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

SCIENTIFIC NAME: *Faxonius virginiensis*

COMMON NAME: Chowanoke crayfish

LEAD REGION: Northeast Region (R5)

LEAD REGION CONTACT: Martin Miller, Northeast Regional Office, 413-253-8615, martin_miller@fws.gov

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DATE INFORMATION CURRENT AS OF: July 2022

STATUS/ACTION
___Species petitioned for listing which we have determined is not a listable entity

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

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

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

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

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

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

___ New candidate

___ Continuing candidate
Date when the species first became a candidate (as currently defined):
___ Listing priority number change
Former LPN: ___
New LPN: ___

___ Candidate removal: Former LPN: ___
- ___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
- ____U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.
- ___ M – Taxon mistakenly included in past notice of review.
- ___ N – Taxon does not meet the Act's definition of "species."
- ___ X – Taxon believed to be extinct.

Petition Information:
___ Nonpetitioned
_X__ Petitioned; Date petition received: April 20, 2010
90-day substantial finding FR publication date: September 27, 2011
12-month warranted but precluded finding FR publication date: N/A

PREVIOUS FEDERAL ACTIONS
On November 21, 1991, Chowanoke crayfish (*Faxonius virginiensis*) was identified as a Category 2 candidate species by the U.S. Fish and Wildlife Service (Service) under the Endangered Species Act of 1973, as amended (Act) on July 1, 1975 (56 FR 58804). A subsequent Federal Register Candidate Notices of Review (CNOR) in 1994 (59 FR 58982) maintained the Chowanoke crayfish as a category 2 species. However, after the publication of the Service's February 28, 1996, CNOR (61 FR 7596), which revised the Service's candidate list to include only Category 1 species, the Chowanoke crayfish was no longer considered a candidate species. On April 20, 2010, the Service received a petition from the Center for Biological Diversity, Alabama Rivers Alliance, Clinch Coalition, Dogwood Alliance, Gulf Restoration Network, Tennessee Forests Council, and West Virginia Highlands Conservancy to list 404 aquatic, riparian, and wetland species, including Chowanoke crayfish, as endangered or threatened species under the Act. On September 27, 2011, the Service published a 90-day finding in the *Federal Register* (76 FR 59836) announcing that the petition presented substantial scientific or commercial information indicating that listing may be warranted.

ANIMAL GROUP AND FAMILY:
Crustaceans, Order Decapoda, Family Cambaridae

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

withstand catastrophic events (for example, droughts, large pollution events), and representation supports the ability of the species to adapt to both near-term and long-term changes in its physical and biological environment (for example, climate change, disease). A species with a high degree of resiliency, representation, and redundancy is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306). Using these principles, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing the species' viability.

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

The SSA report does not represent a decision by the Service on whether the Chowanoke crayfish should be listed as an endangered species or threatened species under the Act. It does, however, provide the scientific basis that informs our regulatory decisions, which involve the further application of standards within the Act and its implementing regulations and policies. The Species Status Assessment Report for the Chowanoke Crayfish *(Faxonius virginiensis)* - October 2021, Version 1.0] (SSA Report) is a summary of the information assembled and reviewed by us and incorporates the best scientific and commercial information available for this species. Excerpts of the SSA Report are provided in the sections below. For more detailed information, please refer to the SSA Report (Service 2021, entire).

<u>Species Description</u>

The Chowanoke crayfish is a freshwater crustacean native to the Chowan and Roanoke River basins in Virginia and North Carolina. The crayfish is approximately 50 millimeters (2 inches) in total length (figure 1). The Chowanoke crayfish is tan colored with a distinctive dark blue or blue-black saddle across the carapace (Cooper and Cooper 1977, pp. 214–215). The claws have a dark band, orange tips, have bristly patches of hairs, and a portion of the claws have a dark outer edge.

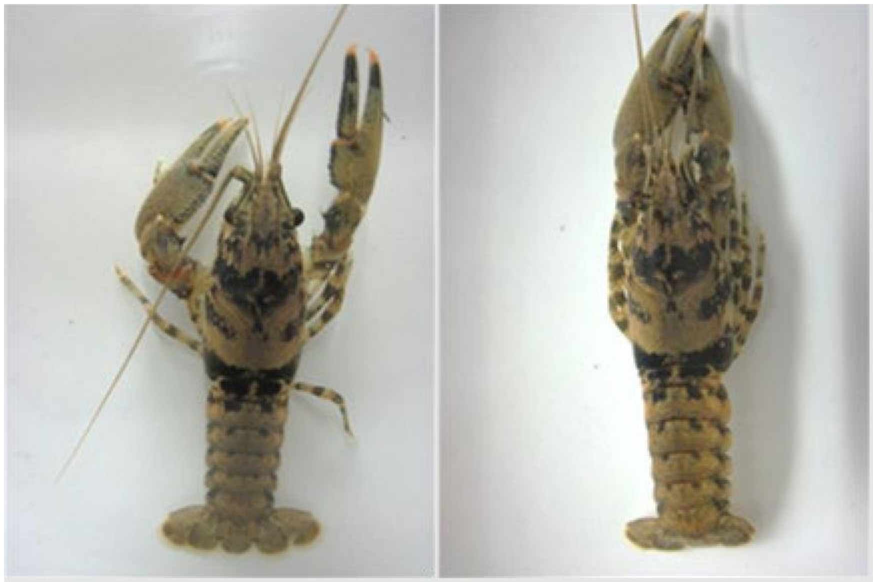

Figure 1. Photos of Chowanoke crayfish (taken by T. Black, Meherrin River, 2014).

Taxonomy

The Chowanoke crayfish is in the family Cambaridae (Hobbs 1951, pp. 122–128). The Chowanoke crayfish is a unique species and recognized as a valid taxon in the Integrated Taxonomic Information System (ITIS) database (Hobbs 1951, pp. 122–128; Fitzpatrick 1967, p. 168; Hobbs 1989, p. 38; McLaughlin et al. 2005, p. 232; ITIS 2019). The first description of the species was in 1951 (Hobbs 1951, pp. 122–128) and identified as *Orconectes virginiensis*. Specimens examined for this description were collected in tributaries of the Nottoway River in Greensville, Brunswick, and Dinwiddie Counties, Virginia. The classification of Chowanoke crayfish changed in 2017 from genus *Orconectes* to genus *Faxonius* when an updated classification of crayfish worldwide based on recent taxonomic and phylogenetic distinctions was developed. Genus *Faxonius* are surface-dwelling crayfish that only dig shallow holes or tunnels while the genus *Orconectes* are cave-dwelling crayfish (Crandall and De Grave 2017, pp. 619, 631). There has been limited genetic analysis conducted on this species, but studies thus far support that the Chowanoke crayfish is a distinct species.

Habitat/Life History

The following information is summarized from chapter 2 of the SSA Report (Service 2021, pp. 19–27); see the full chapter for additional details.

Life history information specific to the Chowanoke crayfish is limited, but aspects of its life history and habitat requirements are presumed to be similar to those of many other stream dwelling crayfish (figure 2). The Chowanoke crayfish lifecycle begins in the spring when fertilized eggs are extruded by the female and are attached with an adhesive substance (glair) to swimmerets located on the underside of the female's tail/abdomen. After hatching, the young remain attached to the female with threadlike structures for approximately four molts. In general, juvenile crayfish often stay with the mother as long as possible, while food and shelter are provided, even after they become unattached (free living) (Pflieger 1996, pp. 26–29; Taylor et al. 1996, p. 27; Loughman and Welsh 2018, p. 48; Service 2019a, entire; Service 2019b, entire). While many stream dwelling crayfish species mate primarily in the fall and the females lay eggs and carry the juveniles in the spring months, there are occasional observations of Chowanoke crayfish mating in the spring and females carrying eggs and juveniles in the fall (Service 2019a, p. 4; Service 2019b, p. 2). Chowanoke crayfish may be sexually mature at approximately 1.5 to 2 years old, as with other species of the same genus (Fielder 1972, p. 143; Service 2019a, p. 3). Although there are no data on the lifespan of wild Chowanoke crayfish, it is estimated to be 3 to 4 years (Service 2019a, p. 3).

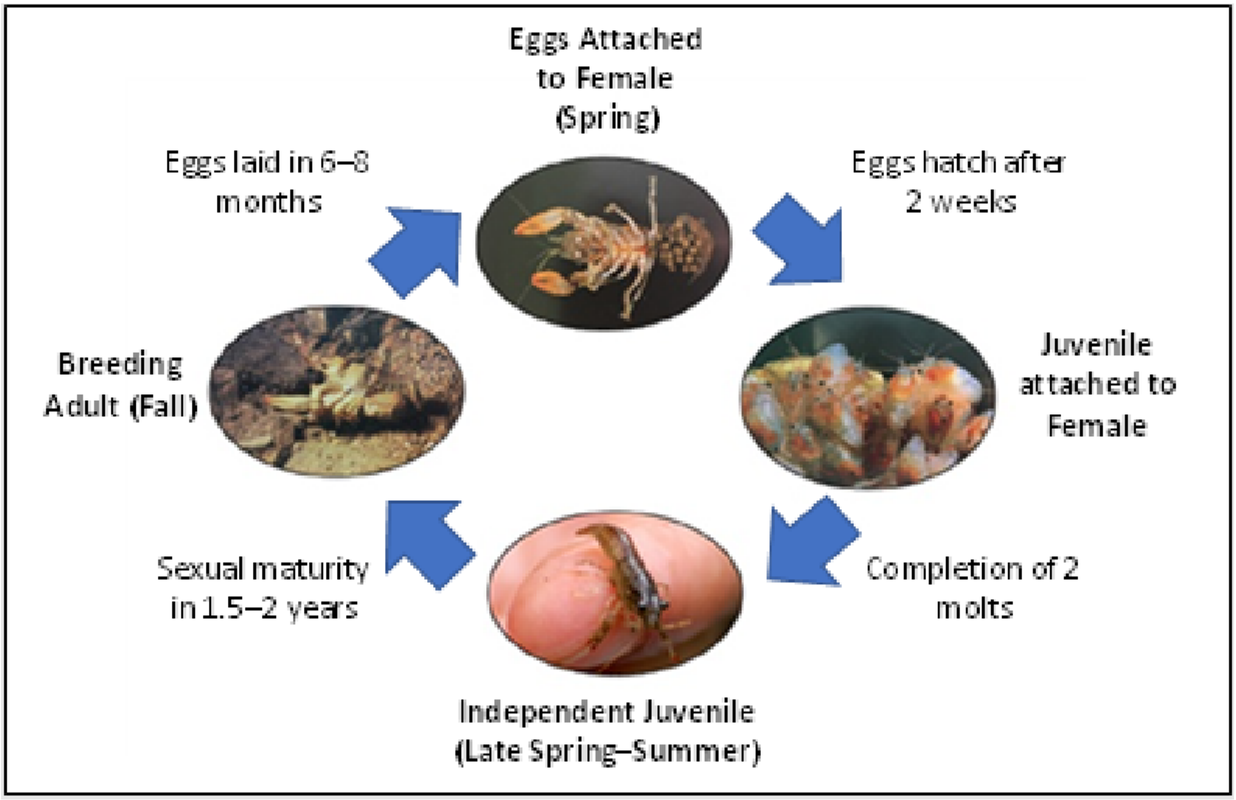

Figure 2. Likely life cycle diagram of Chowanoke crayfish. Photos of breeding adults, eggs, and juveniles attached to females modified from Service 2018 (p. 12) and Pflieger 1996 (pp. 28–29).

Chowanoke crayfish occur in perennial streams and rivers (third order or greater) with moderate to high gradient and flow, with rocky substrate, woody debris, and/or vegetation for shelter. Chowanoke crayfish find shelter in interstitial spaces between rocks and woody debris, beneath undercut stream banks and vegetation, and in abandoned tertiary burrows of other crayfish (Foltz 2019, pers. comm.; Service 2019a, p. 3; Service 2019b, p. 1). They have also been observed to find shelter under unnatural habitat, including riprap/rocky rubble near bridges, railroad ties, old bridge timbers, asphalt slabs, and other materials that have fallen into the streams (e.g., truck door, cooler lid) (Foltz 2019, pers. comm.; Service 2019a, p. 3). While they have been found in sluggish streams with sandy/silt-laden substrates, they occur there in very low numbers. They are not known to occur in stagnant water. Most of the occupied streams and rivers are nontidal and freshwater, except for near the mouth of the Roanoke River and Chowan River in North Carolina. The occurrence of Chowanoke crayfish near the river mouth with estuarine taxa suggest that they have some tolerance to infrequent low salinity conditions.

The habitat conditions needed for healthy populations include: small- to large-sized stable streams with riffles, runs, and pools; unembedded instream structure that provide shelter (e.g., rocks, boulders, logs, leaf litter, undercut streambanks); sufficient water quality (freshwater, temperature, dissolved oxygen, chemistry, and siltation levels) to provide adequate food sources and conditions for survival and reproduction; sufficient water quantity with noticeable current (i.e., not stagnant) to maintain healthy habitat and water quality; healthy riparian and adjacent upland habitat; and connectivity — waterways without significant barriers (e.g., large dams, reservoirs, lakes, other stream crossings).

Historical and Current Range/Distribution

The Chowanoke crayfish's historical range is the Chowan River basin in southeastern Virginia and northeastern North Carolina, and the Roanoke River basin in northcentral and northeastern North Carolina (figure 3) (Cooper and Braswell 1995, p. 106–107; Adams et al. 2010; Black and Nichols 2015, entire; LeGrand et al. 2015, p. 54; Global Biodiversity Information Facility (GBIF) 2019). In the Chowan River basin, the species is known from the Blackwater, Chowan, Meherrin, and Nottoway subbasins (hydrological unit code (HUC) 8 watersheds) in Virginia and North Carolina. In the Roanoke River basin, the species is known in the Lower Roanoke subbasin and the lower portion of the Middle Roanoke subbasin in North Carolina only.

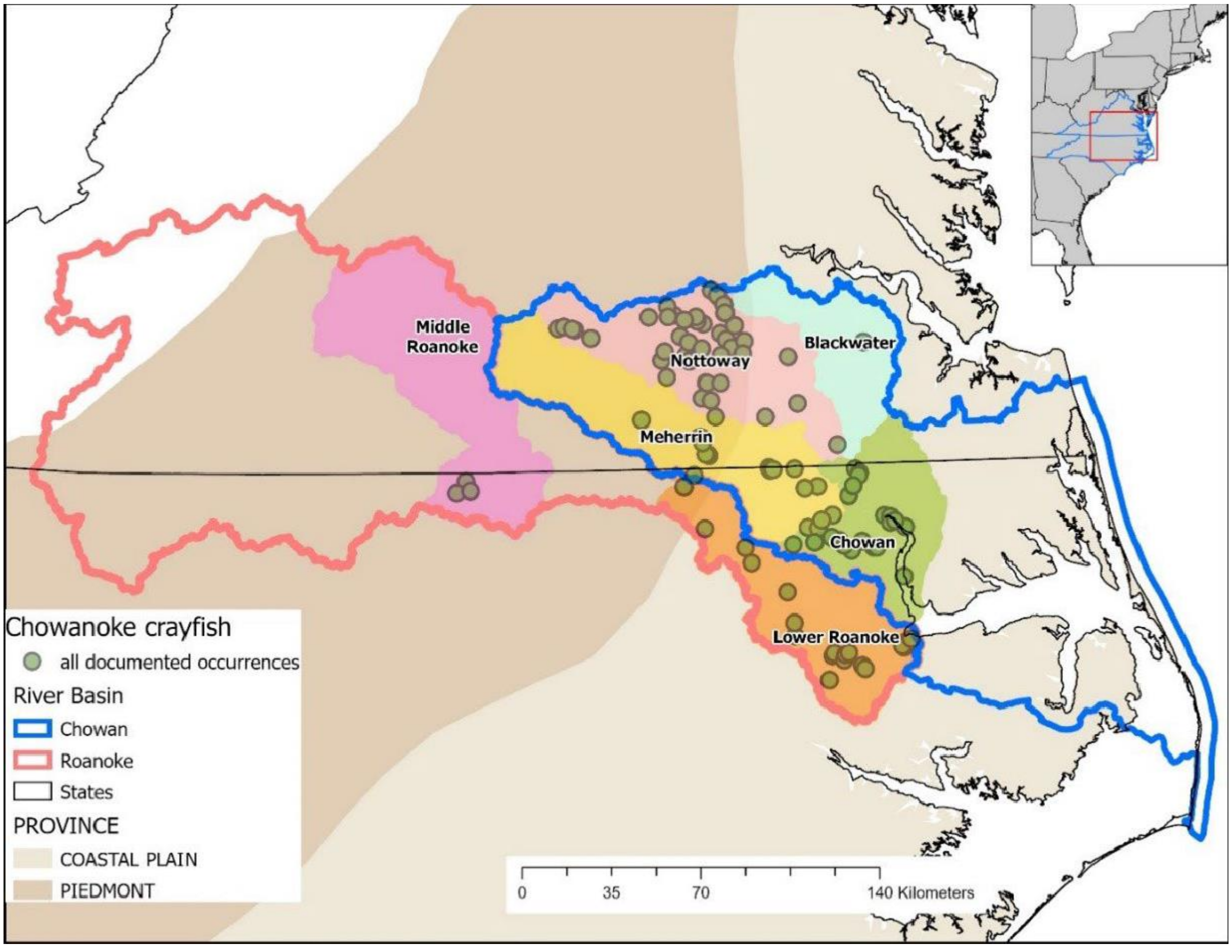

Figure 3. All historical and current occurrences of Chowanoke crayfish in the Chowan and Roanoke River basins (HUC6). HUC8 subbasins are shown by colored polygons and names.

The best available data from recent surveys (2010-2019) suggest that the Chowanoke crayfish continues to occur in the Chowan and Roanoke River basins. The Chowanoke crayfish has been observed in all six subbasins and 86 percent (24/28) historically occupied HUC10 watersheds since 2009, except for four HUC10 watersheds (figure 4). For these four HUC10 watersheds where Chowanoke crayfish occurrences have not been documented since 2009 (i.e., more than 10 years ago from 2019), they are presumed to be unoccupied; however, there are none to limited number (up to two) of surveys conducted in those HUC10 watersheds and experts believe it is possible for the species to be present (see Section 2.7 of the SSA).

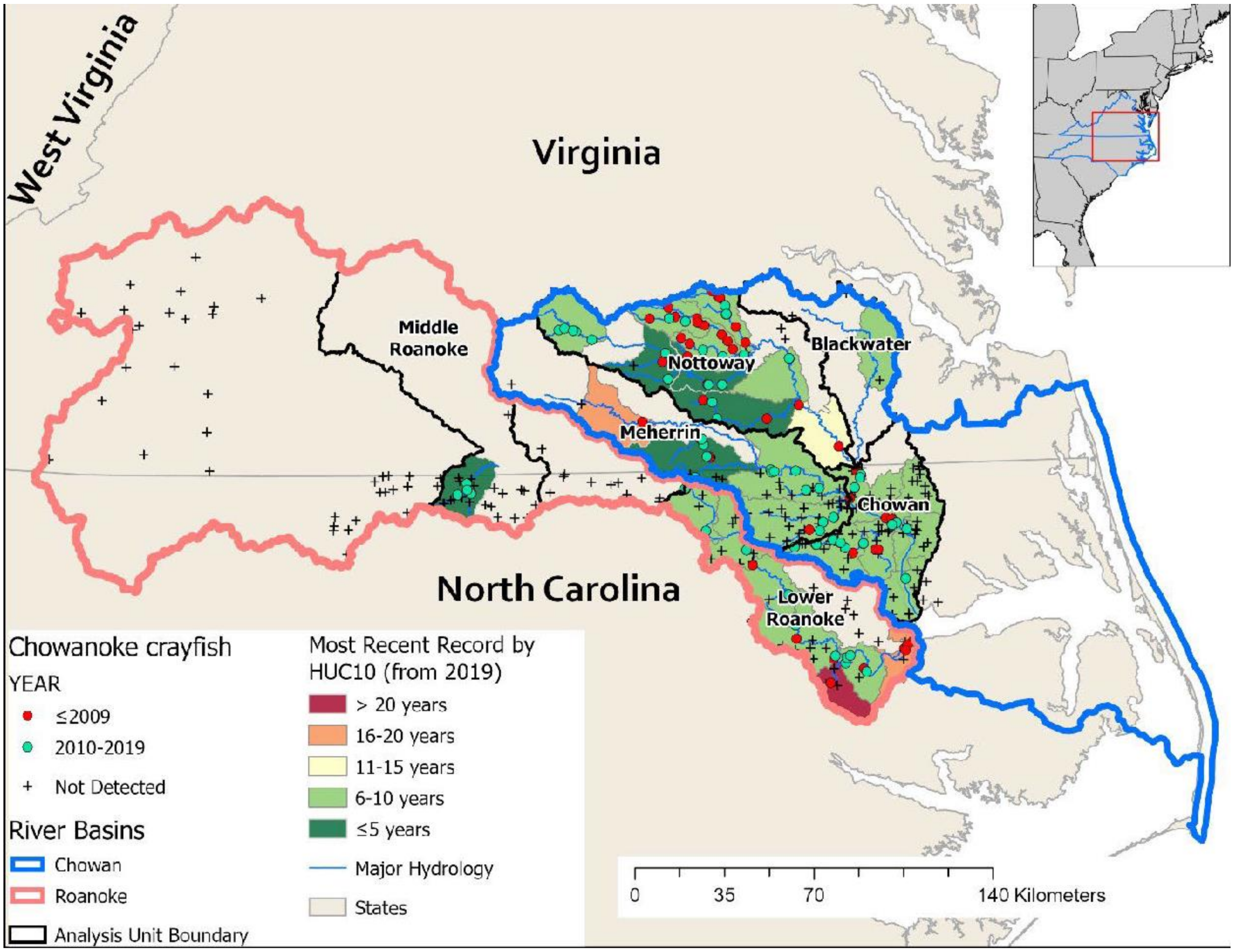

Figure 4. Current and historical range of Chowanoke crayfish in the Chowan and Roanoke River basins. Analysis units are shown by name. Non-detect survey data indicate where Chowanoke crayfish were not observed during crayfish-targeted surveys. However, at sites where Chowanoke crayfish were previously observed, the non-detect data do not conclusively indicate that Chowanoke crayfish are no longer present because crayfish surveys do not have 100-percent detection rates (Black 2019, pers. comm.; Service 2019a, pp. 9–15).

<u>Population Needs</u>

The following information is summarized from chapters 2 and 4 of the SSA Report (Service 2021, pp. 29–35; 71–83); see the full chapters for additional details.

For the purposes of this assessment, we assume that Chowanoke crayfish populations are delineated based on the river basins that they historically occupied, which are the Chowan and Roanoke River basins (HUC6 codes 030102 and 030101, respectively) (figure 3). HUC6 boundaries provide geographic separation of land based on surface water drainage to a point. From here forward, we will use these terms to refer to populations (e.g., Chowan River population). Because the river basin level is at a coarse scale, subpopulations were further delineated using analysis units (AUs). AUs were defined as one or more HUC10 watersheds within a HUC8 subbasin and identified by species experts as most appropriate for assessing population-level resiliency. AUs in the Chowan River population include the Nottaway, Meherrin, Blackwater, and Chowan. AUs in the Roanoke River population include the Middle Roanoke and Lower Roanoke (figure 4).

We do not have specific abundance information for Chowanoke crayfish because surveys varied in methodology, level of effort, and amount of information provided. Thus, we used the cumulative record of the total number of live individuals observed within an AU to provide an approximate estimate of abundance within AUs, as part of the current condition assessment.

The Chowanoke crayfish individual and population needs based on the best available information are summarized in table 1.

Table 1. Summary of resource needs of Chowanoke crayfish.

Type of Resource	Resources and/or Circumstance Needs	Citations
Instream Habitat	Unembedded coarse hard structure (boulder, cobble, and gravel), woody debris, leaf litter, undercut banks, and/or abandoned crayfish burrows for breeding, sheltering, and feeding.	Reynolds et al. 2013 pp. 200–201; Thoma 2014, pp. 25–27; VDGIF 2015, p. 26-71; NatureServe 2019, p. 4; Service 2019a, b; Foltz 2019, pers. comm.
Water Flow and Quantity	Perennial streams that are third order or greater. Sufficient water quantity (not stagnant) with noticeable current to maintain habitat and water quality.	Black and Nichols 2015, entire; appendix A; VDGIF 2015, p. 26-71.
Water Quality	Sufficient water quality: freshwater, low levels of silt, sand, and turbidity to promote food sources and resistance to nonnative, invasive species and disease.	Thoma 2014, p. 27; VDGIF 2015, p. 26-71; Service 2019a, b.
Habitat Connectivity	Habitat connectivity for individuals to access adequate shelter, food, and space and to move to suitable habitat and climate over time.	NatureServe 2019, p. 4; Service 2019b.
Food Source	Invertebrates, periphyton, and live plant material.	Taylor et al. 1996, pp. 26–27; NatureServe 2019, p. 4; Service 2019a, b.

Species Needs

Species needs (i.e., what the species needs for viability) of the Chowanoke crayfish are described below in terms of the 3Rs. Viability is the ability to maintain populations in the wild over time. To do this, Chowanoke crayfish must have the capacity to withstand environmental and demographic stochasticity (periodic disturbances within the normal range of variation) (resiliency) and catastrophes (redundancy) and to adapt to near-term and long-term changes in its physical and biological environments (representation). In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306).

Resiliency

Resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions. Environmental stochasticity can vary at local and regional levels; therefore, the health of populations in any one year can vary over geographical areas (Hanski 1999, p. 372). For this reason, having populations distributed across a diversity of environmental conditions reduces the likelihood of concurrent losses of populations at local and regional scales. For the Chowanoke crayfish, we expect that environmental stochasticity primarily includes differences in precipitation (wet and dry years), prey availability, and habitat conditions (natural disturbance, embeddedness, hard substrate, water quality) throughout its range. Due to the relatively small range of the Chowanoke crayfish, these and other environmental differences could affect the species.

We consider Chowanoke crayfish high resiliency as having healthy populations distributed and inter-connected across its range. A healthy population comprises multiple, healthy, interconnected subpopulations. The greater the number of healthy populations and the greater the distribution and connectedness of those populations relative to the diversity of prey and other habitat conditions, the greater resiliency the species will possess.

Redundancy

Redundancy is a measure of the ability of a species to withstand catastrophic events and is best achieved by having multiple, widely distributed populations relative to the scale of anticipated species-relevant catastrophic events. In addition to guarding against a single or a series of catastrophic events extirpating the entire species, redundancy is important to protect against losing irreplaceable sources of adaptive diversity. To determine what the Chowanoke crayfish requires to guard against catastrophic events, we first considered what catastrophic events to which the species may be subjected (see **Factors Influencing the Status** below). In the SSA, we define a catastrophic event as a biotic or abiotic event that causes significant impacts at the population level such that the population cannot rebound from the effects or the population becomes highly vulnerable to normal population fluctuations or stochastic events.

For the Chowanoke crayfish, we consider severe flood and severe drought events to potentially result in catastrophic impacts to one or more populations (see **Factors Influencing the Status** below). For instance, major flood events have removed boundaries between watersheds where Chowanoke crayfish occur, which could permit nonnative crayfish species to rapidly expand their range, as well as increase siltation and suspended sediments (Service 2019c, p. 1). Floods have the potential to displace or cause mortality of individuals or populations, and can either degrade habitat or replenish habitat, depending on the scope and severity of the flood event. Some species may be adapted to periodic flooding events or not immediately show an effect but may experience an effect in the longer term (Service 2020a, p. 27). Severe drought causes a loss of habitat and prey due to the lack of flow. We did not consider sea level rise or land use modification to be potentially catastrophic events because these changes are typically more gradual that occur over the long term and are more likely to affect the representation and resiliency of the species. See chapter 3 for additional details. We consider multiple occupied HUC10 watersheds within each AU and multiple healthy AUs within the species' range to be important for the species' redundancy.

Representation

Representation is a function of both genetic diversity and adaptive capacity. Genetic diversity is important because it can delineate evolutionary lineages that may harbor unique genetic variation, including adaptive traits. It can also indicate gene flow, migration, and dispersal. Ecological diversity is important because it provides the variation in phenotypes and ecological settings on which natural selection acts. In addition, the processes that drive evolution (gene flow, natural selection, mutations, and genetic drift) are required to maintain species-level representation (Crandall 2000, p. 291).

We do not have specific genetic, morphological, or ecological niche information to inform where there may be differences in the species within the Chowan and Roanoke River basins. However, the species occurs in headwater streams to mainstem rivers within the Piedmont province in the west to Coastal Plain province to the east, and there may be habitat, temperature, or other differences that we are not aware of. Physiographic provinces have different underlying geology and physical and chemical characteristics (e.g., topography, soil pH, elevation, hydrology) that may affect plant and animal species; the boundary between the Piedmont and Coastal Plain provinces is the transition zone from bedrock to softer sediments underlying these areas, called the Fall Line (VDCR 2021, p. 1). Therefore, we are using the species' distribution within the river basins and physiographic provinces to inform representation and infer that the species' representation needs would be best met by retaining its distribution within these geographic areas.

Table 2. Conditions needed for optimum resiliency, redundancy and representation for the Chowanoke crayfish to maintain viability.

3Rs	Requisites	Description
Resiliency (ability to withstand stochastic events)	Healthy populations and habitat.	Subpopulations with: • Small to large sized stable streams with riffles, runs, and pools; • Unembedded instream structure that provide shelter (e.g., rocks, boulders, logs, leaf litter, undercut streambanks); • Sufficient water quality (freshwater, temperature, dissolved oxygen, chemistry, and siltation levels) to provide adequate food sources and conditions for survival and reproduction; • Sufficient water quantity with noticeable current (i.e., not stagnant) to maintain healthy habitat and water quality;

		• Healthy riparian and adjacent upland habitat; • Connectivity — waterways without significant barriers (e.g., large dams, reservoirs, lakes, other stream crossings).
Redundancy (ability to withstand catastrophic events)	Sufficient distribution of healthy populations	Sufficient distribution of healthy subpopulations to prevent catastrophic losses of species' adaptive capacity due to severe flood or drought events. Multiple occupied HUC10s within each AU and multiple occupied AUs within the species' range are important for the species' redundancy.
	Sufficient number of healthy populations	Sufficient number of healthy subpopulations to prevent catastrophic losses of adaptive capacity.
Representation (ability to adapt)	Sufficient capacity to adapt to new, continually changing environments.	Occupied HUC10s distributed across the range including the ecological diversity of river basins and physiographic provinces that contribute to and maintain adaptive capacity. Adequate dispersal ability for the species to migrate to suitable habitat and climate over time.

SUMMARY OF BIOLOGICAL INFORMATION

The Chowanoke crayfish is a freshwater crustacean that is approximately 50 millimeters (2 inches) in total length. The crayfish is historically native to Virginia and North Carolina in the Chowan and Roanoke River basins. The crayfish is current found in both states in all six historically occupied subbasins: Blackwater, Chowan, Meherrin, and Nottoway subbasins in Virginia and North Carolina; and Lower Roanoke subbasin and the lower portion of the Middle Roanoke subbasin in North Carolina only.

Chowanoke crayfish inhabit perennial streams and rivers of varying size with moderate to high gradient and flow, with rocky substrate, woody debris, and/or vegetation for shelter. The habitat conditions needed for healthy population include: small to large sized stable streams with riffles, runs, and pools; unembedded instream structure that provide shelter (e.g., rocks, boulders, logs, leaf litter, undercut streambanks); sufficient water quality (freshwater, temperature, dissolved oxygen, chemistry, and siltation levels) to provide adequate food sources and conditions for survival and reproduction; sufficient water quantity with noticeable current (i.e., not stagnant) to maintain healthy habitat and water quality; healthy riparian and adjacent upland habitat; and connectivity — waterways without significant barriers (e.g., large dams, reservoirs, lakes, other stream crossings).

FACTORS INFLUENCING THE STATUS

Regulatory Framework

Section 4 of the Act (16 U.S.C. 1533) and the implementing regulations in title 50 of the Code of Federal Regulations set forth the procedures for determining whether a species is an endangered species or a threatened species, issuing protective regulations for threatened species, and designating critical habitat for threatened and endangered species. The Act defines an endangered species as a species that is "in danger of extinction throughout all or a significant portion of its range," and a threatened species as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The Act requires that we determine whether any species is an "endangered species" or a "threatened species" because of any of the following factors:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; or
(E) Other natural or manmade factors affecting its continued existence.

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

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

We use the term "threat" to refer in general to actions or conditions that are known to or are reasonably likely to negatively affect individuals of a species. The term "threat" includes actions or conditions that have a direct impact on individuals (direct impacts), as well as those that affect individuals through alteration of their habitat or required resources (stressors). The term "threat" may encompass—either together or separately—the source of the action or condition or the action or condition itself.

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

In 2019, jointly with the National Marine Fisheries Service, the Service issued final rules that revised the regulations in 50 CFR parts 17 and 424 regarding how we add, remove, and reclassify threatened and endangered species and the criteria for designating listed species' critical habitat (84 FR 45020 and 84 FR 44752; August 27, 2019).

However, on July 5, 2022, the U.S. District Court for the Northern District of California vacated the 2019 regulations (Center for Biological Diversity v. Haaland, No. 4:19-cv-05206-JST, Doc. 168 (N.D. Cal. July 5, 2022) (CBD v. Haaland)), reinstating the regulations that were in effect before the effective date of the 2019 regulations as the law governing species classification and critical habitat decisions. Subsequently, on September 21, 2022, the U.S. Circuit Court of Appeals for the Ninth Circuit stayed the district court's July 5, 2022, order vacating the 2019 regulations until a pending motion for reconsideration before the district court is resolved (In re: Cattlemen's Ass'n, No. 22-70194). The effect of the stay is that the 2019 regulations are the governing law as of September 21, 2022.

Due to the continued uncertainty resulting from the ongoing litigation, we undertook an analysis of whether our determination would be different if we were to apply the pre-2019 regulations. That analysis, which we described in a separate memo in the decisional file and posted on https://www.regulations.gov, concluded that we would have reached the same determination if we had applied the pre-2019 regulations because both before and after the 2019 regulations, the standard for whether a species warrants listing has been, and will continue to be, whether the species meets the definition of an endangered species or a threatened species. Further, we concluded that our determination of the foreseeable future would be the same under the 2019 regulations as under the pre-2019 regulations.

Threats

The primary metrics used to assess the Chowanoke crayfish's viability currently and in the future are (1) habitat quality (i.e., quality of instream breeding, feeding, and sheltering features) and (2) population demographics (i.e., its abundance and distribution). Habitat quality metrics are sufficient water quality and quantity, sufficient unembedded moderately-sized instream structure and undercut banks for shelter, healthy riparian and upland areas, and connectivity. Population demographic metrics are the historical and current abundance and distribution.

While we have evaluated multiple influencing factors on habitat quality and population demographics, the primary current and future threats to the species are land use modifications (i.e., through sedimentation and loss of riparian and instream habitats), nonnative red swamp crayfish and virile crayfish, and the effects of climate change (increased severe flood and drought events, increased temperatures, and sea level rise).

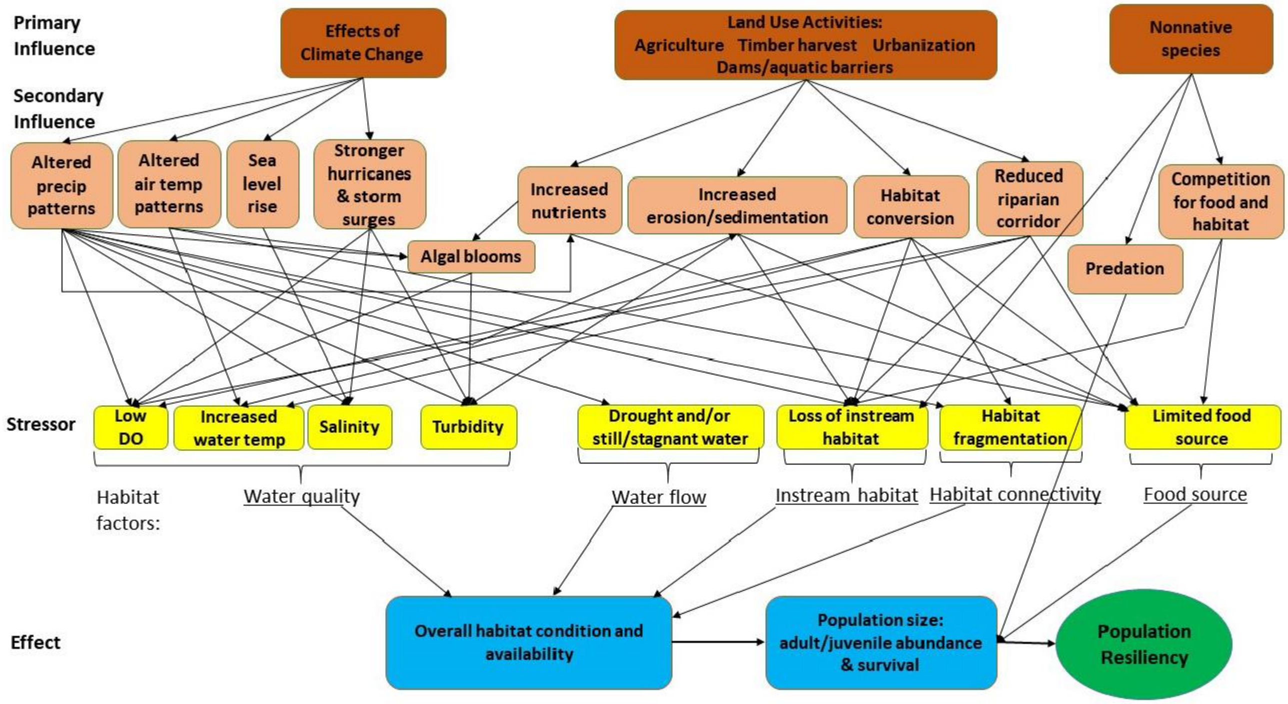

Figure 5. Influence diagram for the Chowanoke crayfish. The dark orange and light orange boxes represent primary and secondary influences, respectively. Yellow boxes represent stressors and the corresponding species' resource needs that have an effect on the resiliency of populations and the status of the species.

Land use modification: Land use modification and the stressors associated with development, forestry activities (i.e., when best management practices (BMPs) are not implemented properly or applied), and agricultural practices within the Chowan and Roanoke River basins have the potential to negatively impact the Chowanoke crayfish directly and indirectly. Excessive pollution, sedimentation, water quality declines, riparian and instream habitat fragmentation and degradation, and reduced water quantity can directly disrupt the species' breeding, feeding and sheltering needs at varying stages of life, which indirectly affects the species' demography over time. The Chowanoke crayfish range in the Chowan and Roanoke River basins consists primarily of forested land and wetland areas (43.4 to 76.9 percent in the HUC10 watersheds), which has historically been the dominant land use type with little change over the years. However, in watersheds with less forested land and wetland areas, there are greater agricultural land and farming operations, which can contribute to nutrient pollution of aquatic habitats when not properly managed. The lack of stable streambanks from agricultural clearing and/or the lack of cover crops between rotations on farmed lands can increase the amount of sediment and nutrients that enter nearby streams by way of increased soil erosion (cover crops and other vegetation will use excess nutrients and increase soil stability). The percentage of agricultural land cover in the HUC10 watersheds in the range of Chowanoke crayfish range from 11.9 to 38.4 percent. Development grew at a slow pace from 2001 to 2016, with relatively low to moderate percentages (2.5 to 14.8 percent) of developed land cover in the HUC10 watersheds in the range of Chowanoke crayfish (see Section 3.1 of the SSA). While land use modifications vary in size, intensity, and duration, development and urban sprawl are expected to continue and increase into the future as predicted by Terando et al. (2014), which will contribute to habitat fragmentation and forested lands being cleared for residential development and roads.

Dams, culverts, and reservoirs/lakes have historically impeded connectivity and created unsuitable habitat and will continue to do so in the future. Therefore, the Chowanoke crayfish is potentially impacted by the negative effects of aquatic barriers and there are no known efforts to remove them. However, there is limited species-specific information to assess the potential effects of human-made barriers on Chowanoke crayfish. Lowhead dams are noted to be common in the Chowan basin in Virginia (Watson 2021, pers. comm.). Therefore, we acknowledge that there are human-made barriers that may impact aquatic species within the species' range, but we are unaware of the specific effects that such barriers may have on the Chowanoke crayfish. Some crayfish species have been documented to move upstream over small barriers and have been seen climbing up rock faces around waterfalls or moving overland (Kerby et al. 2005, p. 407; Puky 2014, 143). Although it is possible that Chowanoke crayfish have the ability to migrate past some of the natural and human-made barriers that occur within their range, these barriers still impede connectivity, and moving past barriers is likely a species-specific and/or site-specific phenomenon. In addition, the presence of invasive crayfish and the effects of sea level rise (see Sections 3.2.2 and 3.3 of the SSA) may decrease connectivity in the future.

Nonnative species: Nonnative species can negatively impact native species via habitat alteration, competition, and predation, leading to native species population declines and extirpation. The red swamp crayfish (*Procambarus clarkii*), a nonnative crayfish, is present within the Lower Roanoke, Meherrin, and Chowan AUs, but only known to co-occur with the Chowanoke crayfish in Potecasi Creek and the Meherrin River in the Meherrin AU (NCWRC

2019b and 2020b, unpublished data). The virile crayfish (*Faxonius virilis*), another nonnative crayfish, is present within the Middle and Lower Roanoke AUs, but only known to co-occur with the Chowanoke crayfish in Grassy Creek in the Middle Roanoke AU with no documented expansion (NCWRC 2019b, unpublished data). Impacts to Chowanoke crayfish by both the red swamp crayfish and virile crayfish are unknown. The red swamp crayfish and virile crayfish have been shown to replace native crayfish species in southeastern North Carolina and West Virginia/Maryland, respectively (Loughman and Welsh 2010, p. 70; Service 2019c, p. 1). Native Chowanoke crayfish populations may be able to withstand the presence of red swamp crayfish, as has apparently occurred in Potecasi Creek for at least 9 years where Chowanoke crayfish and red swamp crayfish co-occur; however, nonnative crayfish have extirpated populations of other native crayfish, particularly in streams that are already degraded by anthropogenic nutrient inputs or high levels of sedimentation (Loughman 2013, pp. 66–67).

To reduce the rate of bait bucket introductions, virile and rusty crayfish (*Orconectes rusticus*) are on North Carolina's prohibited species list, making it illegal to possess, propagate or sell the species (North Carolina Administrative Code 2021, p. 1). In Virginia, it is unlawful to sell any crayfish species live as bait or for personal use, except for personal consumption (Virginia Law 2021, p. 1).

The flathead catfish (*Pylodictis olivaris*) has also been documented in the Roanoke and Chowan basins; however, we did not include the flathead catfish in our analysis based on the lack of data to indicate occurrence of the flathead catfish in Chowanoke crayfish streams and the unknown specific threats they may pose to Chowanoke crayfish.

Climate Change: Uncertainty exists as to the extent of the effects of climate change currently affecting Chowanoke crayfish because specific temperature and salinity tolerances are unknown for the species. Chowanoke crayfish appear to be distributed throughout much of their range and are potentially present in a variety of habitat conditions in the Chowan and Roanoke River basins. Based on the best available science, rising sea level that increases salinity and reduces the suitability and amount of habitat available; more frequent and severe precipitation events that cause excessive erosion and sedimentation and degradation of instream habitat; severe flooding that facilitates the dispersal of invasive species; and higher temperatures with more frequent and severe heat waves and drought conditions that increase the expansion rate of invasive species will continue to alter habitat within the range of the Chowanoke crayfish (see SSA Section 3.3, pp. 63-67 for details and citations within) . Therefore, these stressors and the synergistic effects of climate change will likely continue to act as ongoing threats to the Chowanoke crayfish.

Disease: Neither crayfish plague or Porcelain disease has been documented in the range of the species; therefore, based on the best available information they do not appear to affect the Chowanoke crayfish at the watershed or species level.

<u>Conservation Measures</u>

We are aware of few conservation measures currently being implemented that target or benefit

Chowanoke crayfish specifically. However, conservation efforts for other federally listed, aquatic species, such as the federally endangered Roanoke logperch (*Percina rex*) and federally threatened yellow lance (*Elliptio lanceolata*), could benefit the Chowanoke crayfish in areas where they overlap in range. The Service's Roanoke River National Wildlife Refuge (RRNWR) is within the Chowanoke crayfish's range in the Lower Roanoke subbasin and manages land that borders the lower Roanoke River in multiple locations. Although the Chowanoke crayfish is not included, the RRNWR's Habitat Management Plan identifies other aquatic species and management and monitoring efforts for those species that could also benefit the Chowanoke crayfish, including restoring and enhancing floodplain forest, supporting habitat with sufficient submerged woody debris and detritus for feeding, sheltering, and breeding, and increasing access to spawning sites by removing impediments (Service 2013, pp. 46, 47, 68).

Cumulative Effects

We note that, by using the SSA framework to guide our analysis of the scientific information documented in the SSA report, we have not only analyzed individual effects on the species, but we have also analyzed their potential cumulative effects. We incorporate the cumulative effects into our SSA analysis when we characterize the current and future condition of the species. Our assessment of the current and future conditions encompasses and incorporates the threats individually and cumulatively. Our current and future condition assessment is iterative because it accumulates and evaluates the effects of all the factors that may be influencing the species, including threats and conservation efforts. Because the SSA framework considers not just the presence of the factors, but to what degree they collectively influence risk to the entire species, our assessment integrates the cumulative effects of the factors and replaces a standalone cumulative effects analysis.

The Chowanoke crayfish is exposed to a variety of stressors that can interact to affect the species synergistically, meaning that the effects of two or more stressors are more harmful than the effects of each stressor acting alone. Several significant interacting stressors can act in combination to cause shifts and declines in native aquatic communities through the introduction of invasive species, habitat loss, disease, and changing climate (Martinez 2012, pp. 226–230; Kernan 2015, pp. 326–330).

For example, an increase in water temperature can occur from an increase in air temperature. Increasing water temperatures and changes in precipitation can affect crayfish movement and the quality of instream habitat, as well as the salinity levels in the lower watershed due to sea level rise. As described in earlier sections above, water quality can also be negatively affected by an increase in precipitation and flood events. In addition, these stressors reduce the quality of instream habitat for the benthic community and prey resource for Chowanoke crayfish. Further, as described above, the range expansion of invasive species (crayfish and catfish) as the habitat becomes more suitable for invasive species from increasing temperatures and as more frequent flood events increase the spread of these species, can lead to an increase in competition with and predation of Chowanoke crayfish. These synergistic effects are considered when assessing current and future conditions.

CURRENT CONDITION

The current condition is a qualitative estimate based on the analysis of two population factors (AU occupancy, approximate abundance) and four habitat factors (instream habitat, water quality, water quantity/flow, salinity). We assessed the current condition of the Chowanoke crayfish using these six metrics, as described in detail in chapter 4 and appendix B of the SSA Report (Table 3; Service 2021, pp. 71–83; 127–138). These are derived from a combination of GIS analyses, survey data, land cover data, NOAA drought index data, and USGS monitoring station salinity data. These metrics correlate to the needs of the Chowanoke crayfish to breed (abundance and number of sites), feed (habitat quality), and find shelter (habitat quality). The summary current condition for an AU was determined by combining the overall population and habitat condition scores. Healthy subpopulations as assessed by the current condition evaluation of AUs is an indicator of resiliency.

Table 3. Population and habitat factors used to create condition categories.

	Population Factors		**Habitat Factors**			
Condition Category	**Analysis Unit Occupancy Decline**[1]	**Approximate Abundance**	**Instream Habitat/Water Quality**[2]	**Water Quality**[2]	**Salinity**	**Water Quantity/Flow**
High	≤30% decline	>100 individuals total observed in past 10 years; and large numbers (10+) of individuals seen during targeted surveys at 3 or more sites (past 10 years)	Predominantly natural (>70% forested/wetlands) active river area	<6% impervious surfaces in HUC10 watersheds	<1 ppt at any site	Optimal flowing water conditions; no known flow issues; infrequent low flow/drought periods
Moderate	31-50% decline	51-100 individuals total observed in past 10 years; and large numbers (10+) of individuals seen during targeted surveys at 2 sites (past 10 years)	20-70% forested/wetlands active river area	6-15% impervious surfaces in HUC10 watersheds	1 to 7 ppt at any site	Moderate flowing water conditions; moderate flow issues, including 3 to 4 years of consecutive drought or moderately flashy flow

	Population Factors		Habitat Factors			
Condition Category	**Analysis Unit Occupancy Decline[1]**	**Approximate Abundance**	**Instream Habitat/Water Quality[2]**	**Water Quality[2]**	**Salinity**	**Water Quantity/Flow**
Low	51-70% decline	2-50 individuals observed in past 10 years	<20% forested/wetlands active river area	>15% impervious surfaces in HUC10 watersheds	>7 ppt at any site	Low flowing water condition- either frequently inundated or dry; severe flow issues; more than 4 consecutive years of drought; flashy flow regime
Very Low	>70% decline	1 individual observed in past 10 years	Instream habitat/water quality unable to support species survival	Water quality unable to support species survival	Salinity conditions do not support species survival	Flow conditions do not support species survival
Ø	Total Loss	Total Loss	N/A	N/A	N/A	N/A

[1] Analysis unit occupancy decline is based on the percentage of historically occupied HUC10s that are presumed unoccupied (i.e., no documented occurrences 2010 and after; calculated as number of presumed unoccupied HUC10s divided by total number of historically occupied HUC10s).

[2] The forested/wetlands active river area is an indicator of both instream habitat and water quality, while impervious surfaces in HUC10 watersheds is an additional indicator of water quality.

Table 3 provides a summary of the metrics and current condition evaluated in terms of the 3Rs. The Chowanoke crayfish is extant in all six AUs and occupies 86 percent (24/28) of the historically occupied HUC10 watersheds, which are evenly distributed within AUs and both populations (figure 6). Of the six AUs, five (83 percent) are estimated to have high resiliency and one (17 percent) moderate resiliency. Scaling up from the AU to the population level, both the Chowan and Roanoke populations are estimated to have high resiliency but have lost some of their representation with a 10-percent and 25-percent decline in occupied HUC10 watersheds, respectively. The species is known to occupy streams/rivers in two physiographic regions and has lost some representation with an estimated 9-percent decline in occupied HUC10 watersheds in the Piedmont province and an estimated 18-percent decline in occupied HUC10 watersheds in the Coastal Plain province. The effects of land use change and climate change (e.g., increasing sea level rise (SLR)) have likely begun to occur in minor portions of the current Chowanoke range and may have contributed to some habitat degradation.

Table 3. Current Condition and the 3Rs

3Rs	Requisites	Description	Current Condition
Resiliency (ability to withstand stochastic events)	Healthy populations and habitat.	Subpopulations with: • Small to large sized stable streams with riffles, runs, and pools; • Unembedded instream structure that provide shelter; • Sufficient water quality (freshwater, temperature, dissolved oxygen, chemistry, and siltation levels) to provide adequate food sources and conditions for survival and reproduction; • Sufficient water quantity with noticeable current (i.e., not stagnant) to maintain healthy habitat and water quality; • Healthy riparian and adjacent upland habitat; • Connectivity — waterways without significant barriers.	AUs were defined at one or more HUC10 watersheds within a HUC8 subbasin that encompass historically or currently documented occupied habitat. Each AU with high or moderate current condition is thought to currently have adequate habitat and healthy subpopulations, thus has high or moderate resiliency. – 6 of 6 AUs (100%) are known to be extant. – AU status: – 5 of 6 AUs (83%) high condition – 1 of 6 AUs (17%) moderate condition
Redundancy (ability to withstand catastrophic events)	Sufficient distribution of healthy populations.	Sufficient distribution of healthy subpopulations to prevent catastrophic losses of species' adaptive capacity due to severe flood or drought events. Multiple occupied HUC10s within each AU and multiple occupied AUs within the species' range are important for the species' redundancy.	• Healthy AUs (moderate or high condition) evenly distributed within both basins and across the range. • Occupied HUC10s evenly distributed within AUs and both basins.
	Sufficient number of healthy populations.	Sufficient number of healthy subpopulations to prevent catastrophic losses of adaptive capacity.	• 6 of 6 AUs (100%) are moderate or high condition. • 24 of 28 HUC10 watersheds (86%) currently occupied.

Representation (ability to adapt)	Sufficient capacity to adapt to new, continually changing environments.	Occupied HUC10s distributed across the range, including the ecological diversity of river basins and physiographic provinces that contribute to and maintain adaptive capacity. Adequate dispersal ability for the species to migrate to suitable habitat and climate over time.	Connected, occupied HUC10s found in both river basins (populations) and physiographic provinces. **River basin:** • Chowan – 18 of 20 HUC10s (90%) occupied. • Roanoke – 6 of 8 HUC10s (75%) occupied. **Physiographic province:** • Piedmont – 10 of 11 HUC10s (91%) occupied. • Coastal Plain – 14 of 17 HUC10s (82%) occupied.

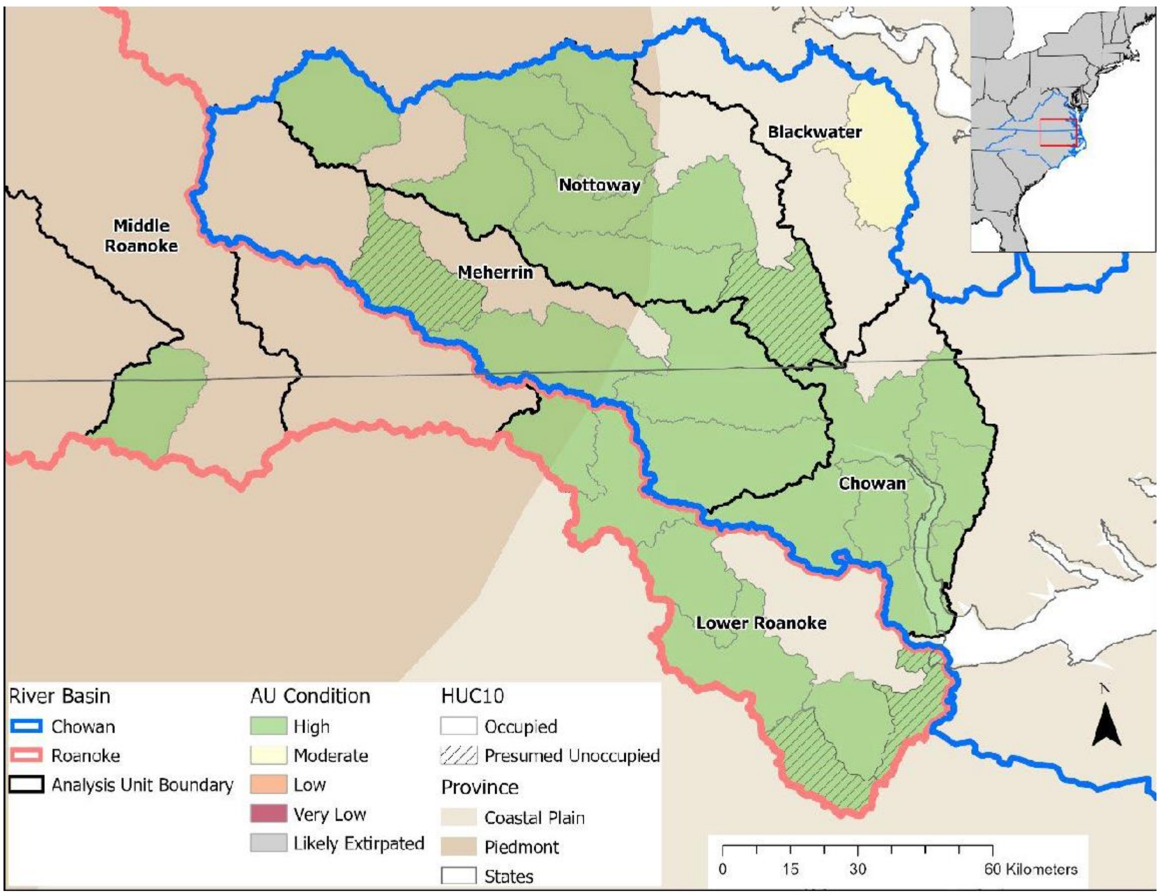

Figure 6. Current condition of the Chowanoke crayfish by AU. AUs are shown by name. AUs were defined as one or more HUC10 watersheds within a HUC8 subbasin and identified by

species experts as most appropriate for assessing population-level resiliency.

FUTURE CONDITION

To assess the future condition of the Chowanoke crayfish, the primary threats of land use change, climate change, and nonnative crayfish and their potential effects on resiliency were considered. Populations with very low resiliency are considered to be more vulnerable to extirpation, which, in turn, would decrease species' level representation and redundancy. To help address uncertainty associated with the degree and extent of potential future stressors and their impacts on the species, the 3Rs were assessed using three plausible future scenarios out to 50 years (table 4), which represents approximately 14 Chowanoke crayfish life cycles. Fifty years is also a period that allows us to reasonably predict the potential effects of the various stressors within the range of the species. The 50-year timeframe is predicted in 10- to 20-year increments from 2020 (2030, 2050, and 2070). We chose 10 years for the immediate future because the SLEUTH projections for the Southeast and SLR models are based on 10-year increments starting with 2010 and 2000, respectively (Belyea and Terando et al. 2012, unpublished data; Sweet et al. 2017, entire; NOAA 2020a, 2020b, 2020c, unpublished data); however, we chose 20-year increments thereafter because a 10-year increment is too fine a scale to reasonably predict changes for Chowanoke crayfish in the long term. These timeframes are supported by approximately 10 to 20 years of Chowanoke crayfish persistence data, which we deem biologically reasonable to use as a surrogate to project forward a similar amount of time; available land cover data (percent forest cover and impervious surface) that serves as a surrogate for instream habitat and water quality, salinity (SLR), and water quantity (drought) data, nonnative crayfish data, and climate data (50 years) to predict potential significant effects of stressors (up to 50 years); and other potential, but plausible, conservation actions.

Table 4. Summary of Future Scenario influencing factors[1] as compared to current condition.

Influencing Factor	**Scenario 1: Continuation of Current Trends**	**Scenario 2: Increase in Rates of Land Use Changes and Climate Change Effects**	**Scenario 3: Continuation Plus Conservation**
Habitat Factors			
Instream Habitat/ Water Quality (% forested/ wetlands)	↓ (due to moderate increase in urbanization)	↓↓ (due to maximum increase in urbanization)	↓ (due to moderate increase in urbanization)
Water Quality (% impervious surface)	↓ (due to moderate increase in urbanization)	↓↓ (due to maximum) increase in urbanization)	↓ (due to moderate increase in urbanization)
Water Quantity/Flow (drought)	↓	↓↓	↓
Salinity (SLR)	↑↑ (Intermediate High)	↑↑↑ (High)	↑ (Intermediate)
Climate Projection	RCP 8.5	RCP 8.5	RCP 4.5

Climate Effects	↑ air temperature and variation in precipitation and flooding	↑↑ air temperature and variation in precipitation and flooding	↑ air temperature and variation in precipitation and flooding
Red swamp crayfish and virile crayfish's effects on instream habitat	Same	↓	Same
Conservation Actions			
Conservation Actions (habitat enhancement and restoration, nonnative species control, etc.)	Same	Same	↑
Population Factors			
Distribution (AU Occupancy Decline)	↓	↓	Same
Demography (Approximate Abundance) [2]	Same	↓	Same
[1] Influencing Factor Rate of Change Compared to Current Condition: some increase (↑), greater increase (↑↑), greatest increase (↑↑↑), some decrease (↓), greater decrease (↓↓), no change in rate (Same). [2]Approximate abundance remains the same, except decreases due to overall low habitat quality condition or crayfish condition becomes very low. See appendix C for additional information.			

The three plausible future scenarios were based, in part, on the results of urbanization (Terando et. al. 2014, entire), climate models (International Panel on Climate Change 2014, entire; Sweet et al. 2017, entire), and nonnative crayfish effects that were used to project changes in habitat used by the Chowanoke crayfish. An important assumption of the future analysis was that future resiliency is largely dependent on water quality (including freshwater conditions), water quantity/flow, and riparian and instream habitat conditions. Our assessment projected that some currently extant Chowanoke crayfish populations would experience negative changes to these important habitat requisites; projected viability varied among scenarios and is summarized below, and in tables 4, 5, and 6 and figure 7.

For Scenario 1, the "Continuation of Current Trends" option, a minor loss of resiliency, representation, and redundancy is expected at the end of 50 years. Under this scenario, we projected that the species will continue to occupy all six AUs, with three (50 percent) AUs in high condition and three (50 percent) in moderate condition. More AUs with moderate condition are projected in the eastern and southern portions of the range, mainly due to projected moderate increase in inundation of higher salinity waters and associated loss of suitable habitat caused by SLR and moderate decline in water quantity. However, instream habitat and water quality are projected to remain high for most of the AUs. Scaling up from the AU to the population level, the Chowan population is projected to have high resiliency and the Roanoke population moderate resiliency; both populations will lose some representation with a 20-percent and 37-

percent decline in occupied HUC10 watersheds, respectively. Redundancy would be reduced to 21 occupied HUC10 watersheds (75 percent of the historically occupied HUC10 watersheds) across the range, with uneven distribution in the Chowan and Lower Roanoke AUs and both populations. Representation is projected to be the same for the Piedmont province but Chowanoke crayfish is projected to occupy 11 of the 17 historically occupied HUC10s, a 35-percent decline in occupied HUC10 watersheds in the Coastal Plain province.

For Scenario 2, the "Increase in Rates of Land Use Changes and Climate Change Effects" option, we projected additional losses of resiliency, representation, and redundancy at the end of 50 years. We projected that the Middle Roanoke AU in the Roanoke population will likely be extirpated due to projected loss of significant instream habitat caused by nonnative virile crayfish, thereby displacing Chowanoke crayfish. As described in Section 3.2.2 of the SSA, streams that are most susceptible to virile crayfish are those that are affected by impoundments, degraded by other anthropogenic disturbances, or at lower elevations and have naturally high silt loads (Loughman 2013, pp. 63–66). In this scenario, we projected that the Middle Roanoke AU will experience greater expansion of virile crayfish because its streams have lower stream order (fourth and fifth order) and the Chowanoke crayfish subpopulation is isolated. However, the other five AUs in the Chowan and Roanoke populations will be in moderate or high condition, thus maintaining high (33 percent) and moderate (50 percent) resiliency in the remaining five subpopulations. More AUs with moderate condition are projected in the eastern and southern portions of the range, mainly due to projected greater increase in inundation of higher salinity waters and associated loss of suitable habitat caused by SLR, moderate/low instream habitat condition, and low water quantity condition. In Scenario 2, the nonnative red swamp crayfish is also projected to contribute to a decrease in instream habitat condition for all AUs. Chowanoke crayfish populations currently co-occur with red swamp crayfish in two locations, however, the impacts to Chowanoke crayfish by the red swamp crayfish are unknown, and red swamp crayfish have been shown to replace native crayfish species, particularly in streams degraded by anthropogenic nutrient inputs or high levels of sedimentation (Loughman 2013, pp. 66–67). Scenario 2 is based on the effects of high-level increase in land use changes and climate change on the 3Rs. This scenario includes the effects resulting from a plausible, maximum increase in development (affecting percent impervious surface and forest/wetlands land cover), according to the SLUETH urban change analysis as described in the SSA Section 3.1 Land Use Modification.

Scaling up from the AU to the population level, both the Chowan and Roanoke populations are projected to have moderate resiliency and reduced representation with a 25-percent and 50-percent decline in occupied HUC10 watersheds, respectively. Redundancy would be further reduced to 19 occupied HUC10 watersheds (68 percent of the historically occupied HUC10 watersheds) across the range, with uneven distribution across the range and no occupied HUC10 watershed in the Middle Roanoke AU. Representation is also projected to decline in both the Piedmont and Coastal Plain provinces, with an 18-percent and 41-percent decline in occupied HUC10 watersheds, respectively. With the range contracting in the western and eastern portions of the Roanoke basin and eastern portion of the Coastal Plain province under Scenario 2, the species' representation is projected to be reduced, and the Chowanoke crayfish may not be as adaptive to changing conditions after the 50-year period.

For Scenario 3, the "Continuation Plus Conservation" option, we projected high levels of resiliency, representation, and redundancy at the end of 50 years. We projected that the species would continue to occupy all six AUs, with five (83 percent) AUs in high condition and one (17 percent) AU in moderate condition, because instream habitat and water quality is projected to remain high for most of the AUs, mainly due to continuing high percentage of forested/wetland land cover and a low percentage of impervious surfaces in the watersheds. In addition, with an intermediate level increase in SLR, it is not anticipated that salinity levels will become high enough to cause a significant loss of suitable, occupied habitat. Conservation actions will also contribute to protecting and maintaining high quality habitat for the Chowanoke crayfish. Redundancy and representation are projected to remain the same as current conditions and the occupied HUC10s will be evenly distributed within AUs and both populations.

Table 5. Projected Chowanoke crayfish overall conditions (resiliency) under current and three plausible, future scenarios in 50 years.

			Future Scenarios of Overall Conditions		
Population	**Analysis Units**	**Current**	**#1: Continuation of Current Trends**	**#2: Increase in Rates of Land Use Changes and Climate Change Effects**	**#3: Continuation Plus Conservation**
Chowan		**High**	**High**	**Moderate**	**High**
	Nottoway	High	High	High	High
	Meherrin	High	High	High	High
	Blackwater	Moderate	Moderate	Moderate	Moderate
	Chowan	High	Moderate	Moderate	High
Roanoke		**High**	**Moderate**	**Moderate**	**High**
	Middle Roanoke	High	High	**Likely Extirpated**	High
	Lower Roanoke	High	Moderate	Moderate	High

Table 6: Current and Future Conditions and the 3 Rs

3Rs	**Requisites**	**Current Condition**	**Future Condition in 50 years**
Resiliency (ability to withstand stochastic events)	Healthy populations and habitat.	AUs were defined at one or more HUC10 watersheds within a HUC8 subbasin that encompass historically or currently documented occupied habitat. Each AU	Scenario 1: • 6 of 6 AUs (100%) extant • 3 of 6 AUs (50%) high condition • 3 of 6 AUs (50%) moderate condition Scenario 2:

		with high or moderate current condition is thought to currently have adequate habitat and healthy subpopulations, thus has high or moderate resiliency. – 6 of 6 AUs (100%) are known to be extant. – AU status: – 5 of 6 AUs (83%) high condition – 1 of 6 AUs (17%) moderate condition	• 2 of 6 AUs (33%) high condition • 3 of 6 AUs (50%) moderate condition • 1 of 6 AUs (17%) likely extirpated <u>Scenario 3:</u> • 6 of 6 AUs (100%) extant • 5 of 6 AUs (83%) high condition • 1 of 6 AUs (17%) moderate condition
Redundancy (ability to withstand catastrophic events)	Sufficient distribution of healthy populations	• Healthy AUs (moderate or high condition) evenly distributed within both basins and across the range. • Occupied HUC10s evenly distributed within AUs and both basins.	<u>Scenario 1:</u> • More AUs with moderate condition in the eastern and southern portions of the range. • Occupied HUC10s will be unevenly distributed within the Chowan and Lower Roanoke AUs and both basins. <u>Scenario 2:</u> • More AUs with moderate condition in the eastern and southern portions of the range. High condition AUs will occur in the middle/northern portion of range. 1 AU in southwest likely extirpated. • Occupied HUC10s will be unevenly distributed within the Chowan and Lower Roanoke AUs and both basins; no occupied HUC10 in the Middle Roanoke AU. <u>Scenario 3:</u> • Healthy AUs evenly distributed across the range • Occupied HUC10s will be evenly distributed within AUs and both basins.
	Sufficient number of	• 6 of 6 AUs (100%) are healthy (moderate or high	<u>Scenario 1:</u> • 6 of 6 AUs (100%) moderate or

	healthy populations	condition). • 24 of 28 HUC10 watersheds (86%) currently occupied.	high condition. • 21 of 28 HUC10 watersheds (75%) occupied. <u>Scenario 2:</u> • 5 of 6 AUs (83%) moderate or high condition; 1 AU likely extirpated. • 19 of 28 HUC10 watersheds (68%) occupied. <u>Scenario 3:</u> • 6 of 6 AUs (100%) moderate or high condition. • 24 of 28 HUC10 watersheds (86%) occupied.
Representation (ability to adapt)	Sufficient capacity to adapt to new, continually changing environments.	Connected, occupied HUC10s found in both river basins (populations) and physiographic provinces. **River basin:** • Chowan – 18 of 20 HUC10s (90%) occupied. • Roanoke – 6 of 8 HUC10s (75%) occupied. **Physiographic province:** • Piedmont – 10 of 11 HUC10s (91%) occupied. • Coastal Plain – 14 of 17 HUC10s (82%) occupied.	<u>Scenario 1:</u> **River basin:** • Chowan – 16 of 20 HUC10s (80%) occupied. • Roanoke – 5 of 8 HUC10s (63%) occupied. **Physiographic province:** • Piedmont – HUC10 occupancy unchanged. • Coastal Plain – 11 of 17 HUC10s (65%) occupied. <u>Scenario 2:</u> **River basin:** • Chowan – 15 of 20 HUC10s (75%) occupied. • Roanoke – 4 of 8 HUC10s (50%) occupied. **Physiographic province:** • Piedmont – 9 of 11 HUC10s (82%) occupied. • Coastal Plain – 10 of 17 HUC10s (59%) occupied. <u>Scenario 3:</u> **River basin:** • Chowan – HUC10 occupancy unchanged. • Roanoke – HUC occupancy unchanged.

			Physiographic province: • Piedmont – HUC10 occupancy unchanged. • Coastal Plain – HUC10 occupancy unchanged.

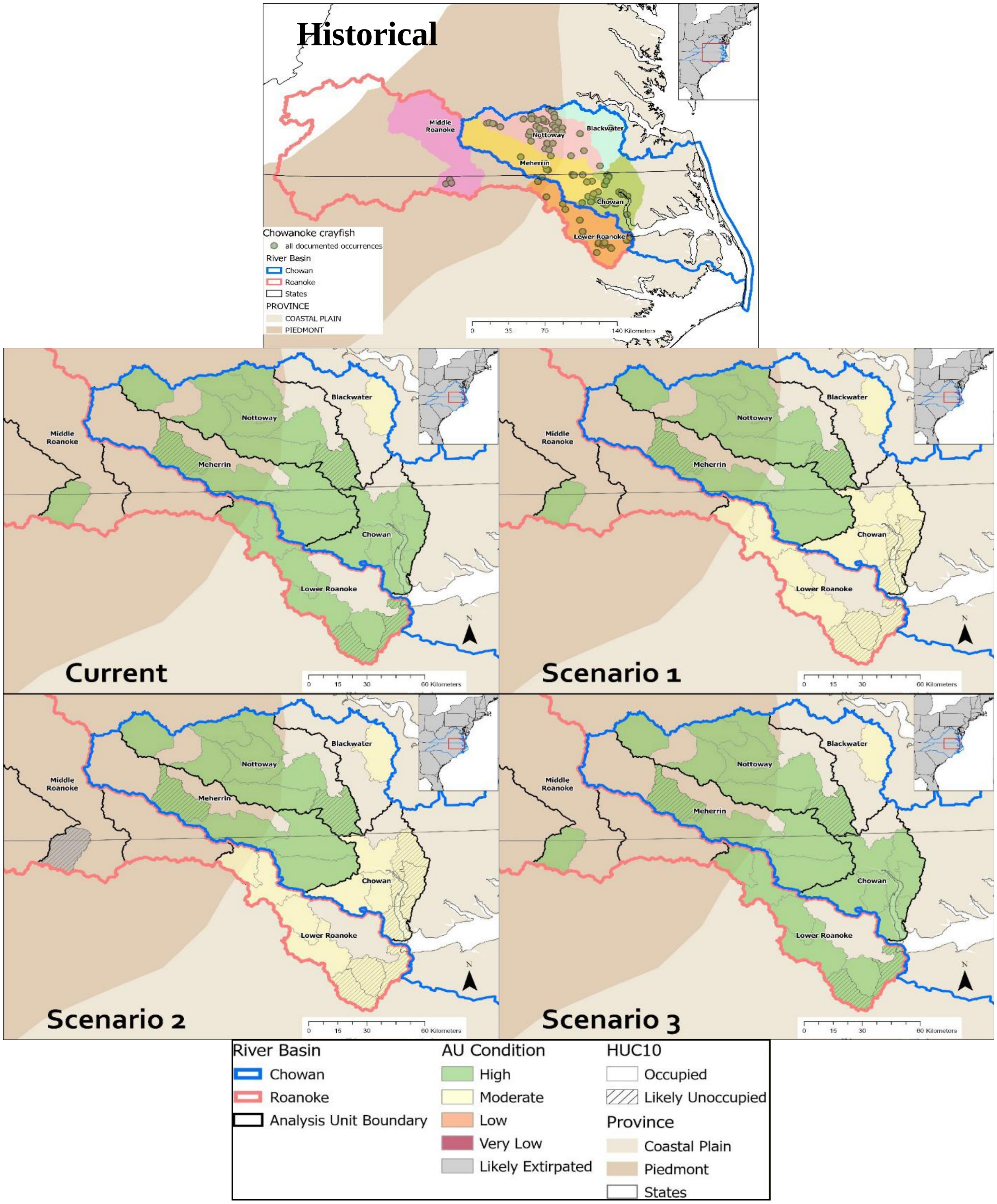

Figure 7. Maps of historical range, current condition, and predicted Chowanoke crayfish future conditions under each scenario.

FINDING

Regulatory Framework

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

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; or
(E) Other natural or manmade factors affecting its continued existence.

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

Status Assessment

Status Throughout All of Its Range

After evaluating threats to the species and assessing the cumulative effect of the threats under the section 4(a)(1) factors, we assessed the current status of the Chowanoke crayfish to determine if it meets the definition of an endangered species. The Chowanoke crayfish's current distribution has not substantially changed from its known historical distribution. The species has maintained multiple resilient population analysis units (100 percent of units at moderate or high current condition) distributed throughout both physiographic provinces and river basins. The species currently occurs in 24 out of the 28 historically occupied HUC10 watersheds and 6 out of 6 analysis units. The effects of land use change and climate change have likely begun to occur in minor portions of the current Chowanoke range and may have contributed to some habitat degradation. However, these threats appear to have low imminence and magnitude, and the current risk of extinction is low. Therefore, after assessing the best available information, we conclude that the Chowanoke crayfish is not in danger of extinction throughout all of its range and does not meet the definition of an endangered species.

We therefore proceed with determining whether Chowanoke crayfish is likely to become endangered within the foreseeable future throughout all of its range. In considering the foreseeable future as it relates to the status of the Chowanoke crayfish, we considered the relevant risk factors (threats) acting on the species and whether we could draw reliable predictions about the species' response to these factors. We considered whether we could reliably assess the risk posed by the threats to the species, recognizing that our ability to assess risk is limited by the variable quantity and quality of available data about effects to Chowanoke crayfish and its response to those effects. The Chowanoke crayfish faces a variety of stressors from declines in water quality, reduction of stream flow, riparian habitat loss, and deterioration of instream habitats. The primary threats affecting the Chowanoke crayfish are land use modification, climate change, and nonnative crayfish; therefore, these factors were included in our assessment of the future condition of the Chowanoke crayfish. When resiliency is very low, populations become more vulnerable to extirpation, in turn, resulting in concurrent losses in representation and redundancy.

The results of the future scenario analysis describe a range of possible future conditions for the Chowanoke crayfish populations and AUs. The SSA's analysis of future scenarios over a 50-year timeframe encompasses the best available information for future projections of urbanization and future changes in salinity, under two climate change scenarios (RCP 4.5 and 8.5). This 50-year timeframe enabled us to consider the threats/stressors acting on the species and draw reliable predictions about the species' response to these factors. Based on current and projected habitat conditions and population factors for two future scenarios (1 and 3), estimates of current and future resiliency for Chowanoke crayfish are high to moderate in all the AUs and Chowan and Roanoke populations, as are estimates for redundancy and representation at the end of 50 years. For Scenario 2, the Middle Roanoke AU in the Roanoke population is predicted to be likely extirpated, but the other five AUs in the Chowan and Roanoke populations will be in moderate or high condition, thus maintaining resiliency for five (83 percent) subpopulations. Redundancy is predicted to be reduced, but still at a moderate level across the range, with 68 percent of the HUC10 watersheds occupied. Representation in the Roanoke population and Coastal Plain province will decline, with the range contracting in the southwestern and eastern portions of the range. Under Scenario 2, the Chowanoke crayfish may not be as adaptive to changing conditions after the 50-year period. After assessing the best available information, we conclude that Chowanoke crayfish is not likely to become endangered within the foreseeable future throughout all of its range.

Status Throughout a Significant Portion of Its Range

Under the Act and our implementing regulations, a species may warrant listing if it is in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range. Having determined that the Chowanoke crayfish is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we now consider whether it may be in danger of extinction or likely to become so in the foreseeable future in a significant portion of its range - that is, whether there is any portion of the species' range for which it is true that both (1) the portion is significant; and (2) the species is in danger of extinction now or likely to become so in the foreseeable future in that portion. If we reach a negative answer with respect to the first question that we address, we do not need to evaluate the other question for that portion of the species' range.

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

We evaluated the range of the Chowanoke crayfish to determine if the species is in danger of extinction now or likely to become so in the foreseeable future in any portion of its range. The range of a species can theoretically be divided into portions in an infinite number of ways. We focused our analysis on portions of the species' range that may meet the definition of an endangered species or a threatened species. For Chowanoke crayfish, we considered whether the threats or their effects on the species are greater in any biologically meaningful portion of the species' range than in other portions such that the species is in danger of extinction now or likely to become so in the foreseeable future in that portion. We examined the following threats: land use modification, climate change, and nonnative crayfish, including cumulative threats.

Currently, the effects of land use change and climate change (e.g., increasing sea level rise (SLR)) have likely begun to occur in minor portions of the current Chowanoke range and may have contributed to some habitat degradation. The risks associated with the negative effects of land use modification and climate change on Chowanoke crayfish habitat are likely to continue, as well the potential risk of nonnative species range expansion resulting in habitat degradation, competition, and predation. However, based on current habitat conditions and population factors, estimates of current resiliency of Chowanoke crayfish are high to moderate in all the AUs (figure 7, table 5). The species currently occurs in 6 out of 6 historically occupied AUs (Redundancy). There are no portions of the range that are currently in danger of extinction.

For future scenarios 1 and 3, estimates of future resiliency for Chowanoke crayfish are high to moderate in the Middle Roanoke and the lower Roanoke/Chowan AUs, as are estimates for redundancy and representation at the end of 50 years. In future scenario 2, the Middle Roanoke AU in the Roanoke population is predicted to be likely extirpated due to the predicted loss of instream habitat caused by nonnative virile crayfish, thereby displacing Chowanoke crayfish, although there is no evidence of such displacement having occurred anywhere to date.

We also identified that under future scenario 2, representation in small portions of the Lower Roanoke AU and eastern portions of lower Chowan River AU would decline, with range contraction occurring due to an increased frequency of inundation of higher salinity water. However, the remainder of the habitat area within each of these AUs is not predicted to be affected by sea level rise, and connectivity is predicted to remain throughout, and while redundancy is predicted to be reduced, each AU would remain in moderate condition.

Although every AU may provide some contribution to a species' resiliency, representation, and redundancy, the potentially affected areas of the AUs under future scenario 2 only comprise a small portion of the species range while the majority of the AUs remain in moderate to high condition; the AUs habitat is projected to retain connectivity and remain available to support the species; and the AUs are projected to remain occupied and provide species resiliency and redundancy. Thus, even in these units where stressors may increase into the future, there is no concentration of threats in these units acting on the Chowanoke crayfish at a biologically meaningful scale.

We found no biologically meaningful portion of the Chowanoke crayfish range where threats are impacting individuals differently from how they are affecting the species elsewhere in its range, or where the condition of the species differs from its condition elsewhere in its range such that the status of the species in that portion differs from any other portion of the species' range.

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

Determination of Status

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

COORDINATION WITH STATES

While conducting our SSA for the Chowanoke crayfish, we coordinated and received information from both States within the species' current range of Virginia and North Carolina. A draft of the SSA Report was provided to both States within the species' range, and we received comments from both States (Virginia, North Carolina).

LITERATURE CITED

Adams, S. G.A. Schuster, C.A. Taylor. 2010. *Orconectes virginiensis*. The IUCN Red List of Threatened Species 2010: eT153883A4558366. http://dx.doi.org/10.2305/IUCN.UK.2010-3.RLTS.T153883A4558366.en

Black, T.R. and R.B. Nichols. 2015. Distribution of *Orconectes virginiensis* (Chowanoke Crayfish) in the Chowan and Roanoke River Basins of North Carolina. Oral presentation at the 2015 Southern Division of the American Fisheries Society Meeting, Savannah, GA.

Black, T.R. 2019. Observation and notes on Chowanoke crayfish. Email from Tyler Black, formerly with the North Carolina Wildlife Resources Commission, to Jennifer Stanhope, U.S. Fish and Wildlife Service and Brian Watson, Virginia Department of Wildlife Resources, October 23, 2019.

Cooper, J. E. and A. L. Braswell. 1995. Observations of North Carolina crayfishes (Decapoda: Cambaridae). Brimleyana 22:87-132

Cooper, M.R. and J.E. Cooper 1977. Freshwater and Terrestrial Arthropods – Special Concern. pp. 214-215.

Crandall, K.A. and S. DeGrave. 2017. An updated classification of the freshwater crayfishes (Decapoda: Astacidae) of the world, with a complete species list. Journal of Crustacean Biology 37(5):615-653. Doi:10.1093/jcbiol.rux070

Crandall, K.A. O.R.P. Bininda-Edmonds, G.M. Mace, and R.K. Wayne. 2000. Considering evolutionary processes in conservation biology. Trends in Ecology and Evolution 15:290-295.

Fielder, D.D. 1972. Some Aspects of the Life Histories of Three Closely Related Crayfish Species. *Orconectes obscurus, O. sanborni*, and *O. propinquus*. The Ohio Journal of Science 72(3):129-145.

Fitzpatrick, J.F. Jr. 1967. The propinquus group of the crawfish genus *Orconectes* (Decapoda: Astacidae). The Ohio Journal of Science 67(3):129-172.

Foltz, D. 2019. Observation and notes document on Chowanoke crayfish provided by David Foltz, consultant/West Liberty University. Email from Bronwyn Williams, North Carolina Museum of Natural History, to Emily Wells, U.S. Fish and Wildlife Service, October 25, 2019.

Global Biodiversity Information Facility (GBIF). 2019. GBIF.org Occurrence Download, Denmark. https://doi.org/10.15468/dl.udkcyv; accessed March 22, 2019 and September 12, 2019.

Hanski, I. 1999. Metapopulation ecology. Oxford University Press, Oxford. 313 pp.

Hobbs, H.H., Jr. 1951. A New Crayfish of the Genus *Orconectes* form Southeastern Virginia (Decapoda, Astacidae). The Virginia Journal of Science. Pp. 122-128.

Hobbs, H. H. Jr. 1989. An Illustrated Checklist of the American crayfishes (Decapoda: Astacidae, Cambaridae & Parastacidae). Smithsonian Contributions to Zoology 480.

Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

ITIS Report. 2019. Integrated Taxonomic Information System: *Orconectes virginiensis* Hobbs, 1951, https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=97487#null ; accessed March 12, 2019.

Kerby, J. L., P. D. Seth, L. B. Riley, and P. W. Kats. 2005. Barriers and flow as limiting factors in the spread of an invasive crayfish (*Procambarus clarkii*) in southern California streams. Biological Conservation 126:402–409.

Kernan, M. 2015. Climate change and the impact of invasive species on aquatic ecosystems. Aquatic Ecosystems Health & Management, 18 (3):321-333.

LeGrand, H.E., Jr., J. Ratcliffe, J.T. Finnegan. 2015. Natural Heritage Program List of the Rare Animal Species of North Carolina. North Carolina Natural Heritage Program, Raleigh, North Carolina. 172 pp.

Loughman, Z.J. 2013. Determination of invasive crayfish post invasion dynamics on a diverse West Virginia crayfish community with an emphasis on impacts to *Cambarus chasmodactylus.* Report prepared for the West Virginia Division of Natural Resources, South Charleston, WV.

Loughman, Z.J. and S.A. Welsh. 2010. Distribution and conservation standing of West Virginia crayfishes. Southeastern Naturalist 9(Special Issue 3):63–78.

Loughman, Z.J. and S.A. Welsh. 2018. Ecology and Conservation of North American Crayfishes. U.S. Fish and Wildlife Service, National Conservation Training Center, Shepherdstown, West Virginia. 90 pp.

Martinez, P.J. 2012. Invasive crayfish in a high desert river: Implications of concurrent invaders and climate change. Aquatic Invasions 7(2):219-234. Doi: http://dx.doi.org/10.3391/ai/2012.7.2.008

McLaughlin, P.A., D.K. Camp, M.V. Angel, E.L. Bousfield, P. Brunel, R.C. Brusca, D. Cadien, A.C. Cohen, K. Conlan, L.G. Eldredge, D.L. Felder, J.W. Goy, T. Haney, B. Hann, R.W. Heard, E.A. Hendrycks, H.H. Hobbs III, J.R. Holsinger, B. Kensley, D.R. Laubitz, S.E. LeCroy, R. Lemaitre, R.F. Maddocks, J.W. Martin, P. Mikkelsen, E. Nelson, W.A. Newman, R.M. Overstreet, W.J. Poly, W.W. Price, J.W. Reid, A. Robertson, D.C. Rogers, A. Ross, M. Schotte, F. Schram, C. Shih, L. Watling, G.D.F. Wilson, and D.D. Turgeon. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: Crustaceans. American Fisheries Society Special Publication 31: 545 pp.

NatureServe. 2019. NatureServe Explorer: An online encyclopedia of life (web application). Ver. 7.1. NatureServe, Arlington, VA. http://explorer.natureserve.org; accessed March 22, 2019.

North Carolina Administrative Code (NCAC). 2021. Enacted code. 15A NCAC 10C .0211. http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2010%20-%20wildlife%20resources%20and%20water%20safety/subchapter%20c/15a%20ncac%2010c%20.0211.pdf; accessed April 13, 2021.

North Carolina Wildlife Resources Commission. 2019b. Unpublished nonnative crayfish data from the NCWRC database. Emails from Michael Fisk, NCWRC, to Jennifer Stanhope, Krishna Gifford, Sandra Lary, and Emily Wells, U.S. Fish and Wildlife Service. November 14, 2019 and December 3, 2019.

North Carolina Wildlife Resources Commission. 2020b. Unpublished red swamp crayfish and Chowanoke crayfish data from recent site visits. Email from Michael Fisk, NCWRC, to Emily Wells, Sandra Lary, Jennifer Stanhope, Michelle Shoultz, and Doug Newcomb, U.S. Fish and Wildlife Service, June 11, 2020.

Pflieger, W.L. 1996. The crayfishes of Missouri. Missouri Department of Conservation, Jefferson City, MO. 152 pp.

Puky, M. 2014. Invasive Crayfish on Land: *Orconectes limosus* (Rafinesque, 1817) (Decapoda: Cambaridae) Crossed a Terrestrial Barrier to Move from a Side Arm into the Danube River at Szeremle, Hungary. Acta Zoologica Bulgarica Suppl. 7: 143-146.

Reynolds, J., C. Souty-Grosset, and A. Richardson. 2013. Ecological Roles of Crayfish in Freshwater and Terrestrial Habitats. Freshwater Crayfish 19 (2):197-218.

Shaffer, M.L. and B.A. Stein. 2000. Safeguarding our precious heritage. pp. 301-321 in Stein BA, Kutner LS, Adams JS, eds. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press.

Smith, D., N.L. Allan, C.P. McGowan, J. Szymanski, S.R. Oetker, and H.M. Bell. 2018. Development of a species status assessment process for decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9(1):1-19.

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017. Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services, Silver Spring, MD. https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

Taylor, C.A., M.L.Warren Jr., J.F. Fitzpatrick Jr., H.H. Hobbs III, R.F. Jezerinac, W.L. Pflieger, and H.W. Robison. 1996. Conservation status of crayfishes of the U.S. and Canada. Fisheries 21 (4):25-38.

Terando, A.J., J. Constanza, C. Belyea, R.R. Dunn, A. McKerrow, and J.A. Collazo. 2014. The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S. PLoS ONE 9(7):e102261. https://doi.org/10.1371/journal.pone.0102261

Thoma, R.F. 2014. Conservation Status of Eleven Virginia Crayfish Species. Midwest Biodiversity Institute - Report Number: MBI/2014-7-7. 31 pp.

U.S. Fish and Wildlife Service. 2013. Roanoke River National Wildlife Refuge Habitat Management Plan. Bertie County, NC. 206 pp.

U.S. Fish and Wildlife Service. 2018. Species status assessment report for the Big Creek Crayfish (*Faxonius peruncus*) and St. Francis River Crayfish (*Faxonius quadruncus*). Version 1.0, December 2018. Midwest Region, Bloomington, MN. 69 pp.

U.S. Fish and Wildlife Service. 2019a. Final call notes from the Chowanoke crayfish species expert call on September 10, 2019, 3-5pm, with additional comments provided by experts when reviewing draft notes. Version December 3, 2019. U.S. Fish and Wildlife Service, Virginia Field Office, Gloucester, VA.

U.S. Fish and Wildlife Service. 2019b. Final call notes with Zac Loughman, crayfish expert, on October 30, 2019. U.S. Fish and Wildlife Service, North Atlantic-Appalachian Region, Hadley, MA.

U.S. Fish and Wildlife Service. 2019c. Final call notes with Michael Kendrick, Assistant Marine Scientist at SCDNR Marine Resources Research Institute on red swamp crayfish, on December 19, 2019. Version February 13, 2020. U.S. Fish and Wildlife Service, Virginia Field Office, Gloucester, VA.

U.S. Fish and Wildlife Service. 2020a. Species Status Assessment Report for the Elk River Crayfish (*Cambarus elkensis*), Version 1.1. January 2020. Elkins, WV.

U.S. Fish and Wildlife Service. 2021. Species Status Assessment Report for the Chowanoke Crayfish (*Faxonius virginiensis*), Version 1.0. October 2021. Gloucester, VA.

Virginia Department of Conservation and Recreation. 2021. Virginia's Physiographic Provinces. https://www.dcr.virginia.gov/natural-heritage/va-physiographic-provinces; accessed April 30, 2021.

Virginia Department of Game and Inland Fisheries. 2015. Virginia's 2015 Wildlife Action Plan. Richmond, VA. 1135 pp.

Virginia Law. 2021. Virginia Administration Code 4VAC15-360-70. Prohibit the sale of crayfish species. https://law.lis.virginia.gov/admincode/title4/agency15/chapter360/section70/#:~:text=%2D360%2D70.-,Prohibit%20the%20sale%20of%20crayfish%20species.,of%20the%20Code%20of%20Virginia; accessed April 15, 2021.

Watson, B. 2021. Observations and comments on Chowanoke crayfish. Email from Brian Watson, Virginia Department of Wildlife Resources, to Jennifer Stanhope, U.S. Fish and Wildlife Service, March 9, 2021.

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

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Martha Williams,
Director,
U.S. Fish and Wildlife Service.