

**Guyandotte River crayfish
(*Cambarus veteranus*)
5-Year Review:
Summary and Evaluation**



Photo by: Dr. Zachary J. Loughman

**U.S. Fish and Wildlife Service
West Virginia Field Office
Davis, West Virginia
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**5-YEAR REVIEW
Guyandotte River crayfish
(*Cambarus veteranus*)**

1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2 Methodology used to complete the review:

This 5-year review was conducted by the lead species biologist for the Guyandotte River crayfish (*Cambarus veteranus*) in coordination with other U.S. Fish and Wildlife Service (Service) staff. This document was reviewed by the West Virginia Division of Natural Resources (WVDNR) endangered species expert, Alexander Silvis, who contributed additional information on species biology, distribution, and factors influencing the viability of the species. Dr. Zachary Loughman, the lead academic expert on the species, contributed information on species biology. Nicole Sadecky, the lead investigator of the Guyandotte River crayfish life history study, provided consultation through personal communications as needed throughout the development of this 5-year review. The goal of the document is to summarize and evaluate new information and recommend whether the listing status of the species should be changed.

New data and information regarding the species' population status and habitat used in this report included peer-reviewed literature, information and occurrence data from the WVDNR and researchers, unpublished reports, and personal communications. The administrative record, including all pertinent literature and documents used for this review, is on file at the West Virginia Field Office.

1.3 Background:

1.3.1 Federal Register (FR) notice announcing initiation of this review:

85 FR 64527-64529

1.3.2 Listing History

Original Listing

FR notice: 81 FR 20449-20481

Date listed: April 7, 2016

Entity listed: Species; Entire Range

Classification: Endangered

1.3.3 Associated Rulemakings:

A final critical habitat rule for the species was published on March 15, 2022, and became effective on April 14, 2022 (87 FR 14662-14719). Designated critical habitat consists of 135 stream kilometers (skm; 84 stream miles [smi]) in the Upper Guyandotte Unit, consisting of five subunits in West Virginia. Critical habitat is referred to as “occupied” or “unoccupied” based on its status at the time of species listing. Approximately 67 skm (42 smi) within two of the five subunits (Pinnacle Creek and Clear Fork) were considered occupied at the time of listing and represented all known extant populations in 2016. The Service determined three subunits (Guyandotte River, Indian Creek, and Huff Creek) of unoccupied critical habitat (covering 68 skm [42 smi]) were essential because the two occupied subunits did not provide sufficient resiliency, representation, or redundancy for the species (87 FR 14664).

1.3.4 Review History

This review constitutes the first formal status review of the Guyandotte River crayfish since the species’ listing in 2016.

1.3.5 Species Recovery Priority Number at Start of 5-Year Review

The Guyandotte River crayfish was assigned a recovery priority number of 5C on a scale of 1C (highest) to 18C (lowest) in the Recovery Outline (U.S. Fish and Wildlife Service (USFWS) 2018b). The ranking scale is based on the degree of threat, degree of conflict with construction, other development or other economic activity (denoted by the “C”), recovery potential, and taxonomy (48 FR 43098-43105, 48 FR 51935).

1.3.6 Recovery Plan or Outline

A recovery plan for the Guyandotte River crayfish has yet to be completed, but the Recovery Outline for the Guyandotte River Crayfish and Big Sandy Crayfish (Service 2018b) established the Service’s recovery vision for the species. Although subject to change, the recovery outline provides the following long-range targets: (1) multiple viable populations that are well distributed throughout the species’ historical range and in habitats that are managed and protected sufficiently to conserve the species, and (2) threats to the species, primarily modification and degradation of river and stream habitat from localized and watershed impacts, are sufficiently abated (Service 2018b). The strategy for meeting these targets includes providing sufficient representation, resiliency, and redundancy to ensure the species’ survival for the foreseeable future. The Service will further define what constitutes a viable population as recovery planning progresses. In general, populations should be self-sustaining, have stable or increasing numbers, demonstrate successful reproduction, and be sufficiently large and connected to other populations to withstand foreseeable threats. The Service will work with partners to prepare a recovery plan for this species and will refine these objectives and develop criteria that provide specific, measurable standards for recovery.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

Yes

No

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes

No

2.3 Updated Information and Current Species Status

Two subpopulations, both in Wyoming County, WV, occur in the indigenous range of the species: Pinnacle Creek and Clear Fork watershed. At the time of listing in 2016, the Guyandotte River crayfish was known to occur within approximately 4.8 skm (3.0 smi) in Pinnacle Creek, and 21.7 skm (13.5 smi) in the Clear Fork watershed, totaling 26.5 skm (16.5 smi) (Loughman 2015). Since 2016, surveys in both watersheds resulted in detections of the species beyond the previously recorded locations. In 2019, the species was found in new Clear Fork watershed locations approximately 8.6 skm (5.3 smi) upstream from the previously known most upstream Laurel Fork site and 1.2 skm (0.75 smi) upstream from the inlet Clear Fork site (Little Clear Fork; Tidmore 2020; figure 1). In 2021, surveys in Pinnacle Creek resulted in confirmation of the species in 11.3 skm (7.0 smi; WVDNR 2021b).

Additionally, in 2021, surveys in the mainstem of the Guyandotte River resulted in the capture of three adult Guyandotte River crayfish in locations that are within the species' historical range, but which were presumed to be unoccupied (figure 1). A nonreproductive adult male was captured in the mainstem directly next to the confluence with Pinnacle Creek, and both a female and a male were captured approximately 0.35 skm (0.21 smi) downstream from the confluence of the mainstem with Pinnacle Creek (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021; R. Aulick, U.S. Fish and Wildlife, Davis, WV; WVDNR 2021a).

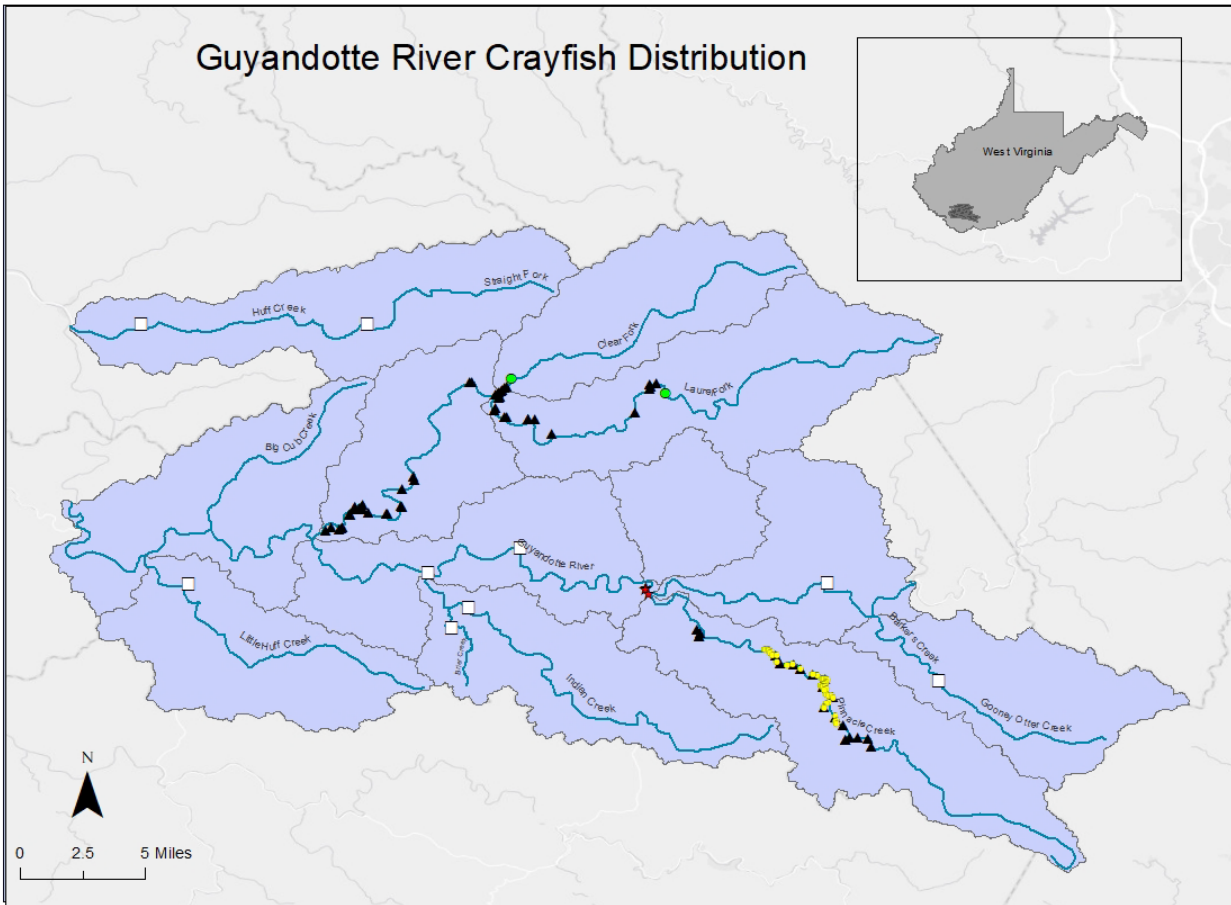


Figure 1. The updated Guyandotte River crayfish distribution map. New data since species listing in 2016 include 2019 and 2021 survey detections. The upper Guyandotte River watershed is sectioned into Hydrologic Unit Code 12 units (light gray lines outline these units in the map). White squares indicate sites where Guyandotte River crayfish was historically known but is now extirpated. Black triangles indicate the known extent of Guyandotte River crayfish occurrences at the time of listing in 2016. Green circles represent Guyandotte River crayfish occurrences in the Clear Fork inlet and Laurel Fork (Clear Fork watershed) discovered in 2019. Yellow circles represent 2021 Pinnacle Creek Guyandotte River crayfish occurrence data. Red stars represent 2021 new occurrence records for the Guyandotte River crayfish in the mainstem of the Guyandotte River.

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

New information on the biology and life history of the Guyandotte River crayfish has contributed to a greater understanding of the species' life history and ecology, habitat selection, movements, and status in Pinnacle Creek (Sadecky 2020; WVDNR 2021a; WVDNR 2021b).

Sadecky (2020) reported finding young of the year in both late fall and spring, suggesting a prolonged spawning window and egg release periods for the species (figure 2). Reproductively active female Guyandotte River crayfish select slab boulders closer to stream banks in late summer and fall when egg extrusion occurs (Sadecky 2020). This habitat selection likely allows crayfish to avoid faster velocity flows, which could increase egg loss. Eggs develop and hatch on the underside

of the female crayfish' abdomen and stay attached via a byssal thread until they have developed enough to become free-living. Once juveniles have developed the female Guyandotte River crayfish then selects slab boulders near the head of a riffle to help facilitate dispersal of young (Sadecky 2020). Juveniles tend to select habitat in shallows along the stream margin after dispersing from the female (Sadecky 2020).

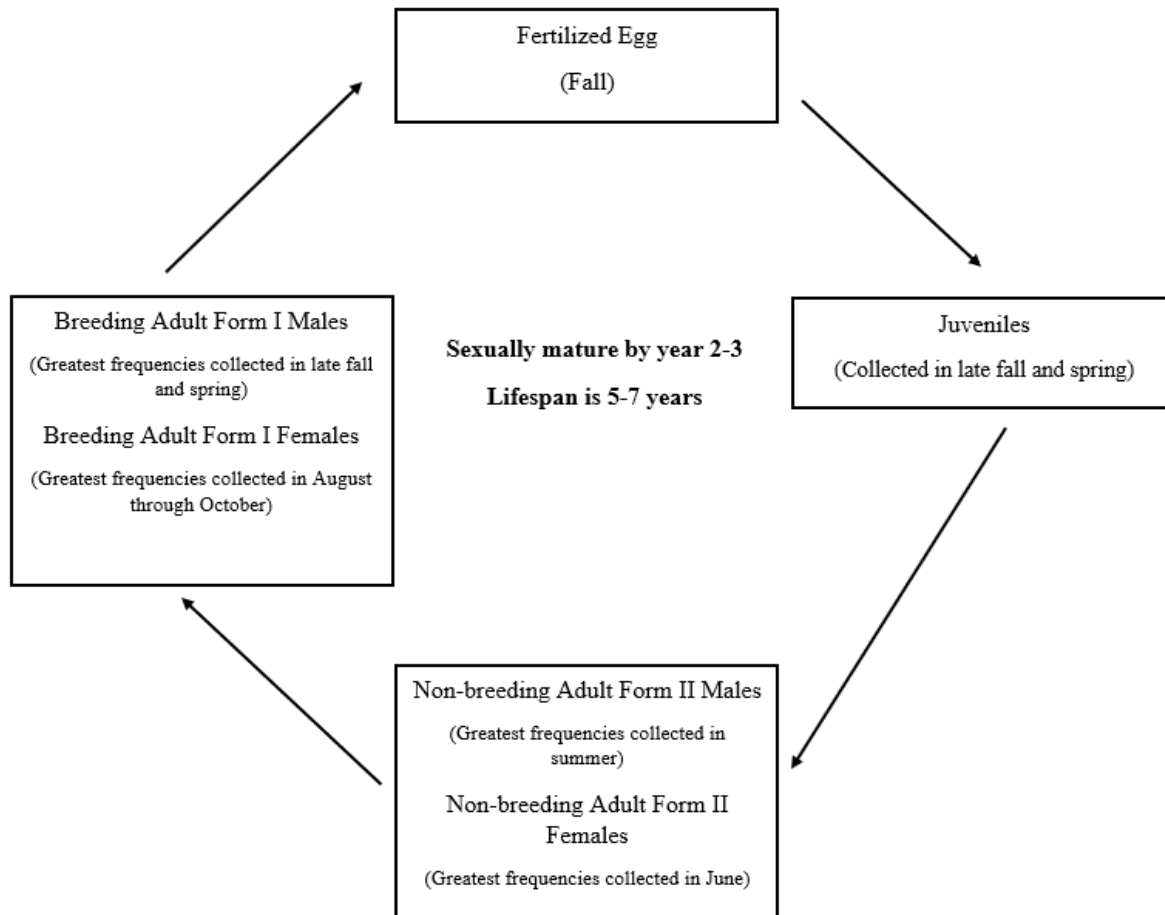


Figure 2: A description of the Guyandotte River crayfish life history cycle showing times of year for reproduction, mating, and changes from reproductive form to and from nonreproductive form (Sadecky 2020).

Reproductively inactive female and male Guyandotte River crayfish primarily selected slab boulders at the head of riffles, as well as runs that are closely associated with riffles (Sadecky 2020). Though much remains to be learned about the species' life history, this new information will help target habitat protection and restoration efforts.

2.3.1.2 Abundance, population trends, demographic features-and/or demographic trends:

Sampling efforts by WVDNR and university researchers have occurred yearly since the Guyandotte River crayfish was listed in 2016 (WVDNR 2021a). However, not all populations were sampled annually, and sampling efforts varied in intensity depending on survey objective (i.e., presence/absence survey, life history study), making it difficult to use the resulting information to calculate population abundances.

2.3.1.2.1 Clear Fork Watershed

New surveys since listing suggest the Clear Fork watershed subpopulation appears to be the more stable of the two subpopulations. The streams where Guyandotte River crayfish occur in the Clear Fork watershed consist of Laurel Fork, Little Clear Fork, and Clear Fork (WVDNR 2021a). Sadecky (2020) conducted surveys in all three streams from 2017 to 2019 and concluded that the Laurel Fork population is the most stable due to an abundance of suitable habitat, higher capture rates, and representation of all life history stages (Fig. 2).

2.3.1.2.2 Pinnacle Creek

In May 2021, a separate study of Pinnacle Creek assessed the condition of habitat and Guyandotte River crayfish population there (WVDNR 2021b). The objectives for the study included (1) assess Guyandotte River crayfish habitat quality in Pinnacle Creek; (2) determine whether the Pinnacle Creek Guyandotte River crayfish population persists and estimate population size; (3) document age and sex class structure; (4) provide information on individual condition; and (5) identify evidence of ongoing reproduction or lack thereof.

Approximately 11.3 skm (7.0 smi) of stream were surveyed over two days. Habitat quality in Pinnacle Creek was found to be poor due to the amount of sedimentation and embeddedness of available habitat (WVDNR 2021b). A total of 234 individual Guyandotte River crayfish were recorded during the survey (WVDNR 2021b). After adjusting for capture rate and accounting for areas not surveyed within the sample frame, the study estimated a minimum population size of 243 and a maximum population of 486 Guyandotte River crayfish for the entire Pinnacle Creek subpopulation (WVDNR 2021b). Pinnacle Creek contained multiple age classes of Guyandotte River crayfish (WVDNR 2021b), with a greater proportion of juveniles compared to the Clear Fork watershed subpopulation. Juvenile bias in Pinnacle Creek may indicate a) low survival of adults, and/or b) low transition rate of juveniles to adults (WVDNR 2021b). Alternatively, juvenile bias could be explained by the timing of the sampling period; 2021 sampling occurred in spring, which typically coincides with the stage in Guyandotte River crayfish life cycle when juveniles become free-living (Fig. 2; Sadecky 2020). Juvenile bias in Pinnacle Creek could be explained by a boom in reproductive success, but this seems unlikely because of the low numbers overall in the creek, including the number of adults (R. Aulick, U.S. Fish and Wildlife, Davis, WV, pers. obs. 2021).

Low numbers of adults affect the species' ability to maintain population numbers (WVDNR 2021b). Sex ratios in Pinnacle Creek were skewed towards males for both adults and juveniles. It is unclear how this will affect population viability in the long-term; however, lower female reproductive capacity is more likely than male reproductive capacity to limit population growth (WVDNR 2021b).

2.3.1.2.3 Mainstem Guyandotte River

In September 2021, two Guyandotte River crayfish were documented in the mainstem of the Guyandotte River (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021). An additional individual was documented in the mainstem of the Guyandotte River near the confluence with Pinnacle Creek in October 2021 (R. Aulick, U.S. Fish and Wildlife, Davis, WV pers. obs., 2021; figure 1). Loughman (West Liberty University, West Liberty, West Virginia, pers. comm., 2021) suggested that these individuals could have been transported from the Pinnacle Creek subpopulation during high water events.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding):

The Service's assessment at the time of listing suggested the two isolated remaining Guyandotte River crayfish subpopulations (Clear Fork watershed subpopulation and Pinnacle Creek subpopulation) are vulnerable to loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression and reducing the fitness of individuals. No new genetic information has become available since the species' listing. However, rangewide genetic sampling efforts occurred in October 2021 and data are currently being processed (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021).

2.3.1.4 Taxonomic classification or changes in nomenclature:

There have been no changes in nomenclature or taxonomic classification of the Guyandotte River crayfish since its listing as a full species in 2016.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors), or historical range (e.g., corrections to the historical range, change in distribution of the species within its historical range):

At the time of listing, Guyandotte River crayfish known occurrences were restricted to 21.7 skm (13.5 smi) in the Clear Fork watershed and 4.8 skm (2.9 smi) in Pinnacle Creek (Loughman 2015). Surveys since 2016 documented additional locations for Guyandotte River crayfish in Clear Fork, Laurel Fork, and Pinnacle Creek including 9.8 skm (6.05 smi) in the Clear Fork watershed, and 6.5 skm (4.0 smi) in Pinnacle Creek (Tidmore 2020; WVDNR 2021b; figure 1).

In 2021, the Guyandotte River crayfish was detected for the first time in the mainstem of the Guyandotte River near its confluence with Pinnacle Creek (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021) These new occurrence records are within the limits of designated unoccupied critical habitat (87 FR 14662-14719). The new occurrence records imply that the Guyandotte River crayfish can colonize new areas if habitat is available. This finding underscores the importance of maintaining and restoring habitat between existing subpopulations for the successful recovery of the species.

2.3.1.6 Habitat or ecosystem conditions:

In 2021, the Qualitative Habitat Evaluation Index (QHEI) was used to assess habitat quality in a seven-mile segment of Pinnacle Creek (WVDNR 2021b). QHEI values can range from "0" to "100," with "0" reflecting the worst and "100" the best (reference) stream conditions. A prior study by Loughman (2016) demonstrated that Guyandotte River crayfish presence was associated with high QHEI scores greater than 80. The 7 miles surveyed correspond with most of the Pinnacle Creek subpopulation's extent, but Guyandotte River crayfish were not documented in each survey reach. The mean QHEI value for the sampled stream reaches was 70.8. The lowest QHEI value for a reach was 34.5, and the highest was 88. Reaches with low QHEI values had high scores for sediment deposition and embeddedness. Several factors may be responsible for the excess sedimentation and embeddedness of riffle habitat in Pinnacle Creek: (1) the number of sediment input locations (e.g., trail crossings, slurry spills) and the severity of sediment release from those locations; (2) stream sinuosity and morphology; and (3) the legacy of historical impacts (WVDNR 2021b).

Indices for habitat quality have not been calculated for streams in the Clear Fork watershed. Laurel Fork, however, was selected as the stream for the life history study on the species due to its

abundance of riffle and run complexes and slab boulders, higher capture rates, and representation of all demographics (Sadecky 2020).

2.3.2 Five Factor Analysis

The following five-factor analysis describes and evaluates the threats attributable to one or more of the five listing factors outlined in the ESA, Section 4(a)(1). The purpose of a 5-year review is to recommend whether a listed taxon continues to warrant protection under the ESA and, if so, whether it should be reclassified (from threatened to endangered or from endangered to threatened). This requires that the analysis of the threats to the species be performed while assuming that the species is not receiving the regulatory protections, funding, recognition, and other benefits of ESA listing. Summaries of ongoing applications of ESA regulatory protections – e.g., section 7(a)(2) consultations – may shed light on additional activities that constitute threats to the species. The analysis under Factor D (Inadequacy of Existing Regulatory Mechanisms), however, focuses on the adequacy of *existing* non-ESA mechanisms to address the continuing and foreseeable threats – in other words how would the species fare if its protection under the ESA were removed.

The final listing rule described threats to the Guyandotte River crayfish to include: sedimentation and siltation from development; water quality degradation; habitat changes; isolation of populations; and direct habitat disturbance (81 FR 20472).

2.3.2.1 Factor A. Present or threatened destruction, modification or curtailment of its habitat or range:

Since the species was listed in 2016, habitat degradation and water quality stressors on the Guyandotte River crayfish have increased in Pinnacle Creek. Stressors such as offroad vehicle tourism, mining traffic, and chemical spills increase sedimentation and introduce harmful elements into the stream.

Offroad vehicle trail systems in southern West Virginia (including in Wyoming County) consist of over 1,000 miles designed specifically for offroad vehicle recreation. The Pinnacle Creek trails within these trail systems, are adjacent to one of the only remaining Guyandotte River crayfish occupied streams and encompass approximately 80 miles of trails. From 2020 to 2021, these trail systems had a forty-six percent increase in permit sales (Booth 2022). Offroad vehicles have been observed driving across and through Pinnacle Creek, which may alter habitat through substrate compaction and increased turbidity and may cause direct mortality of crayfish by crushing (R. Aulick, U.S. Fish and Wildlife, Davis, WV, pers. obs., 2021; Loughman pers. comm., 2021). This increase in stressors since listing may increase Pinnacle Creek subpopulation’s likelihood of extirpation.

A coal “slurry” spill occurred in Pinnacle Creek in 2018 that may have killed Guyandotte River crayfish at the spill site (Service 2018a). Surveys conducted after the spill recorded the species upstream and downstream of the initial area of the spill, but not at the site of the spill. In addition to the potential for direct mortality, coal “slurry” spills also degrade habitat and water quality.

Water quality is a general concern in both Clear Fork and Pinnacle Creek. The West Virginia Department of Environmental Protection (WVDEP) and U.S. Environmental Protection Agency (EPA) have recognized that neither Clear Fork or Pinnacle Creek have met water quality standards for aquatic life and have developed total maximum daily loads (TMDLs) for iron, selenium, and fecal coliform bacteria to regulate chemical and biological constituents in these streams (WVDEP 2020).

The species' range is restricted compared to its historical range, but no additional curtailment of its geographic range is known to have occurred since the species listing 2016. New information on species occurrences has expanded the species' current known locations within its historical distribution since listing. New detections in historically occupied streams where the species has since been presumed extirpated may indicate that the species can recolonize areas when suitable habitat is available.

2.3.2.2 Factor B. Overutilization for commercial, recreational, scientific, or educational purposes:

Overutilization is not known to be a threat to the species. Currently, the primary source of utilization is for scientific purposes focused on better understanding the species and planning for its recovery. Research activities have minimal potential to harm individuals through the removal of tissues for genetic analyses or crushing of individuals by foot traffic during survey efforts.

2.3.2.3 Factor C. Disease or predation:

There currently is no evidence that disease or predation is a significant threat to the species.

2.3.2.4 Factor D. Inadequacy of existing regulatory mechanisms:

Because the purpose of this 5-year review is to determine whether the Guyandotte River crayfish continues to warrant protection under the ESA, we focus here on the sufficiency of other (i.e., non-ESA) existing regulatory mechanisms to address the continuing and foreseeable threats discussed under factors A, B, C, and E, should the species not be listed under the ESA. Few existing Federal or State regulatory mechanisms specifically protect Guyandotte River crayfish or the aquatic habitats where it occurs. However, the species' habitat is afforded some protection from water quality and habitat degradation under the Federal Clean Water Act (CWA; 33 U.S.C. 1251 et seq.) and the Surface Mining Control and Reclamation Act of 1977 (SMCRA; 30 U.S.C. 1201 et seq.), respectively. State laws, such as the West Virginia Water Pollution Control Act (WVSC Sec. 22–11) and Logging and Sediment Control Act (WVSC Sec.19–1B) also provide limited protections for the species (81 FR 20473).

Clean Water Act

The CWA establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (CWA; 33 U.S.C. 1251 et seq.). Under the CWA, it is unlawful to discharge any pollutant from a point source into navigable waters, unless a permit is obtained under the National Pollutant Discharge Elimination system (NPDES) permit program (CWA; 33 U.S.C. 1251 et seq.). While the CWA regulates point source pollutants, non-point source pollutants, such as runoff from agricultural and residential lands, chemicals from urban runoff and energy production, and sediment from improperly managed development sites still degrade water quality and are difficult to regulate (EPA 2021).

The West Virginia Water Pollution Control Act

The West Virginia Water Pollution Control Act designates the West Virginia Office of Water Resources (OWR), within the West Virginia Division of Environmental Protection (WVDEP), as the water pollution control agency for the State. The WVDEP is authorized by statute to control pollution, conduct investigations, make arrests, execute warrants, issue orders, issue certifications required under the Federal Clean Water Act, and enforce the State environmental protection acts.

While some limited protection may be conferred to the crayfish under the state's enforcement of the Federal CWA, this Act is insufficient in reducing sedimentation and pollution from offroad vehicle usage in and around Pinnacle Creek, one of the last remaining populations of Guyandotte River crayfish.

Surface Mining Control and Reclamation Act

Per federal regulations at 50 CFR 780.16 that partially govern the process for surface coal mining permit applications under the Surface Mining Control and Reclamation Act (SMCRA), WVDEP permit applicants must submit a protection and enhancement plan (PEP) with species specific protective measures when their projects may affect the Guyandotte River crayfish. The intent of these measures is to “minimize disturbances and adverse impacts” to federally listed species during lawful mining activity [Service 2020; 30 CFR 780.16(b)].

As a federally endangered species, the Guyandotte River crayfish is afforded greater protection under SMCRA; if the species was not listed under the ESA, regulations under SMCRA would arguably be less effective in limiting habitat degradation. Under SMCRA regulations at 30 CFR 780.16(a) each application must include “site-specific resource information necessary to address” listed species, “habitats of unusually high value for fish and wildlife such as important streams”, and “other species or habitats identified through agency consultation as requiring special protection under State or Federal law.” The streams important to conservation of the Guyandotte River crayfish might receive special attention and be the subject of PEPs under these provisions even if the species were not listed – likewise if the WVDEP determined that the species warranted protection under these provisions in the absence of federal ESA listing. The species’ listing under ESA, however, guarantees that applicants address it and its habitat’s protection and enhancement in mining applications and their associated PEPs. Moreover, the terms and conditions of the incidental take statement provided with the 2020 Biological Opinion (BO) issued to the U.S. Office of Surface Mining Reclamation and Enforcement (OSMRE) under SMCRA, provide additional avenues to help ensure effective coordination between the Service, the state regulatory authority, and the Office of Surface Mining Reclamation and Enforcement with the intention of minimizing the effects of incidental take of the species that would occur.

SMCRA, as implemented, however, has not adequately alleviated all mining-related stressors to the species. Legacy effects from reclaimed mines and abandoned mine lands, which are prevalent in watersheds important to the Guyandotte River crayfish, contribute to the continuing degradation of water quality. Studies show that conductivity, sulfate, and aluminum levels are higher in watersheds with reclaimed mine lands, and these levels are increased as the areal extent of the affected land is increased (Hopkins II 2013). Abandoned mine lands that have not been reclaimed have similar legacy effects but have the potential to allow more harmful constituents, in comparison, due to the lack of vegetation to filter sediments from entering waterways (EPA 2021).

Logging and Sediment Control Act

The purpose of the Logging and Sediment Control Act (WVSC Sec.19–1B) act is to protect and maintain forest, water, and site productivity by minimizing soil erosion from areas disturbed during timber harvesting operations. This act requires the implementation of best management practices and

helps reduce sediment and other constituents from entering water ways during logging operations. Information regarding the effectiveness of this Act on Guyandotte River crayfish is unknown.

Summary

While these regulatory mechanisms are intended to help improve overall water quality, they are not sufficient to alleviate the threats to the species. Neither Clear Fork nor Pinnacle Creek have met water quality standards for aquatic life and TMDLs for iron, selenium, and fecal coliform bacteria have been established for some streams to regulate chemical and biological constituents (WVDEP 2020). Research is needed to understand thresholds of certain constituents (heavy metals associated with high conductivity) that the Guyandotte River crayfish can withstand. Without this information, it will be difficult to determine if water quality standards are sufficiently protective of the species. Finally, no regulatory mechanisms are in place that help abate water quality degradation, caused by offroad vehicle usage, and this is an especially important issue for the Pinnacle Creek subpopulation.

2.3.2.5 Factor E. Other natural or manmade factors affecting its continued existence:

The Intergovernmental Panel on Climate Change (IPCC) concluded that the evidence for warming of the global climate system is unequivocal (IPCC 2013). 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). An increasingly large body of scientific research indicates climate change poses a significant threat to a variety of species and ecosystems (Thomas et al. 2004; Byers and Norris 2011; IPCC 2014, Chapter 4), with freshwater ecosystems being considered especially vulnerable to the direct effects of climate change, such as altered thermal regimes and altered precipitation and flow regimes (IPCC 2014).

Temperatures in West Virginia have increased by one degree Fahrenheit since the beginning of the 20th century. Unprecedented warming is also projected during this century, with increases in heat wave intensity and decreases in cold wave intensity. Total precipitation has increased since 1900, with greater overall precipitation and more intense precipitation events projected to occur during winter and spring. Along with these more intense, prolonged precipitation events, droughts are expected to occur more frequently due to temperature-caused increases in the rate of soil moisture loss during dry spells (Runkle et al. 2022).

Climatic changes could pose a threat to the Guyandotte River crayfish by increasing the frequency and intensity of stochastic and catastrophic events. These events have the potential to directly affect habitat, as well as individual Guyandotte River crayfish. An increase in the frequency and duration of droughts in the summer may affect Guyandotte River crayfish by reducing dissolved oxygen, physically available habitat, and food sources during the Guyandotte River crayfish mating season (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022; A. Silvis, West Virginia Division of Natural Resources, Elkins, WV, pers. comm. 2022). Additionally, an increase in the intensity and frequency of flooding events will increase the amount of pollutants entering the stream, as well as increase substrate embeddedness (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022; A. Silvis, West Virginia Division of Natural Resources, Elkins, WV, pers. comm. 2022). An increase in pollutants has the potential to disrupt important life history events, such as molting and reproduction, and increased substrate embeddedness will reduce the amount of available habitat for Guyandotte River crayfish (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022; A. Silvis,

West Virginia Division of Natural Resources, Elkins, WV, pers. comm. 2022). Prolonged droughts and an increase in high water events may ultimately reduce the recruitment of juvenile Guyandotte River crayfish as climate change progresses.

Climatic changes have the potential to shift important life history events for the Guyandotte River crayfish (Sadecky 2020). *Faxonius obscurus*, a Cambarid crayfish native to the upper Ohio River drainage, was observed releasing eggs in early March after a long warm spell – egg extrusion generally occurs in April for this species. Shortly after the warm spell, a cold front occurred; females entered a diapause, a water mold began to form on the egg masses and the eggs eventually died, ultimately reducing juvenile recruitment rates for that year (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2022). Unlike the Guyandotte River crayfish, most *Faxonius* crayfish are “r” selected species, meaning they produce many young and have the potential to recover populations more easily after adverse stochastic and catastrophic events (Aulick 2020; Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022). Guyandotte River crayfish have a much more restricted range and have fewer young compared to *Faxonius* crayfish, making them even more susceptible to extinction if these events occur.

2.4 Synthesis

The distribution of the Guyandotte River crayfish was restricted to the Clear Fork and Pinnacle Creek watersheds at the time of listing in 2016. In 2021, however, three individuals were recorded beyond the known areas when the species was listed in the mainstem of the Guyandotte River below the confluence of Pinnacle Creek and the Guyandotte River (Loughman, West Liberty University, West Liberty, West Virginia, pers. comm., 2021). This suggests that the Guyandotte River crayfish may recolonize areas if suitable habitat is present. These new detections may indicate an increase in the species’ redundancy since listing, but the species remains in danger of extinction throughout all or a significant portion of its range due to ongoing threats and its still-limited distribution.

The limited habitat in which the Guyandotte River crayfish occurs, and the isolation of the remaining sub-populations makes the species vulnerable to the identified ongoing threats as well as stochastic and catastrophic events. Primary threats to the Guyandotte River crayfish throughout its range are land-disturbing activities that increase erosion and sedimentation and decrease overall water and stream habitat quality. Identified sources of ongoing erosion and sedimentation that occur throughout the range of the species include active surface coal mining, timber harvesting, unpaved roads, gas and oil development, road construction, offroad vehicle recreation, and stream modifications that cause channel instability (81 FR 20466). These threats are expected to continue or increase into the future.

Both extant subpopulations of Guyandotte River crayfish are expected to decline in the future, with the possibility of extinction if actions to ameliorate habitat loss and degradation are not implemented effectively. In particular, the Pinnacle Creek subpopulation may have a greater chance of extirpation in the near-term due to the intensity of sediment loads into the creek and crushing by offroad vehicles (R. Aulick, U.S. Fish and Wildlife, Davis, WV, pers. obs., 2021; Loughman, West Liberty University, West Liberty, West Virginia, pers. comm. 2022; WVDNR 2021b). For both subpopulations, sediment inputs will continue to degrade Guyandotte River crayfish habitat by eliminating interstitial spaces between habitat and the substrate. The elimination of habitat due to

sedimentation will decrease the overall diversity and abundance of resources available to the Guyandotte River crayfish.

Based on our review of the status of the species, information regarding threats to the species throughout its range, we recommend that the species remain listed as “endangered.”

3.0 RESULTS

3.1 Recommended Classification:

Downlist to Threatened

Uplist to Endangered

Delist (*Indicate reasons for delisting per 50 CFR 424.11*):

Extinction

Recovery

Original data for classification in error

No change is needed

3.2 New Recovery Priority Number: The Guyandotte River crayfish’s priority number of 5C indicates it is a full species (as opposed to a subspecies) exposed to a high degree of threat, with a low potential for recovery. There is the potential for conflict with existing land uses for the crayfish throughout its range (e.g., mining, ATV trails, residential development). The high degree of threat is based on the pervasive and imminent nature of the threats throughout the species’ current range. Both remaining isolated subpopulations are threatened by instream disturbance, habitat and water quality degradation, and catastrophic events such as spills. Recovery potential is considered low because the species' biological and ecological limiting factors are poorly understood, the threats are difficult to alleviate, and mitigating these threats will require intensive management and development of new techniques. Therefore, the recovery priority number of 5C remains valid.

RECOMMENDATIONS FOR FUTURE ACTIONS

Recovery efforts should focus on gaining cooperation to prevent disturbances and degradation of streams where the Guyandotte River crayfish exists; restoring habitat in the upper Guyandotte watershed; identifying all areas of potential habitat with high quality stream survey techniques; further investigating potential causes of species declines; conducting additional research on the species to address key information gaps, such as life history and water quality parameters (thresholds) that are necessary to support viable populations of the species; developing a spill prevention and remedial action plans; and developing captive holding/propagation techniques. It will be particularly important to avoid actions that could (1) result in mortality or injury to the species, (2) reduce reproduction or recruitment of young into populations, (3) increase stress to remaining individuals in the wild, or (4) alter habitats such that survival or reproduction is reduced. Especially critical is the protection of Guyandotte River crayfish populations within Pinnacle Creek and Clear Fork.

Progress has been made on several of these components, and the Service recommends continued efforts on these tasks as a Recovery Plan is developed.

The primary recommendation is for the Service to engage partners across West Virginia and develop a draft Recovery Plan, complete with detailed, prioritized recovery actions. A Recovery Implementation Strategy should be developed and kept current through regular updates.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the GUYANDOTTE RIVER CRAYFISH (*Cambarus veteranus*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable

REGIONAL OFFICE APPROVAL

Approve SHARON MARINO  Digitally signed by SHARON MARINO
Date: 2023.08.18 14:40:30 -04'00'

Assistant Regional Director, Ecological Services