FEDERAL REGISTER

Vol. 80 Tuesday,

No. 66 April 7, 2015

Part II

Department of the Interior

Fish and Wildlife Service

50 CFR Part 17

Endangered and Threatened Wildlife and Plants; Endangered Species Status for the Big Sandy Crayfish and the Guyandotte River Crayfish; Proposed Rule

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

[Docket No. FWS–R5–ES–2015–0015; 4500030113]

RIN 1018–BA85

Endangered and Threatened Wildlife and Plants; Endangered Species Status for the Big Sandy Crayfish and the Guyandotte River Crayfish

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Proposed rule; 12-month finding and status review.

SUMMARY: We, the U.S. Fish and Wildlife Service (Service), announce a 12-month finding on a petition to list the Big Sandy crayfish (known at the time of the petition as *Cambarus veteranus,* but now known as two distinct species: Guyandotte River crayfish, *C. veteranus,* and Big Sandy crayfish, *C. callainus*) as endangered or threatened under the Endangered Species Act, as amended (Act), and to designate critical habitat. After review of the best available scientific and commercial information, we find that listing the Big Sandy crayfish and the Guyandotte River crayfish is warranted. Accordingly, we propose to list both the Big Sandy crayfish (*C. callainus*), a freshwater crustacean from Kentucky, Virginia, and West Virginia, and the Guyandotte River crayfish (*C. veteranus*), a freshwater crustacean from West Virginia, as endangered species under the Act. If we finalize this rule as proposed, it would extend the Act's protections to both species and would add both species to the Federal List of Endangered and Threatened Wildlife. The Service seeks data and comments from the public on this proposed listing rule.

DATES: We will accept comments received or postmarked on or before June 8, 2015. Comments submitted electronically using the Federal eRulemaking Portal (see **ADDRESSES**, below) must be received by 11:59 p.m. Eastern Time on the closing date. We must receive requests for public hearings, in writing, at the address shown in **FOR FURTHER INFORMATION CONTACT** by May 22, 2015.

ADDRESSES: You may submit comments by one of the following methods:

(1) *Electronically:* Go to the Federal eRulemaking Portal: *http://www.regulations.gov.* In the Search box, enter FWS–R5–ES–2015–0015, which is the docket number for this rulemaking. Then, in the Search panel on the left side of the screen, under the Document Type heading, click on the Proposed Rules link to locate this document. You may submit a comment by clicking on ''Comment Now!''

(2) *By hard copy:* Submit by U.S. mail or hand-delivery to: Public Comments Processing, Attn: FWS–R5–ES–2015–0015; U.S. Fish and Wildlife Service, MS: BPHC, 5275 Leesburg Pike, Falls Church, VA 22041–3803.

We request that you send comments only by the methods described above. We will post all comments on *http://www.regulations.gov.* This generally means that we will post any personal information you provide us (see *Public Comments* below for more information).

FOR FURTHER INFORMATION CONTACT: Martin Miller, Chief, Endangered Species, U.S. Fish and Wildlife Service, Northeast Regional Office, 300 Westgate Center Drive, Hadley, MA 01035; telephone 413–253–8615; facsimile 413–253–8482. Persons who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 800–877–8339.

SUPPLEMENTARY INFORMATION:

Executive Summary

Why we need to publish a rule. Under the Act, if we find that a species may be an endangered or threatened species throughout all or a significant portion of its range, we are required to promptly publish a proposed rule to list the species in the **Federal Register** and make a final determination on our proposal within 1 year. Critical habitat shall be designated, to the maximum extent prudent and determinable, for any species determined to be an endangered or threatened species under the Act. Listing a species as an endangered or threatened species and designations and revisions of critical habitat can only be completed by issuing a rule.

This document consists of:

- Our 12-month finding that listing is warranted for the petitioned Big Sandy crayfish.
- Our status review finding that listing is warranted for the nonpetitioned Guyandotte River crayfish.
- A proposed rule to list the Big Sandy crayfish (*Cambarus callainus*) and the Guyandotte River crayfish (*C. veteranus*) as endangered species.

The basis for our action. Under the Act, we may determine that a species is an endangered or threatened species based on any of five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. We have determined that the Big Sandy crayfish and Guyandotte River crayfish are in danger of extinction primarily due to the threats of land-disturbing activities that increase erosion and sedimentation, which degrades the stream habitat required by both species (Factor A), and the effects of small population size (Factor E).

We will seek peer review. We will seek comments from independent specialists to ensure that our listing determination is based on scientifically sound data, assumptions, and analyses. We will invite these peer reviewers to comment on our listing proposal. Because we will consider all comments and information we receive during the comment period, our final determinations may differ from this proposal.

Information Requested

Public Comments

We intend that any final action resulting from this proposed rule will be based on the best scientific and commercial data available and be as accurate and as effective as possible. Therefore, we request comments or information from other concerned governmental agencies, Native American tribes, the scientific community, industry, or any other interested parties concerning this proposed rule. We particularly seek comments concerning:

(1) The Big Sandy and Guyandotte River crayfishes' biology, ranges, and population trends, including:

(a) Biological or ecological requirements of these species, including habitat requirements for feeding, breeding, and sheltering.

(b) Genetics and taxonomy.

(c) Historical and current ranges, including distribution and abundance patterns, and quantitative evidence of the species' occurrence, especially in lower elevation sites within the known watersheds.

(d) Historical and current population levels and current and projected population trends.

(e) Past and ongoing conservation measures for these species, their habitats, or both.

(2) Factors that may affect the continued existence of these species, which may include habitat modification or destruction, overutilization, disease, predation, the inadequacy of existing

regulatory mechanisms, or other natural or manmade factors. Particularly:

(a) Information regarding current conditions and future trends of managing residential and commercial wastewater and how those conditions and trends may affect the Big Sandy and Guyandotte River crayfishes.

(b) Information on total number of stream miles monitored within the Big Sandy and Upper Guyandotte watershed for compliance with Clean Water Act of 1977 (CWA; 33 U.S.C. 1251 *et seq.*).

(c) Quantitative water quality parameters (*e.g.,* conductivity) at historical and current Big Sandy and Guyandotte River crayfish occurrence and sampling sites.

(d) Trends in Big Sandy and Guyandotte River crayfish population estimates or abundance as it relates to water quality parameters.

(3) Biological, commercial trade, or other relevant data concerning any threats (or lack thereof) to these species and existing regulations that may be addressing those threats.

(4) Additional information concerning the historical and current status, range, distribution and abundance, and population size of each of these species, including the locations and habitat conditions of any additional populations.

(5) Information concerning dispersal mechanisms and distances for these species.

(6) Locations of likely suitable habitat where previously unknown populations of either species may occur.

(7) Information related to climate change within the ranges of the Big Sandy and Guyandotte River crayfish and how it may affect the species' habitat.

(8) The reasons why areas should or should not be designated as critical habitat as provided by section 4 of the Act (16 U.S.C. 1531 *et seq.*), including the possible risks associated with publication of maps designating any area on which these species may be located, now or in the future, as critical habitat.

(9) The following specific information on:

(a) The amount and distribution of habitat for the Big Sandy and Guyandotte River crayfishes.

(b) What areas, that are currently occupied and that contain the physical and biological features essential to the conservation of these species, should be included in a critical habitat designation and why.

(c) Special management considerations or protection that may be needed for the essential features in potential critical habitat area, including managing for the potential effects of climate change.

(d) What areas not occupied at the time of listing are essential for the conservation of these species and why.

Please include sufficient information with your submission (such as scientific journal articles or other publications) to allow us to verify any scientific or commercial information you include.

Please note that submissions merely stating support for or opposition to the action under consideration without providing supporting information, although noted, will not be considered in making a determination, as section 4(b)(1)(A) of the Act directs that determinations as to whether any species is an endangered or threatened species must be made "solely on the basis of the best scientific and commercial data available."

You may submit your comments and materials concerning this proposed rule by one of the methods listed in the **ADDRESSES** section. We request that you send comments only by the methods described in the **ADDRESSES** section.

If you submit information via *http://www.regulations.gov,* your entire submission—including any personal identifying information—will be posted on the Web site. If your submission is made via a hardcopy that includes personal identifying information, you may request at the top of your document that we withhold this information from public review. However, we cannot guarantee that we will be able to do so. We will post all hardcopy submissions on *http://www.regulations.gov.*

Comments and materials we receive, as well as supporting documentation we used in preparing this proposed rule, will be available for public inspection on *http://www.regulations.gov,* or by appointment, during normal business hours, at the U.S. Fish and Wildlife Service, Northeast Regional Office (see **FOR FURTHER INFORMATION CONTACT**).

Public Hearing

Section 4(b)(5) of the Act provides for one or more public hearings on this proposal, if requested. Requests for a public hearing must be received within 45 days after the date of publication of this proposed rule in the **Federal Register**. Such requests must be sent to the address shown in the **FOR FURTHER INFORMATION CONTACT** section. We will schedule public hearings on this proposal, if any are requested, and announce the dates, times, and places of those hearings, as well as how to obtain reasonable accommodations, in the **Federal Register** and local newspapers at least 15 days before the hearing.

Peer Review

In accordance with our joint policy on peer review published in the **Federal Register** on July 1, 1994 (59 FR 34270), we will seek the expert opinions of three appropriate and independent specialists regarding this proposed rule. The purpose of peer review is to ensure that our listing determination is based on scientifically sound data, assumptions, and analyses. The peer reviewers have expertise in freshwater crayfish biology, habitat, or stressors to crayfish and their habitat. We will invite comment from the peer reviewers during this public comment period.

Previous Federal Action

We identified the Big Sandy crayfish, then known as *Cambarus veteranus,* as a Category 2 species in the November 21, 1991, notice of review titled Animal Candidate Review for Listing as Endangered or Threatened Species (56 FR 58804). Category 2 candidates were defined as species for which we had information that proposed listing was possibly appropriate, but conclusive data on biological vulnerability and threats were not available to support a proposed rule at the time. The species remained a Category 2 species in our November 15, 1994, candidate notice of review (59 FR 58982). In the February 28, 1996, candidate notice of review (61 FR 7596), we discontinued the designation of Category 2 species as candidates; therefore, the Big Sandy crayfish was no longer a candidate species.

In 2010, the Center for Biological Diversity (CBD) petitioned the Service to list 404 aquatic, riparian, and wetland species from the southeastern United States under the Act. On September 27, 2011, the Service published a substantial 90-day finding for 374 of the 404 species, including what was then known as the Big Sandy crayfish (*Cambarus veteranus*), soliciting information about, and initiating status reviews for, those species (76 FR 59836). In 2012, CBD filed a complaint against the Service for failure to complete a 12-month finding for the Big Sandy crayfish within the statutory timeframe. In 2013, the Service entered into a settlement agreement with CBD to address the complaint; the court-approved settlement agreement specified a 12-month finding for the Big Sandy crayfish would be delivered to the **Federal Register** by April 1, 2015.

Since the settlement agreement, we received information indicating that the Big Sandy crayfish is two separate species (see the *Taxonomy* section, below): the Big Sandy crayfish

(*Cambarus callainus*) and the Guyandotte River crayfish (*C. veteranus*). Although the settlement agreement specified that we must make a 12-month finding for *C. veteranus,* the Service chose to conduct a status review, and subsequently prepare a proposed listing rule, for both *C. veteranus* and *C. callainus.* As discussed below, we will propose to designate critical habitat for the Big Sandy crayfish and Guyandotte River crayfish under the Act in the near future.

Background

Taxonomy

The crayfish subspecies *Cambarus bartonii veteranus* was first described in 1914 by Faxon (1914, pp. 389–390) from specimens collected from Indian Creek in Wyoming County, West Virginia, in 1900. Hobbs (1955, p. 330) later elevated the taxon to species-level, referring to the animal as *Cambarus veteranus.* In 1969, Hobbs described several new *Cambarus* subgenera and reclassified the species as *C. (Puncticambarus) veteranus* (Hobbs 1969, p. 102).

From the late 20th century until 2011, *Cambarus veteranus* was thought to occur in two disjunct river systems, the Upper Guyandotte basin in West Virginia, from where it was originally described, and the upper tributaries of the Big Sandy basin in eastern Kentucky, southwestern Virginia, and southern West Virginia, from where it has been known since 1989 (Hobbs 1989, pp. 27–28). In 2011, a genetic comparison of extant specimens from the Upper Guyandotte and Big Sandy populations found significant genetic divergence between the two populations, indicative of possible species-level differences (Fetzner 2011, pp. 8–10, 25). Later, Thoma *et al.* (2014, entire) conducted the first physical comparison of all known, intact, museum specimens (292 specimens from the Big Sandy basin and 32 from the Upper Guyandotte) and noted significant morphological characteristics that distinguish the two populations. Based on the previous genetic evidence and the diagnostic morphological differences noted between specimens from the two river basins, Thoma *et al.* (2014, entire) recommended that the Big Sandy basin population be recognized as a new species, *Cambarus (Puncticambarus) callainus.*

We have carefully reviewed the peer-reviewed genetic and taxonomic information referenced above and conclude that the crayfish from the Big Sandy basin formerly thought to be *Cambarus veteranus* is a new, valid taxon, *Cambarus callainus.* The crayfish native to the Upper Guyandotte basin remains *C. veteranus* because the scientific name is linked with the type specimen. Additionally, Thoma *et al.* (2014, p. 551) proposed the common name ''Big Sandy crayfish'' be allied to the newly recognized species *C. callainus,* and that *C. veteranus,* which is endemic to the Upper Guyandotte system, be referred to as the ''Guyandotte River crayfish.'' We will follow this naming convention herein and for clarity ascribe the appropriate species and common names when discussing information from older studies that did not distinguish between the two species.

Species Description

Cambarus callainus, the Big Sandy crayfish, and *C. veteranus,* the Guyandotte River crayfish, are freshwater, tertiary burrowing crustaceans of the Cambaridae family. Tertiary burrowing crayfish do not exhibit complex burrowing behavior; instead, they shelter in shallow excavations under loose cobbles and boulders on the stream bottom. The two species are closely related and share many basic physical characteristics. Adult body lengths range from 75.7 to 101.6 millimeters (mm) (3.0 to 4.0 inches (in)), and the cephalothorax (main body section) is streamlined and elongate, and has two well-defined cervical spines. The elongate convergent rostrum (the beak-like shell extension located between the crayfish's eyes) lacks spines or tubercles (bumps). The gonopods (modified legs used for reproductive purposes) of Form I males (those in the breeding stage) are bent 90 degrees to the gonopod shaft (Loughman 2014, p. 1). Diagnostic characteristics that distinguish the Big Sandy crayfish from the Guyandotte River crayfish include the former's narrower, more elongate rostrum; narrower, more elongate chelea (claw); and lack of a well-pronounced lateral impression at the base of the claw's immovable finger (Thoma *et al.* 2014, p. 551).

Carapace (shell) coloration ranges from olive brown to light green, and the cervical groove is outlined in light blue, aqua, or turquoise. The rostral margins and post orbital (behind the eye) ridges are crimson red. The abdominal terga (dorsal plates covering the crayfish's abdomen) range from olive brown to light brown to light green and are outlined in red. The walking legs of the Guyandotte River crayfish are blue, while those of the Big Sandy crayfish range from light green to green blue to green. Chelae of the Guyandotte River crayfish range from blue green to light blue, while those of the Big Sandy crayfish are usually aqua but sometimes green blue to blue (Loughman 2014, p. 1–2; Thoma *et al.* 2014, p. 547).

Life History and Habitat

Reproduction

Thoma (2009, entire; 2010, entire) reported demographic and life-history observations for the Big Sandy crayfish in Virginia and Kentucky. Based on these observations and professional expertise, he concluded that the general life cycle pattern of the species is 2 to 3 years of growth, maturation in the third year, and first mating in midsummer of the third or fourth year. Following midsummer mating, the annual cycle involves egg laying in late summer or fall, spring release of young, and late spring/early summer molting. He hypothesized the likely lifespan of the Big Sandy crayfish to be 5 to 7 years, with the possibility of some individuals reaching 10 years of age. Of 60 Big Sandy crayfish juvenile and adult specimens collected, Loughman (2014, p. 20) noted 5 total carapace length (TCL) size cohorts—8.0 to 19.0 mm (0.31 to 0.75 in); 32.0 to 35.0 mm (1.26 to 1.38 in); 36.0 to 43.0 mm (1.42 to 1.69 in); 44.0 to 49.0 mm (1.73 to 1.93 in); and 51.0 to 53.0 mm (2.01 to 2.09 in), indicating at least 6 molts likely occurred over an individual's lifetime after the first year of life. The smallest Form I male was 25.1 mm (0.99 in) TCL; the smallest ovigerous (egg-carrying) female was 42.0 mm (1.65 in) TCL.

In Virginia, Thoma (2009, p. 4) reported the presence of males, females, and juveniles during all months sampled (March and May through October). The author noted Form I males and females cohabiting under rocks in July, presumably in some stage of mating, with ovigerous females reported in July, August, and October and females carrying instars (larval crayfish) in September, October, and March (the March observation indicating that late spawning females may overwinter with instars attached). Two ovigerous females with TCLs of 42 mm (1.65 in) and 46 mm (1.81 in) were observed with 90 and 142 eggs, respectively (Thoma 2009, p. 4). Thoma (2010, pp. 3, 5) reported males, females, and juveniles in both months sampled (July and September) in Kentucky, with ovigerous females reported in September.

There is less information available specific to the life history of the Guyandotte River crayfish, but based on other shared characteristics with the Big Sandy crayfish, we conclude the life span and age to maturity are similar.

Jezerinac *et al.* (1995, p. 170) noted demographic information for the species in the months surveyed (April and June through September), reporting that Form II (the nonreproductive phase) males were present in all months sampled and were the dominant demographic. Form I males were found in April, July, and August. No ovigerous females were collected by Jezerinac *et al.* (1995, entire); however, Loughman (2014, p. 20) collected a female in June 2009, and maintained the specimen live in the laboratory. It extruded eggs the following month. Loughman also noted females carrying instars in March, just as Thoma (2009, p. 4) had reported for some Big Sandy crayfish females. Loughman also observed that females carrying instars sought out slab boulders in loose, depositional sands and silts in stream reaches with slower velocities (Loughman 2014, p. 20). Loughman examined all known Guyandotte River crayfish museum specimens (n=41) and determined five TCL size cohorts—13 to 17 mm (0.51 to 0.67 in); 22 to 23 mm (0.87 to 0.91 in); 28 to 32 mm (1.10 to 1.26 in); 34 to 38 mm (1.34 to 1.50 in); and 42 to 49 mm (1.65 to 1.93 in), with a mean TCL of 31.0 mm (1.22 in) (Loughman 2014, p. 20).

Diet

Thoma (2009, pp. 3, 13) conducted a feeding study using 10 Big Sandy crayfishes collected from Virginia. Each animal was offered a variety of food items, and observations were made daily to monitor consumption. The test period was 1 week, and each animal was tested twice. The food items offered represented the following broad categories: insect, fish, worm, crayfish, root, nut, herbaceous plant, fruit, and leaf litter. Results indicated that the Big Sandy crayfish had a preference for animal tissue. In each test, animal matter was always consumed first; however, plant material was at least partially consumed in most trials. Thoma concluded that the species was best classified as a carnivore (Thoma 2009, p. 13). However, Loughman (2014, p. 21) reviewed field studies of other tertiary burrowing *Cambarus* species, which indicated that crayfish filling the ecological niche similar to that of the Big Sandy and Guyandotte River crayfish functioned as opportunistic omnivores, with seasonal-mediated tendencies for animal or plant material. Loughman (2014, p. 20) concluded that under natural conditions the Big Sandy and Guyandotte River crayfish likely exhibit similar omnivorous tendencies.

Habitat

Habitat requirements for these two closely related species appear to be similar in their respective, separate river basins. The Big Sandy crayfish is known only from the Big Sandy River basin in eastern Kentucky, southwestern Virginia, and southern West Virginia; the Guyandotte River crayfish is known only from the Guyandotte River basin in southern West Virginia (Figure 1). Both the Big Sandy and the Guyandotte Rivers flow in a northerly direction where they each join the Ohio River.

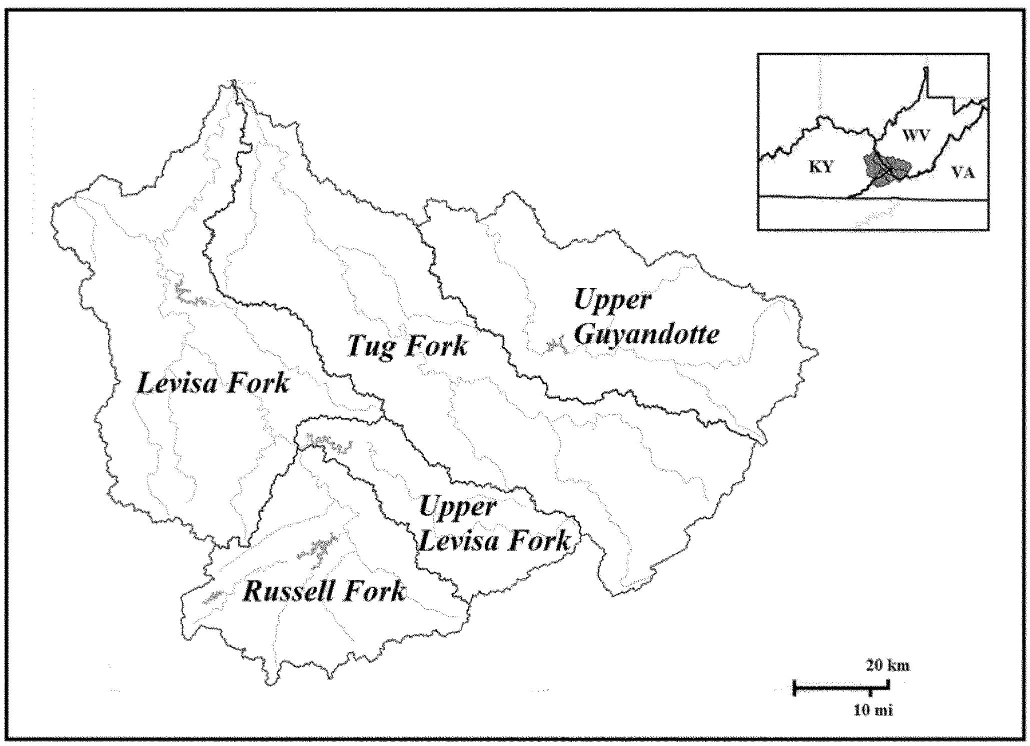

Figure 1.—The Big Sandy crayfish is native to the Tug Fork, Levisa Fork, upper Levisa Fork, and Russell Fork watersheds in the Big Sandy River basin. The Guyandotte River crayfish is native to the Upper Guyandotte watershed in the Guyandotte River basin.

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Both river basins are in the Appalachian Plateaus physiographic province, which in this region is characterized by rugged, mountainous terrain with steep hills and ridges dissected by a network of deeply incised valleys (Ehlke *et al.* 1982, pp. 4, 8; Kiesler *et al.* 1983, p. 8). Geologically, the area is underlain primarily by sandstones, siltstones, shales, and coals (Ehlke *et al.* 1982, p. 1; Kiesler *et al.* 1983, p. 8). The dominant land cover in the two basins is forest, with the natural vegetation community being characterized as mixed mesophytic (moderately moist) forest and Appalachian oak forest (McNab and Avers 1996, section 221E).

Suitable instream habitat for both species is generally described as clean, third order or larger (width of 4 to 20 meters (m) (13 to 66 feet (ft))), fast-flowing, permanent streams and rivers with unembedded slab boulders on a bedrock, cobble, or sand substrate (Channell 2004, pp. 21–23; Jezerinac *et al.* 1995, p. 171; Loughman 2013, p. 1; Loughman 2014, pp. 22–23; Taylor and Shuster 2004, p. 124; Thoma 2009, p. 7; Thoma 2010, pp. 3–4, 6). Jezerinac *et al.* (1995, p. 170) found that specimens were more abundant in pools with current than in riffles. Loughman (2013, p. 1; Loughman and Welsh 2013, p. 23) noted that all historical Guyandotte River crayfish locations originally maintained rocky substrates with abundant slabs and boulders, which is supported by the watershed's geomorphology and available habitat descriptions from early survey efforts. Loughman (2013, p. 2) characterized the Guyandotte River crayfish as ''a habitat specialist primarily associated with slab boulders in the immediate up and downstream margins of fast moving riffles.'' However, some information indicates adult and juvenile Big Sandy crayfish, and presumably Guyandotte River crayfish, may use different microhabitats within the more generalized stream parameters described above. In Dry Fork (upper Tug Fork drainage, McDowell County, West Virginia), a stream described as having characteristics approaching those of a headwater stream, lacking both fast velocity and deep riffles (Loughman 2014, pp. 9–11), adult Big Sandy crayfish specimens were captured from under slab boulders in the midchannel, fast-moving waters of riffles and runs, while juvenile Big Sandy crayfish were limited to smaller cobbles and boulders in the shallow, slower velocity waters near stream banks. Loughman (2014, pp. 9–11) notes that this habitat partitioning between age classes has been observed in other Cambarus species.

Jezerinac *et al.* (1995, p. 170) noted that all occurrences of the Big Sandy and Guyandotte River crayfishes occurred above 457 m (1,500 ft) elevation. However, our analyses of both species' location data (both pre- and post-Jezerinac *et al.* 1995) show that all known occurrences of the Big Sandy crayfish occurred from about 180 to 500 m (600 to 1,640 ft) elevation, and all known occurrences of the Guyandotte River crayfish occurred from about 230 to 520 m (750 to 1,700 ft) elevation.

Both species also appear to be intolerant of excessive sedimentation and other pollutants. This statement is based on observed habitat characteristics from sites that either formerly supported either the Big Sandy or Guyandotte River crayfish or from sites within either of the species' historical ranges that were predicted to be suitable for the species, but where neither of the species (and in some cases no crayfish from any species) were observed (Channell 2004, pp. 22–23; Jezerinac *et al.* 1995, p. 171; Loughman 2013, p. 6; Thoma 2009, p. 7; Thoma 2010, pp. 3–4). See Summary of Factors Affecting the Species for additional information.

Summary of Habitat—Suitable habitat for both the Big Sandy crayfish and the Guyandotte River crayfish appears to be limited to higher elevation, clean, medium-sized streams and rivers in the upper reaches of the Big Sandy and Upper Guyandotte basins, respectively. Both species are associated with the faster moving water of riffles and runs or pools with current. An important habitat feature for both species is an abundance of large, unembedded slab boulders on a sand, cobble, or bedrock stream bottom. Excessive sedimentation appears to create unsuitable conditions for both the Big Sandy and the Guyandotte River crayfishes.

Species Distribution and Status

Historical Range and Distribution

Results from multiple crayfish surveys dating back to 1900 and a 2014 examination of all existing museum specimens indicate that the historical range of the Guyandotte River crayfish is limited to the Upper Guyandotte River basin in West Virginia and that the historical range of the Big Sandy crayfish is limited to the upper Big Sandy River basin in eastern Kentucky, southwest Virginia, and southern West Virginia. Within these larger river basins, the two species were apparently more narrowly distributed to certain stream reaches that exhibited the habitat characteristics required by the species, as discussed in the previous section. Evidence of each species' historical distribution is presented below.

Guyandotte River crayfish—Specimens collected from Indian Creek in the Upper Guyandotte basin in Wyoming County, West Virginia, in 1900 were the basis for the Guyandotte River crayfish's initial description (Faxon 1914, pp. 389–390), and additional collections in the basin in 1947, 1953, and 1971 confirmed the species' presence in Wyoming County and added a new record in Logan County, West Virginia (Jezerinac *et al.* 1995, p. 170; Loughman 2014, p.5). From 1987 to 1989, Jezerinac *et al.* (1995, p. 170) conducted a Statewide survey of the crayfish of West Virginia, and devoted considerable sampling effort to the Upper Guyandotte basin (Logan, McDowell, Mingo, and Wyoming Counties, West Virginia). Jezerinac *et al.* (1995, p. 170) sampled 13 of the 15 known Guyandotte River crayfish locations (as well as 42 other potentially suitable sites) in the Upper Guyandotte basin and documented the species at only two of the known historical locations (a single Wyoming County site and the Logan County site) and reported a new occurrence in Wyoming County (Jezerinac *et al.* 1995, p. 170). A 2001 survey of the 15 historical locations in the Upper Guyandotte system failed to locate the species at any site (Channell 2004, pp. 16–21; Jones *et al.* 2010 entire).

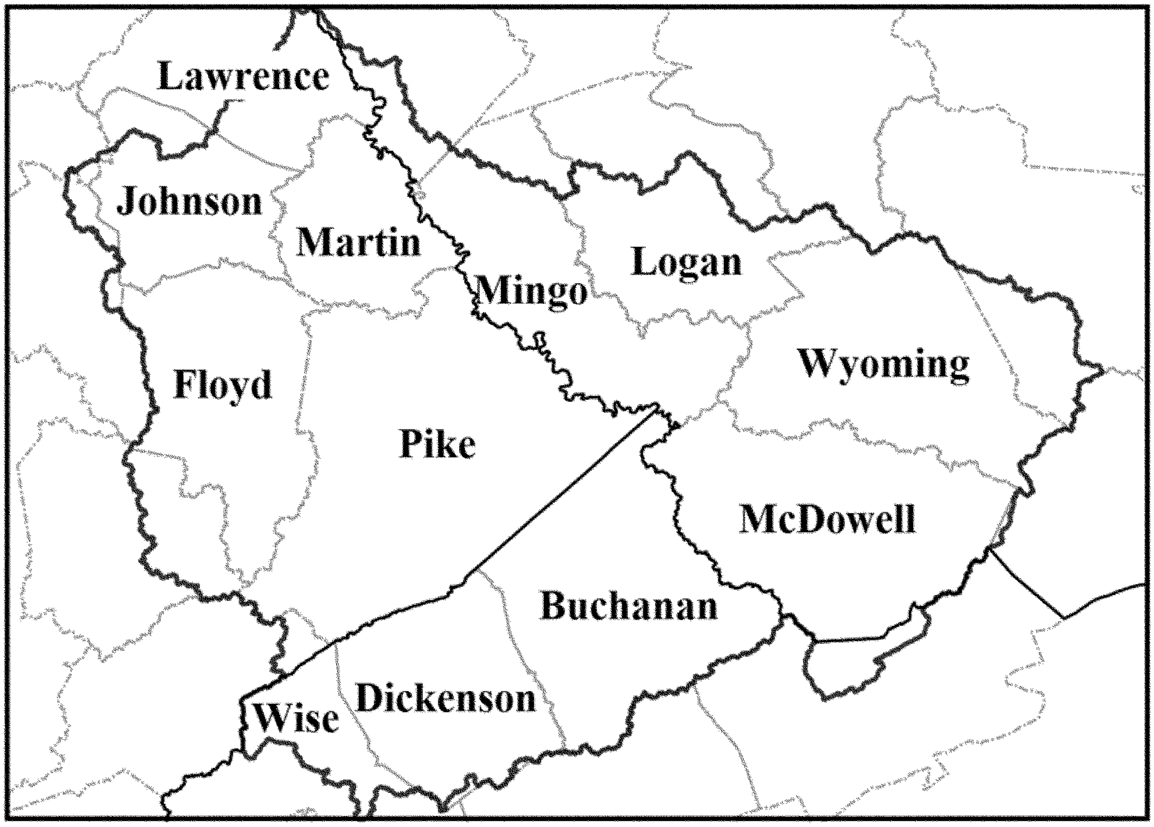

Figure 2.—Counties within the historical ranges of the Big Sandy and Guyandotte River crayfishes.

Big Sandy crayfish—Records of the Big Sandy crayfish in the Virginia portions of the Big Sandy basin date to 1937, with a specimen collected from the Russell Fork drainage in Dickenson County. A series of surveys conducted in 1950 confirmed the species' presence in Dickenson County and added an occurrence in Buchanan County, Virginia. Surveys in 1998–99 collected specimens from several locations in Dickenson County and added a new occurrence record for Buchanan County (Loughman 2014, pp. 14–15). In 2001, Channell (2004, pp. 21–23) confirmed the presence of the species in the Levisa Fork drainage in Buchanan and Dickenson Counties.

Prior to Thoma (2009, entire), little information exists regarding the species' status in Kentucky. The earliest reference of the species was Hobbs (1969, pp. 134–135), who provided no specific collection records but did provide a shaded range map including portions of the Levisa Fork, Russell Fork, and Tug Fork basins as part of the species' range. A survey of the region by the U.S. National Museum in 1972–74 did not record the species' presence (Loughman 2014, p. 11). The first confirmed specimens from Kentucky were collected in 1991, from two locations in the Russell Fork in Pike County, and in 1998, another survey confirmed the species' presence in this river (Loughman 2014, p. 11). In 1999, the species was found in the Levisa Fork in Floyd County, and in 2002, the species was found in Knox Creek (Tug Fork drainage) in Pike County (Loughman 2014, p. 11). Based on his best professional judgment, Thoma (2010, p. 6) concludes that prior to the widespread habitat degradation in the region (see Summary of Factors Affecting the Species—Factor A), the species likely occupied suitable streams throughout the basin, from the Levisa Fork/Tug Fork confluence to the headwaters. Evidence that the species once occupied suitable habitat down to the Levisa Fork/Tug Fork confluence is also provided by Fetzner and Thoma (2011, pp. 9–10), who found that the pattern of certain genetic markers in Big Sandy crayfish specimens collected from the now isolated Russell Fork, Levisa Fork, and Tug Fork watersheds indicate that the species once had a significantly larger range than it currently occupies. In his 2014 report describing the species, Thoma *et al.* (2014, p. 12) reported the species as endemic to the Levisa Fork, Tug Fork, and Russell Fork watersheds in the upper Big Sandy basin.

There are three known occurrences of the Big Sandy crayfish in West Virginia, all occurring in 2009 or later and from McDowell County (Loughman 2014, pp. 9–11). See the *Current Range and Distribution* section below for additional information.

Erroneous or Dubious Records

Collections of crayfish specimens from the region are held at the United States National Museum, Eastern Kentucky University, Ohio State University, West Liberty University, and the Virginia Department of Game and Inland Fisheries. Several vouchered specimens in some of these collections were labeled as *Cambarus veteranus* and were reported to have originated from river basins other than the Upper Guyandotte or Big Sandy. Upon further examination these were found to be erroneous or dubious records. Jezerinac *et al.* (1995, p. 170) examined specimens identified as *C. veteranus* collected from the Greenbrier, Little

Kanawha, and Elk River basins in 1948, and determined that they were misidentified *C. robustus* and *C. elkensis.* Subsequent analysis of these specimens by Loughman (2014, p. 16) determined that the Greenbrier River specimens were actually *C. smilax* and that the Elk River specimens were in fact Big Sandy crayfish (*C. callainus*) (identification based on the morphological characteristics described previously). However, Loughman (2014, p. 16) questioned the recorded origin of this collection, noting that the Elk River and Big Sandy basins are separated by hundreds of stream kilometers and that thorough sampling in the Elk River basin by Jezerinac *et al.* (1995, pp. 170–171) and Loughman and Welsh (2013, p. 64) were negative for the species. Both Loughman and Jezerinac *et al.* (1995) surmise that neither *C. veteranus* nor *C. callainus* is native to the Elk River basin (Loughman 2014, p. 16).

Also questionable are specimens collected in 1900, reportedly from Crane Creek in the New River basin in Mercer County, West Virginia. While Loughman (2014, p. 17) did confirm that these specimens are Big Sandy crayfish (*Cambarus callainus*), he concluded that the collection location was likely not ''Crane Creek'' in the New River system, but the identically named ''Crane Creek'' in McDowell County, West Virginia, part of the Big Sandy River basin. Loughman (2014, p. 17) notes that several surveys of the New River's Crane Creek (Jezerinac *et al.* 1995, p. 170; Loughman and Welsh 2013, p. 64) confirmed the presence of other *Cambarus* species in this creek, indicating habitat conditions were favorable for the genus, but failed to produce any Big Sandy crayfish. In Loughman's best professional judgment, the species is not native to the New River basin (Loughman 2014, p. 17).

The Virginia Department of Game and Inland Fisheries possesses a collection of specimens from the New River Watershed that were originally identified as *Cambarus veteranus;* these specimens were later determined by Thoma to be misidentified and are actually *C. sciotensis* (Loughman 2014, p. 17).

Taylor and Shuster (2004) report a single 1967 *Cambarus veteranus* collection from the Kentucky River basin in Estill County, Kentucky. However, subsequent survey efforts in the area have been negative for *C. veteranus* and *C. callainus.* In addition, the Kentucky River basin has no direct connectivity with either the Big Sandy or Upper Guyandotte River basins—the mouths of the Kentucky River and the Big Sandy River are separated by more than 230 kilometers (km) (143 miles (mi)) of the Ohio River mainstem and the mouth of the Guyandotte River is separated by about 255 km (158 mi). Therefore, the authors concluded that the Estill County record was dubious.

After reviewing the best available information, we conclude that the historical range of the Guyandotte River crayfish (*Cambarus veteranus*) is limited to the Upper Guyandotte River basin in West Virginia, including Wyoming County and parts of Logan and Mingo Counties. We conclude that the historical range of the Big Sandy crayfish (*C. callainus*) is limited to the upper Big Sandy River basin (Levisa Fork, Tug Fork, and Russell Fork watersheds) in eastern Kentucky (Pike and Floyd Counties where the species has been confirmed, and perhaps Johnson, Martin, and Lawrence Counties based on the watershed boundary and stream connectivity), southwestern Virginia (Buchanan and Dickenson Counties and parts of Wise County), and southern West Virginia (McDowell and Mingo Counties).

Current Range and Distribution

The best available scientific information indicates that both the Guyandotte River crayfish and the Big Sandy crayfish initially occurred in suitable stream habitat throughout their respective historical ranges (Loughman, pers. comm., October 24, 2014; Thoma 2010, p. 10; Thoma *et al.* 2014, p. 2). However, by the late 1800s, commercial logging and coal mining in the region had begun to severely alter the landscape and affect the streams and rivers (Eller 1982, pp. 93–111, 128–162). These widespread and intensive timber and mining enterprises, coupled with rapid human population growth that led to increased development in the narrow valley riparian zones, sewage discharges, road construction, and similar activities throughout both the Big Sandy and the Upper Guyandotte basins, degraded the aquatic systems and apparently extirpated both crayfish species from many subwatersheds within much of their respective historical ranges (discussed below in Summary of Factors Affecting the Species). The best available information on each species' current range and distribution, based on survey data collected since 2004, is presented below.

Guyandotte River crayfish—The current range of the Guyandotte River crayfish appears to be limited to the midreach of a single stream, Pinnacle Creek, in Wyoming County, West Virginia (Figure 3). In 2001, targeted sampling of the 9 streams (15 individual sites) where the species had previously been confirmed failed to produce the species (Channell 2004, pp. 17–18), and it was theorized that the species might be extirpated from West Virginia (Jones *et al.* 2010, entire). In 2009, considerable sampling effort was dedicated toward assessing the species' status in West Virginia with 30 likely sites being sampled in the Upper Guyandotte basin. Thirteen of these sites were historical locations, and the remaining 17 sites were randomly and nonrandomly selected sites meeting the basic habitat characteristics for the species (*e.g.,* size, gradient, bottom substrate) (Loughman 2013, pp. 4–5). This effort succeeded in collecting two specimens from one of the historical locations, Pinnacle Creek (Loughman 2013, pp. 5–6). In 2011, Loughman (2014, p.10) returned to the Pinnacle Creek site and collected five specimens. In 2014, Loughman (2014, pp. 10–11) surveyed a different downstream location at Pinnacle Creek but was unable to confirm the species' presence; he was not able to survey the historical Pinnacle Creek site during this 2014 effort because of time constraints. See Table 1a for all known stream occurrences of the species.

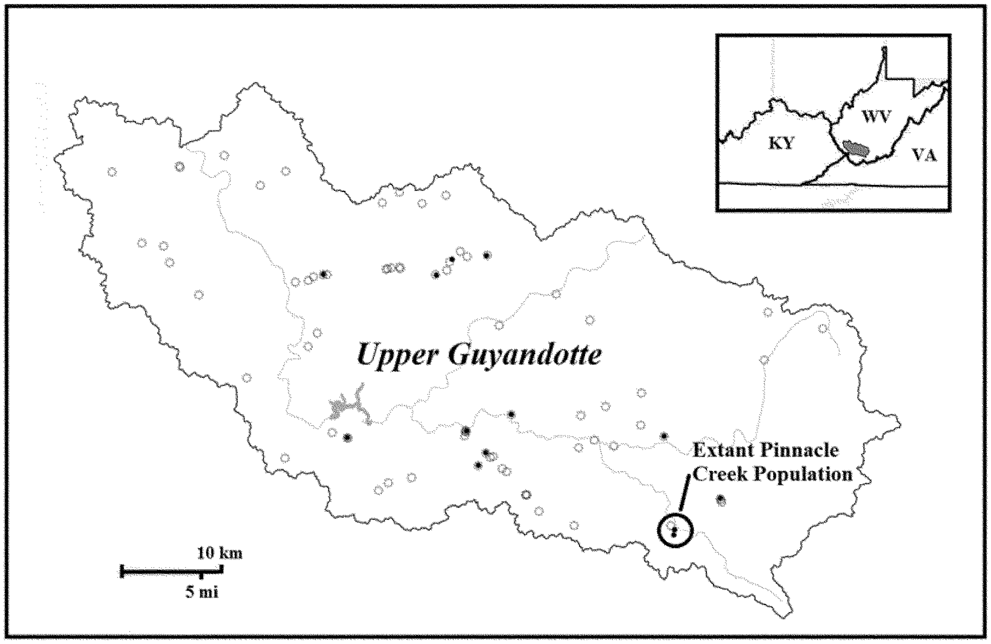

Figure 3.—Survey history for the Guyandotte River crayfish (1988 to 2014). The open (clear) circles indicate likely suitable sites that were surveyed but were negative for the species. The closed (dark) circles indicate known historical locations; however, all but one of these occurrences has been negative for the species since the mid-20th century. The large circle indicates the extant Pinnacle Creek population.

Table 1a.—All known stream occurrences of the Guyandotte River crayfish (some streams may have multiple survey locations). An asterisk indicates that the surveyed location is different than the earlier location.

Watershed	Stream	State	County	1st Detected	Last Detected	Last Surveyed
Upper Guyandotte	Indian Creek	WV	Wyoming	1900	1900	2009
Upper Guyandotte	Little Indian Creek	WV	Wyoming	1900	1900	1989
Upper Guyandotte	Barkers Creek	WV	Wyoming	1947	1947	2009
Upper Guyandotte	Brier Creek	WV	Wyoming	1947	1947	2001
Upper Guyandotte	Still Run	WV	Wyoming	1947	1947	2001
Upper Guyandotte	Turkey Creek	WV	Wyoming	1947	1947	2001
Upper Guyandotte	Huff Creek	WV	Logan	1953	1953	2009
Upper Guyandotte	Little Huff Creek	WV	Wyoming	1971	1971	2009
Upper Guyandotte	Huff Creek	WV	Wyoming	1989	1989	2009
Upper Guyandotte	Pinnacle Creek	WV	Wyoming	1989	2011	2014*

Table 1b.—All known stream occurrences of the Big Sandy crayfish (some streams may have multiple survey locations). An asterisk indicates that the surveyed location is different than the earlier location.

Watershed	Stream	State	County	1st Detected	Last Detected	Last Surveyed
Russell Fork	Prater Creek	VA	Dickenson	1937	2008	2008
Russell Fork	McClure River	VA	Dickenson	1950	2008*	2008
Russell Fork	Russell Fork	KY	Pike	1997	2012	2012
Russell Fork	Barts Lick	VA	Dickenson	1998	1998	1998
Russell Fork	Cranes Nest River	VA	Dickenson	1998	2008	2008
Russell Fork	Hurricane Creek	VA	Buchanan	1998	1998	1998
Russell Fork	Lick Creek	VA	Dickenson	1998	2008*	2008
Russell Fork	Middle Fork	VA	Dickenson	1998	1998	1998
Russell Fork	Open Fork	VA	Dickenson	1998	2014	2014
Russell Fork	Roaring Fork	VA	Dickenson	1998	1998	2007
Levisa Fork	Levisa Fork	KY	Floyd	1999	2009	2009
Tug Fork	Knox Creek	KY	Pike	2002	2009*	2009
Russell Fork	Russell Fork	VA	Dickenson	2006	2008*	2008
Upper Levisa Fork	Dismal Creek	VA	Buchanan	2007	2009*	2009
Russell Fork	Pound River	VA	Dickenson	2007	2007	2007
Russell Fork	Birchfield Creek	VA	Wise	2008	2008	2008
Levisa Fork	Levisa Fork	KY	Pike	2009	2009	2009
Levisa Fork	Shelby Creek	KY	Pike	2009	2012	2012
Russell Fork	Elkhorn Creek	KY	Pike	2009	2009	2009
Tug Fork	Blackberry Creek	KY	Pike	2009	2009	2009
Tug Fork	Peter Creek	KY	Pike	2009	2009	2009
Tug Fork	Dry Fork	WV	McDowell	2011	2014*	2014
Tug Fork	Tug Fork	WV	McDowell	2011	2011	2011

Big Sandy crayfish—In 2009 and 2010, Thoma (2010, p. 6) conducted a survey of likely Big Sandy crayfish locations to determine the range of the species in Kentucky, sampling sites in Pike (n=15), Floyd (n=10), and Martin (n=2) Counties. The Big Sandy crayfish was confirmed at 10 sites in Pike County and 1 in Floyd County. Broken down by watershed, of the 18 likely sites sampled in the Levisa Fork portion of the basin, the species was found at 8 sites; 2 in the mainstem of the Levisa Fork, 3 in Shelby Creek, 3 in Russell Fork, and 1 in Elkhorn Creek. In the Tug Fork portion of the Big Sandy basin, eight likely sites were surveyed, with the species being confirmed at single sites in three tributary streams near their respective confluences with the mainstem of the Tug Fork (Figure 4).

In 2007 and 2012, the Kentucky Division of Water (KDOW; 2014) noted two occurrences of the Big Sandy crayfish in Pike County, Kentucky. In 2007, the species was reported in the Russell Fork near the Virginia border, the same area from which the species was reported in 1991 and 1998 (as discussed previously). In 2012, the species was again confirmed at this location and at a site in Shelby Creek, from where the species was known since Thoma's 2009 survey work (discussed above).

From 2007 to 2009, Thoma (2009, pp. 2, 10) conducted a comprehensive survey of the Big Sandy River basin of Virginia and confirmed the species' continued presence in Buchanan and Dickenson Counties, and added a new occurrence in Wise County. Buchanan County is drained primarily by the Levisa Fork tributary system; however, the southwestern portion of the county is drained by the Russell Fork system, and a section of the north portion is drained by the Tug Fork system. Thoma sampled 16 likely Big Sandy crayfish sites in the Levisa Fork system in Buchanan County and found the species at 5 sites, all in a single stream, Dismal Creek. One site was sampled in the Tug Fork drainage of Buchanan County, but the species was not found. In the Russell Fork drainage of Buchanan, Dickenson and Wise Counties, the Big

Sandy crayfish was noted at 16 of the 24 sites surveyed. Thoma also reported the species' presence in the Russell Fork system in Buchanan County, finding the species at both of the sites sampled. However, it is important to note that two of the streams (the Pound River and Cranes Nest River) that were positive for the species (at five individual sites) are physically isolated from each other and from the remainder of the Russell Fork (and wider) system by the Flannagan Dam and Reservoir (completed in 1964). In October 2014, the Virginia Department of Transportation (VDOT) surveyed a site in the Open Fork (Russell Fork system) in Dickenson County and confirmed the presence of the Big Sandy crayfish at that location (VDOT 2014, entire).

In 2009, Loughman (2014, pp. 8–11) surveyed 22 likely sites in the upper Tug Fork basin in McDowell and Mingo Counties, West Virginia, with the species being found at 1 site in Dry Fork. This was the first observation of the species in the West Virginia section of the Big Sandy basin. In 2011, Loughman confirmed the species' presence at the Dry Fork site and reported a new occurrence in the Tug Fork mainstem. In 2014, Loughman again confirmed the species' presence at the Dry Fork site and reported a new location 25.8 km (16.0 mi) farther upstream in the Dry Fork. This is the farthest upstream occurrence in the Tug Fork drainage of West Virginia (Loughman 2014, p. 11). See Table 1b for all stream occurrences of the Big Sandy crayfish.

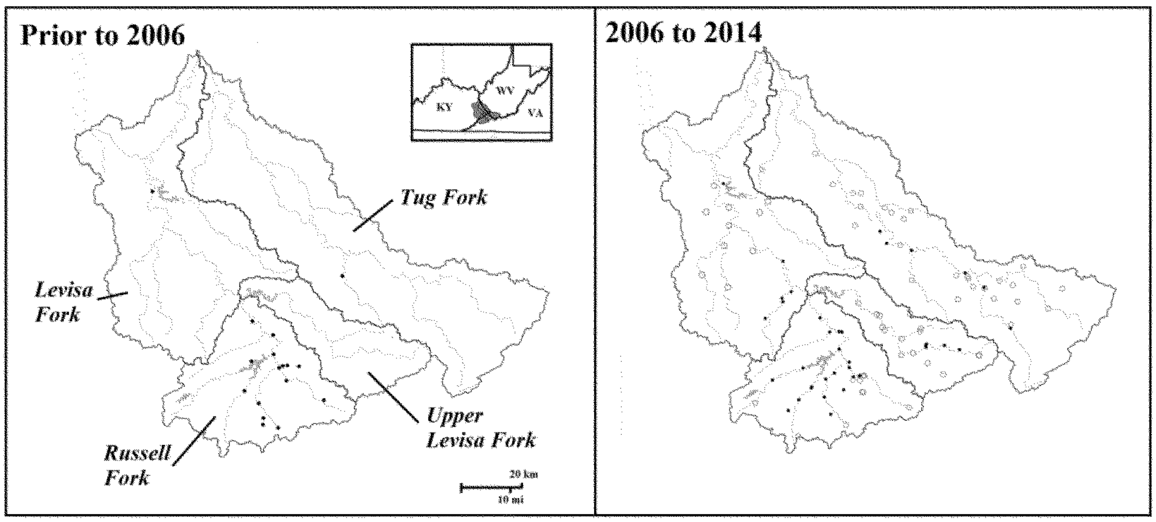

Figure 4.—Survey history for the Big Sandy crayfish. The map on the left shows historical occurrences of the species (closed dark circles). The map on the right shows the results of surveys conducted between 2006 and 2014. The open (clear) circles indicate likely suitable sites that were surveyed but were negative for the species. The closed (dark) circles indicate sites where the species was present. This map does not show locations in Kentucky that were surveyed where no crayfish of any species could be found or sites that were not surveyed due to unsuitable habitat conditions.

Population Estimates and Status

Data to inform a rangewide population estimate for either the Big Sandy crayfish or the Guyandotte River crayfish are sparse, but historical evidence, observations from existing healthier sites, and expert opinion suggest that, prior to the significant land-disturbing activities that began in the late 1800s (see Summary of Factors Affecting the Species—Factor A), these species were the dominant tertiary burrowing crayfish occupying the previously described habitat type throughout their respective ranges (Loughman, pers. comm., October 24, 2014; Thoma 2010, p. 10). Loughman (pers. comm., October 24, 2014) surmises that, within each suitable stream reach (*e.g.,* the riffles and runs of third order or larger streams with a sand, gravel, or bedrock substrate and abundant unembedded slab boulders), each large slab boulder in midstream likely harbored an adult specimen. This is based on his observations of the population densities of similar stream-dwelling *Cambarus* species, historical accounts, and the results of Thoma's (2009) surveys for *C. callainus* in Virginia. It is also reasonable to conclude based on the historical range of each species, that the instream habitat conditions (including an absence of physical obstacles such as dams) were once conducive to the movement of individuals between subpopulations or to the colonization (or recolonization) of unoccupied sites. This movement (via downstream drift or active upstream migration) has been documented in other stream crayfish (Kerby *et al.* 2005, p. 407; Momot 1966, pp. 158–159), and contributes to the genetic diversity of the species and the flexibility of individuals to occupy or abandon different sites as environmental conditions change.

Guyandotte River crayfish—While the collection methods and level of effort is not described for the early surveys, it is notable that on August 16, 1900, a researcher visited the Upper Guyandotte River and was able to collect 25 Guyandotte River crayfish specimens from Indian Creek and 15 specimens from Little Indian Creek in Wyoming

County, West Virginia (Faxon 1914, p. 390; Loughman 2014, p. 5). These sites are approximately 5 km (3 mi) apart, indicating the historical relative abundance of the species and providing an indication of the historical ''catch per unit effort'' (CPUE) discussed in detail below. A subsequent survey of Indian Creek in 1947 produced six specimens, and since that time, no single site in the Upper Guyandotte basin has produced more than five individual specimens during a survey.

The best available information indicates that, of the nine streams where the Guyandotte River crayfish had previously been confirmed, it persists in only one: Pinnacle Creek. The R.D. Bailey Dam (completed in 1980) and Lake, on the Guyandotte River near the town of Justice, West Virginia, physically isolates two of the streams with historical records of the species (Huff Creek and Little Huff Creek) from the remaining seven subwatersheds known to have harbored the species, including Pinnacle Creek. The species was confirmed in Little Huff Creek in 1971, and Huff Creek in 1989 (Jezerinac *et al.* 1995, p. 170), and while survey efforts in 2001 and 2009 failed to find the species in either creek, Loughman did remark that unlike most streams in the basin, in 2009 Huff Creek appeared to have habitat conducive to the species (Channell 2004, p. 17; Loughman 2013, pp. 5–6, 9).

Since 1978, four Pinnacle Creek sites have been surveyed for the species. One of these sites is located near the creek's confluence with the Guyandotte River, and the other three are located approximately 21 km (13 mi) upstream of this site. The three upstream sites are within about 1.6-km (1.0-mi) stream distance of each other and were surveyed in 1988, 2001, 2009, and 2011, with one, zero, two, and five individual Guyandotte River crayfish reported in each respective year (Channell 2004, pp. 16–17, Jezerinac *et al.* 1995, p. 170; Loughman, 2013, pp. 6–10). The site near the confluence was surveyed in 1978 and in 2014 but was negative for the species. In addition, during the 2014 survey, Loughman (2014, pp. 10–11) did not find crayfish of any species.

Big Sandy crayfish—In the Big Sandy basin of Virginia, Thoma (2009, p. 10) noted apparently healthy populations of the Big Sandy crayfish in the Russell Fork drainage in Dickenson and parts of Buchanan and Wise Counties. Of the 18 sites sampled in 8 individual streams that harbored the species, a total of 344 individuals were observed (an average of 19 individuals per site). Two of the occupied streams (Pound River and Cranes Nest River) (five individual sites) are physically isolated from each other and from the rest of the Russell Fork system (and remainder of the species' range) by the Flannagan Dam and Reservoir.

In the upper Levisa Fork drainage of Buchanan County, Virginia, the species was found only in a single stream: Dismal Creek. During separate sampling events in 2007, 2008, and 2009, 33 specimens were collected from 4 sites (3 to 12 individuals per site) in Dismal Creek. The upper Levisa Fork (including Dismal Creek) is physically isolated from the rest of the species' range by the Fishtrap Dam and Lake (completed in 1969), located on the Levisa Fork about 4.5 km (2.8 mi) upstream of the Levisa Fork-Russell Fork confluence in Kentucky.

In the Kentucky portion of the Big Sandy crayfish's range, Thoma (2010, p. 6) found the species in very low numbers (one to two individuals) at two sites in the lower portion of the Levisa Fork and described the population as stressed and in poor condition (Thoma 2010, p. 6). He also found the species in two tributaries to the Levisa Fork: Shelby Creek and Russell Fork. Specimens were collected at 3 sites in Shelby Creek, with the farthest downstream site producing 12 individuals and the farthest upstream site producing 4. The author described these populations as ''very healthy,'' but noted that the middle sampling site produced only two specimens. In the Russell Fork upstream of Shelby Creek, 7 specimens were collected from 1 site and 20 from another; this section was also described as a ''healthy'' population. Thoma did not detect the species in the mainstem of the Levisa Fork between Shelby Creek and the Virginia State line. However, the previously mentioned Fishtrap Dam and Lake makes much of this stretch of river unsuitable for the species and isolates the Big Sandy crayfish population in the lower Levisa Fork system from the upper reaches, including the only remaining population in Dismal Creek, Virginia.

In the Tug Fork drainage of Kentucky, Thoma (2010, p. 6) surveyed seven sites and confirmed the species in low numbers (one, three, and seven individuals) at three sites. Those sites that produced specimens were all located in tributary streams near their confluences with the Tug Fork mainstem. In 2009, Loughman and Welsh (as reported in Loughman 2014, pp. 8–11) surveyed 24 likely sites in the Tug Fork basin in West Virginia, and observed the species at one site, collecting three individuals from Dry Creek, an upper Tug Fork tributary. In 2011, Loughman returned to the area and, with the same level of sampling effort, recovered nine specimens from Dry Creek and eight individuals from a site in the Tug Fork mainstem. The Tug Fork site had produced zero specimens in 2009. In 2014, Loughman again confirmed the species' presence at the Dry Fork site, collecting 11 individuals, and reported a new occurrence 25.8 km (16.0 mi) farther upstream in the Dry Fork, where he collected seven individuals. See Tables 2a and 2b for a summary of the survey results for the Big Sandy crayfish (2006 to 2014) by watershed boundaries and by State boundaries.

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Tables 2a and 2b.—Summary of survey results for the Big Sandy crayfish (2006 to 2014). These results do not include otherwise suitable sites in Kentucky that were surveyed and no crayfish of any species were found or sites that were not surveyed due to unsuitable habitat conditions.

Table 2a.—Results by watershed boundaries

Watershed	Likely Sites Surveyed	Positive for *C. callainus*	Percent	Likey Streams Surveyed	Positive for *C. callainus*	Percent
Russell Fork	34	22	65%	14	9	64%
Levisa Fork	16	6	38%	9	2	22%
Upper Levisa Fork	19	6	32%	6	1	17%
Tug Fork	34	7	21%	21	5	24%
Cummulative	103	41	40%	50	17	34%

Table 2b.—Results by State boundaries

State	Likely Sites Surveyed	Positive for *C. callainus*	Percent	Likey Streams Surveyed	Positive for *C. callainus*	Percent
Kentucky	30	14	47%	20	7	35%
Virginia	48	23	48%	20	9	45%
West Virginia	25	4	16%	13	2	15%
Cummulative	103	41	40%	53	18	34%

To better compare the status of the Big Sandy and the Guyandotte River crayfish populations among existing sites, Loughman (2014, pp. 8–15) standardized the results of his and Thoma's (2009; 2010) survey work, which used the same sampling techniques, to the common metric CPUE (*i.e.,* ''crayfish per hour of searching''). The results indicate that, compared to the seemingly healthy population of Big Sandy crayfish in the Russell Fork system (including the Pound and Cranes Nest Rivers), where the average CPUE ranged from 12 to 21.7 crayfish/hour (hr), the remaining populations of Big Sandy crayfish in the Levisa Fork and Tug Fork drainages, and the single remaining Guyandotte River crayfish population in Pinnacle Creek, are depressed, ranging from 1 to 11 crayfish/hr in the Levisa Fork and Tug Fork, and 2 to 2.5 crayfish/hr in the Guyandotte (see Table 3). The data also illustrate an apparent decrease in abundance of the Big Sandy crayfish from upstream waters (*i.e.,* Virginia) to downstream waters (*i.e.,* Kentucky). Loughman (2014, pp. 13, 15) pooled the data from all sites sampled in Kentucky and Virginia (including the sites that were negative for the species) and determined the average CPUEs for the Big Sandy crayfish in those States to be 1.9 and 3.83, respectively. The pattern is stark for the Guyandotte River crayfish, as the species is known to persist in only one upstream subwatershed, Pinnacle Creek, with a CPUE of 2.0 to 2.5 crayfish/hr; all other likely sites downstream of this were negative for the species (*i.e.,* zero crayfish/hr). The Guyandotte River crayfish has apparently been extirpated from all waters downstream of Pinnacle Creek.

Table 3.—Crayfish abundance at occupied sites (data from sample sites that were negative for the species are not included).

River	Stream	State	Year	CPUE
Upper Guyandotte	Pinnacle Creek	WV	2009	2
	Pinnacle Creek	WV	2011	2.5
Upper Tug Fork	Blackberry Creek	KY	2009	1
	Knox Creek	KY	2009	7
	mainstem	WV	2011	3.2
	Dry Fork	WV	2009	3
	Dry Fork	WV	2014	11
	Dry Fork (upper)	WV	2014	7
Upper Levisa Fork	Dismal Creek	VA	2007	5.3 (avg, n=4)
Russell Fork/ Levisa Fork	Shelby Creek	KY	2009	6 (avg, n=3)
	Elkhorn Creek	KY	2009	1
	Russell Fork	KY	2009	13.5 (avg, n=2)
	McClure River	VA	2007	12 (avg, n=5)
Pound River/ Cranes Nest River	Cranes Nest	VA	2007	12 (avg, n=2)
	Pound River	VA	2007	21.7 (avg, n=3)

Summary of Population Estimates/Status—Multiple survey results dating back to 1900 and the best professional judgment of crayfish experts indicate a significant reduction in the Guyandotte River crayfish's historical range and a likely reduction in the Big Sandy crayfish's historical range. Specifically, the best available information indicates a contraction in range from the lower reaches of each watershed to the higher elevation streams. Based on a reduction in CPUE and a reduction in the number of observed specimens, the populations of both the Big Sandy crayfish and the Guyandotte River crayfish appear to be depressed, and critically so for the latter. Neither species is particularly cryptic. Multiple researchers have demonstrated that, given suitable habitat conditions, individuals of each species are readily located, collected, and identified. Survey efforts since 2004 have adequately covered the ranges of both the Big Sandy and the Guyandotte River crayfishes; therefore, if individuals of either species occupied a surveyed site it is reasonable to conclude that their presence would have been noted. While it is possible that future survey efforts could identify additional occurrences of either the Big Sandy or Guyandotte River crayfishes, the best available information indicates a reduction in distribution and abundance for both species.

Summary of Factors Affecting the Species

Section 4 of the Act (16 U.S.C 1533) and its implementing regulations at 50 CFR part 424 set forth the procedures for adding species to the Federal Lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, we may list a species based on any of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or manmade factors affecting its continued existence. Listing actions may be warranted based on any of the above threat factors, singly or in combination. Each of these factors is discussed below.

Factor A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Based on the best available information, and as previously described, the Guyandotte River crayfish and the Big Sandy crayfish exist only in suitable stream habitats in the Upper Guyandotte basin of southern West Virginia and the Big Sandy basin of eastern Kentucky, southwestern Virginia, and southern West Virginia, respectively. Within the historical range of each species, aquatic habitat has been severely degraded by past and ongoing human activities (Channell 2004, pp. 16–23; Jezerinac *et al.* 1995, p. 171; Loughman 2013, p. 6; Loughman 2014, pp. 10–11; Loughman and Welsh 2013, p. 23; Thoma 2009, p. 7; Thoma 2010, pp. 3–4). Visual evidence of habitat degradation, such as excessive bottom sedimentation, discolored sediments, or stream channelization and dredging, is often obvious, while other water quality issues such as changes in pH, low dissolved oxygen (DO) levels, high dissolved solids, high conductivity, high metals concentrations, and changes in other chemical parameters are less visually obvious. These perturbations may occur singly or in combination, and may vary temporally from chronic issues to acute episodic events. Degradation of the aquatic habitat can affect the stream biota and community structure in multiple ways. Some conditions can cause direct mortality to stream organisms (*e.g.,* exceedingly high or low pH, exceedingly low DO), while others such as sedimentation may make the stream uninhabitable for some species (by removing access to shelter or breeding substrates), but not uninhabitable for other species. Within the range of each species, water quality monitoring reports, most recently from the KDOW (2013, entire), the EPA

(2004, entire), the Virginia Department of Environmental Quality (VADEQ 2012, entire), and the West Virginia Department of Environmental Protection (WVDEP 2014, entire), have linked these widespread and often interrelated direct and indirect stressors to coal mining (and abandoned mine land (AML)), commercial timber harvesting, residential and commercial development, roads, and sewage discharges.

Historical context—The initial degradation of the rivers and streams within the ranges of the Big Sandy and Guyandotte River crayfishes was a result of industrial-scale forestry and coal mining. By the late 1800s, the timber resources in the Northeast and Great Lakes region were in decline, and companies began focusing on the largely intact forests of the southern Appalachian Mountains. Initially the cutting was selective and only the most valuable trees were taken, but beginning in about 1900 and continuing into the 1920s, the cutting became more intensive, widespread, and indiscriminate. During this same period, the coal fields of eastern Kentucky, southwestern Virginia, and southern West Virginia began to be mined and railroads expanded throughout the region to transport the lumber and coal to outside markets (Forest History Society 2008, entire). Since this period, many thousands of individual underground and surface mines have been constructed throughout the region, and extensive areas have been disturbed (Kentucky Surface Mining Viewer 2015; Virginia Department of Mines, Minerals, and Energy (VDMME) 2015; West Virginia Geological and Economic Survey 2015). Figure 5 provides historical coal extraction data for those counties making up the core ranges of the Big Sandy and Guyandotte River crayfishes. To date, the cumulative tonnage of coal extracted from these counties, standardized by area, ranges from 1.16 million to 2.78 million tons of coal per square mile (Virginia Energy Patterns and Trends 2015; Kentucky Geological Survey (KGS) 2015; West Virginia Office of Miners' Health Safety and Training 2014; U.S. Census Bureau 2014).

The regional timber and coal booms led to a concurrent increase in human population as people moved into the area for work. Between 1900 and 1950, the human populations of the five counties that constitute the core ranges of the Big Sandy and Guyandotte River crayfishes increased by a range of 300 percent to more than 500 percent (Figure 6). And because of the rugged topography of the region, most of the main roads, railroads, and residential and commercial development was (and remains) confined to the narrow valley bottoms, through which the region's streams and rivers also flow. This pattern of development resulted in the destruction of riparian habitat and the direct discharge of sewage, refuse, and sediments into the adjacent waters (Eller 1982, pp. 162, 184–186).

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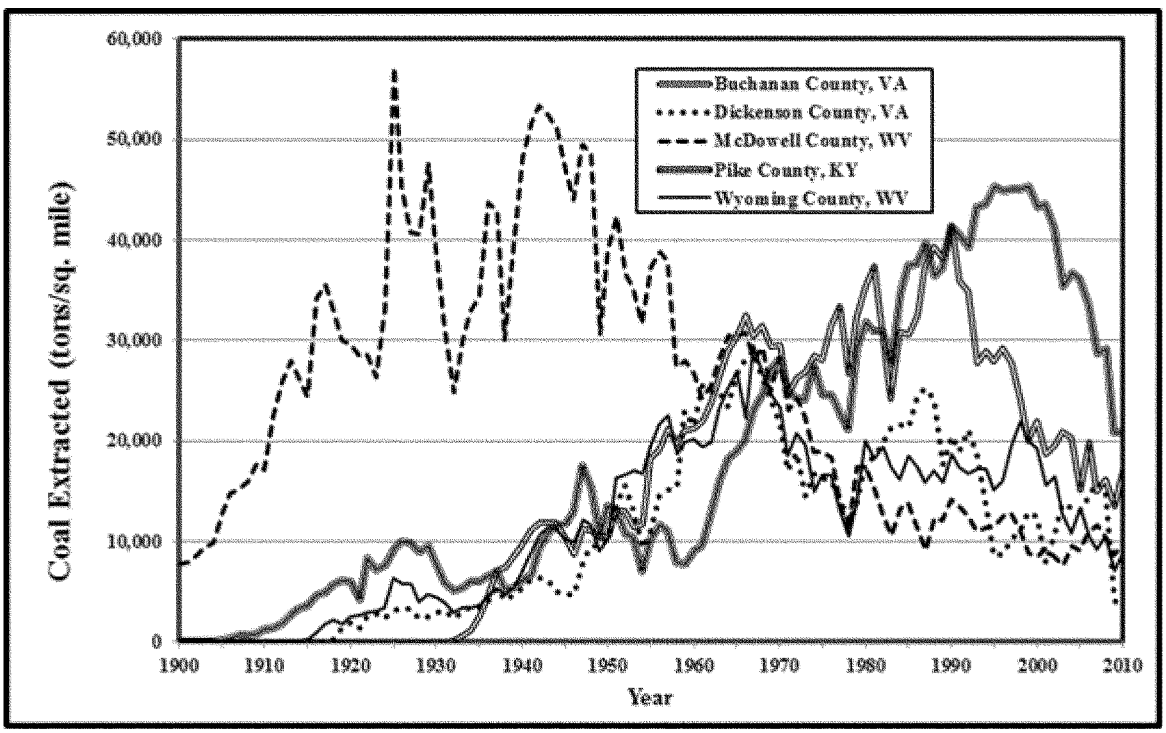

Figure 5.—Annual coal extraction (tons per square mile) from the counties within the core ranges of the Big Sandy and Guyandotte River crayfishes.

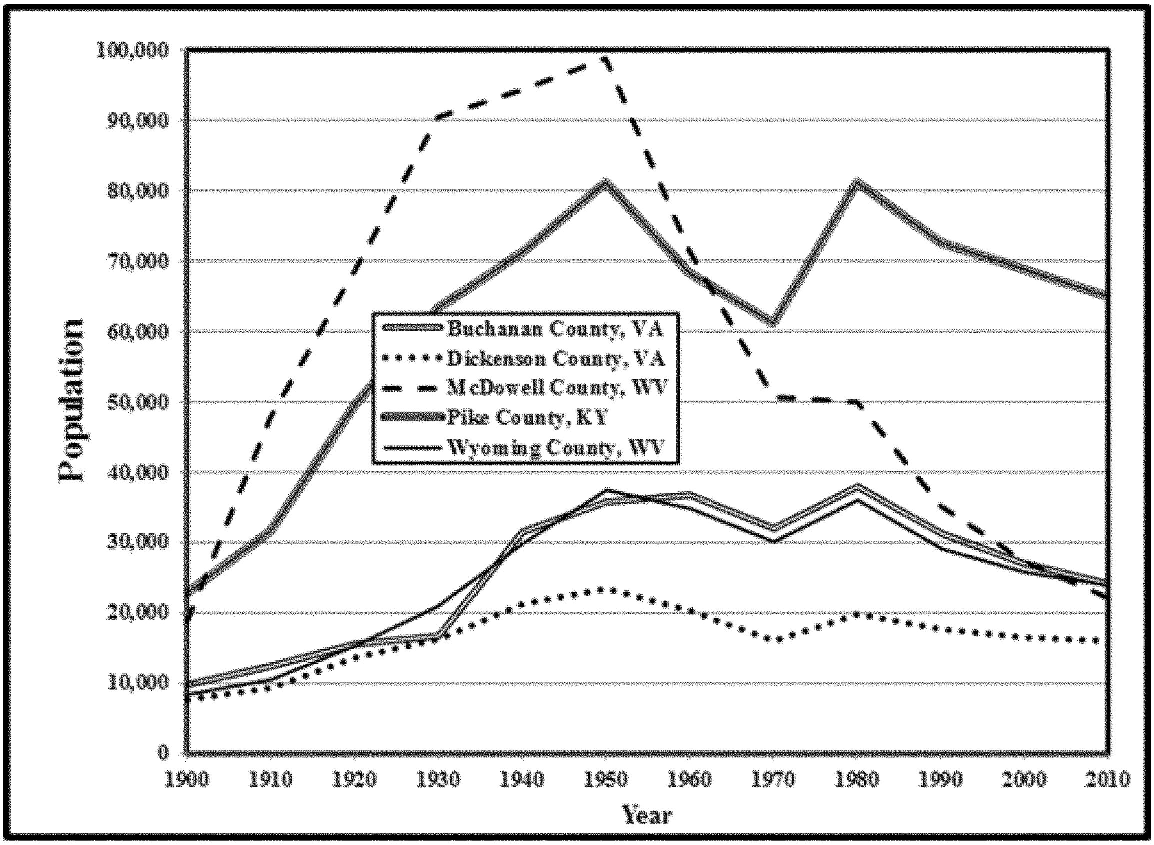

Figure 6.—Human population trends in the counties within the core ranges of the Big Sandy and Guyandotte River crayfishes.

While most of the residential and commercial development was, and remains, concentrated in the valley bottoms, the timber cutting and coal mining operations occurred throughout, including the ridges and steep mountainsides, resulting in severe soil erosion and sedimentation of the region's streams and rivers. An account from the 1920s described the regional landscape as being ''scarred and ugly, and streams ran brown with garbage and acid runoff from the mines'' (Eller 1982, p. 162). While we are not aware of rigorous water quality or habitat studies from this early period, a U.S. Geological Survey (USGS) report on the coal resources in Pike County, Kentucky (Big Sandy basin) provides evidence that by 1937, habitat conditions conducive to the Big Sandy crayfish were likely degraded, noting that throughout the county the clearing of timber from the hillsides and subsequent attempts at cultivating the steep slopes caused severe soil erosion into the basin's streams ''keeping them muddy and partly filling their channels'' (Hunt *et al.* 1937, p. 7). Because timber cutting and coal mining were ubiquitous in the region, it is reasonable to conclude that these conditions were common throughout the historical ranges of the Big Sandy and the Guyandotte River crayfishes and that this habitat degradation led to the extirpation of the species from much of their historical ranges.

Current conditions—The KDOW reported that in the Big Sandy basin in Pike County (Tug Fork and Levisa Fork drainages), 30 streams or stream segments (about 285 km (177 mi) of stream length) are impaired, meaning they violate water quality standards or do not meet one or more of their designated uses (*e.g.,* human health, aquatic life) (KDOW 2013, appendix E). Of these, 25 are listed for aquatic habitat impairment, 9 for coliform bacteria (indicators of sewage discharges), and 1 for a fish consumption advisory due to chemical contamination (KDOW 2013, appendix E). Many of the streams have multiple impairments. Of those streams listed for aquatic habitat impairment, coal mining is cited as a cause in all but two cases (which are listed as ''unknown''). According to the report, the next most commonly cited cause of stream habitat degradation is sedimentation, which is associated with mining, stream channelization, urban runoff, road runoff, and silviculture (which are also cited individually as sources of impairment). The WVDEP reported that in the Tug Fork drainage in West Virginia, 47 streams or stream segments (about 523 km (325 mi) of stream length) are impaired, primarily for ''biological impairment'' (as measured by the WVSCI), coliform bacteria, and selenium (a toxic metal) (WVDEP 2012, pp. 32–33).

In the Big Sandy basin of Virginia, the VADEQ reported that 25 streams, stream segments, or stream systems (about 475 km (295 mi) of stream length) were impaired. Impairment assessments for aquatic life are based on measures such as benthic macroinvertebrate community structure or water temperature and for recreational use based on measures such as *Escherichia coli* and fecal coliform bacteria contamination (*e.g.,* sewage) (VADEQ 2014, pp. 1098–1124). The primary causes of these impairments are listed as coal mining (n=5), rural residential development (n=12), forestry (n=1), or unknown (n=7). Additionally, more than 212 km (138 mi) of the Knox Creek (Tug Fork drainage) and Levisa Fork systems are impaired, the assessment of which is based on a fish consumption advisory due to chemical contamination.

Water quality monitoring data for the Upper Guyandotte basin indicate that 62 streams (362 km (225 mi) of stream length) in the basin are impaired. Forty-four streams are listed for biological impairment, 14 streams exceed the water quality standard for selenium, and 4 streams are listed for fecal coliform bacteria (WVDEP 2012, pp. 28, 42–44). Although the specific sources of these impairments are listed as ''unknown,'' a 2004 report by the EPA (2004, entire) links the metals and pH impairments to coal mining-related activities, including AML drainage, and links the fecal coliform impairments to ''urban and residential runoff, leaking sanitary sewers, failing septic systems, straight pipe discharges, grazing livestock, runoff from cropland, and wildlife'' (EPA 2004, p. 2).

Water quality information appears to be correlated with the presence or absence of the Guyandotte River crayfish. For example, during their 1988 and 1989 surveys for the Guyandotte River crayfish at 13 of the 15 known locations for the species (as well as 42 other potentially suitable sites) in the Upper Guyandotte basin, Jezerinac *et al.* (1995, p. 171) a noted an absence of the species in many otherwise suitable streams that displayed visible evidence of sewage, sedimentation, and coal fines.

In 2001, Channell (2004, pp. 16–21) surveyed and assessed habitat conditions at each of the 15 historical Guyandotte River crayfish locations. Habitat quality was assessed and scored per the U.S. Environmental Protection Agency's (EPA) rapid bioassessment protocol (RBP) (Barbour *et al.* 1999, entire) and the West Virginia Stream Condition Index (WVSCI) (Tetra Tech, Inc. 2000, entire). The RBP (see *http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm;* last accessed March 3, 2015) is ''an integrated assessment, comparing habitat (*e.g.,* physical structure, flow regime), water quality and biological measures with empirically defined reference conditions (via actual reference sites, historical data, and/or modeling or extrapolation)'' (Barbour *et al.* 1999, chapter 2) using benthic macroinvertebrate assemblages (see *http://www.dep.wv.gov/wwe/watershed/bio_fish/pages/bio_fish.aspx#wvwvsci;* last accessed March 3, 2015). The index allows comparison of assessed streams to reference streams that contain little to no human disturbance. Although the RBP and WVSCI use macroinvertebrates instead of crayfish as indicators, the WVSCI is a valid screening tool for water quality assessment because macroinvertebrates are sensitive to changes in water quality due to their limited mobility and short life span (*e.g.,* sensitive life stages respond quickly to deteriorating conditions). Macroinvertebrates are also abundant in most streams and easy to sample, and are food for other stream biota (Barbour *et al.* 1999, chapter 3). The WVSCI was the best available screening tool at the time of the 2001 crayfish surveys and is a standard measure used to comply with the monitoring requirements of the CWA. Of five crayfish species native to the basin (the presence of each having been confirmed in 1988 and 1989 by Jezerinac *et al.* (1995)), two species (*Cambarus veteranus* and *C. robustus*) were not detected at any site during this effort. Four of the historical sites produced no species in the genus Cambarus (*e.g.,* crayfish of the same genus as *C. veteranus*). Results of the habitat assessment indicated that 7 of 15 sites were ''impaired'' per the EPA protocol, with 3 sites also being ''impaired'' per the WVSCI definition. Impairment indicates that habitat conditions at these sites exhibited some level of degradation, as compared to high-quality reference streams in the region.

In 2009, Pinnacle Creek was the only site in the Upper Guyandotte system confirmed to still harbor the Guyandotte River crayfish. This site is located in a mostly forested floodplain and was characterized as having coal fines and moderate sedimentation but with an abundance of unembedded slab boulders in both riffles and runs (Loughman 2013, p. 6). At another historical site, Huff Creek, the species had been reported as ''moderately abundant'' in 1989 (Jezerinac *et al.* 1995). However in 2009, while the habitat appeared conducive to the species, Loughman (2013, p. 6) did not observe the species in Huff Creek. Based on personal observation, Loughman (2013, pp. 6, 9) concluded that the Guyandotte River crayfish was eliminated from Huff Creek by channel bulldozing in the early 2000s, and perhaps chemical inputs from upstream coal mines.

In association with her study of the Guyandotte River crayfish population, Channell (2004, pp. 21–23) also surveyed suitable locations in the Levisa Fork system (Big Sandy basin) in Virginia. Big Sandy crayfish were confirmed at three of the six sites surveyed, with the author noting that the species was found under large rocks (greater than 0.5 m (1.6 ft) across) in streams from 4 to 15 m (13 to 49 ft) wide and without coal fines in the substrate. While RBP scores for the six sites did not indicate impairment, the author noted that the three streams where the Big Sandy crayfishes were not observed were included on the Virginia Department of Environmental Quality's 303(d) list of impaired waters as a result of damming, urban influence, mining activities, or sewage (Channell 2004, pp. 22–23).

Thoma (2009, p. 7 and 2010, pp. 3–4) examined the relationship of *Cambarus callainus* abundance and various habitat parameters in Kentucky and Virginia, and correlated his results with several habitat variables at each site, quantified using the Ohio Environmental Protection Agency's Qualitative Habitat Evaluation Index (QHEI) (Ohio EPA 2006, entire). The QHEI ''is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat characteristics that are important to fish communities'' (Ohio EPA 2006, p. 3). The habitat variables captured in the QHEI include substrate quality, instream cover, riparian zone and bank erosion, and pool/glide and riffle/run quality (Thoma 2009, p. 7). At sample sites in Virginia, he found Big Sandy crayfish numbers positively correlated with higher quality habitat, as measured by the QHEI, and negatively correlated with pollution, fine bottom sediments, and stream gradient (Thoma 2009, p. 7). A similar analysis of the species' status in Kentucky supported his findings from Virginia that the Big Sandy crayfish ''was most strongly associated with clean, third order or larger streams, low in bedload sediments, with moderate gradient, and an abundance of boulder/cobble substrate'' (Thoma 2010, p. 3). The Kentucky data indicated a strong positive correlation between Big Sandy crayfish numbers and general habitat quality (*i.e.,* QHEI), riffle quality, and percent boulders. A site's riffle quality and riffle embeddedness (bottom sedimentation) were the best correlates of the species' abundance (Thoma 2010, p. 4).

In 2009 and 2011, Loughman and Welsh (2013) surveyed specifically for the species in the Upper Guyandotte River basin, Tug Fork basin (Big Sandy River basin), and the Bluestone River basin (a tributary of the New River) in West Virginia. Results of this intensive effort (69 sites surveyed in 2009) indicated that most sites exhibited excessive sedimentation and embedded slab boulders, or had been channelized and were devoid of large boulders (Loughman and Welsh 2013, p. 23;

Loughman 2013, p. 6). Loughman (2013, p. 6) also reported that most surveyed sites harbored other native crayfish species, with *Cambarus theepiensis,* a newly described *Cambarus* species associated with lower gradient streams dominated by depositional bottom substrate (*e.g.,* finer substrates) and fewer slab boulders, being common in the region's streams. In these situations, *C. theepiensis* has been observed sheltering in simple burrows in the stream bottom or stream banks. Neither the Big Sandy crayfish nor the Guyandotte River crayfish has been observed exhibiting this sheltering behavior (Loughman *et al.* 2013, p. 70).

Coal mining—The past and ongoing effects of coal mining in the Appalachian Basin are well documented, and both underground and surface mines are reported to degrade water quality and stream habitats (Bernhardt *et al.* 2012, entire; Demchak *et al.* 2004, entire; Hartman *et al.* 2005, pp. 94–100; Hopkins *et al.* 2013, entire; Lindberg *et al.* 2011, entire; Matter and Ney 1981, pp. 67–70; Merriam *et al.* 2011, entire; Palmer and Hondula 2014, entire; Pond *et al.* 2008, entire; Pond 2011, entire; Sams and Beer 2000, entire; USEPA 2011, entire; Wang *et al.* 2013, entire; Williams *et al.* 1996, p. 41–46). Notable water quality changes associated with coal mining in this region include increased concentrations of sulfate, calcium, and other ions (measured collectively by a water's electrical conductivity); increased concentrations of iron, magnesium, manganese, and other metals; and increased alkalinity and pH, depending on the local geology (Lindberg *et al.* 2011, pp. 2–6; Matter and Ney 1981, pp. 67–68; Pond *et al.* 2008, pp. 717–718; Sams and Beer 2000, pp. 3–5; Williams *et al.* 1996, pp. 10–17). The common physical changes to local waterways associated with coal mining include increased erosion and sedimentation, changes in flow, and in many cases the complete burial of headwater streams (Hartman *et al.* 2005, pp. 91–92; Matter and Ney 1981, entire; Pond *et al.* 2008, pp. 717–718; USEPA 2011, pp. 7–9). These mining-related effects are commonly noted in the streams and rivers within the ranges of the Big Sandy and the Guyandotte River crayfishes (KDOW 2013; USEPA 2004; VADEQ 2014; WVDEP 2012).

The response of aquatic species to coal mining-induced degradation are also well documented, commonly observed as a shift in a stream's macroinvertebrate (*e.g.,* insect larva or nymphs, aquatic worms, snails, clams, crayfish) or fish community structure and resultant loss of sensitive taxa and an increase in tolerant taxa (Diamond and Serveiss 2001, pp. 4714–4717; Hartman *et al.* 2005, pp. 96–97; Hitt and Chambers 2014, entire; Lindberg *et al.* 2011b, p. 1; Matter and Ney 1981, pp. 66–67; Pond *et al.* 2008). As mentioned above, coal mining can cause a variety of changes to water chemistry and physical habitat; therefore, it is often difficult to attribute the observed effects to a single factor. It is likely that the observed shifts in community structure (including the extirpation of some species) are, in many cases, a result of a combination of factors.

There is less specific information available on the effects of coal mining–induced degradation to crayfishes. A study in Ohio using juvenile Appalachian Brook crayfish (*Cambarus bartonii cavatus*), a stream-dwelling species in the same genus as the Big Sandy and Guyandotte River crayfishes, found that individuals from downstream of a mine drainage were somewhat more tolerant of high conductivity conditions than individuals from upstream of the discharge (Gallaway and Hummon 1991, pp. 168–170). The authors noted that during ecdysis (molting, a particularly vulnerable stage in the animal's lifecycle), however, individuals were more sensitive to high conductivity levels. In the laboratory, conductivity levels of 1,200 to 2,000 micro Siemens/centimeter (µS) resulted in the crayfish having difficulty molting, while field observations indicated that crayfish in isolated pools with conductivity levels of 800 to 1,920 µS died in midmolt or experienced obviously stressful molts as demonstrated by missing chelea and/or periopods or other physical malformations. The authors also noted that a 1-week exposure to water with a conductivity level of 3,000 µS, as might be experienced during summer low flow conditions, would be lethal to all of the crayfish in the study (Gallaway and Hummon 1991, pp. 168–170).

Welsh and Loughman (2014, entire) analyzed crayfish distributions in the heavily mined upper Kanawha River basin in southern West Virginia and determined that physical habitat quality (including substrate type and quality, embeddedness, instream cover, channel morphology, and gradient) and stream order (size) were the best predictors of crayfish presence or absence and crayfish diversity. They observed that, in general, secondary and tertiary burrowing species such as Big Sandy and Guyandotte River crayfishes were associated with high-quality physical habitat conditions. The exception to this pattern was *Cambarus bartonii cavatus* (a secondary burrower), the same species studied by Gallaway and Hummon (1991) and discussed above, that was found to be more closely associated with low-quality physical habitat but high-quality water (*i.e.*, low conductivity). For most species studied, the results did not demonstrate a relationship between conductivity levels and a species' presence or absence. However, Welsh and Loughman (2014, entire) noted that stream conductivity levels can vary seasonally or with flow conditions, making assumptions regarding species' presence or absence at the time of surveys difficult to correlate with prior ephemeral conductivity conditions.

In addition to degrading water quality, coal mining increases erosion and sedimentation in downgradient streams and rivers (Hartman *et al.* 2005, pp. 91–92; Matter and Ney 1981; Pond *et al.* 2008, pp. 717–718; USEPA 1976, pp. 3–11; USEPA 2011, pp. 7–9); this is of particular importance for the Big Sandy and Guyandotte River crayfishes, which, as tertiary burrowers, rely on unembedded slab boulders for shelter. While some other crayfish species (secondary burrowers) are known to excavate burrows in the streambank or bottom, or utilize leaf packs or other vegetation for shelter, neither the Big Sandy crayfish nor the Guyandotte River crayfish has been observed exhibiting this behavior. Channell (2004, p. 18), Jezerinac *et al.* (1995, p. 170), Loughman (2014, pp. 32–33), and Loughman and Welsh (2013, pp. 22–24) theorize that, because of habitat degradation, the habitat-specialist Big Sandy and Guyandotte River crayfishes may be at a competitive disadvantage to other more generalist crayfish species (see Factor E—*Interspecific competition,* below, for additional information), which has contributed to the decline, extirpation, and continued low abundance of the former two species. Whatever the exact mechanism may be, multiple researchers have observed that excessive bottom sedimentation appears to make otherwise suitable stream reaches uninhabitable by the Big Sandy and Guyandotte River crayfishes (Channell 2004, pp. 16–23; Jezerinac *et al.* 1995, p. 171; Loughman 2013, p. 6; Loughman 2014, pp. 10–11; Loughman and Welsh 2013, p. 23; Thoma 2009, p. 7; Thoma 2010, pp. 3–4).

While coal extraction from the southern Appalachian region has declined from the historical highs of the 20th century, and is unlikely to ever return to those levels (McIlmoil, *et al.* 2013, pp. 1–8, 49–57; Milici and Dennen 2009, pp. 9–10), significant mining still occurs within the ranges of the Big Sandy and the Guyandotte River crayfishes. The U.S. Department of Energy (2013, table 2) reports that in 2012, there were 192 active coal mines (119 underground mines and 73 surface mines) in the counties that constitute the core ranges of the Big Sandy and Guyandotte River crayfishes. The total amount of coal extracted from these operations in 2012 was more than 32.6 million tons. Underground mining accounts for most of the coal excavated in the region, but since the 1970s, surface mining (including ''mountaintop removal mining'' or MTR) has become more prevalent. Mountaintop removal mining is differentiated from other mining techniques by the shear amount of overburden that is removed to access the coal seams and the use of ''valley fills'' to dispose of the overburden. This practice results in the destruction of springs and headwater streams and often leads to water quality degradation in downstream reaches (USEPA 2011, pp. 7–10). An immediate threat to the continued existence of the Guyandotte River crayfish is several active and inactive surface coal mines (including MTR mines) in the mid and upper reaches of the Pinnacle Creek watershed (discussed in detail below).

The detrimental effects of coal mining often continue long after active mining ceases. Hopkins *et al.* (2013, entire) studied water quality in a southeast Ohio watershed where most of the coal mining operations are closed and in varying stages of reclamation, and found that, while pH levels were not correlated with mining activity (and appeared to be within the tolerance limits of most stream taxa), conductivity, aluminum, and sulfate concentrations were correlated with past mining activity and that, despite mine reclamation efforts, these parameters were measured at levels associated with the impairment of aquatic biota. While the Hopkins et al. (2013, entire) study does not include crayfish species specifically, the results are compared to water quality parameters that may negatively affect all aquatic species, including crayfish. Sams and Beer (2000, pp. 11–16) studied the effects of acid mine drainage in the Allegheny and Monongahela River basins in Pennsylvania and West Virginia, and estimated trends in sulfate concentrations over a 30-year period (1965 to 1995). For several creeks and rivers they found that sulfate concentrations were correlated with coal production in the individual basins. In one stream system with long-term data and where coal mining had been in decline since 1950, they noted a decrease in sulfate concentrations over time as abandoned mine lands were reclaimed and with the natural weathering of the exposed sulfide minerals. However, while the decline in sulfate concentrations was initially rapid, the rate of improvement slowed over time, and they concluded that mine drainage would continue to degrade water quality for many years.

By-products of deep and surface mines include manganese and iron (Sams and Beers 2000, pp. 2, 4, 6). When these by-products enter the aquatic environment, they can affect crayfish in two ways: directly through the body and indirectly through food sources (Loughman 2014, p. 27). Both iron and manganese are upregulated into the body through gill respiration and stomach and intestinal absorption (Baden and Eriksson 2006, pp. 67–75). In addition, both iron and manganese bioaccumulate in crayfish when they feed on benthic macroinvertebrates. Although manganese is ''an essential metal and is thus required in at least a minimum concentration for an animal to be able to fulfil its metabolic functions'' (Baden and Eriksson 2006, p. 64), it can be physiologically toxic to crayfishes when levels are too high (Loughman 2014, p. 27). While manganese absorption may not directly cause mortality, it may adversely affect reproductive cycles and oocytes (immature egg cells) (Baden and Eriksson 2006, p. 73). ''Iron and manganese also physically bond to crayfish exoskeletons following ecydisis [*e.g.,* molting], clogging sensory sensila [*e.g.,* receptor] and reducing overall health of crayfish'' (Loughman 2014, p. 27).

Loughman (2014, pp. 26–27) has observed Guyandotte River crayfish that have visible signs of manganese encrustation. While Hay's 1900 Indian Creek, Wyoming County, West Virginia, specimen did not exhibit manganese encrustation, Hobbs' 1947 specimens from Indian Creek did. In addition, Big Sandy crayfish specimens collected by Loughman in 2014, from Dry Fork, McDowell County, West Virginia, also exhibited manganese encrustation. The Dry Fork specimens were sampled from a site immediately downstream of deep mine effluents entering Dry Fork (Loughman 2014, p. 27). While manganese encrustations have been found on both Guyandotte River and Big Sandy crayfish specimens, we are uncertain the extent to which these deposits occur across the species' ranges or if and to what extent the effects of the manganese and iron exposure has contributed to the decline of the Big Sandy or Guyandotte River crayfishes.

Ancillary to the coal mines are the processing facilities that use various mechanical and hydraulic techniques to separate the coal from rock and other geological waste material. This process results in the creation of large volumes of ''coal slurry,'' a blend of water, coal fines, and sand, silt, and clay particles, which is commonly disposed of in large impoundments created in the valleys near the coal mines. In multiple instances, these impoundments have failed catastrophically and caused substantial damage to downstream aquatic habitats (and in some cases the loss of human life) (Frey *et al.* 2001, entire; Michael *et al.* 2010, entire; Michalek *et al.* 1997, entire; National Academy of Sciences (NAS) 2002, pp. 23–30). In 2000, a coal slurry impoundment in the Tug Fork watershed failed and released approximately 946 million liters (250 million gallons) of viscous coal slurry to several tributary creeks of the Tug Fork, which ultimately affected 177.5 km (110.3 mi) of stream length, including the Tug Fork and Levisa Fork mainstems (Frey *et al.* 2001, entire). The authors reported a complete fish kill in 92.8 km (57.7 mi) of stream length, and based on their description of the instream conditions following the event, it is reasonable to conclude that all aquatic life in these streams was killed, including individuals of the Big Sandy crayfish, if they were present at that time. The authors also noted that the effects of this release will continue to negatively affect aquatic species, including benthic macroinvertebrates, for a considerable time into the future. Coal slurry impoundments are common throughout the ranges of the Big Sandy and Guyandotte River crayfishes, and releases have been documented in each of the States within these ranges (NAS 2002, pp. 25–30). However, the exact location of impoundments as they relate to the streams known to support Big Sandy and Guyandotte River crayfishes is unknown.

In addition to the stressors described above, several active surface coal mines in the Pinnacle Creek watershed may pose an immediate threat to the continued existence of the Guyandotte River crayfish. These mines represent geographic extents of 13 to 242 hectares (ha) (33 to 598 acres (ac)) and are located either on Pinnacle Creek (*e.g.,* encroaching to within 0.5 km (0.31 mi) of the creek) and directly upstream (*e.g.,* within 7.0 km (4.4 mi)) of the last documented location of the Guyandotte River crayfish or on tributaries that drain into Pinnacle Creek upstream of the Guyandotte River crayfish location

(WVDEP 2014a; WVDEP 2014b; WVDEP 2014c; WVDEP 2014d). Some of these mines also have reported violations related to mandatory erosion and sediment control measures (*e.g.,* 3 to 37) within the last 2 years (WVDEP 2014a; WVDEP 2014b; WVDEP 2014d).

Coal mining summary— While coal extraction in the Appalachian region has declined from the historical highs of the 20th century, we expect that the ongoing and legacy effects of coal mining, including the drainage from closed and abandoned mine lands, will continue to degrade aquatic habitats and act as a stressor to both the Big Sandy and the Guyandotte River crayfishes into the future.

Residential and commercial development—Because of the rugged topography within the ranges of the Big Sandy and the Guyandotte River crayfishes, most residential and commercial development and the supporting transportation infrastructure is confined to the narrow valley floodplains (Ehlke *et al.* 1982, p. 14; Kiesler *et al.* 1983, p. 14). The close proximity of this development to the region's streams and rivers has historically resulted in the loss of riparian habitat and the continued direct discharge of sediments, chemical pollutants, sewage, and other refuse into the aquatic systems (KDOW 2013; VADEQ 2014; WVDEP 2012), which degrades habitat quality and complexity (Merriam *et al.* 2011, p. 415). The best available information indicates that the human population in these areas will continue to decrease over the next several decades (see Figure 6, above). For example, between 2010 and 2030, the human populations of the five counties that make up the core ranges of the Big Sandy and Guyandotte River crayfishes are projected to decline between 3 to 28 percent (University of Louisville 2011; University of Virginia 2012; West Virginia University 2012). However, while the human populations may decline, the human population centers are likely to remain in the riparian valleys. We have no information on whether the historical trend of releasing untreated waste into the streams will decrease, increase, or stay the same, but are seeking comments on this knowledge gap.

In summary, we conclude that even with the observed and projected decline in human population within the ranges of the Big Sandy and Guyandotte River crayfishes, development will still be concentrated in the narrow valley riparian zones and may contribute to the degradation of water quality and the aquatic habitat required by both species.

Roads—Both paved and unpaved roads can degrade the aquatic habitat required by the Big Sandy and Guyandotte River crayfishes. Paved roads, coincident with and connecting areas of residential and commercial development, generally occur in the narrow valley bottoms adjacent to the region's streams and rivers. Runoff from these paved roads can include a complex mixture of metals, organic chemicals, deicers, nutrients, pesticides and herbicides, and sediments that, when washed into local streams, can degrade the aquatic habitat and have a detrimental effect on resident organisms (Buckler and Granato 1999, entire; Boxall and Maltby 1997, entire; NAS 2005, pp. 72–75, 82–86). We are not aware of any studies specific to the effects of highway runoff on the Big Sandy or Guyandotte River crayfishes; however, one laboratory study from Khan *et al.* (2006, pp. 515–519) evaluated the effects of cadmium, copper, lead, and zinc exposure on juvenile *Orconectes immunis,* a species of pond crayfish. These particular metals, which are known constituents of highway runoff (Sansalone *et al.* 1996, p. 371), were found to inhibit oxygen consumption in *O. immunis.* We are uncertain to what extent these results may be comparable to how Big Sandy or Guyandotte River crayfishes may react to these contaminants, but it was the only relevant study exploring the topic in crayfish. Boxall and Maltby (1997, pp. 14–15) studied the effects of roadway contaminants (specifically the polycyclic aromatic hydrocarbons or PAHs) on *Gammarus pulex,* a freshwater amphipod crustacean commonly used in toxicity studies. The authors noted an acute toxic response to some of the PAHs, and emphasized that because of possible interactions between the various runoff contaminants, including deicing salts and herbicides, the toxicity of road runoff likely varies depending on the mixture. We are uncertain to what extent these results may be comparable to how Big Sandy or Guyandotte River crayfishes may react to these contaminants.

The construction of new roads also has the potential to further degrade the aquatic habitat in the region, primarily by increasing erosion and sedimentation and perhaps roadway contaminant loading to local streams. Two new, multi-lane highway projects, the King Coal Highway and the Coalfields Expressway, are in various stages of development within the Big Sandy and Upper Guyandotte River watersheds (VDOT 2015; West Virginia Department of Transportation (WVDOT) 2015a; WVDOT 2015b). In West Virginia, the King Coal Highway right-of-way runs along the McDowell and Wyoming County line, the dividing line between the Tug Fork and Upper Guyandotte watersheds, and continues into Mingo County (which is largely in the Tug Fork watershed). This highway project will potentially affect the current occupied habitat of both crayfish species, but is of particular concern for the Guyandotte River crayfish because of a section that will parallel and cross Pinnacle Creek.

In West Virginia, the Coalfields Expressway right-of-way crosses Wyoming and McDowell Counties roughly perpendicular to the King Coal Highway and continues into Buchanan, Dickenson, and Wise Counties, Virginia. This project runs through the Upper Guyandotte, Tug Fork, Levisa Fork, and Russell Fork watersheds and has the potential to affect the aquatic habitats in each basin. Of particular concern are sections of the Coalfields Expressway planned through perhaps the most robust Big Sandy crayfish populations in Dickenson County, Virginia.

Unpaved forest roads (*e.g.,* haul roads, access roads, and skid trails constructed by the extractive industries or others) are often located on the steep hillsides and are recognized as a major source of sediment loading to streams and rivers (Christopher and Visser 2007, pp. 22–24; Clinton and Vose 2003, entire; Greir *et al.* 1976, pp. 1–8; MacDonald and Coe 2008, entire; Morris *et al.* 2014, entire; Stringer and Taylor 1998, entire; Wade *et al.* 2012, pp. 408–409; Wang *et al.* 2013, entire). These unpaved roads, especially those associated with mining, forestry, and oil and gas activities, are ubiquitous throughout the range of the Big Sandy and Guyandotte River crayfishes. The estimated erosion rate for undisturbed forested sites in mountainous terrain ranges from about 0.16 tonnes of sediment/ha/year (yr) (0.063 tons/ac/yr) to 0.31 tonnes/ha/yr (0.12 tons/ac/yr) (Grant and Wolff 1991, p. 36; Hood *et al.* 2002, p. 56); however, the construction of unpaved forest roads in an area greatly increases this natural erosion process. Wade *et al.* (2012, p. 403) cite typical erosion rates for unpaved roads and trails as being from 10 to greater than 100 tonnes/ha/yr (4 to greater than 40 tons/ac/yr), with one study of trails established on steep slopes in the western United States resulting in an erosion rate of 163 tonnes/ha/yr (64.7 tons/ac/yr). Christopher and Visser (2007, pp. 23–24) estimated soil erosion rates for forestry operations in the coastal plain, piedmont, and mountains of Virginia, and determined that access roads and skid trails lost an average of 21.1 and

11.2 tonnes/ha/year (8.4 and 4.4 tons/ac/yr), respectively. The authors estimated the erosion from one hillside skid trail to be in excess of 50 tonnes/ha/yr (19.8 tons/ac/yr) and erosion from another undescribed site to be 270 tonnes/ha/year (107.1 tons/ac/yr). The authors concluded that in mountainous areas, access roads and skid trails accounted for an average of 27 and 54 percent of the erosion from a timber harvest operation, respectively. We anticipate the number of unpaved roads throughout the crayfishes' range to remain the same or expand as new oil and gas facilities are built and new areas are logged.

In addition to erosion from unpaved road surfaces, we expect erosion from unpaved road stream crossings throughout the range of the Big Sandy and Guyandotte River crayfishes to also contribute significant sediment loading to local waters. Wang *et al.* (2013, entire) studied stream turbidity levels and suspended sediment loads following construction of a forest haul road stream crossing in West Virginia. The authors reported significant increases in both parameters following construction of the stream crossing and noted that, with site revegetation, sediment loads improved over time. However, sediment remained in the stream channel 2 years after construction, and the authors concluded that it could require decades to flush from the system. Morris *et al.* (2014, entire) studied sediment loading from an unpaved, but properly sized and installed, culvert stream crossing in the Virginia piedmont. Their results indicated that, by applying the minimal Virginia Department of Forestry (VDOF) ''Best Management Practices'' (BMPs) for this type of stream crossing, the estimated annual sediment load to the creek was 98.5 tonnes/yr (96.5 tons/yr). By instituting the standard (vice minimum) BMP measures and installing a geotextile and stone covering on the running surface, the sediment loading was reduced to 28.5 tonnes/yr (27.9 tons/yr). A Statewide survey of these types of crossings by the VDOF found that 33 percent met the minimum criteria and 64 percent met the standard BMP recommendations. About 3 percent of the crossings exceeded the State BMP recommendations, but even with additional erosion control measures the estimated sediment load was 22.5 tonnes/yr (22.1 tons/yr). Christopher and Visser (2007, p. 23–24) estimated the average erosion rate for stream crossings at logging sites in Virginia to be 20.8 tonnes/ha/yr (8.3 tons/ac/yr). This average includes sites in the mountain, coastal plain, and piedmont physiographic provinces, the latter two of which would be expected to have less erosion potential than the steep mountainous terrain indicative of Big Sandy and Guyandotte River crayfish habitat.

Offroad Vehicles (ORVs)—Offroad vehicle use of haul roads and trails has become an increasingly popular form of recreation in the region (see *http://www.riderplanet-usa.com,* last accessed February 13, 2015). Recreational ORV use, which includes the use of unimproved stream crossings, stream channel riding, and ''mudding'' (the intentional and repeated use of wet or low-lying trail sections that often results in the formation of deep ''mud holes''), may cause increased sediment loading to streams and possibly kill benthic organisms directly by crushing them (Switalski and Jones 2012, pp. 14–15; YouTube.com 2008; YouTube.com 2010; YouTube.com 2011; YouTube.com 2013). Ayala *et al.* (2005, entire) modeled long-term sediment loading from an ORV stream crossing in a ridge and valley landscape in Alabama, and estimated that the ORV crossing contributed 45.4 tonnes/ha/yr (18 tons/ac/yr) to the stream. Chin *et al.* (2004, entire) studied ORV use at stream crossings in Arkansas, and found that pools below ORV crossings experienced increased sedimentation and decreased pool depth, compared to unaffected streams. The quantitative data on stream bottom embeddedness were unclear, but the authors did note that none of the sites below ORV crossings was less than 10 percent embedded, while some of the control sites had little or no embeddedness. Christopher and Visser (2007, p. 24) looked at the effect of ORV use on previously logged sites and found that ORV use significantly increased erosion at stream crossings and access roads, as compared to sites that were closed to ORV use.

Nearly all of the land within the ranges of the Big Sandy and Guyandotte River crayfishes is privately owned. Offroad vehicle use on private land is largely unregulated, and we found no comprehensive information on the extent of offroad trails in the region, ridership numbers, or the effects to local streams. However, the Hatfield-McCoy Trail system, which was created in 2000 to promote tourism and economic development in southern West Virginia, may provide some insight into the scale of ORV recreation within the ranges of the Big Sandy and Guyandotte River crayfishes (Pardue *et al.* 2014, p. 1). As of 2014, the Hatfield-McCoy Trail system had eight individual trail networks totaling more than 700 mi of cleared trails, with the stated long-term goal being approximately 2,000 mi of accessible trails (Pardue *et al.* 2014, pp. 4–5), and in 2013, 35,900 trail permits were sold (Hatfield-McCoy presentation 2013, p. 8). Two of the designated Hatfield-McCoy trail networks, Pinnacle Creek and Rockhouse, are located in the Upper Guyandotte basin and one, Buffalo Mountain, is in the Tug Fork basin.

The Pinnacle Creek Trail System, opened in 2004, is located entirely within the Pinnacle Creek watershed and may pose a significant threat to the continued existence of the Guyandotte River crayfish. The majority of this unpaved trail network runs along the ridgelines or up and down the steep mountainsides; however, approximately 13 km (8.0 mi) of ORV trail is located in the Pinnacle Creek riparian zone, including the area last known to harbor the Guyandotte River crayfish. At several locations along this section of trail, riders are known to operate their vehicles in the streambed or in adjacent ''mud holes'' (You Tube 2008; You Tube 2010; You Tube 2011; You Tube 2013; Loughman, pers. comm., October 24, 2014). It is reasonable to conclude that these activities increase erosion and sedimentation in Pinnacle Creek and degrade the habitat of the Guyandotte River crayfish. In addition, the instream operation of ORVs in Pinnacle Creek has the potential to crush or injure individual crayfish directly.

Summary of Roads (Paved and Unpaved) and ORVs—In summary, we conclude that contaminant runoff from paved road surfaces and erosion and sedimentation from road construction projects, unpaved roads and trails, and ORV use throughout the ranges of the Big Sandy and Guyandotte River crayfishes likely contribute directly to degradation of the species' habitat and will continue to do so into the future.

Forestry—The dominant land cover within the ranges of the Big Sandy and Guyandotte River crayfishes is forest, and commercial timber harvesting occurs throughout the region. While not approaching the scale of the intensive cutting that occurred in the early 20th century, commercial logging still has the potential to degrade aquatic habitats, primarily by increasing erosion and sedimentation (Arthur *et al.* 1998, entire; Hood *et al.* 2002, entire; Stone and Wallace 1998, entire; Stringer and Hilpp 2001, entire; Swank *et al.* 2001, entire). The most recent records available on timber harvesting within the ranges of the Big Sandy and Guyandotte River crayfishes indicate that in 2007, McDowell and Wyoming Counties, West Virginia, produced

238,711 cubic meters (m^3) (8,426,498 cubic feet (ft^3)) of timber; in 2009, Pike County, Kentucky, produced 75,266 m^3 (2,656,890 ft^3) of timber, and Buchanan, Dickenson, and Wise Counties, Virginia, produced 264,338 m^3 (9,331,131 ft^3) of timber (Cooper *et al.* 2011a, p. 27; Cooper *et al.* 2011b, pp. 26–27; Piva and Cook 2011, p. 46). While we were unable to locate data on how much land area was subject to harvesting, the West Virginia Forestry Association (2001, p. 2) reported that a well-stocked timber stand in this region contains about 45.9 m^3/ha (8,000 board feet/ac or 664 ft^3/ac) of timber. By dividing the total amount of timber harvested, 578,315 m^3 (20,414,520 ft^3), by 45.9 m^3/ha (664 ft^3/ac), we estimate that approximately 12,600 ha (30,745 ac) of forest were harvested within the core ranges of the Big Sandy and Guyandotte River crayfishes during a single year (either 2007 or 2009, depending on the State). Based on land cover data from the USGS (2015, entire) this represents approximately 1.9 percent of the total forest cover within this area.

Hood *et al.* (2002, p. 56) estimated the erosion rate for an undisturbed forested site in the southern Appalachians to be about 0.31 tonnes/ha/yr (0.12 tons/ac/yr). The authors then estimated the erosion rates resulting from several different timber harvest techniques (*e.g.,* clearcut, leave tree, group selection, and shelterwood) and found that during the first year postharvest, erosion rates ranged from 5.33 to 11.86 tonnes/ha/yr (2.11 to 4.71 tons/ac/yr). Applying these erosion rates to the estimated single-year harvested area calculated above (12,600 ha (30,745 ac)) indicates that, if the forest is undisturbed, about 3,906 tonnes (3,828 tons) of sediment will erode, while logging the same area will produce perhaps 67,158 to 149,436 tonnes (65,815 to 146,447 tons) of sediment. While Hood *et al.* (2002) found that erosion rates improved quickly in subsequent years following logging, Swank, *et al.* (2001, pp. 174–176) studied the long-term effects of timber harvesting at a site in the Blue Ridge physiographic province in North Carolina, and determined that 15 years postharvest, the annual sediment yield was still 50 percent above predisturbance levels.

This analysis of potential erosion within the ranges of the Big Sandy and Guyandotte River crayfishes likely underestimates actual erosion rates. Hood *et al.* (2002, p. 54) provide the caveat that the model they used does not account for gully erosion, landslides, soil creep, stream channel erosion, or episodic erosion from single storms, and, therefore, their estimates of actual sediment transport are low. The authors also reported that applicable BMPs were applied diligently at their study sites and that all skid trails were closed to vehicle traffic after harvesting was completed (Hood *et al.* 2002, p. 55). The rates of BMP adherence and effectiveness at other logging sites within the ranges of the Big Sandy and Guyandotte River crayfishes vary. Stringer and Queary (1997, entire) found that in eastern Kentucky, which includes the Big Sandy drainage, BMPs were either not used or not effective at 43.2 percent of the logging sites and that at 13.5 percent of the sites the BMPs were used but not effective. Wang *et al.* (2007, p.15) studied randomly selected sites that were logged between November 2003 and March 2004 and determined that, within the West Virginia Forestry District that includes the Upper Guyandotte watershed, BMP adherence was 80 percent. A 2012 report on forestry BMP implementation in the southeast United States (Southern Group of State Foresters 2012, p. 6) indicates that the Statewide level of compliance in Virginia improved from about 75 to 86 percent between 2007 and 2011. The implementation of forestry BMPs to reduce erosion and sedimentation is not required for certain timber cutting operations. In Kentucky, tree clearing incidental to preparing coal mining sites is specifically exempted, and in West Virginia, tree-clearing activities incidental to ground-disturbing construction activities, including those related to oil and gas development, are exempted (Kentucky Division of Forestry undated fact sheet, downloaded February 5, 2015); West Virginia Division of Forestry 2014, pp. 3–4).

Swank *et al.* (2001) also referenced several associated studies on the response of stream invertebrates to the timber harvest and resultant sediment loading. These studies showed an alteration in abundance, biomass, and productivity of taxa, notably a decrease in abundance of species that inhabit lower gradient sand and pebble habitats. They also note that after more than 15 years, the stream invertebrate community was gradually returning toward that found in a reference stream (Swank, *et al.* 2001, p. 175).

Because timber harvesting occurs year to year on a rotational basis throughout the Big Sandy and Upper Guyandotte watersheds, and because the excess sedimentation from harvested sites may take decades to flush from area streams, we conclude that soil erosion and sedimentation from commercial timber harvesting is likely relatively constant and ongoing in the region, and continually degrades the aquatic habitat required by the Big Sandy and Guyandotte River crayfishes.

Stream channelization and dredging—Flooding is a recurring problem for people living in the southern Appalachians, and many individuals and mountain communities have resorted to unpermitted stream dredging or bulldozing to deepen channels and/or remove obstructions in an attempt to alleviate damage from future floods (West Virginia Conservation Agency (WVCA), pp. 4, 36–38, 225–229). As recently as 2009, Loughman (pers. comm., October 24, 2014) observed heavy equipment being operated in stream channels in the Upper Guyandotte basin. Unfortunately, these efforts are rarely effective at reducing major flood damage and often cause other problems such as stream bank erosion, lateral stream migration, channel downcutting, and sedimentation (WVCA, pp. 225–229). Stream dredging or bulldozing also causes direct damage to the aquatic habitat by removing benthic structure, such as slab boulders, and likely kills benthic organisms by crushing or burial. Because these dredging and bulldozing activities are unpermitted, we have little data on exactly how widespread or how often they occur within the ranges of the Big Sandy or Guyandotte River crayfishes. However, during their 2009 survey work for *Cambarus veteranus* in the Upper Guyandotte and Tug Fork basins, Loughman and Welsh (2013, p. 23) noted that 54 percent of the sites they surveyed (these were sites predicted to be suitable to the species) appeared to have been dredged, evidenced by monotypic gravel or cobble bottoms and a conspicuous absence of large slab boulders. These sites were thus rendered unsuitable for occupation by *C. veteranus* and confirmed so by the absence of the species.

Gas and oil development—The Appalachian Plateaus physiographic province is underlain by numerous geological formations that contain natural gas, and to a lesser extent oil. The Marcellus shale formation underlies the entire range of the Guyandotte River crayfish and a high proportion of the range of the Big Sandy crayfish, specifically McDowell County, West Virginia, and part of Buchanan County, Virginia (U.S. Department of Energy (USDOE) 2011, p. 5), and various formations that make up the Devonian Big Sandy shale gas play (*e.g.,* a favorable geographic area that has been targeted for exploration) underlie the entire range of the Big Sandy crayfish and some of the range of the Guyandotte

River crayfish (USDOE 2011, p. 9). In addition to these shale gas formations, natural gas also occurs in conventional formations and in coal seams (referred to as ''coal bed methane'' or CBM) in each of the counties making up the ranges of the two species. The intensity of resource extraction from these geological formations has varied over time depending on market conditions and available technology, but since the mid- to late 20th century, many thousands of gas and oil wells have been installed within the ranges of the Big Sandy and Guyandotte River crayfishes (KGS 2015; VDMME 2015, WVDEP 2015).

Numerous studies have reported that natural gas development has the potential to degrade aquatic habitats (Adams *et al.* 2011, pp. 8–10, 18; Boelter *et al.* 1992, pp. 1192–1195; Drohan and Brittingham, 2012, entire; Harkness *et al.* 2015, entire; McBroom *et al.* 2012, pp. 953–956; Olmstead *et al.* 2013, pp. 4966–4967; Papoulias and Velasco 2013, entire; USEPA 2014, entire; Vegosh *et al.* 2014, pp. 8339–8342; Vidic *et al.* 2013, entire; Warner *et al.* 2013, entire). The construction of well pads and related infrastructure (*e.g.,* gas pipelines, compressor stations, wastewater pipelines and impoundments, and access roads) can increase erosion and sedimentation, and the release of drilling fluids, other industrial chemicals, or formation brines can contaminate local streams.

Within the ranges of the Big Sandy and Guyandotte River crayfishes the topography is rugged and the dominant land cover is forest; therefore, the construction of new gas wells and related infrastructure usually involves timber cutting and significant earth moving to create level well pads, access roads, and pipeline rights-of-way. Drohan and Brittingham (2012, entire) analyzed the runoff potential for shale gas development sites in the Allegheny Plateau region of Pennsylvania, and found that 50 to 70 percent of existing or permitted pad sites had medium to very high runoff potential and were at an elevated risk of soil erosion. McBroom *et al.* (2012, entire) studied soil erosion from two well pads constructed in a forested area in the Gulf Coastal Plain of east Texas. One well was constructed in the channel of an intermittent stream, which was rechanneled around the pad following construction. The second well was constructed on a terraced hillside but with a 15-m (50-ft) vegetated riparian buffer. The observed sediment losses were 14 and 0.7 tonnes/ha/yr (5.54 and 0.28 tons/ac/yr), respectively. The authors reference their earlier study in east Texas that found the average sediment yield from undisturbed forested sites to be 0.042 tonnes/ha/yr (0.017 tons/ac/yr) (McBroom *et al.* 2012, pp. 954–955). As noted previously, Hood *et al.* (2002, p. 56) estimated the erosion rate for an undisturbed forested site in the steeper terrain of the southern Appalachians to be about 0.31 tonnes/ha/yr (0.12 tons/ac/yr), an order of magnitude greater than that reported by McBroom *et al.* (2012) for an undisturbed site in east Texas. Therefore, it is reasonable to conclude that the erosion potential from disturbed sites within the ranges of the Big Sandy and Guyandotte River crayfishes is also much greater than that observed by McBroom *et al.* (2012) in east Texas.

Natural gas well drilling and well stimulation, especially the technique of hydraulic fracturing, can also degrade aquatic habitats when drilling fluids or other associated chemicals or high salinity formation waters (*e.g.,* flowback water and produced water) are released, either intentionally or by accident, into local surface waters (Harkness *et al.* 2015, entire; McBroom *et al.* 2012, p. 951; Papoulias and Velasco 2013, entire; USEPA 2014, entire; Vidic *et al.* 2013, entire; Warner *et al.* 2013, entire). We anticipate the rate of oil and gas development within the ranges of the Big Sandy and Guyandotte River crayfishes to increase based on projections from a report by IHIS Global, Inc. (2013, p. 4) produced for the American Petroleum Institute, which indicate that the ''recent surge in oil and gas transportation and storage infrastructure investment is not a short lived phenomenon. Rather, we find that a sustained period of high levels of oil and gas infrastructure investment will continue through the end of the decade.'' While this projection is generalized across all oil and gas infrastructure within the United States, an increase of new infrastructure within the ranges of the Big Sandy and Guyandotte River crayfishes is also anticipated because of the yet untapped Marcellus and Devonian Big Sandy shale resources discussed above.

Summary of Factor A—The best available information indicates the primary threats to both the Big Sandy and Guyandotte River crayfishes throughout their respective ranges are land-disturbing activities that increase erosion and sedimentation, which degrades the stream habitat required by both species. Identified sources of ongoing erosion and sedimentation that occur throughout the ranges of the species include active surface coal mining, commercial forestry, unpaved roads, gas and oil development, and road construction. These activities are ongoing (*e.g.,* imminent) and expected to continue at variable rates into the future. For example, while active coal mining may decline, the legacy effects will continue, and oil and gas activities and road construction are expected to increase. An additional threat specific to the Guyandotte River crayfish is the ongoing operation of ORVs in and adjacent to the species' last known location in Pinnacle Creek; this ORV use is expected to continue. Contributing stressors include water quality degradation resulting from abandoned coal mine drainage; untreated (or poorly treated) sewage discharges; road runoff; unpermitted stream dredging; and potential catastrophic spills of coal slurry, fluids associated with gas well development, or other contaminants.

Factor B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

We found no information indicating that overutilization has led to the loss of populations or a significant reduction in numbers of individuals for either the Big Sandy crayfish or Guyandotte River crayfish. Therefore, we conclude based on the best scientific and commercial information available that overutilization for commercial, recreational, scientific, or educational purposes does not currently pose a threat to the Big Sandy crayfish or the Guyandotte River crayfish. However, because the best available information indicates that the Guyandotte River crayfish persists only in very low numbers in the midreach of a single stream, increased awareness of the species' rarity may make it more desirable to collectors. Similarly, because the Big Sandy crayfish is now recognized as a newly described species, it too could become more desirable to collectors. Any future collection of either species, but especially of the Guyandotte River crayfish, could pose a threat to their continued existence.

Factor C. Disease or Predation

We found no information indicating that disease or predation has led to the loss of populations or a significant reduction in numbers of individuals of the Guyandotte River crayfish. However, because the species is known to persist only in very low numbers in the midreach of a single stream, any source of mortality or any impairment of growth, reproduction, or fitness may pose a threat to its continued existence. Additionally, it is possible that this remnant population lacks the genetic diversity of the original wider population, which may now make it more vulnerable to disease.

Similarly, we have no information indicating that disease or predation has led to the decline of the Big Sandy crayfish. However, the existing population is fragmented into at least four isolated subpopulations in several different watersheds, the upper Tug Fork system, the upper Levisa Fork system, Russell Fork/Levisa Fork system, and the Pound River/Cranes Nest River system (see Factor E, below). While this isolation may provide the species some resiliency should disease (or other catastrophe) affect any one of the subpopulations, this potentially positive aspect of habitat fragmentation is countered by the fact that each isolated subpopulation is at a higher risk of extirpation. However, the best scientific and commercial information available indicates that disease or predation do not pose a threat to the existence of either the Guyandotte River crayfish or the Big Sandy crayfish now or in the future.

Factor D. The Inadequacy of Existing Regulatory Mechanisms

Few existing Federal or State regulatory mechanisms specifically protect the Big Sandy or Guyandotte River crayfishes or the aquatic habitats where they occur. The species' habitats are afforded some protection from water quality and habitat degradation under the Federal 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.*), along with State laws and regulations such as the Kentucky regulations for water quality, coal mining, forest conservation, and natural gas development (401 KAR, 402 KAR, 405 KAR, 805 KAR); the Virginia State Water Control Law (Va. Code sec. 62.1–44.2 *et seq.*); and the West Virginia Water Pollution Control Act (WVSC sec. 22–11) and Logging and Sediment Control Act (WVSC sec.19–1B). Additionally, the Big Sandy crayfish is listed as endangered by the State of Virginia (Va. Code sec. 29.1–563 to 570), which provides that species some direct protection within the Virginia portion of its range. However, while water quality has generally improved since 1977, when the CWA and SMCRA were enacted or amended, there is continuing, ongoing degradation of habitat for both species, as detailed under Factor A, above. Therefore, despite the protections afforded by these laws and implementing regulations, both the Big Sandy and Guyandotte River crayfishes continue to be affected by degraded water quality and habitat conditions.

In 1989, 12 years after enactment of the CWA and SMCRA, the Guyandotte River crayfish was known to occur in low numbers in Huff Creek and Pinnacle Creek (Jezerinac *et al.* 1995, p. 170). However, surveys since 2002 indicate the species has been extirpated from Huff Creek and continues to be found only in very low numbers in Pinnacle Creek. Despite more than 35 years of CWA and SMCRA regulatory protection, the range of the Guyandotte River crayfish has declined substantially, and the single known population contains few individuals. There is little information available to determine trends in the Big Sandy crayfish's range or population since enactment of the CWA or SMCRA. However, as discussed previously, surveys conducted between 2007 and 2010 (Thoma 2009 and 2010, entire) indicate that the species' current range is significantly reduced from its historical range, and that much of the historical habitat continues to be degraded by sediments and other pollutants. In addition, at many of the sites that do continue to harbor the species, the Big Sandy crayfish is found only in low numbers with individual crayfish often reported to be in poor physical condition (Thoma 2010, p. 6; Loughman, pers. comm., October 24, 2014). Reduction in the range of the Big Sandy Crayfish and continued degradation of its habitat lead us to conclude that neither the CWA nor the SMCRA has been wholly effective at protecting this species.

As discussed in previous sections, erosion and sedimentation caused by various land-disturbing activities, such as surface coal mining, roads, forestry, and oil and gas development, pose an ongoing threat to the Big Sandy and Guyandotte River crayfishes. State efforts to address excessive erosion and sedimentation involve the implementation of BMPs; however, as discussed under Factor A, above, BMPs are often not strictly applied, are sometimes voluntary, or are situationally ineffective. Additionally, studies indicate that even when BMPs are properly applied and effective, erosion rates at disturbed sites are still significantly above erosion rates at undisturbed sites (Christopher and Visser 2007, pp. 22–24; Grant and Wolff 1991, p. 36; Hood *et al.* 2002, p. 56; McBroom *et al.* 2012, pp. 954–955; Wang *et al.* 2013, pp. 86–90).

Although the majority of the land throughout the ranges of the two species is privately owned, publicly managed lands in the region include a portion of the Jefferson National Forest in Virginia, and 10 State wildlife management areas and parks in the remainder of the Big Sandy and Upper Guyandotte watershed (one in Russell Fork, three in Levisa Fork, four in Tug Fork, two in Upper Guyandotte). However, three of these parcels surround artificial reservoirs that are no longer suitable habitat for either the Big Sandy crayfish or Guyandotte River crayfish, and six others are not in known occupied crayfish habitat. Only the Jefferson National Forest and the Breaks Interstate Park in the Russell Fork watershed at the Kentucky/Virginia border appear to potentially offer additional protections to extant Big Sandy crayfish populations, presumably through stricter management of land-disturbing activities that cause erosion and sedimentation. However, the extent of publically owned land adding to the protection of the Big Sandy and Guyandotte River crayfishes is minimal and not sufficient to offset the rangewide threats to either species.

Summary of Factor D—Degradation of Big Sandy and Guyandotte River crayfish habitat (Factor A) is ongoing despite existing regulatory mechanisms. While these regulatory efforts have led to some improvements in water quality and aquatic habitat conditions, the precipitous decline of the Guyandotte River crayfish and the decline of the Big Sandy crayfish within most of its range indicate that these regulatory efforts have not been effective at protecting these two species. In addition, the threat resulting from the species' endemism and their isolated and small population sizes (discussed below under Factor E) cannot be addressed through regulatory mechanisms.

Factor E. Other Natural or Manmade Factors Affecting Its Continued Existence

Locally endemic, isolated, and small population size—It is intuitive and generally accepted that the key factors governing a species' risk of extinction include small population size, reduced habitat size, and fragmented habitat (Hakoyama *et al.* 2000, pp. 327, 334–336; Lande 1993, entire; Pimm *et al.* 1988, pp. 757, 774–777; Wiegand *et al.* 2005, entire). Relevant to wholly aquatic species, such as the Big Sandy and Guyandotte River crayfishes, Angermeier (1995, pp. 153–157) found that fish species that were limited by physiographic range or range of waterbody sizes were also more vulnerable to extirpation or extinction, especially as suitable habitats became more fragmented. As detailed in previous sections, both the Big Sandy crayfish and the Guyandotte River crayfish are known to exist only in the

Appalachian Plateaus physiographic province and are limited to certain stream classes and habitat types within their respective river basins. Furthermore, the extant populations of each species are limited to certain disjunct subwatersheds, which are physically isolated from the others by distance, human-induced inhospitable intervening habitat conditions, and/or physical barriers (*e.g.,* dams and reservoirs).

Genetic fitness—Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression, and reducing the fitness of individuals (Allendorf and Luikart 2007, pp. 117–146; Hunter 2002, pp. 97–101; Soule 1980, pp. 157–158). Similarly, the random loss of adaptive genes through genetic drift may limit the ability of the Big Sandy crayfish and, especially, the Guyandotte River crayfish to respond to changes in their environment such as the chronic sedimentation and water quality effects described above or catastrophic events (Noss and Cooperrider 1994, p. 61). Small population sizes and inhibited gene flow between populations may increase the likelihood of local extirpation (Gilpin and Soulé 1986, pp. 32–34). The long-term viability of a species is founded on the conservation of numerous local populations throughout its geographic range (Harris 1984, pp. 93–104). These separate populations are essential for the species to recover and adapt to environmental change (Harris 1984, pp. 93–104; Noss and Cooperrider 1994, pp. 264–297). The populations of the Big Sandy crayfish are isolated from other existing populations and known historical habitats by inhospitable stream conditions and dams that are barriers to crayfish movement. The current population of the Guyandotte River crayfish is restricted to one location in one stream. This population is isolated from other known historical habitats by inhospitable stream conditions. The level of isolation and the restricted ranges seen in each species make natural repopulation of historical habitats or other new areas following previous localized extirpations virtually impossible without human intervention.

Guyandotte River crayfish—As discussed previously, the historical range of the Guyandotte River crayfish has been greatly reduced. Early surveys confirmed the species in 9 streams (15 individual sites) in the Upper Guyandotte basin, and prior to the widespread habitat degradation that began in the early 20th century, it undoubtedly occurred at other suitable sites throughout the system (Loughman, pers. comm. October 24, 2014). In 2009, 35 likely sites were surveyed in the Upper Guyandotte basin (including 13 of the historical sites), and the species was found only in very low numbers at a single site in the midreach of Pinnacle Creek (Loughman 2013, pp. 5–6). Any further reduction in the range of the Guyandotte River crayfish (*i.e.,* loss of the Pinnacle Creek population) would likely result in the species' extinction.

Based on the Guyandotte River crayfish's original distribution and the behavior of other similar stream-dwelling crayfish, it is reasonable to surmise that, prior to the widespread habitat degradation in the basin, individuals from the various occupied sites were free to move between sites or to colonize (or recolonize) suitable vacant sites (Kerby *et al.* 2005, pp. 407–408; Momot 1966, entire). According to Loughman (2013, p. 9), Huff Creek, where the species was last noted in 1989 (Jezerinac *et al.* 1995, p. 170), is one of the few streams in the basin that still appears to maintain habitat conducive to the species. However Huff Creek and another historical stream, Little Huff Creek, are physically isolated from the extant Pinnacle Creek population by the R.D. Bailey Dam on the Guyandotte River near the town of Justice, West Virginia. This physical barrier, as well as generally inhospitable habitat conditions throughout the basin, makes it unlikely and perhaps impossible for individuals from the extant Pinnacle Creek population to successfully disperse to recolonize other locations in the basin.

And, as noted above in Factor A, the persistence of the last known Guyandotte River crayfish population is threatened by several proximate active surface coal mines and ORV use in the Pinnacle Creek watershed. The species lacks redundancy (*e.g.,* the ability of a species to withstand catastrophic events) and representation (*e.g.,* the ability of a species to adapt to changing environmental conditions), and has very little resiliency (*e.g.,* the ability of the species to withstand stochastic events); therefore, this single small population is at an increased risk of extirpation, and in this case likely extinction, from natural demographic or environmental stochasticity, a catastrophic event, or even a modest increase in any existing threat at the single known site of occurrence.

Big Sandy crayfish—The survey work of Thoma (2009, p. 10; 2010, p. 6) and Loughman (2013, pp. 7–8) demonstrates that the geographic extent of the Big Sandy crayfish's occupied habitat, in the context of the species' historical range, is significantly reduced. Additionally, their research indicates that, because of widespread habitat degradation, the species is notably absent from many individual streams where its presence would otherwise be expected, and at most sites where it does still persist, it is generally found in low numbers.

Because the Big Sandy crayfish is wholly aquatic and therefore limited in its ability to move from one location to another by the basin's complex hydrology, the species' overall population size and current geographic range must be considered carefully when evaluating its risk of extinction. Prior to the significant habitat degradation that began in the late 1800s, the Big Sandy crayfish likely occurred in suitable stream habitat throughout its range (from the Levisa Fork/Tug Fork confluence to the headwater streams in the Russell Fork, Levisa Fork, and Tug Fork basins) (Thoma 2010, p. 6; Thoma *et al.* 2014, p. 549), and individuals were free to move between occupied sites or to colonize (or recolonize) suitable vacant sites. The current situation is quite different, with the species' occupied subwatersheds being isolated from each other by linear distance (of downstream and upstream segments), inhospitable intervening habitat, and/or dams. Therefore, the status and risk of extirpation of each individual subpopulation must be considered in assessing the species' risk of extinction. Based on habitat connectedness (or lack thereof), we consider the existing Big Sandy crayfish subpopulations to be the upper Tug Fork population, the upper Levisa Fork population, the Russell Fork/Levisa Fork population (including Shelby Creek), and the Pound River/Cranes Nest River population (Figure 7). While the Pound River and Cranes Nest River are in the same subwatershed, they both flow into the Flannagan Reservoir, which is unsuitable habitat for the species. Therefore, the Big Sandy crayfish populations in these streams are not only isolated from other populations by the dam and reservoir, but also most likely isolated from each other by the inhospitable habitat in the reservoir itself (Loughman, pers. comm., December 1, 2014). It is conceivable, however, that on occasions when reservoir levels are low, crayfish from the Pound and Cranes Nest Rivers could intermix. Also, because the Fishtrap Dam physically isolates the upper Levisa Fork (Dismal Creek) population from the remainder of the species' range, only the upper Tug Fork and the

Russell Fork/Levisa Fork subpopulations still maintain any possible connection. However, intervening stream distance (240 km (150 mi)) and poor habitat conditions in both the lower Tug Fork and the lower Levisa Fork make it unlikely that individuals from either subpopulation can migrate out of their respective subbasins to intermix or recolonize other sites.

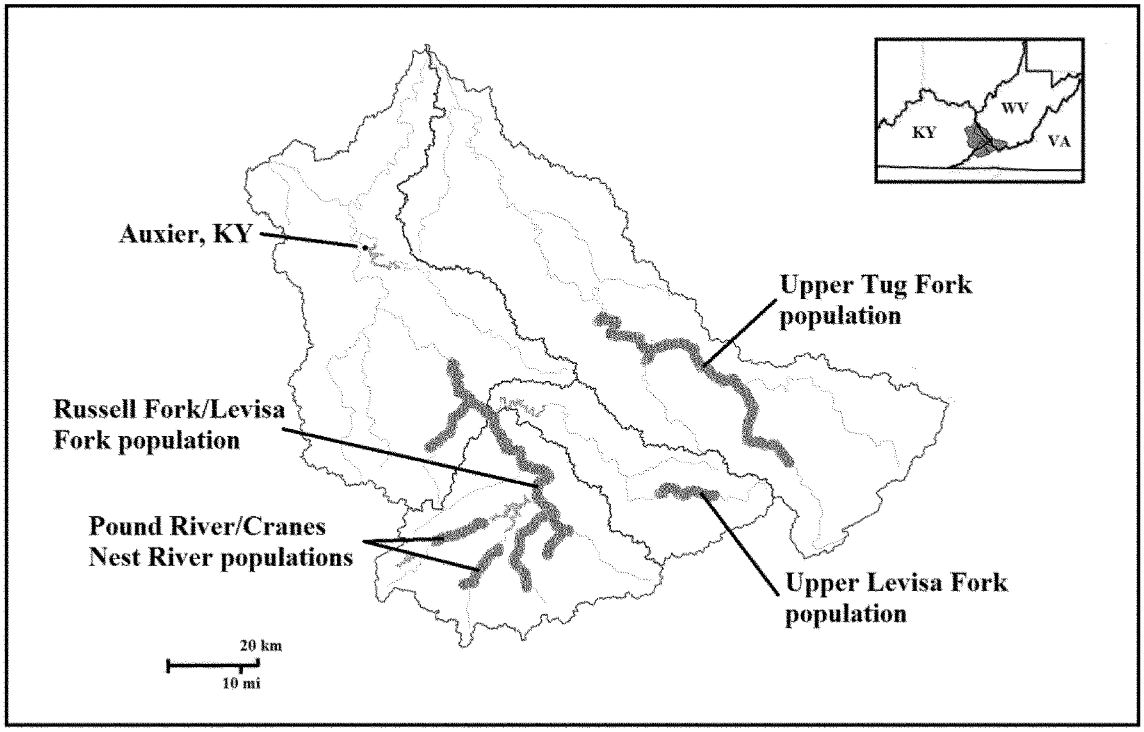

Figure 7.—Fragmentation of the existing Big Sandy crayfish populations. In 1999 and 2009, single specimens were noted at Auxier, KY (indicated by the closed dark circle).

There is one exception to this subpopulation organization. In 2009, a single Big Sandy crayfish was recovered by Thoma (2010, p. 6) in the lower Levisa Fork at the town of Auxier, Kentucky, more than 50 km (31 mi) downstream of the nearest other occupied site near the town of Coal Run Village, Kentucky (Figure 7). The author surveyed 8 other likely sites in the lower Levisa system between Auxier and Coal Run Village, but did not confirm the species at any location. Therefore, we conclude that the lower Levisa Fork system does not represent a viable subpopulation.

The four remaining subpopulations differ in their resiliency. The upper Levisa Fork population persists in a single stream, as do the Pound River/Cranes Nest River populations. While the species appears to be moderately abundant in these streams (see Table 3, above), the fact that they are restricted to single streams (versus a network of streams) makes them especially susceptible to catastrophic loss as a result of a contaminant spill, disease, stream dredging, or other perturbation. The upper Tug Fork population also appears to be relatively insecure, with most sites where the species is still found showing very low abundance. Thoma (2010, p. 6) found the species in low numbers in the Kentucky portion of the upper Tug Fork system and described their status there as ''highly tenuous.''

This isolation, caused by habitat fragmentation, reduces the resiliency of the species by eliminating the potential movement of individuals from one subpopulation to another, or to unoccupied sites that could become habitable in the future. This inhibits gene flow in the species as a whole and will likely reduce the genetic diversity and perhaps the fitness of individuals in the remaining subpopulations.

Interspecific competition—A contributing factor to the imperilment of the habitat-specialist Big Sandy and Guyandotte River crayfishes may be increased interspecific competition brought about by habitat degradation. In the Upper Guyandotte, researchers surmise that as the benthic habitat was degraded by sedimentation, competition between the habitat-specialist Guyandotte River crayfish and more generalist native crayfish species may have contributed to the former's decline (Loughman 2014, pp. 32–33). The Guyandotte River crayfish has always been associated with faster moving water of riffles and runs, while other native species such as *Cambarus theepiensis* are typically associated with the lower velocity portions of streams. Loughman surmises that, because these lower velocity stream habitats suffer the effects of increased sedimentation and bottom embeddedness before the effects are manifested in the faster moving reaches, the native crayfish using these habitats migrated into the relatively less affected riffle and run habitats that are normally the niche of the Guyandotte River crayfish. In the ensuing competition between the habitat-specialist Guyandotte River crayfish and the more generalist species, the former is thought to be at a competitive disadvantage. Survey results support this hypothesis, with *C. theepiensis* being found commonly in the riffle habitats of streams suffering from high sediment loads, including the historical Guyandotte River crayfish locations. At the Pinnacle Creek location, Loughman (2014, pp. 9, 33) noted a 40:1 ratio between *C. theepiensis* and Guyandotte River crayfish numbers. We have no information to determine whether or not the Big Sandy crayfish faces similar competitive pressures.

Direct Mortality Due to Crushing

As discussed above under Factor A, ORV use of unpaved trails are a source of sedimentation into the aquatic habitats within the range of the Guyandotte River crayfish. In addition to this habitat degradation, there is the potential for direct crayfish mortality as a result of crushing when ORVs use stream crossings, or when they deviate from designated trails or run over slab boulders that the Guyandotte River crayfish use for shelter (Loughman 2014, pp. 30–31).

Summary of Factor E—The habitat of the Big Sandy and Guyandotte River crayfishes is highly fragmented, thereby isolating the remaining populations of each species from each other. The remaining individuals are found in very low numbers at most locations where they still exist. The level of isolation and the restricted ranges seen in each species make natural repopulation of historical habitats or other new areas following previous localized extirpations virtually impossible without human intervention. This reduction in redundancy and representation significantly impairs the resiliency of each species and poses a threat to their continued existence. In addition, direct mortality due to crushing may have a significant effect on the Guyandotte River crayfish. Interspecific competition from other native crayfish species that are more adapted to degraded stream conditions may also act as an additional stressor to the Guyandotte River crayfish.

Cumulative Effects From Factors A Through E

Based on the risk factors described above, the Big Sandy crayfish and the Guyandotte River crayfish are at an increased risk of extinction primarily due to land-disturbing activities that increase erosion and sedimentation, and subsequently degrade the stream habitat required by both species (Factor A), and due to the effects of small population size (Factor E). Other contributing factors are degraded water quality and unpermitted stream dredging (Factor A). While events such as collection (Factor B) or disease and predation (Factor C) are not currently known to affect either species, any future incidences will further reduce the resiliency of the Guyandotte River and Big Sandy crayfishes.

12-Month Petition Finding

Big Sandy Crayfish

As required by the Act, we considered the five factors in assessing whether the Big Sandy crayfish is an endangered or threatened species, as cited in the petition, throughout all of its range. We examined the best scientific and commercial information available regarding the past, present, and future threats faced by the Big Sandy crayfish. We reviewed the petition, information available in our files, and other available published and unpublished information, and we consulted with recognized crayfish experts and other Federal and State agencies.

We identify that the primary threats to the Big Sandy crayfish are attributable to land disturbance that increases erosion and sedimentation, which degrades the stream habitat required by both species (Factor A), and to the effects of small population size (Factor E). Other contributing factors are degraded water quality and unpermitted stream dredging (Factor A). Existing regulatory mechanisms are inadequate to reduce these threats (Factor D).

On the basis of the best scientific and commercial information available, we find that the petitioned action to list the Big Sandy crayfish as an endangered or threatened species is warranted. A determination on the status of the species as an endangered or threatened species is presented below in the proposed listing determination.

Status Review Finding

Guyandotte River Crayfish

As required by the Act, we considered the five factors in assessing whether the Guyandotte crayfish is an endangered or threatened species throughout all of its range. We examined the best scientific and commercial information available regarding the past, present, and future threats faced by the Guyandotte River crayfish. We reviewed information available in our files, and other available published and unpublished information, and we consulted with recognized crayfish experts and other Federal and State agencies.

We identify that the primary threats to the Guyandotte River crayfish are attributable to land disturbance that increases erosion and sedimentation, which degrades the stream habitat required by both species (Factor A), and to the effects of small population size (Factor E). Other contributing factors are degraded water quality and unpermitted stream dredging (Factor A). Existing regulatory mechanisms are inadequate to reduce these threats (Factor D).

On the basis of the best scientific and commercial information available, we find that the Guyandotte River crayfish warrants listing as an endangered or threatened species. A determination on the status of the species as an endangered or threatened species is presented below in the proposed listing determination.

Determination

Section 4 of the Act (16 U.S.C. 1533), and its implementing regulations at 50 CFR part 424, set forth the procedures for adding species to the Federal Lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, we may list a species based on (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. Listing actions may be warranted based on any of the above threat factors, singly or in combination.

As discussed above, we have carefully assessed the best scientific and commercial information and data available regarding the past, present, and future threats to the Big Sandy crayfish and the Guyandotte River crayfish. Rangewide habitat loss and degradation (Factor A) is occurring from land-disturbing activities that increase erosion and sedimentation, which degrades the stream habitat required by both species. Identified sources of ongoing erosion include active surface coal mining, commercial forestry, unpaved roads, gas and oil development, and road construction. An additional threat specific to the Guyandotte River crayfish is the operation of ORVs in and adjacent to Pinnacle Creek, the last known remaining extant population. Contributing stressors to both species include water quality degradation (Factor A) resulting from abandoned coal mine drainage; untreated (or poorly treated) sewage discharges; road runoff; unpermitted stream dredging; and potential catastrophic spills of coal slurry, fluids associated with gas well development, or other contaminants. The effects of habitat loss have resulted in a significant range contraction of the

Big Sandy crayfish to all but higher elevation habitats, and the Guyandotte River crayfish's current distribution is limited to one site with five known individuals confirmed during last survey in 2011. Existing State wildlife laws and Federal regulations such as the CWA and SMCRA are insufficient to address the threats to the species (Factor D). Additionally, the habitat of the Big Sandy and Guyandotte River crayfishes is highly fragmented, thereby isolating the remaining populations of each species (Factor E) from each other. The remaining individuals are found in very low numbers at most locations where they still exist. The single remaining population of the Guyandotte River crayfish has no redundancy and significantly reduced representation. The level of isolation and the restricted range of each species make natural repopulation of historical habitats or other new areas following previous localized extirpations virtually impossible without human intervention. The reduction in redundancy and representation for each species significantly impairs their resiliency and poses a threat to their continued existence. The interspecific competition (Factor E) from other native crayfish species that are more adapted to degraded stream conditions may act as an additional stressor to the Guyandotte River crayfish. These Factor A and Factor E threats are rangewide; are not likely to be reduced in the future; are likely to increase (*e.g.,* for Factor A, oil and gas development and road construction; for Factor E, extirpation and further isolation of populations); and are significant because they further restrict limited available habitat and decrease the resiliency of Big Sandy crayfish and Guyandotte River crayfish within those habitats.

The Act defines an endangered species as any species that is ''in danger of extinction throughout all or a significant portion of its range'' and a threatened species as any species ''that is likely to become endangered throughout all or a significant portion of its range within the foreseeable future.'' As discussed above, we find that the Big Sandy crayfish and the Guyandotte River crayfish are in danger of extinction throughout their entire ranges based on the severity and immediacy of threats currently affecting these species. For the Big Sandy crayfish, although the species still occupies sites located throughout the breadth of its historical range, the remaining sites are significantly reduced to only the higher elevations within the watersheds; the remaining habitat and populations are threatened by a variety of factors acting in combination to reduce the overall viability of the species. The risk of extinction is high because the remaining populations are small and isolated, and because there is limited potential for recolonization. For the Guyandotte River crayfish, the species has been reduced to a single site, and its habitat and population are threatened by a variety of factors acting in combination to reduce, and likely eliminate, the overall viability of the species. The risk of extinction is high because the single population is very small and isolated, and has essentially no potential to recolonize other sites. Therefore, on the basis of the best available scientific and commercial information, we propose to list the Big Sandy crayfish and the Guyandotte River crayfish as endangered species in accordance with sections 3(6) and 4(a)(1) of the Act because the threats are impacting both of the species at a high level of severity across their severely contracted ranges now, and are expected to increase into the future. All of these factors combined lead us to conclude that the threat of extinction is high and immediate, thus warranting a determination as an endangered species rather than a threatened species for both the Big Sandy crayfish and the Guyandotte River crayfish.

Under the Act and our implementing regulations, a species may warrant listing if it is endangered or threatened throughout all or a significant portion of its range. Because we have determined that the Big Sandy crayfish and the Guyandotte River crayfish are endangered throughout all of their ranges, no portion of their ranges can be ''significant'' for purposes of the definitions of ''endangered species'' and ''threatened species.'' See the Final Policy on Interpretation of the Phrase ''Significant Portion of Its Range'' in the Endangered Species Act's Definitions of ''Endangered Species'' and ''Threatened Species'' (79 FR 37577, July 1, 2014).

Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened under the Act include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing results in public awareness and conservation by Federal, State, Tribal, and local agencies; private organizations; and individuals. The Act encourages cooperation with the States and other countries and calls for recovery actions to be carried out for listed species. The protection required by Federal agencies and the prohibitions against certain activities are discussed, in part, below.

The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Subsection 4(f) of the Act calls for the Service to develop and implement recovery plans for the conservation of endangered and threatened species. The recovery planning process involves the identification of actions that are necessary to halt or reverse the species' decline by addressing the threats to its survival and recovery. The goal of this process is to restore listed species to a point where they are secure, self-sustaining, and functioning components of their ecosystems.

Recovery planning includes the development of a recovery outline shortly after a species is listed and preparation of a draft and final recovery plan. The recovery outline guides the immediate implementation of urgent recovery actions and describes the process to be used to develop a recovery plan. Revisions of the plan may be done to address continuing or new threats to the species, as new substantive information becomes available. The recovery plan also identifies recovery criteria for review of when a species may be ready for downlisting or delisting, and methods for monitoring recovery progress. Recovery plans also establish a framework for agencies to coordinate their recovery efforts and provide estimates of the cost of implementing recovery tasks. Recovery teams (composed of species experts, Federal and State agencies, nongovernmental organizations, and stakeholders) are often established to develop recovery plans. When completed, the recovery outline, draft recovery plan, and the final recovery plan will be available on our Web site (*http://www.fws.gov/endangered*), or from the Northeast Regional Office (see **FOR FURTHER INFORMATION CONTACT**).

Implementation of recovery actions generally requires the participation of a broad range of partners, including other Federal agencies, States, Tribes, nongovernmental organizations, businesses, and private landowners. Examples of recovery actions include habitat restoration (*e.g.,* restoration of native vegetation, removal of sedimentation), research, captive propagation and reintroduction, and outreach and education. The recovery of many listed species cannot be accomplished solely on Federal lands because they may occur primarily or solely on non-Federal lands. To achieve recovery of these species requires cooperative conservation efforts on private, State, and Tribal lands. If these species are listed, funding for recovery actions will be available from a variety of sources, including Federal budgets; State programs; and cost share grants for non-Federal landowners, the academic community, and nongovernmental organizations. In addition, pursuant to section 6 of the Act, the States of Kentucky, Virginia, and West Virginia would be eligible for Federal funds to implement management actions that promote the protection or recovery of the Big Sandy crayfish, and the State of West Virginia would be eligible for Federal funds to implement management actions that promote the protection or recovery of the Guyandotte River crayfish. Information on our grant programs that are available to aid species recovery can be found at: *http://www.fws.gov/grants.*

Although the Big Sandy crayfish and Guyandotte River crayfish are only proposed for listing under the Act at this time, please let us know if you are interested in participating in recovery efforts for these species. Additionally, we invite you to submit any new information on these species whenever it becomes available and any information you may have for recovery planning purposes (see **FOR FURTHER INFORMATION CONTACT**).

Section 7(a) of the Act requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as an endangered or threatened species and with respect to its critical habitat, if any is designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. Section 7(a)(4) of the Act requires Federal agencies to confer with the Service on any action that is likely to jeopardize the continued existence of a species proposed for listing or result in destruction or adverse modification of proposed critical habitat. If a species is listed subsequently, section 7(a)(2) of the Act requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the species or destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into consultation with the Service.

Federal agency actions within the species' habitat that may require conference or consultation or both as described in the preceding paragraph include management and any other landscape-altering activities on Federal lands administered by the U.S. Forest Service and the U.S. Army Corps of Engineers (ACOE); issuance of section 404 CWA permits by the ACOE; issuance or oversight of coal mining permits by the Office of Surface Mining (OSM); and construction and maintenance of roads, bridges, or highways by the Federal Highway Administration.

The Act and its implementing regulations set forth a series of general prohibitions and exceptions that apply to endangered wildlife. The prohibitions of section 9(a)(1) of the Act, codified at 50 CFR 17.21, make it illegal for any person subject to the jurisdiction of the United States to take (which includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect; or to attempt any of these) endangered wildlife within the United States or on the high seas. In addition, it is unlawful to import; export; deliver, receive, carry, transport, or ship in interstate or foreign commerce in the course of commercial activity; or sell or offer for sale in interstate or foreign commerce any listed species. It is also illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to employees of the Service, the National Marine Fisheries Service, other Federal land management agencies, and State conservation agencies.

We may issue permits to carry out otherwise prohibited activities involving endangered wildlife under certain circumstances. Regulations governing permits are codified at 50 CFR 17.22. With regard to endangered wildlife, a permit may be issued for the following purposes: For scientific purposes, to enhance the propagation or survival of the species, and for incidental take in connection with otherwise lawful activities. There are also certain statutory exemptions from the prohibitions, which are found in sections 9 and 10 of the Act.

It is our policy, as published in the **Federal Register** on July 1, 1994 (59 FR 34272), to identify to the maximum extent practicable at the time a species is listed, those activities that would or would not constitute a violation of section 9 of the Act. The intent of this policy is to increase public awareness of the effect of a proposed listing on proposed and ongoing activities within the ranges of species proposed for listing. Based on the best available information, the following actions are unlikely to result in a violation of section 9, if these activities are carried out in accordance with existing regulations and permit requirements; this list is not comprehensive:

(1) Normal agricultural and silvicultural practices, including herbicide and pesticide use, which are carried out in accordance with any existing regulations, permit and label requirements, and best management practices; and

(2) Surface coal mining and reclamation activities conducted in accordance with the 1996 Biological Opinion between the Service and OSM.

Based on the best available information, the following activities may potentially result in a violation of section 9 the Act; this list is not comprehensive:

(1) Unlawful destruction or alteration of the habitat of the Big Sandy crayfish or Guyandotte River crayfish (*e.g.*, unpermitted instream dredging, impoundment, water diversion or withdrawal, channelization, discharge of fill material) that impairs essential behaviors such as breeding, feeding, or sheltering, or results in killing or injuring a Big Sandy crayfish or Guyandotte River crayfish.

(2) Unauthorized discharges or dumping of toxic chemicals or other pollutants into waters supporting the Big Sandy crayfish or Guyandotte River crayfish that kills or injures individuals, or otherwise impairs essential life-sustaining behaviors such as breeding, feeding, or finding shelter.

Questions regarding whether specific activities would constitute a violation of section 9 of the Act should be directed to the appropriate office:

- Kentucky Ecological Services Field Office, 330 West Broadway, Suite 265, Frankfort, KY 40601; telephone (502) 695–0468; facsimile (502) 695–1024.
- Southwest Virginia Ecological Services Field Office, 330 Cummings Street, Abingdon, VA 24210; telephone (276) 623–1233; facsimile (276) 623–1185.
- West Virginia Field Office, 694 Beverly Pike, Elkins, WV 26241; telephone (304) 636–6586; facsimile (304) 636–7824.

Critical Habitat for the Big Sandy Crayfish and Guyandotte River Crayfish

Background

Critical habitat is defined in section 3 of the Act as:

(1) The specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the Act, on which are found those physical or biological features:

(a) Essential to the conservation of the species, and

(b) Which may require special management considerations or protection; and

(2) Specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.

Conservation, as defined under section 3 of the Act, means to use and the use of all methods and procedures that are necessary to bring an endangered or threatened species to the point at which the measures provided pursuant to the Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking.

Critical habitat receives protection under section 7 of the Act through the requirement that Federal agencies ensure, in consultation with the Service, that any action they authorize, fund, or carry out is not likely to result in the destruction or adverse modification of critical habitat. The designation of critical habitat does not affect land ownership or establish a refuge, wilderness, reserve, preserve, or other conservation area. Such designation does not allow the government or public to access private lands. Such designation does not require implementation of restoration, recovery, or enhancement measures by non-Federal landowners. Where a landowner requests Federal agency funding or authorization for an action that may affect a listed species or critical habitat, the consultation requirements of section 7(a)(2) of the Act would apply, but even in the event of a destruction or adverse modification finding, the obligation of the Federal action agency and the landowner is not to restore or recover the species, but to implement reasonable and prudent alternatives to avoid destruction or adverse modification of critical habitat.

Section 4 of the Act requires that we designate critical habitat on the basis of the best scientific data available. Further, our Policy on Information Standards Under the Endangered Species Act (published in the **Federal Register** on July 1, 1994 (59 FR 34271)), the Information Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Pub. L. 106–554; H.R. 5658)), and our associated Information Quality Guidelines, provide criteria, establish procedures, and provide guidance to ensure that our decisions are based on the best scientific data available. They require our biologists, to the extent consistent with the Act and with the use of the best scientific data available, to use primary and original sources of information as the basis for recommendations to designate critical habitat.

Prudency Determination

Section 4(a)(3) of the Act, as amended, and implementing regulations (50 CFR 424.12), require that, to the maximum extent prudent and determinable, the Secretary designate critical habitat at the time the species is determined to be endangered or threatened. Our regulations (50 CFR 424.12(a)(1)) state that the designation of critical habitat is not prudent when one or both of the following situations exist: (1) The species is threatened by taking or other human activity, and identification of critical habitat can be expected to increase the degree of threat to the species, or (2) such designation of critical habitat would not be beneficial to the species.

There is currently no imminent threat of take attributed to collection or vandalism under Factor B for either the Big Sandy crayfish or Guyandotte River crayfish, and identification and mapping of critical habitat is not likely to increase any such threat. In the absence of finding that the designation of critical habitat would increase threats to a species, if there are any benefits to a critical habitat designation, then a prudent finding is warranted. The potential benefits of designation include: (1) Triggering consultation under section 7 of the Act, in new areas for actions in which there may be a Federal nexus where it would not otherwise occur because, for example, it is or has become unoccupied or the occupancy is in question; (2) focusing conservation activities on the most essential features and areas; (3) providing educational benefits to State or county governments or private entities; and (4) preventing people from causing inadvertent harm to the species. Therefore, because we have determined that the designation of critical habitat will not likely increase the degree of threat to these species and may provide some measure of benefit, we find that designation of critical habitat is prudent for the Big Sandy crayfish and the Guyandotte River crayfish.

Critical Habitat Determinability

Having determined that designation is prudent, under section 4(a)(3) of the Act we must find whether critical habitat for the species is determinable. Our regulations at 50 CFR 424.12(a)(2) state that critical habitat is not determinable when one or both of the following situations exist: (i) Information sufficient to perform required analyses of the impacts of the designation is lacking, or (ii) The biological needs of the species are not sufficiently well known to permit identification of an area as critical habitat.

As discussed above, we have reviewed the available information pertaining to the biological needs of these species and habitat characteristics where these species are located. Because we are seeking additional information regarding water quality conditions within the range of the Big Sandy and Guyandotte River crayfishes, updated occurrence records for both species, future climate change effects on the species' habitat, and other analyses, we conclude that the designation of critical habitat is not determinable for the Big Sandy crayfish or the Guyandotte River crayfish at this time. We will make a determination on critical habitat no later than 1 year following any final listing determination.

Required Determinations

Clarity of the Rule

We are required by Executive Orders 12866 and 12988 and by the Presidential Memorandum of June 1, 1998, to write all rules in plain language. This means that each rule we publish must:

(1) Be logically organized;

(2) Use the active voice to address readers directly;

(3) Use clear language rather than jargon;

(4) Be divided into short sections and sentences; and

(5) Use lists and tables wherever possible.

If you feel that we have not met these requirements, send us comments by one of the methods listed in the **ADDRESSES** section. To better help us revise the rule, your comments should be as specific as possible. For example, you should tell us the numbers of the sections or paragraphs that are unclearly written, which sections or sentences are too long, the sections where you feel lists or tables would be useful, etc.

National Environmental Policy Act (42 U.S.C. 4321 et seq.)

We have determined that environmental assessments and environmental impact statements, as defined under the authority of the National Environmental Policy Act (NEPA; 42 U.S.C. 4321 *et seq.*), need not be prepared in connection with listing a species as an endangered or threatened species under the Endangered Species Act. We published a notice outlining our reasons for this determination in the **Federal Register** on October 25, 1983 (48 FR 49244).

Government-to-Government Relationship With Tribes

In accordance with the President's memorandum of April 29, 1994 (Government-to-Government Relations with Native American Tribal Governments; 59 FR 22951), Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments), and the Department of the Interior's manual at 512 DM 2, we readily acknowledge our responsibility to communicate meaningfully with recognized Federal tribes on a government-to-government basis. In accordance with Secretarial Order 3206 of June 5, 1997 (American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act), we readily acknowledge our responsibilities to work directly with tribes in developing programs for healthy ecosystems, to acknowledge that tribal lands are not subject to the same controls as Federal public lands, to remain sensitive to Indian culture, and to make information available to tribes. We are not aware of any Big Sandy Crayfish or Guyandotte River Crayfish populations on tribal lands.

References Cited

A complete list of references cited in this rulemaking is available on the Internet at *http://www.regulations.gov* and upon request from the Northeast Regional Office (see **FOR FURTHER INFORMATION CONTACT**).

Authors

The primary authors of this proposed rule are the staff members of the Northeast Regional Office.

List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and recordkeeping requirements, Transportation.

Proposed Regulation Promulgation

Accordingly, we propose to amend part 17, subchapter B of chapter I, title 50 of the Code of Federal Regulations, as set forth below:

PART 17—[AMENDED]

■ 1. The authority citation for part 17 continues to read as follows:

Authority: 16 U.S.C. 1361–1407; 1531–1544; and 4201–4245, unless otherwise noted.

■ 2. Amend § 17.11(h) by adding entries for "Crayfish, Big Sandy" and "Crayfish, Guyandotte River" to the List of Endangered and Threatened Wildlife in alphabetical order under CRUSTACEANS to read as set forth below:

§ 17.11 Endangered and threatened wildlife.

* * * * *

(h) * * *

Species		Historic range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
*	*	*	*	*	*		*
CRUSTACEANS							
*	*	*	*	*	*		*
Crayfish, Big Sandy	*Cambarus callainus*	U.S.A. (KY, VA, WV)	Entire	E	TBD	NA	NA
*	*	*	*	*	*		*
Crayfish, Guyandotte River.	*Cambarus veteranus*	U.S.A. (WV)	Entire	E	TBD	NA	NA
*	*	*	*	*	*		*

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Dated: March 17, 2015.

Stephen Guertin,

Acting Director, U.S. Fish and Wildlife Service.

[FR Doc. 2015–07625 Filed 4–6–15; 8:45 am]

BILLING CODE 4310–55–P