1 Analytical Units

As described above, historically, all Elk River crayfish were likely part of one metapopulation that had some limited connectivity. There is little information available regarding the demographic or genetic processes that define the spatial structure of Elk River crayfish populations, thereby precluding our ability to make reliable groupings of biological populations. Therefore, we used USGS HUC 10 watersheds as a surrogate to define analytical units for the purpose of evaluating the status of the species in this SSA report.

As described in chapter 3, there are multiple factors that can influence the Elk River crayfish at the individual, population/watershed, or species level (see figure 7). However, the primary influences to the Elk River crayfish's viability are: (1) population demographics (i.e., distribution and abundance); (2) the quality of instream breeding, feeding, and sheltering features; (3) water quality; and (4) riparian conditions. We have consistent, quantitative data to assess water quality, and some aspects of instream features and demographics. We assess other aspects of instream features and population demographics qualitatively. See the sections below for a summary of the quantitative and qualitative parameters we use to assess the Elk River crayfish's current condition, and appendix A for more details.

4.2 Analytical Metrics[2]

4.2.1 Condition Metrics (included in the condition scoring)

4.2.1.1 Habitat Quality (VBHA)

As described in *chapter 2—section 2.5*, habitat elements that are important to the Elk River crayfish include moderately sized streams with riffles, runs, or pools that have some current; unembedded stream substrates that have larger particle sizes and provide instream cover; stable streams that have low levels of sedimentation; and healthy riparian and instream characteristics (e.g., adequate riparian cover to moderate temperature, appropriate prey resources). We used the data collected by WVDEP using the Environmental Protections Agency's (EPA) Rapid Bioassessment Protocol Visual Based Habitat Assessment (VBHA) (Barbour *et al*. 1999, entire) to evaluate the presence and quality of these habitat elements throughout the species' range. The VBHA, used since 1996 throughout the State and since 1997 in the Elk River basin, consistently evaluates the quality of stream conditions by measuring 10 instream and riparian area parameters that are relevant to the species needs listed above. See appendix A for more detailed information.

4.2.1.2 Prey Base Condition (WVSCI)

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[2] We used our own analytical approach because we were unaware of the 2013 West Virginia Watershed Assessment Pilot Project: Elk River Watershed Assessment (The Nature Conservancy (TNC) 2013, entire) until we sent the draft SSA out for peer review in October 2019. The TNC report uses a similar approach to assessing watershed health, but it is conducted at a different scale, makes assumptions based on data limitations, and is not specific to the Elk River crayfish. Therefore, while some of the conclusions are consistent with our analysis, we consider this SSA to be the best available information to inform the Elk River crayfish's viability.

Elk River crayfish are opportunistic omnivores and thus depend on healthy stream and riparian systems to provide stream macroinvertebrates and detritus for forage. The West Virginia Stream Condition Index (WVSCI), used on data since 1997 throughout West Virginia, consistently evaluates the quality of benthic macroinvertebrate populations using six parameters (Gerritsen *et al*. 2000, entire). We used WVSCI as a measurement for assessing the condition of the prey base available to the Elk River crayfish. See appendix A for more detailed information.

4.2.1.3 Water Quality

As described above, the specific chemical water quality parameters (e.g., DO, pH) for the Elk River crayfish are unknown and the information to inform a rangewide analysis of those chemical parameters are not available. Therefore, we used siltation as a surrogate for water quality because silt is transported through the water column from natural (e.g., flooding) or anthropogenic (e.g., land clearing) disturbances. We obtained individual siltation scores from the WVDEP long-term water quality sampling sites in the Elk River watershed. These scores provide a subjective measurement of the amount of fine particle deposition in the substrate, and serve as an indicator of the extent to which disturbances in the watershed could increase sediment loading or other types of water quality degradation in adjacent streams. Additional information on this metric is available in appendix A.

4.2.1.4 Demographics

Demographics are measured through survey data collected during the 2009 survey effort by Loughman (Loughman and Welsh 2013, p. 5; Loughman 2017b, p. 1). This survey effort uses a consistent level of effort, and therefore catch-per-unit-effort can be compared between sites. Thus, this metric allows us to assess the number of individuals and compare relative abundance across subpopulations. Additional information on this metric is available in appendix A.

4.2.1.5 Distribution

The species is primarily concentrated in the Upper Elk River and the Holly River watersheds, with the Upper Elk River forming the headwaters for the Elk River. Catastrophic events, especially flooding, spills, and discharges (see *chapter 3—Factors Affecting the Species*), within these areas of the species' range could affect a large proportion of individuals. However, the occupied sites are spread throughout multiple streams within each watershed; therefore, if a catastrophic event on one occupied stream occurred, occupied streams would still persist elsewhere. Distribution, as the metric for redundancy, is measured by adding the total number of known sites per watershed; the higher the number of sites in each watershed, the better the species is able to recover from catastrophic events.

4.2.1.6 Invasive Crayfish

Nonnative invasive crayfish are currently present within the Lower Elk, Middle Elk, and Birch River watersheds (Loughman 2013 p. 6; Loughman and Welsh 2013 p. 56; Loughman 2017b, entire). As described above, native crayfish populations may be able to withstand the presence of invasive crayfish in high gradient streams that have low levels of siltation and nutrient inputs. However, invasive crayfish have also extirpated populations of other native crayfish, particularly in streams that are already degraded by anthropogenic nutrient inputs or high levels of sedimentation (Loughman 2013, pp. 66–67). Therefore, presence or absence of nonnative crayfish was included as a metric. However, this metric affected condition scores only when degradation of other metrics resulted in an overall low condition score in that watershed for more than 20 years. Twenty years was selected because that is the timeframe within which the spread has been documented, and in which extirpations of other native species have occurred in other watersheds. In those cases, we projected that invasive crayfish could spread within that watershed and extirpate Elk River crayfish populations.

4.2.2 Condition Metrics (not included in condition scoring)

4.2.2.1 Reproductive State

Populations of Elk River crayfish can be self-sustaining only with adults of both sexes. Twenty of the 30 sample sites with observations in 2009 of Elk River crayfish appear to be reproducing, either with having at least one individual of each sex or having juveniles present (Loughman 2017b, entire). All but one of the watersheds (i.e., the Lower Elk River) have at least one reproducing observation. As previously stated in *chapter 2—section 2.6 Historical and Current Range and Distribution*, we consider all the streams occupied in 2009 to be currently occupied.

4.2.2.2 Connectivity

As discussed above in *section 3.1—Connectivity*, Elk River crayfish habitat is presumed to have been destroyed by the creation of the Sutton Dam (figure 10). Further, we presume that Elk River crayfish cannot move from areas above the dam to below the dam due to the substantial barrier to movement that the dam creates, as well as the lack of suitable habitat within the impounded area, thus isolating the Birch and Lower Elk crayfish populations from the Holly, Laurel, Middle Elk, and Upper Elk populations. Additionally, the Lower Elk River subpopulation is isolated from the Birch River subpopulation based on the inability to travel through the mainstem Elk River because of the lack of suitable habitat and the presence of competing crayfish species (see figure 11).

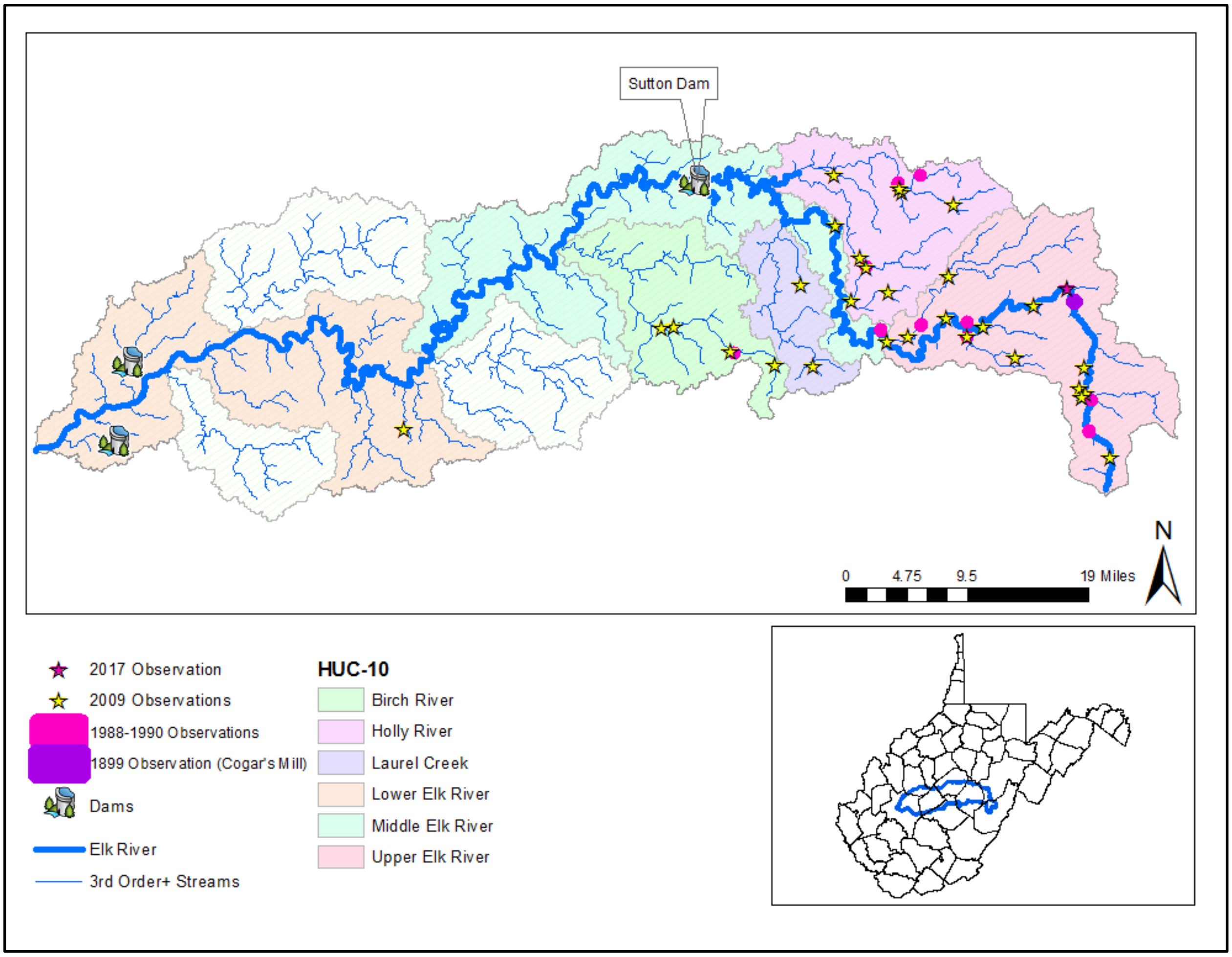

Figure 11. Map of the Elk River watershed showing Sutton Dam in relation to Elk River crayfish observations.

4.3 Current Condition

We assessed the current condition of the Elk River crayfish using six metrics, as described above and with additional detail in appendix A. These are derived from a combination of GIS analyses, survey data, and WVDEP water and habitat quality data. Each of these metrics correlate to one of the Elk River crayfish's needs, specifically for breeding (abundance, number of sites), feeding (WVSCI), and sheltering (VBHA and silt score).

Table 3. Current condition of the Elk River crayfish analytical units.

Resiliency Factor	Prey Availability Condition			Habitat Condition			Demographics (Average CPUE)			Redundancy		Sedimentation		Current Condition	
Watershed	**WVSCI Median Score 2007 to 2017**	**Current WVSCI Narrative Score**	**Score**	**VBHA Median Score 2007 to 2017**	**Current VBHA Narrative Score**	**Score**	**Avg. CPUE**	**Narrative Pop. Status**	**Score**	**# of Sites**	**Score**	**Average Silt Ranking 2007 to 2017** *(0=none, 1=low, 2=moderate, 3 = high)*	**Score**	**Sum**	**Current Condition Ranking**
Lower Elk River	65.4	Impaired - Slightly	2	131	Sub-optimal	2	2	Low	1	1	1	1.42	2	**8**	**Mod-Low**
Birch River	77.8	Unimpaired - Good	3	144	Sub-optimal	2	5	Moderate	2	4	1	0.82	3	**11**	**Mod**
Middle Elk River	73.5	Unimpaired - Good	3	128	Sub-optimal	2	2	Low	1	1	1	1.40	2	**9**	**Mod**
Laurel Creek	77.6	Unimpaired - Good	3	153	Sub-optimal	2	7	Moderate	2	2	1	1.80	1	**9**	**Mod**
Holly River	79.9	Unimpaired - Good	3	152	Sub-optimal	2	11	High	3	8	2	1.43	2	**12**	**Mod-High**
Upper Elk River	80.8	Unimpaired - Good	3	169	Optimal	3	9	High	3	12	3	1.00	3	**15**	**High**

4.3.1 Species Representation

The Elk River crayfish has inherently limited representation. The species is a narrow endemic whose range is restricted to one watershed. This limited range makes it vulnerable to anthropogenic disturbances and environmental perturbations throughout its range (Taylor *et al*. 1996, p. 27; Loughman and Welsh 2010, p. 68). In addition, downstream sites in aquatic systems are vulnerable to the effects from upstream sources. A limited natural range is one of the primary factors responsible for the imperilment of many crayfish species, and previous conservation assessments have noted that crayfish that are limited to one drainage system are at greater risk of conservation declines (Taylor *et al*. 2007, pp. 372, 377). As a result, the Elk River crayfish has been classified as vulnerable or imperiled in previous status assessments conducted by crayfish experts (Taylor *et al*. 2007, p. 382; Simon 2011, p. 75).

Furthermore, very little morphological variation has been noted in this species (Loughman 2017a, entire). There is also relatively little variation in the habitat types used by the species. As noted above, the species has not been found in small headwater streams and is not typically found in larger streams such as the lower Elk River mainstem where stream gradients and velocities become more moderate (Jezerinac and Stocker 1993, p. 351; Loughman *et al.* 2009, p. 231; Loughman and Welsh 2013, p. 38). For example, during 2010 to 2011 surveys in the Monongahela National Forest in the Upper Elk River, the Elk River crayfish was documented in several second order tributaries to the Elk River; these tributaries have watershed areas that range between 700 acres and 1800 acres (283 ha and 728 ha, respectively) (Owen 2019, p. 1). There is no genetic information available with which to evaluate genetic diversity. As described in *section 2.6—Historical and Current Range and Distribution and section 2.7.2—Species Needs—Representation*, we are assessing the Elk River crayfish across its eastern to western gradient in the Elk River watershed. While the species as a whole is restricted to a single HUC 8 watershed (Elk River watershed), the Elk River crayfish remains distributed in the HUC 10 watersheds throughout its historical eastern to western extent, which we consider as a surrogate for potential adaptive capacity.

4.3.2 Species Redundancy

Redundancy reduces the risk that a large area of the species' range will be negatively affected by a natural or anthropogenic catastrophic event at a given point in time. An adequate number of sites within each watershed would ensure that, if flooding makes portions of the range unsuitable, the species will still persist. It is unknown whether the Elk River crayfish occurred throughout the entire Elk River watershed; it is currently known from six watersheds and that is assumed to be its range. Elk River crayfish redundancy is evaluated through reviewing the number of occupied sites within each watershed.

The species occurs in 6 HUC 10 watersheds within the Elk River subbasin, and in a total of 18 streams within those watersheds (1 to 7 streams per watershed, depending on the watershed). See table 1, above in *section 2.7.1—Individual and 'Population' Needs*. The species is also currently present and showing evidence of reproduction both below and above Sutton Dam.

4.3.3 Species Resiliency

Given its small range, the Elk River crayfish is inherently vulnerable to environmental variation and stochastic events that could impact individual subpopulations or entire populations (e.g., extreme flooding), depending on the severity of the event. The Elk River crayfish occurs in six HUC 10 watersheds within the Elk River subbasin. The watersheds currently are of variable quality/condition: one high, one moderate-high, three moderate, and one moderate-low (see table 4, above).

4.4 Summary of Current Condition

The Elk River crayfish currently occurs in six HUC 10 watersheds (Redundancy) where it has been documented, including five historical locations (Birch River, Holly River, Laurel Creek, Middle Elk River, and Upper Elk River) and an additional watershed (Lower Elk) where it was not previously documented (2009 - new). It occupies the full east to west gradient of the Elk River HUC 8 watershed (Representation). Five out of the six HUCs are in moderate to high conditions and one is in moderate-low condition (Resiliency). The moderate-low reduced resiliency is due to reduced habitat and prey conditions, as well as lower demographics.

CHAPTER 5 FUTURE CONDITIONS

As discussed in chapter 1, for the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time (in this case, 50 years). Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs). Using various timeframes and the current and projected levels of the 3Rs, we thereby describe the species' level of viability over time.

We have considered the Elk River crayfish's life history characteristics, identified the habitat and analysis unit characteristics needed for viability (chapter 2); reviewed the factors that may be driving the historical, current, and future conditions of the species (chapter 3); and estimated the current condition of those needs through the lens of the 3Rs (chapter 4). Next, we predict the Elk River crayfish's future conditions to inform our understanding of the species' risk of extinction. We used the demographic and habitat information to predict how the six watersheds will respond to the primary factors likely to influence the species' condition in the future. These influencing factors include population demographics (i.e., distribution and abundance); the quality of instream breeding, feeding, and sheltering structures; water quality; and riparian conditions. Our analysis is limited to projecting three future scenarios, which are representative examples from the potential range of plausible scenarios, and that describe how these stressors to the species may drive changes from current conditions.

5.1 Future Scenarios

Projections of Elk River crayfish's resiliency, redundancy, and representation were forecast out to 50 years. The 50-year timeframe is projected in 10-year increments. This timeframe is supported by: approximately 20 years of Elk River crayfish persistence data, which we deem biologically reasonable to use as a surrogate to project forward a similar amount of time; available water quality (20 years), published projections of energy development (50 years), and reasonably reliable climate data (50 years) to reasonably predict potential significant effects of stressors (up to 50 years); the current Monongahela National Forest management plan, which has been in place since 2006 and is anticipated to be reevaluated approximately every 10 years; and other potential, but plausible, conservation actions (see chapters 2, 3, and 5). A summary of the three scenarios are presented in table 4 and detailed narratives, below.

5.1.1 Scenario 1: Continuation of Current Trends

The first future scenario evaluates the continuation of current trends, specifically with regards to rate of oil and gas development and their effects on the 3Rs. The scale of changes to the 3Rs metrics are based on the likelihood of increased oil and gas development, including increased risk of spills and discharges, and whether MVP or ACP traverse the watershed, as described in *section 3.2.1.2*. This scenario includes the effects resulting from a plausible potential increase in timber harvest on USFS lands (Landress 2018, entire). The Monongahela National Forest would see increased timber harvest, which would affect forest cover in the Upper Elk watershed. This scenario also assumes that the Elk River crayfish is not sensitive to air and water temperature changes resulting from a changing climate, but that precipitation and catastrophic flooding projected under the RCP 8.5 climate scenario will increase greatly in frequency and intensity.

Because there is currently no information regarding an increase in development or planning for development, this scenario assumes that Snowshoe Mountain Resort would not expand its footprint within the Upper Elk watershed. And lastly, there would be an occasional dispersal of invasive crayfish into the range of the Elk River crayfish.

5.1.2 Scenario 2: Increase In Rates of Energy and Commercial Development and Timber Harvest

The second future scenario evaluated is based on the effects of an increase in oil and gas and other development on the 3Rs. The scale of changes to the 3R metrics are based on the likelihood of oil and gas development, according to LCC predictions, including increased risk of spills and discharges, and whether MVP or ACP traverse the watershed, as described in *section 3.2.1.2*. This scenario includes the effects resulting from a plausible potential increase in timber harvest on USFS lands (Landress 2018, entire). The Monongahela National Forest would see increased timber harvest, which would affect forest cover in the Upper Elk watershed, without implementation of any additional watershed restoration or enhancement measures that would reduce sedimentation. Japanese knotweed would spread from the Upper Elk watershed downstream into the Middle Elk watershed and control efforts in the Upper Elk would cease or be ineffective. Further, this scenario assumes that the Elk River crayfish is sensitive to air and water temperature changes resulting from a changing climate, that climate change scenario RCP 8.5 trajectory is met, and that precipitation and catastrophic flooding greatly increases in frequency and intensity. Snowshoe Mountain Resort would expand its footprint within the Upper Elk watershed. Additionally, under this scenario, the isolated observation of the Elk River crayfish in the Lower Elk watershed would become extirpated after 20 years of presence. There would be an increase in the dispersal of invasive crayfish into the range of the Elk River crayfish.

5.1.3 Scenario 3: Continuation Plus Conservation

The third future scenario evaluates the continuation of current trends, specifically with regards to the effects of oil and gas development on the 3Rs, but assumes that conservation measures will be implemented to minimize the impacts of this development. The scale of changes to the 3R metrics is based on the likelihood of increased oil and gas development, including increased risk of spills and discharges, and whether MVP or ACP traverse the watershed, as described in *section 3.2.1.2*. This scenario includes the effects resulting from a plausible potential increase in timber harvest on USFS lands (Landress 2018, entire). The Monongahela National Forest would see increased timber harvest, which would affect forest cover in the Upper Elk watershed, but the USFS would implement conservation measures sufficient to minimize sediment transport into the Elk River as well as implement additional aquatic habitat restoration and protect riparian buffer areas, by expanding their current watershed restoration program to focus on the Upper Elk watershed. This scenario also assumes that the Elk River crayfish is not sensitive to air and water temperature changes resulting from a changing climate, that climate change scenario RCP 4.5 is met, and that catastrophic flooding increases moderately in frequency and intensity. Snowshoe Mountain Resort would expand its footprint within the Upper Elk watershed but also actively include conservation measures for stream restoration. Japanese knotweed would not spread from the Upper Elk watershed downstream into the Middle Elk watershed, and control efforts in the Upper Elk would be effective. There would be an occasional dispersal of invasive crayfish into the range of the Elk River crayfish.

Table 4. Summary of Future Scenario Influencing Factors as Compared to Current Condition.

Influencing Factor	Scenario 1	Scenario 2	Scenario 3
Quality of Instream Conditions			
Habitat Condition (VBHA)	↓[a]	↓↓[a]	↓[a]
Prey Availability (WVSCI)	↓[a]	↓↓[a]	↓[a]
Water Quality (Siltation)	↓[a]	↓↓[a]	↓[a]
Climate Projection	RCP 8.5	RCP 8.5	RCP 4.5
Climate Effects	↑[a] air temperature and variation in precipitation and flooding	↑↑[a] air temperature and variation in precipitation and flooding	↑[a] air temperature and variation in precipitation and flooding
Riparian Conditions			
Conservation Actions (habitat restoration, Japanese knotweed control, etc.)	Same	Same	↑[a]
Population Demographics			
Demography (Abundance)	Same	↓[a]	Same
Distribution (# sites)	Same	↓[a]	Same
Nonnative crayfish	Same	↑	Same
Connectivity	Same	Same	Same

[a] Influencing Factor Rate of Change Compared to Current Condition: some increase (↑), greater increase (↑↑), some decrease (↓), greater decrease (↓↓), no change in rate (Same).

5.2 Future Conditions

5.2.1 Scenario 1

5.2.1.1 Representation

At the end of 50 years, we predict that the Elk River crayfish has reduced east to west distribution due to the predicted extirpation of two western HUC 10 watersheds: Lower Elk River and Middle Elk River.

5.2.1.2 Redundancy

At the end of 50 years, we predict that the Elk River crayfish has reduced redundancy, from six to four HUC 10 populations. The species is predicted to become extirpated from two watersheds, one below Sutton Dam (Lower Elk River) and one that spans areas both above and below Sutton Dam (Middle Elk River).

5.2.1.3 Resiliency

At the end of 50 years, we predict that the species will have one high, one moderate, two moderate-low, and two low (extirpated) condition HUC 10 populations. Of the six current HUCs, we predict that the species will become extirpated in the Lower Elk River and Middle Elk River due to the synergistic effects between poor water and prey quality conditions combined with the predicted spread of invasive crayfish. Of these two, Lower Elk currently has lower quality habitat conditions, one subpopulation with low demographics with no evidence of reproduction, and an invasive crayfish has already been documented in the watershed. In addition, the Lower and Middle Elk are at greatest probability of energy development, which is likely to result in increased sedimentation. Therefore, because the poor habitat quality (impaired WVSCI and suboptimal VBHA) is conducive to the further spread of the nonnative crayfish, we project that after 20 years the nonnative species will fully outcompete the Elk River crayfish, causing extirpation. The Middle Elk HUC contains Sutton Dam and has impaired WVSCI, suboptimal VBHA, a single subpopulation with low demographics, and the invasive crayfish is already present. Therefore, because the poor habitat quality is conducive to the further spread of the nonnative crayfish, we project that after 20 years the nonnative species will fully outcompete the Elk River crayfish, causing extirpation.

The Holly River HUC is currently rated in moderate-high condition due to unimpaired WVSCI, suboptimal VBHA, high demographics (with the highest CPUE) and moderate number of subpopulations, but is predicted to become reduced to moderate condition at 50 years due to moderate probability of energy development, including pipelines.

The Birch River and Laurel Creek HUCs are currently in moderate condition because of unimpaired WVSCI scores but suboptimal VBHA scores and moderate demographics (four and two sites, respectively). These two HUCs become degraded to moderate-low condition in 30 years, and stay that way through the remainder of the 50-year timeframe, due to the synergistic effects between poor water and prey quality conditions combined with the presence of invasive crayfish. These HUCs have moderate probability of energy development. The Upper Elk HUC remains in high condition due to unimpaired WVSCI, optimal VBHA, high demographics, highest number of subpopulations, and low probability of overall energy development

5.2.2 Scenario 2

5.2.2.1 Representation

At the end of 50 years, we predict that the Elk River crayfish has reduced east to west distribution due to the predicted extirpation of two western HUC 10 watersheds: Lower Elk River and Middle Elk River.

5.2.2.2 Redundancy

At the end of 50 years, we predict that, of the six current HUCs, the Elk River crayfish will become extirpated in one HUCs below Sutton Dam (Lower Elk River) and one that spans areas above and below Sutton Dam (Middle Elk River).

5.2.2.3 Resiliency

At the end of 50 years, we predict that the Elk River crayfish will have two extirpated HUCs (Lower Elk River, Middle Elk River), two low HUCs (Birch River and Laurel Creek), one moderate HUC (Holly River), and one high condition HUC (Upper Elk River). Similar to Scenario 1, two HUCs (Lower Elk River and Middle Elk River) become extirpated in due to the synergistic effects between poor water and prey quality conditions combined with lower demographics, the predicted spread of invasive crayfish, and highest probability of energy development. The Birch River and Laurel Creek HUCs are currently in moderate condition because of unimpaired WVSCI scores but suboptimal VBHA scores and moderate demographics (four and two sites, respectively), but become degraded to low condition in 40 and 50 years, respectively. The Holly River HUC is currently rated in moderate-high condition due to unimpaired WVSCI, suboptimal VBHA, high demographics (with the highest CPUE), and moderate number of sites, but is predicted to become reduced to moderate condition at 10 years, and remain so, due to moderate probability of energy development, including pipelines. We predict Holly River will not be reduced to low condition or become extirpated because of its higher demographics and number of subpopulations, despite declining habitat and prey conditions. The Upper Elk River HUC remains in high condition due to unimpaired WVSCI, optimal VBHA, high demographics, highest number of subpopulations, and low probability of overall energy development, despite the predicted expansion of Snowshoe Mountain Resort and projected increase in timber harvest.

5.2.3 Scenario 3

5.2.3.1 Representation

At the end of 50 years, we predict that the Elk River crayfish has reduced east to west distribution due to the predicted extirpation of two western HUC 10 watersheds: Lower Elk River and Middle Elk River.

5.2.3.2 Redundancy

At the end of 50 years, we predict that the Elk River crayfish has reduced redundancy, from six to four HUC 10 populations. The species is predicted to become extirpated from two watersheds, one below Sutton Dam (Lower Elk River) and one that spans areas above and below Sutton Dam (Middle Elk River), but persist in the remaining four HUCs (including below (Birch) and above Sutton Dam (Laurel Creek, Holly River, and Upper Elk River).

5.2.3.3 Resiliency

At the end of 50 years, we predict that the Elk River crayfish will have one moderate-low, two moderate, one high, and two extirpated watersheds. Of the six current HUCs, we predict that the species will become extirpated in the Lower Elk and Middle Elk at 30 years due to the synergistic effects of poor water and prey quality conditions combined with the predicted spread of invasive crayfish.

The Lower and Middle Elk watersheds are at greatest probability of energy development, which is likely to result in increased sedimentation. Therefore, because the poor habitat quality (impaired WVSCI and suboptimal VBHA) is conducive to the further spread of the nonnative crayfish, we project that after 30 years the nonnative species will fully outcompete the Elk River crayfish in each watershed, respectively, causing extirpation.

The Holly River HUC is currently rated in moderate-high condition due to unimpaired WVSCI, suboptimal VBHA, high demographics (with the highest CPUE) and moderate number of subpopulations, and is predicted to be reduced to moderate condition at 20 years. It is not predicted to be reduced to a low condition due to the presence of protected land (Holly River State Park) and conservation actions (Japanese knotweed control and implementation of sedimentation control measures during timber harvest upstream) within the watershed, which ameliorates the effects of moderate probability of energy development.

The Birch River and Laurel Creek HUCs are currently in moderate condition because of unimpaired WVSCI scores but suboptimal VBHA scores and moderate demographics (four and two subpopulations, respectively). Birch River maintains its moderate condition in 50 years, despite the synergistic effects between poor water and prey quality conditions combined with the presence of invasive crayfish, because of its higher demographics. Laurel Creek is predicted to remain at moderate condition until 50 years, where it is reduced to a moderate-low condition, due to the synergistic effects of poor water quality and prey quality conditions combined with the presence of invasive crayfish in a lower demographic HUC. These HUCs have moderate probability of energy development.

The Upper Elk HUC remains in high condition due to unimpaired WVSCI, optimal VBHA, high demographics, highest number of subpopulations, implementation of sediment control measures during timber harvest on the Monongahela National Forest, and low probability of overall energy development.

5.3 Summary of Species Viability

This assessment describes the viability of the Elk River crayfish in terms of representation, redundancy, and resiliency by using the best commercial and scientific information available. We used these parameters to describe current and potential future conditions regarding the species' viability. To address the uncertainty associated with potential future impacts and how they will affect the species' resource needs, we assessed potential future conditions using three plausible scenarios. These scenarios were based on a variety of negative and positive influences on the species across its range, allowing us to predict potential changes in population and habitat parameters.

Table 5. Current Condition vs. Future Conditions Table

	Watershed	Current Condition	10 Years	20 Years	30 Years	40 Years	50 Years
Scenario 1	Lower Elk River	Mod-Low	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Birch River	Mod	Mod	Mod	Mod	Mod-Low	Mod-Low
	Middle Elk River	Mod	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Laurel Creek	Mod	Mod	Mod	Mod-Low	Mod-Low	Mod-Low
	Holly River	Mod-High	Mod	Mod	Mod	Mod	Mod
	Upper Elk River	High	High	High	High	High	High
Scenario 2	Lower Elk River	Mod-Low	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Birch River	Mod	Mod	Mod-Low	Mod-Low	Low	Low
	Middle Elk River	Mod	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Laurel Creek	Mod	Mod	Mod-Low	Mod-Low	Mod-Low	Low
	Holly River	Mod-High	Mod	Mod	Mod	Mod	Mod
	Upper Elk River	High	High	High	High	High	High
Scenario 3	Lower Elk River	Mod-Low	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Birch River	Mod	Mod	Mod	Mod	Mod	Mod
	Middle Elk River	Mod	Low	Low	~~Low~~	~~Low~~	~~Low~~
	Laurel Creek	Mod	Mod	Mod	Mod	Mod	Mod-Low
	Holly River	Mod-High	Mod	Mod	Mod	Mod	Mod
	Upper Elk River	High	High	High	High	High	High

5.3.1 Representation

The Elk River crayfish is narrow endemic whose range is restricted to one HUC 8 watershed; therefore, it has inherently limited representation. Because we do not have information on the species' genetic, morphological, or ecological niche which are the typical measures of species representation, we are using the species' east-west distribution as a surrogate for representation. The species retains its representation through maintaining populations across its range. The species currently occurs in six HUC 10 watersheds throughout the Elk River HUC 8 watershed. In all of the future scenarios, the species is predicted to become extirpated in the Middle and Lower Elk watersheds, which are two western watersheds in the species' range. With these watersheds extirpated, the range primarily shifts towards the eastern watersheds. Therefore, under these scenarios, the species' representation is reduced as the range contracts, and as a result, the Elk River crayfish may not be as adaptive to changing conditions over the next 50 years.

5.3.2 Redundancy

Species redundancy for the Elk River crayfish is achieved through multiple, widely distributed populations throughout its range. The species is currently known from 18 streams (i.e., subpopulations) in 6 HUC 10 watersheds, distributed throughout the Elk River HUC 8 watershed. While individual subpopulations are not modeled to change in condition, the species is predicted to become extirpated in two watersheds in each scenario (Middle and Lower Elk watersheds) based on overall habitat conditions in the watershed. Under all scenarios through 50 years, the species is predicted to persist in the two HUC 10 watersheds with a higher number of subpopulations (Holly and Upper Elk), as well as in the two others (Birch River and Laurel Creek), albeit at a lower condition under Scenario 2. Therefore, there will be redundancy both at the subpopulation and species level, but we acknowledge that the two low condition HUCs in Scenario 2 likely do not contribute equivalent value to the species' redundancy as the higher condition HUCS (see *5.3.3 Resiliency*, below). This redundancy will help the species persist in the event of catastrophic events such as flooding, spills, or disease.

5.3.3 Resiliency

Species-level resiliency for the Elk River crayfish is evaluated through the number and condition of healthy populations through the species' range. The species currently has subpopulations in six HUC 10 watersheds within its range. These watersheds are currently in various conditions (i.e., not all are high or low condition), which provide resiliency to environmental stochasticity. The species is predicted to become extirpated in two watersheds (Lower Elk River and Middle Elk River) in all scenarios. However, in all scenarios, the Upper Elk watershed retains its high condition to 50 years, and the Holly River watershed remains in moderate condition at 50 years. Therefore, under these scenarios, while the species loses resiliency through the extirpation of some populations, these watersheds, where the species is currently predominantly found, in combination with the Birch River (below Sutton Dam) and Laurel Creek HUCs at moderate to low (depending on the Scenario) condition, maintain most, if not all, their resiliency and provide a buffer against environmental stochasticity.

CHAPTER 6 KEY UNCERTAINTIES

Inherently, projecting future scenarios and predicting the species' response to those scenarios requires us to make plausible assumptions. Our analyses are predicated on multiple assumptions, which could lead to over and underestimates of the Elk River crayfish's viability. Below, we identify the key sources of uncertainty and indicate the likely effect of our assumptions on the viability assessment. The uncertainty associated with determining species' status and trends underpins all of our analyses, and thus warrants further explanation.

Table 6. Key assumptions encountered in the analysis and the impact on our viability assessment. "Overestimates" means the species' viability is optimistic; "Underestimates" means the species' viability is pessimistic; "Either" means the effect could lead to an over or underestimate of viability.

Assumption	Effect on Viability Assessment
Crayfish survey result from two time periods are not comparable. Therefore, changes in populations/trends may not be apparent.	Either
All survey data, including recent and historical data, were used. There is a paucity of recent (post 2009) range wide survey data. If Elk River crayfish were historically present in an area but no additional information to indicate that habitat conditions have significantly changed, the species was considered still to be present.	Overestimates
The Elk River crayfish sensitivity/tolerance to temperature, sedimentation, and/or other water quality conditions is not known. There is known within genus variation in species sensitivity in other crayfish.	Either
We assume benthic macroinvertebrate community health reflects crayfish health.	Either
Most measurements for other metrics were not taken at the same location as crayfish samples. Although areas within a stream are inherently interrelated, there could be variations in condition between sites. We assume all sites within a HUC are connected and related.	Either
Water quality metrics reflect a single snapshot in time which may not accurately reflect the annual variation in stream conditions.	Either
Lower Elk River site may not be a viable population and may be an introduction. We assume that this location represents a reproducing population.	Overestimates
Presence of nonnative crayfish are assumed to be the same as previously surveyed. It is possible that nonnatives may have continued to spread throughout the Elk River watershed, below Sutton Dam.	Overestimates
We assume that natural predation levels are having only an individual, not watershed or species' level effect.	Overestimates
The direct effects of climate change spatially and temporally are unknown, especially when considering the effect on overall suitable habitat relative to the species' water temperature preferences.	Either

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APPENDIX A CURRENT CONDITION METHODOLOGY

We used available data from the WVDEP, crayfish surveys, and ArcGIS to develop the current condition score for each analytical unit. Watershed assessment data have been collected by the WVDEP at 621 sites in the Elk River subbasin since 1997. Using ArcGIS's Spatial Join tool, each sample site had its intersecting watershed (HUC10) name attributed to the site's data. Additionally, sites were divided between two decades: 1997 to 2007 and 2007 to 2017. We used the median score of each watershed by decade to provide an overall measurement of that watershed's quality during the appropriate timeframe. The 2007 to 2017 scores were used to assess current condition for the Habitat Condition (using RBP as a proxy), Prey Availability and Condition (using median WVSCI as a proxy), and silt levels (average Sediment Deposition - Silt) of each watershed. The same spatial join analysis was performed for the recorded abundance of Elk River crayfish at survey sample sites for the 2009 survey results. This provides the demographic metric of abundance (average catch per unit effort (CPUE)) for each watershed. Finally, the number of crayfish capture sites per watershed were summed to provide a metric for distribution. Each habitat or demographic parameter was assigned a point value: three points for high condition, two points for moderate condition, and one point for low condition. All five metric scores were added to obtain an overall condition score for that watershed, ranging from 5 points as the lowest possible score to 15 points as the highest possible score.

Table A1. Number of sites per watershed for each metric.

Watershed	# Sites with WVSCI Scores	# Sites with VBHA Scores	# Sites with Silt Scores
Lower Elk River	64	63	64
Birch River	24	22	22
Middle Elk River	25	19	20
Laurel Creek	6	5	5
Holly River	20	7	7
Upper Elk River	29	23	22

While there are limited data describing the specific needs of the Elk River crayfish, these metrics provide a connection between the known requirements from other tertiary burrowing crayfish that can be used in lieu of species-specific data.

A summary of these five metrics is available in table A2.

Table A2. Condition Scoring Metrics

Population Resiliency Factor	High (3 points; green shading)	Moderate (2 points; yellow shading)	Low (1 point; red shading)
Habitat Condition (VBHA)	Above 160 (Optimal)	110 to 159 (Sub-optimal)	Below 109 (Poor to Marginal)
Prey Availability/Condition (WVSCI)	Above 72.1 (Unimpaired)	45.1 to 72 (Impaired)	Less than 45 (Impaired - Severely)
Water Quality/Sedimentation (Average Silt Score)	0.82 to 1.12	1.13 to 1.43	1.44 to 1.8
Demographics - Abundance (CPUE)	9 to 11	6 to 8	2 to 5
Distribution (# of sites)	9 to 12	5 to 8	1 to 4

The total condition of the watershed is determined by the sum of the five metrics and is summarized in table A3 below.

Table A3. Watershed Condition Scores by Sum.

Sum	Condition
5, 6, or 7	Low (red shading)
8	Moderate-low (orange shading)
9, 10, or 11	Moderate (yellow shading)
12	Moderate-high (blue shading)
13, 14, or 15	High (green shading)

Habitat Condition (VBHA)

The VBHA measures aquatic habitat condition by assessing the following 10 parameters at a 100-meter reach at each sample site: (1) epifaunal substrate/instream cover; (2) embeddedness; (3) velocity/depth combinations; (4) sediment deposition; (5) channel flow status; (6) channel alteration; (7) frequency of riffles; (8) bank stability; (9) bank vegetative protection; and (10) riparian vegetative zone width (Barbour *et al*. 1999, pp. 5-11–5-31). Each parameter is given a score ranging from a low of 0 to a high of 20, and then the scores for each parameter were summed, for a maximum of 200 possible points. Results were then ranked into four categories as shown in table A4. This protocol has been used by WVDEP's Watershed Assessment Branch since 1997 to assess stream habitat throughout the range of the Elk River crayfish, and therefore provides consistent data that can be used to assess changes over time, and compare results between sites. The VBHA scores within Elk River crayfish watersheds averaged a 2-percent increase between the two decades.

Table A4. VBHA categories, scores, and narrative description.

VBHA Category	Score	Narrative Description
Optimal	160 to 200	Habitat quality meets natural expectations
Sub-optimal	110 to 159	Habitat quality is less than desirable but satisfies expectations in most areas
Marginal	60 to 109	Habitat quality has a moderate level of degradation; severe degradation at frequent intervals.
Poor	0 to 59	Habitat is substantially altered; severe degradation

Prey Availability/Condition (WVSCI)

The WVSCI was developed for the WVDEP's Watershed Assessment Branch in 2000 to assess the biological condition of benthic macroinvertebrate populations within streams (Gerritsen *et al*. 2000, entire). This index has been applied to samples throughout the range of the Elk River crayfish collected since 1997, and therefore provides consistent data that can be used to assess changes over time, and compare results between sites. WVSCI scores in Elk River crayfish watersheds averaged a 5-percent decrease between decades.

The WVSCI provides a quantitative and qualitative ranking of assessment sites that describes the level of impairment for assessed streams relative to reference (unimpaired) streams. The index includes six biological metrics that characterize the structure and composition of benthic macroinvertebrate communities. The overall WVSCI score is determined by averaging the standardized score of each metric to determine a final index score that ranges from 0 to 100 (worst to best). When initially developing the index, sites with a WVSCI score equal to or less than 68 were considered impaired. However, a precision analysis determined that results between individual kick seine samples taken at the same assessment site could vary by 7.4 points. As a result, the WVDEP established a "gray zone" that ranges from 60.6 to 68.0. This "gray zone" was determined not to be scientifically sufficient by the Environmental Protection Agency in reviewing the 2012 303(d) list (WVDEP 2019a, pp. 15–16). The WVDEP instead used the 5th percentile of reference site index scores to determine if a site could be listed as impaired. If a site receives a WVSCI score equal to or less than 72, a single sample can be used to confidently establish that the benthic community at the site is truly biologically impaired.

Table A5 summarizes the WVSCI's levels of impairment.

Table A5. WVSCI numerical and narrative scores.

Numerical Score	Narrative Score
Less than (<) 24	Impaired - Severely
24 to 48	Impaired - Moderately
48 to 72	Impaired - Slightly
72 to 86	Unimpaired – Very Good
86 to 100	Unimpaired – Excellent

WVSCI/VBHA Correlation

Using a Pearson Correlation, the WVSCI score is correlated (Pearson correlation coefficient r = 0.476, significance P<0.05) with total VBHA (Bailey 2018). To avoid using two correlated variables and thus double weighting one aspect of the Elk River crayfish's status, we compared condition scores using the individual measured component of VBHA for benthic macroinvertebrates to the condition scores using WVSCI. Conducting a sensitivity analysis (comparing the total condition score when using either the benthic macroinvertebrate score or using the additive VBHA score) resulted in the same overall condition score. Although VBHA is correlated to WVSCI, using both metrics does not result in the double weighing of this factor. Therefore, we consider both metrics to be appropriate surrogates for evaluating the species' resiliency.

Water Quality/Sedimentation (Silt Score)

We initially proposed to use iron as a surrogate for sedimentation and water quality, because sedimentation from land use and bank erosion are sources of iron in water bodies (WVDEP 2012, p. 51). However, this is not an appropriate measurement for the amount of sedimentation, versus the presence of sedimentation, because iron concentration can vary seasonally and annually, is not always measured at all sampling sites, and is not a direct measurement of the physical sedimentation of the stream bottom (Bailey 2018).

The WVDEP Watershed Assessment Branch assesses overall habitat condition of a site prior to scoring it through the VBHA as described above. The sediment deposition estimates are visual estimations of the intensity of silt and sand particles (same for fine gravel) within the 100-m (328-ft) assessment reach within the watershed assessment site. The sampler scores silt, sand, and fine gravel individually. The ratings are as follows: 0 = None, 1 = Low, 2 = Moderate, 3 = High, 4 = Extreme, and P = Present or NR = Not Rated. Some scores prior to 2003 were originally rated on presence/absence and later given a numeric score based on field notes. The data analysis uses only the silt scores for each site (WVDEP 2018, p. 45).

Demographics (Elk River crayfish sampling data, catch per unit effort)

We do not have a reliable method to estimate the Elk River crayfish's overall population size, but we do have information to inform the relative abundance of the species in each analysis unit. We used Elk River crayfish sampling data from the 2009 survey effort to assess the species' catch per unit effort (CPUE) as a proxy for relative abundance. We were unable to use Jezerinac *et al.'s* (1995, p. 5) 1988–89 data because results between the 1988–1989 and 2009 efforts were not comparable. Even though collection methods used for the 1988–1989 and 2009 sampling periods were similar—both used seines, dip nets, or hand collection (Jezerinac *et al*. 1995, pp. 5; Loughman and Welsh 2013 pp. 5)—the level of effort between the two sampling periods was not consistent. In the 1988-1989 sampling effort, the level of effort varied between sites, and no information is available about the level of effort that was used at any particular site (Loughman 2017b, pp. 1). Thus, CPUE for this sampling period cannot be generated. In addition, the number of individuals captured may not provide an accurate comparison of abundance between sites, and cannot be used to assess trends in abundance at a site over the two sampling time periods. However, a consistent level of effort (10 seine hauls) was used at each site sampled during the 2009 effort (Loughman and Welsh 2013 pp. 5; Loughman 2017b, pp. 1). Therefore, the number of individuals captured can be used to compare relative abundance between sites during this time period. Catch data (number of individuals) was averaged by HUC10 watershed.

Redundancy (number (#) of sites per watershed)

The species is primarily concentrated in the Upper Elk River and the Holly River watersheds, with the Upper Elk River forming the headwaters for the Elk River. Catastrophic events, especially flooding (see *Chapter 3 Factors Affecting the Species*), within this area of the species' range could affect a large proportion of individuals. However, the occupied sites are spread throughout multiple streams within each watershed; therefore, if a catastrophic event occurred on one occupied stream, occupied streams would still persist elsewhere. Subwatersheds with one to two sites are considered to have low redundancy, those with three to seven sites are considered to have moderate redundancy, and those with eight or more sites are considered to have high redundancy. See table A6 for a summary of the number of sites per watershed.

Table A6. Watersheds and number of sites with Elk River crayfish detections.

Watershed	# of sites
Lower Elk River	1
Birch River	4
Middle Elk River	1
Laurel Creek	2
Holly River	8
Upper Elk River	12

Invasive Crayfish Presence

Given the known presence of both species of invasive crayfish within the Elk River watershed, and the documented rate of spread and mobility of these species (see *section 3.4.1—Invasive Crayfish*), invasive crayfish are assumed to have the potential to colonize or be introduced into any HUC10 watershed at any time in the future. The potential presence results in degraded resiliency for the Elk River crayfish only when other habitat conditions are poor. Therefore, when both invasive species and poor habitat condition quality has been present for 20 or more years, the watershed is predicted to become extirpated.

Table A7. Master Influence Table. Narrative definitions follow.

	Resource Need Affected							Connection to the 3 R's			SSA Analysis					
Factors Influencing the Species	**Demography**	**Gene Flow**	**Embeddedness**	**Substrates**	**Prey**	**Water Quality/ Quantity/ Flow**	**Riparian/ stable stream**	**Representation (gene flow, dispersal)**	**Redundancy (# sites, distribution)**	**Resiliency (prey and habitat conditions)**	**Certainty of response/ effect**	**Carried through to condition scoring?**	**Rationale for carrying through to condition scoring**	**Scale of influence (magnitude/scope)**	**Significance to status of species (severity)**	**Metric**
Connectivity (natural and human barriers)	X	X				X		X	X	X	High	Y	Connectivity is not quantifiable but still has a significant influence on redundancy.	High	High	Qualitative narrative
Sedimentation	X		X	X	X	X	X		X	X	High	Y	Sedimentation influences multiple resource needs.	High	High	Demographics, silt score, VBHA, WVSCI
Agriculture (sedimentation/water quality)			X	X		X	X		X	X	High	N	Agriculture comprises a small percentage of overall landcover; effects will be small and limited to watershed-level effects.	Low	Medium	Demographics, silt score, VBHA, WVSCI
Energy Development (sedimentation/direct mortality/water quality)	X		X	X	X	X	X	X	X	X	High	Y	Energy development is the source of multiple direct and indirect influences.	High/Medium	High	Silt score, VBHA, WVSCI, qualitative for mortality
Forestry (sedimentation/direct mortality)			X	X	X		X		X	X	Medium	Y	Assumption that forestry is implemented with BMPs.	Medium	Low	Silt score, VBHA, WVSCI, qualitative for mortality
Residential/commercial development			X	X	X	X	X	X	X	X	Medium	Y	Snowshoe Resort has approached Service about expanding their footprint and they may have approached conservation partners about implementing watershed restoration concurrently with the expansion.	Low	Medium	Demographics, silt score, VBHA, WVSCI
Invasive Plants (sedimentation/water temp)					X	X	X		X	X	High	N	Knotweed has been documented throughout the Elk River watershed; the scale of the total effect of knotweed is unknown but unlikely to reach species level. We assume that conservation actions would include knotweed control and is indirectly captured through VBHA.	Medium	Medium	VBHA
Water Quality	X				X	X		X	X	X	High	Y	Water quality is essential for aquatic species.	High	High	VBHA, WVSCI

	Resource Need Affected							Connection to the 3 R's			SSA Analysis					
Factors Influencing the Species	**Demography**	**Gene Flow**	**Embeddedness**	**Substrates**	**Prey**	**Water Quality/ Quantity/ Flow**	**Riparian/ stable stream**	**Representation (gene flow, dispersal)**	**Redundancy (# sites, distribution)**	**Resiliency (prey and habitat conditions)**	**Certainty of response/ effect**	**Carried through to condition scoring?**	**Rationale for carrying through to condition scoring**	**Scale of influence (magnitude/scope)**	**Significance to status of species (severity)**	**Metric**
Water Temperature	X					X		X	X		Medium	N	Influence of water temperature on Elk River crayfish is unknown.	Medium	Medium	Indirectly through VBHA, WVSCI
Competition (Nonnative crayfish)	X	X			X			X	X	X	High	Y	Competition would only impact individual Elk River crayfish and not rise to the level where populations are affected unless the habitat is already degraded and expected to remain degraded for 20 or more years, at which point we anticipate the Elk River crayfish population to become extirpated.	Low	Medium	Qualitative
Predation (nonnative fish)	X	X			X			X	X	X	High	N	Stocking has been ongoing for many years and have no data or indication that rates or effects will change in the future.	Medium	Low	N/A
Effects of climate change (floods/water temp/water quality)	X	X	X	X	X	X	X	X	X	X	Medium	Y	Climate change influences all needs of the species and exacerbates other influencing factors (i.e., sedimentation).	High	High	Qualitative
Disease	X	X						X	X	X	Low	N	Diseases have not been documented in this basin, and while it is possible that disease may potentially kill individuals, it is not currently affecting the species.	Low	Low	N/A
Conservation Action (sedimentation/invasive plants/riparian corridors/remove barriers)	X	X	X	X	X	X	X	X	X	X	High	Y	Conservation actions within the general vicinity of ERC streams may ameliorate some of the previously described threats, but there are no targeted conservation efforts specifically for this species.	Low	Medium	Qualitative discussion of the rate of decline in VBHA/WVSCI scores

Table A7 Definitions:

Certainty of response/effect:

- Low - Conflicting data or no data to support conclusion.
- Medium - Reasonably infer effects using data from surrogates (e.g., non-Cambarus crayfish species) or life history characteristics to support conclusion.
- High - Clear data exists showing effects to other Cambarus crayfish species or the Elk River crayfish's resource needs to support conclusion.

Scale of influence (magnitude/scope) categories:

- Low - Affects individuals
- Medium - Affects multiple streams/occurrences within a HUC
- Medium/High - Affects multiple HUCs
- High - Affects rangewide

Significance to status of species (severity) categories:

- Low - Minimal effect to viability when/where it occurs
- Medium - Some effect to viability when/where it occurs
- High - Consequential effect to viability when/where it occurs

APPENDIX B FUTURE CONDITIONS METHODOLOGY

Predicting Population Factors

1. Scenario 1 (Continuation):
    a. Population factors remain the same, except the watershed goes extinct due to the presence of invasive crayfish if the overall condition of the watershed is low for 20 years.
2. Scenario 2 (Development intensive):
    a. Population factors remain the same, except the watershed goes extinct due to the presence of invasive crayfish if the overall condition of the watershed is low for 20 years.
3. Scenario 3 (Conservation Actions):
    a. Population factors remain the same, except the watershed goes extinct due to the presence of invasive crayfish if the overall condition of the watershed is low for 20 years.

Predicting Habitat Elements

Table B1: Portions of each Elk River crayfish watershed with each probability of shale gas development. Low: less than (<) 0.33 probability of development; medium: 0.33<x<0.66 probability of development; high: greater than (>) 0.66 probability of development (Dunscomb *et al*. 2015, entire). An asterisk (*) denotes a watershed with a FERC-regulated pipeline crossing through the watershed (Service 2017, entire; Service 2018, entire).

	Percent (%) Probability of Energy Development			
HUC 10 Watershed	**% low**	**% medium**	**% high**	**Overall likelihood**
Lower Elk River	6.8	41.6	51.6	High
Birch River*	39.6	41.6	18.9	Moderate
Middle Elk River*	5.5	63	31.5	High
Laurel Creek*	40.2	58.2	1.5	Moderate
Holly River*	20.4	65.4	14.1	Moderate
Upper Elk River*	80.7	19.2	0.1	Low

The effects of the two FERC-regulated pipelines are incorporated via the watersheds they traverse already having moderate to high probability of oil and gas development, except for the Upper Elk watershed. This watershed is predicted to have habitat conditions decrease at the same rate as watersheds with a moderate probability of oil and gas development due to the presence of ACP.

1. Continuation scenario:
   a. WVSCI:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -2.5 per 10 years
      iii. High probability of O&G development: -5 per 10 years
         1. Upper Elk: -2.5 per 10 years (ACP)
   b. VBHA:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -5 per 10 years
      iii. High probability of O&G development: -10 per 10 years
   c. Average Silt Score:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: +0.10 per 10 years
      iii. High probability of O&G development: +0.15 per 10 years
2. High Development:
   a. WVSCI:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -5 per 10 years
      iii. High probability of O&G development: -7.5 per 10 years
         1. Upper Elk: -2.5 per 10 years (ACP)
   b. VBHA:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -10 per 10 years
      iii. High probability of O&G development: -15 per 10 years
   c. Average Silt Score:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: +0.20 per 10 years
      iii. High probability of O&G development: +0.3 per 10 years
3. Conservation Measures
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -1.25 per 10 years
      iii. High probability of O&G development: -2.5 per 10 years
   b. VBHA:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: -2.5 per 10 years
      iii. High probability of O&G development: -5 per 10 years
   c. Average Silt Score:
      i. Low probability of O&G development: no change in score
      ii. Moderate probability of O&G development: +0.05 per 10 years
      iii. High probability of O&G development: +0.075 per 10 years