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

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SCIENTIFIC NAME: *Lirceus culveri*

COMMON NAME: Rye Cove cave isopod

LEAD REGION: Northeast Region (R5)

LEAD REGION CONTACT: Martin Miller, Northeast Regional Office, 413-253-8615,

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DATE INFORMATION CURRENT AS OF: August 2022

STATUS/ACTION
X_ Nonlisted species assessment determined either we do not have sufficient information on threats or the information on the threats does not support a proposal to list the species and, therefore, it was not elevated to Candidate status.

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

____Nonlisted species discretionary species status assessment for which we have determined that listing is not warranted (does not meet the definition of a threatened or endangered species)

___Listed species petitioned for delisting for which we have made a not warranted finding

____Listed species petitioned for downlisting for which we have made a not warranted finding

____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 for which we have made a not warranted finding

____New candidate
____Continuing candidat
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 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 Rye Cove cave isopod, as endangered or threatened species under the Endangered Species Act of 1973, as amended (Act) on July 1, 1975 (Center for Biological Diversity (CBD) 2010, pp. 1–66, 192–193). 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 Isopoda, Family Asellidae

BIOLOGICAL INFORMATION
To assess the Rye Cove cave isopod 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 Rye Cove cave isopod 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 Rye Cove cave isopod *(Lirceus culveri)* - February 2022, 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 2022, entire).

## Species Description

The Rye Cove cave isopod (*Lirceus culveri*) (Estes and Holsinger 1976) is an eyeless, unpigmented troglobitic species of isopod occupying a small range of approximately 14 km (8.7 mi) of cave streams fed by a drainage area of approximately 19 km$^2$ (7.3 mi$^2$) within the Rye Cove area of Scott County in southwestern Virginia. The Rye Cove cave isopod is a crustacean with a rigid, segmented exoskeleton, where the first segment of the thorax is fused to the head. Isopods also have two pairs of antennae, seven pairs of jointed limbs on the thorax, and five pairs of branching appendages (pleopods) on the abdomen that are used in swimming and for respiration (Brusca 1997, entire).

Figure 1. Photo of Rye Cove cave isopod (taken by Hobson and Orndorff, 2005).

## Taxonomy

The Rye Cove cave isopod, *Lirceus culveri*, was first discovered by John R. Holsinger and David C. Culver in 1974 and was described in 1976 (Estes and Holsinger 1976, pp. 481–482). Although recent research questioned the taxonomic status of the Rye Cove cave isopod, genetic verification found that the taxonomy is valid. The Rye Cove cave isopod is morphologically similar to the Lee County Cave isopod, *Lirceus usdagalun*, and the two species were previously thought to share a relatively recent common ancestor (Estes and Holsinger 1976, p. 488). In 2016, a study found that the morphology of the tip of the endopod of the second pleopod in males, a trait that typically helps define the taxonomic status of freshwater-dwelling isopods, was indistinguishable among the Rye Cove cave isopod, Lee County Cave isopod, and *L. hargeri* (Lewis et al. 2017, p. 24). In a report to the Service, Lewis suggested that they may all represent different variants of the same species and suggested reclassifying the three to subspecies (Lewis et al. 2017, entire). However, a subsequent study using next generation sequencing of transcriptomes, also known as RNA-Seq, found sufficient sequence divergences to maintain the status of the Rye Cove cave isopod as a separate species (Fong et al. 2021, p. 661). Further, preliminary results of an analysis of 4 genes indicated that the Lee County Cave isopod is not in the same clade as the Rye Cove cave isopod as previously thought. While the two are difficult to separate by morphological differences, they are genetically very different (Lewis 2020, pers. comm.). The closest relative to the Rye Cove cave isopod, based on this genetic analysis, is a currently undescribed epigean species (a species that lives on the surface) that inhabits the resurgence springs of the two conduits (Conduit 1 and 2), as well as several other caves in the area (See Figure 3) (Lewis 2021b, pers. comm.).

Molecular evidence suggests that the Rye Cove cave isopod diverged from this epigean species millions of years ago (Lewis 2021a, pers. comm.).

## Habitat/Life History

The following information is summarized from chapter 2 of the SSA Report (Service 2022, pp. 22–24); see the full chapter for additional details.

Very little is known about the Rye Cove cave isopod’s life history or lifespan. Other isopods are estimated to live about 2 years (PNNL 2021, website; Lewis 2021a, pers. comm.); *Lirceus fontinalis* is estimated to live 4 to 7 months (Oecologia 1996, p. 86). The species is thought to be a detritivore, eating organic matter that seeps into the caves, but it may instead scrape bacterial films off substrate (Virginia DCR 1997, p. 1; Orndorff 2022, pers. comm.). All isopod females brood their young in a pouch under their thorax (Ruppert et al. 2004, p. 661). Two Rye Cove cave isopod females collected in 1974 were carrying 18 and 28 eggs, respectively. In 1975, 2 of 17 collected females were carrying 11 and 13 newly hatched young (Estes and Holsinger 1976, p. 488). The Rye Cove cave isopod cannot free swim but moves around under and on the surface of rocks and other substrate (Virginia DCR 1996, p. 2; Orndorff 2022, pers. comm., entire). High flow rates in occupied streams may cause dispersal of adults, although there is evidence that they are able to remain attached to substrate during flow conditions that other invertebrates (such as aselids in the genus *Caecidotea*) are unable to withstand (Virginia DCR 1996, p. 2; Orndorff 2021b, pers. comm.). Juveniles presumably disperse after leaving a female (Virginia DCR 1996, p. 2).

Troglobitic organisms live entirely in continuous darkness and are adapted to unique climatic stability with almost constant temperatures and high humidity approaching saturation (Virginia DCR 1997, p. 1; Mammola 2019, p. 101). However, the water temperatures within cave streams can vary over the course of a year; one stream in southern Indiana varied by approximately 10°C (25°F) due to the influx of melting snow or other cold water in the winter and warm water following summertime torrential storms (Lewis 2021a, pers. comm.). While the range of thermal tolerance of the Rye Cove cave isopod is unknown, we assumed that it could tolerate some fluctuation consistent with above average summer and below average winter water temperatures. Another species in the same genus, *Lirceus brachyurus*, has a lower lethal limit of 0°C (32°F) and an upper lethal limit of 23°C (73.4°F) (Cheper 1980, p. 314), while *L. fontinalis* tolerated 40°C (104°F) for 10 days in a laboratory setting (Styron 1968, p. 134). Isopods are generally very susceptible to changes in water quality and can only survive in clean, good quality water (Virginia DCR 1997, p. 1). There are no water quality or quantity data available for the Rye Cove cave systems.

The Rye Cove cave isopod primarily occupies riffles in cave streams, where it can filter the water for food and oxygen (Hobson and Orndorff 2005, p. 3; Lewis 2021b, pers. comm.). The species is typically found on gravel, cobble, bedrock, and flowstone surfaces within riffles or small waterfalls where there is highly oxygenated, shallow, and fast-moving water (Hobson and

Orndorff 2005, p. 3; Orndorff and Malabad 2016, p. 2). Troglobitic *Lirceus* tend to do well in cave systems that are prone to both floods and droughts, as are the cave systems in the range of the Rye Cove cave isopod. Some troglobitic isopods appear to have adaptations that allow them to outcompete freshwater asellids of the genus *Caecidotea*, including the ability to aestivate on dry surfaces within the stream during drought (observed for the Lee County cave isopod) and the ability to remain attached to substrate during high flow conditions (Orndorff 2021b, pers. comm.). Based on their presence in these caves, we assume the Rye Cove cave isopod is able to withstand normal flood and drought events despite not knowing the mechanism by which it accomplishes this or specifically whether the Rye Cove cave isopod has either of these adaptations.

It is likely that habitat for this species extends beyond the areas accessible for surveying and occurs within smaller passages between the larger caves anywhere the water flows. While caves provide surveyors access points along these cave system streams, isopods are assumed to occur in suitable habitat throughout these underground streams, even where the passages are quite small (Lewis 2021a, pers. comm.). However, we do not know the extent or connectivity of habitat within these cave systems.

### Range and Distribution

The following information is summarized from chapter 2 of the SSA Report (Service 2022, pp. 17-22); see the full chapter for additional details.

The Rye Cove cave isopod is a narrow endemic occupying a small range of approximately 14 km (8.7 mi) of cave streams fed by a drainage area of approximately 19 $km^2$ (7.3 $mi^2$) within the Appalachian Valley, an area of ridges and valleys with underlying belts of limestone and dolomite which run between the Blue Ridge Mountains on the east and the Appalachian Mountains on the west (Virginia DCR 1997, p. 1; Holsinger and Culver 1988, pp. 5-6).

The Rye Cove area of southwestern Virginia is a trough within the Appalachian Valley, bound by Big Ridge to the south and Cove Ridge to the north; the floor of the cove is about 500 feet (152 meters (m)) lower than the surrounding ridges, which exceed 2,000 feet (610 m). Rye Cove has two main cave conduits. Along the first conduit (Conduit 1), there are six significant caves: Cave A, Cave B, Cave C, Cave D, Cave E, and Cave F, with Cave E being the largest (Karst Conservation Priorities 1996, entire). A second parallel conduit (Conduit 2) runs north of this larger one, with two significant caves located along it (Cave G and Cave H) (Figure 3). All the streams and caves appear to eventually resurge over 1 mile east and 200 feet (61 m) lower than the Rye Cove valley floor at a spring (Lewis et al. 2019, p. 9).

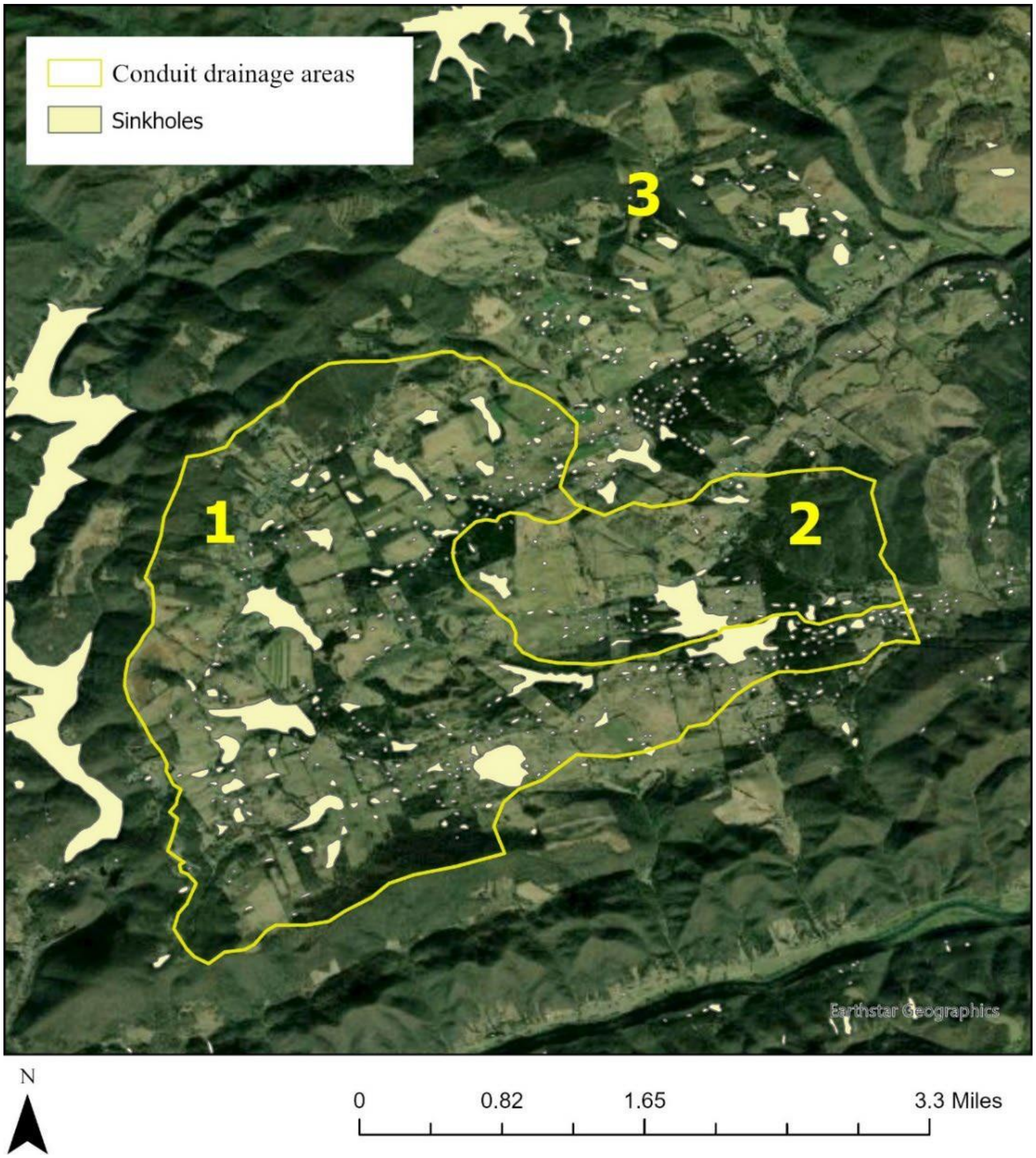

Figure 1. Drainage areas where the two cave conduits (Conduit 1 and Conduit 2) are located in the Rye Cove area, including locations of sinkholes. A third potential conduit location (Conduit 3) is also noted north of Conduit 2, although the drainage area for this conduit is unknown, and the location has not been explored for Rye Cove cave isopod.

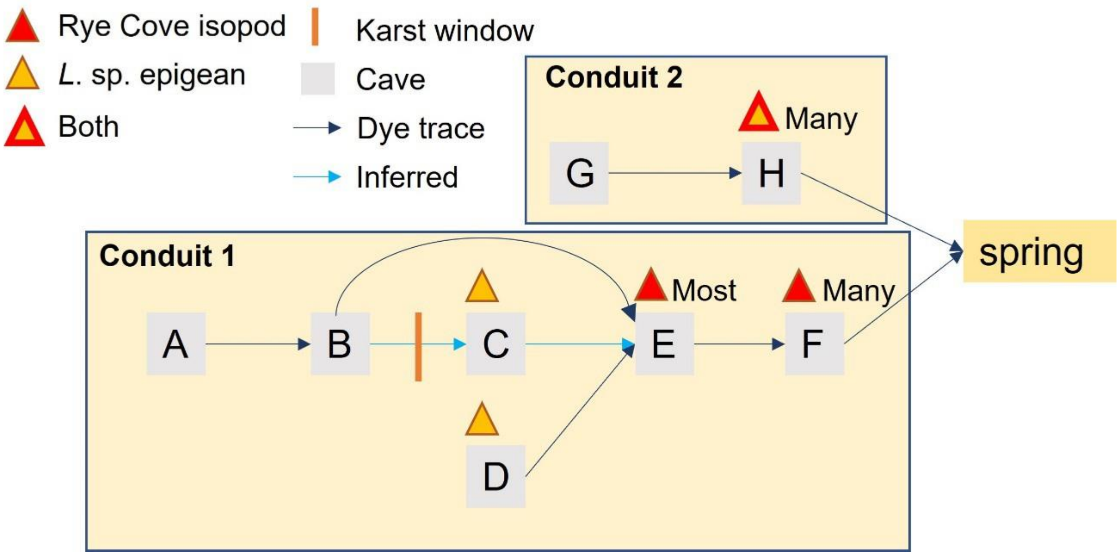

Figure 2. Depiction of how caves are known and inferred to be connected within Conduit 1 and Conduit 2. Note that while dye tracing has revealed that water from Cave B makes it to Cave E, the route is inferred to first flow through Cave C. For caves where the Rye Cove cave isopod has been detected, Cave E is identified as having the most individuals.

The Rye Cove cave isopod was first discovered in 1974 in Cave E in Conduit 1(Estes and Holsinger 1976, pp. 481–482). No other sites had been reported for this species until surveys in 2004 and 2005 of 14 caves in Rye Cove and adjacent limestone areas located 3 additional sites for the species: Cave F in Conduit 1, and Cave G and Cave H in Conduit 2 (Hobson and Orndorff 2005, pp. 1–2). In 2016, an additional cave, Cave D, which contains a tributary stream to Cave E in Conduit 1, was thought to have a small number of the species (Orndorff and Malabad 2016, p. 4), although this record is no longer considered valid and is thought to have been an incorrect identification of a newly molted or juvenile of the closely related epigean species (Orndorff 2021a, pers. comm.). A follow-up survey to Cave D in August of 2021 did not produce any Rye Cove cave isopods, but the epigean species was detected (Lewis 2021c, entire).

The most recent and comprehensive surveys were in 2016 (Orndorff and Malabad 2016, entire), where 11 caves and two springs were surveyed for the Rye Cove cave isopod. In each cave or spring, surveyors also noted the presence of other *Lirceus* species, similar isopods in the genus *Caecidotea*, amphipods, and insect larvae, as well as whether suitable habitat was present (Table 1). Access was later acquired for Cave C (Orndorff 2021b, pers. comm.). Cave I, within a third conduit (Conduit 3) was identified by experts as likely to contain potential habitat, but it was not surveyed due to access issues (Orndorff and Malabad 2016, p. 3). Two additional caves were not surveyed due to previous researchers' note that no suitable habitat exists. Numerous Rye Cove cave isopods were detected in three of the caves previously known to be occupied (Table 1). No individuals were detected in Cave G in Conduit 2, despite being present in 2005 (Hobson and Orndorff 2005, pp. 1–2; Orndorff and Malabad 2016, p. 7). Experts have been unable to survey in Cave D again, but there is suspicion that the isopods in Cave D in 2005 may have been juvenile or newly molted individuals of the epigean species (Orndorff 2021a, pers. comm.). Based on previous and subsequent visits to Cave E in Conduit 1, experts agree that the species is most abundant in this cave, estimating approximately 10 to 15 individuals per square foot (Service 2021, p. 2).

The Rye Cove cave isopod is now known to inhabit only two distinct, adjacent karst drainages within a single moderately-sized spring basin: Conduit 1 and Conduit 2 (Figure 2) (Hobson and Orndorff 2005, p. 4; Orndorff and Malabad 2016, p. 1–2). These sites all occur on privately-owned land. Additional populations may potentially occupy adjacent drainages, but habitat connectivity between the caves to additional suitable caves has not been located, and this species has not been found at and does not appear to occupy streams at the resurgence springs or insurgence cave entrances (Hobson and Orndorff 2005, p. 4; Orndorff and Malabad 2016, p. 1–2).

It is unknown whether the Rye Cove cave isopod exists in Cave I in Conduit 3 due to a lack of landowner permission to access and survey the site. For the purposes of our analysis, we assume presence in Cave I is possible due to expert opinion that suitable habitat may exist, although experts find it unlikely because the Rye Cove cave isopod was not detected in other nearby cave systems (Orndorff 2021b, pers. comm.).

| **Conduit** | **Cave** | **Type** | ***L. culveri*** | ***L.* species (pigmented)** | **Caecidotea** | **Amphipods** | **Insect larvae** | **Habitat?** |
|---|---|---|---|---|---|---|---|---|
| 1 | A | Cave | None | None | Many | Few | Many | Pool/riffle |
|  | B | Cave | None | None | Many | None | Many | Pool/riffle |
|  | C | Cave | None | Some | Not noted |  |  |  |
|  | D | Cave | None | Many | Many |  |  | Pool/riffle |
|  | E | Cave | Many | None | None | None | Many | Pool/riffle/ rimstone |
|  | F | Cave | Many | None | Few | None | None | Pool/riffle |
| 2 | G | Cave | None | None | Many | None | Many | Pool/riffle |
|  | H | Cave | Many | Many | Many | None | None | Pool/riffle |
| 3 | I | Cave | Lack of landowner permission to access survey site |  |  |  |  |  |
| Nearby | other | Cave | None | Some | None | Few | Many | Good; high flow |
|  | other | Cave | No suitable habitat |  |  |  |  |  |
|  | other | Cave | No suitable habitat |  |  |  |  |  |
|  | other | Spring | None | Many | None | None | Many | Spring gravels |
|  | other | Spring | None | Many | None | None | Many | Spring gravels |
| Outliers | other | Cave | None | Many | Many | Few | Many | Pool/riffle |
|  | other | Cave | None | Many | Many | Few | ??? | Pool/riffle/ rimstone |
|  | other | Cave | None | Few | Many | Few | ??? | Pool/riffle |

Table 1. Survey results from 2016 of 13 different sites (an additional 4 were inaccessible) for the Rye Cove cave isopod, updated with additional data. In addition to presence of Rye Cove cave isopod, surveyors documented other *Lirceus* species (multiple species), isopods in the genus

*Caecidotea*, amphipods, and insect larvae, and noted whether habitat existed (adapted from Orndorff and Malabad 2016, p. 7; Orndorff 2022, pers. comm.).

Dye-tracing has indicated how these underground conduit cave systems are likely connected, although there are still uncertainties regarding whether additional blind tributaries to the main channels exist. Flow is known to move from Caves A and B and eventually ends up in Cave E, and it is inferred that the flow travels through Cave C on its way, although this has not been verified and Rye Cove cave isopod have not been found in Cave C (Figure 3). Immediately upstream of Cave C in Conduit 1, there is a “karst window” where the cave collapsed, and the stream now runs on the surface for a stretch. Experts believe this likely acts as a physical dispersal barrier for the Rye Cove cave isopod, effectively separating Caves A and B from the rest of the habitat located downstream in Conduit 1 (Caves C, D, E and F) (Service 2021, p. 1). Cave D is in a separate tributary within Conduit 1 (Figure 3).

The presence of the closely related epigean species within some caves is noted and may be an indication of high nutrient load in some caves, as this can attract surface species into what is usually low-nutrient habitat (Lewis 2021b, pers. comm.). However, neither water quality data nor data on the impact of this epigean species on the Rye Cove cave isopod exists (Service 2021, p. 2). Both species co-occur in Cave H in Conduit 2 (Figure 3).

### Population and Species Needs

The following information is summarized from chapter 3 of the SSA Report (Service 2022, pp. 24–25); see the full chapter for additional details.

The Rye Cove cave isopod has evolved in an ecosystem that is highly connected and responsive to subtle relationships (limited food chain, limited resources, constant environmental conditions), and any disruption of these relationships could cause the species to rapidly decline (Virginia DCR 1997, p. 1).

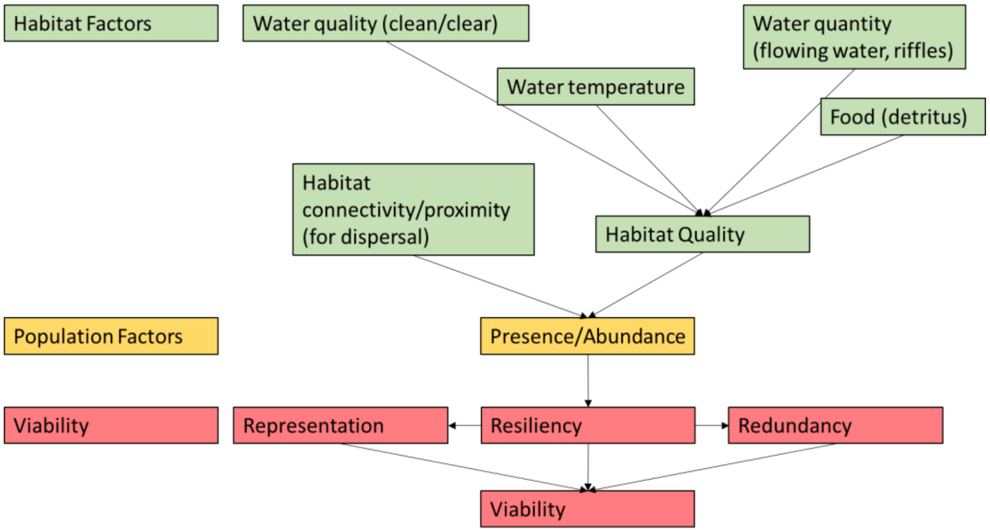

Figure 3. Simplified depiction of the needs of the Rye Cove cave isopod populations for viability.

Rye Cove cave isopods require suitable habitat to survive and reproduce (Figure 4). Suitable habitat consists of areas with suitable substrate within the cave streams where clean water with adequate depth flows through riffles which help oxygenate the water. Streams must carry organic detritus on which the isopod can feed. However, excess nutrients can be too plentiful, such that surface organisms without troglomorphic (cave-adapted) characteristics are able to survive in the cave environment regularly (Graening and Brown 2003, pp. 1497-1498). Thus, nutrient inputs should not be so high that surface-adapted organisms are regularly present and potentially competing with the Rye Cove cave isopod, or that water quality and the overall habitat conditions are degraded. Although we do not know the thermal tolerance of Rye Cove cave isopods, the range of temperatures that the isopod will thrive/survive in is likely dependent on the average stream temperature in the cave and seasonal fluctuations in temperature.

### Population Needs

For resilient populations to persist, the needs of individuals must be met at a larger scale. Sufficient habitat must be present within stream segments that provide suitable water quality, stream flow (riffles), adequate depth, and substrate. Habitat must be available in a long enough stream segment or set of segments to support a large enough population of potential mates while avoiding inbreeding depression, especially given the limited range occupied by the species. Segments need to be close enough to other segments to provide adequate connectivity to allow dispersal between/among them.

### Species Needs

For the species to be viable, there must be adequate redundancy of populations (a suitable number and distribution of resilient populations to allow the species to withstand catastrophic events) and representation (genetic and environmental diversity to allow the species to adapt to changing environmental conditions). Redundancy for the Rye Cove cave isopod would improve with increasing numbers of populations. While redundancy in some species is also important because it can help repopulate areas after catastrophes, the Rye Cove cave isopod appears to currently only occur in two relatively isolated cave systems and one population’s ability to impact the other is limited. It is unknown whether the two occupied conduits are connected upstream of the springs and how connected they are. While it is possible that in the instance of hydrologically connected caves, upstream populations could help repopulate downstream populations after catastrophes, this is virtually impossible for caves that are not connected by underground streams because the isopod is not found on the surface and cannot move between caves except via underground stream networks. Representation improves with increased genetic diversity and/or adaptation to diverse environmental conditions within and among populations. Given the limited range of the Rye Cove cave isopod and a lack of obvious genetic differences or types of this species, we expect genetic representation and the species’ adaptive capacity is inherently low.

## SUMMARY OF BIOLOGICAL INFORMATION

The Rye Cove cave isopod is an eyeless, unpigmented troglobitic species of isopod occupying a small range of approximately 14 km (8.7 mi) of cave streams fed by a drainage area of approximately 19 km2 (7.3 mi2) within the Rye Cove area of Scott County in southwestern Virginia. The Rye Cove cave isopod is a crustacean with a rigid, segmented exoskeleton. Isopods also have two pairs of antennae, seven pairs of jointed limbs on the thorax, and five pairs of branching appendages (pleopods) on the abdomen that are used in swimming and for respiration.

The Rye Cove cave isopod primarily occupies riffles in cave streams, where it can filter the water for food and oxygen. The species is typically found on gravel, cobble, bedrock, and flowstone surfaces within riffles or small waterfalls where there is highly oxygenated, shallow, and fast-moving water. It is assumed that when the flow decreases and these riffles disappear, the species can survive within pools or elsewhere, although with limited survey information it is unknown what range of habitats this species occupies. It is likely that habitat for this species extends beyond the areas accessible for surveying and occurs within smaller passages between the larger caves anywhere the water flows. While caves provide surveyors access points along these cave system streams, isopods are assumed occur in suitable habitat throughout these underground streams, even where the passages are quite small. However, we do not know the extent or connectivity of habitat within these cave systems.

## 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 following information is summarized from chapter 4 of the SSA Report (Service 2022, pp. 25–36); see the full chapters for additional details.

The main factor influencing current and future viability of the Rye Cove cave isopod is land use and management, specifically the potential for pollutants, sediments, and nutrients to enter the caves via runoff and affect water quality. Isopods in general are known to be sensitive to pollution or other water contaminants (Virginia DCR 1997, p. 1); however, we do not have data concerning the sensitivity of the Rye Cove cave isopod to pollutants or its range of tolerances.

Although this region, and Rye Cove specifically, is sparsely populated and is at very low risk of urbanization, current land uses present the largest threat to this species. The drainage area of the two stream systems is largely privately owned and is therefore difficult to regulate or protect. The Rye Cove cave isopod is at risk of both stressors from the aggregation of pollutants, sediments, and nutrients that occur on the landscape over time that enter into the cave system as runoff, as well as more acute catastrophic events or incompatible land use practices that may occur. A single action by one landowner, such as the storage of sawdust on the ground in the case of the Lee County Cave isopod, could lead to the extirpation of a population. It is likely that contaminants and sediments in the runoff and drainage of the area are cumulatively already influencing both Rye Cove cave isopod populations. However, water quality data do not exist for this area, hindering the ability to determine impacts from any one land use practice or location.

While the changing climate also has the potential to adversely affect the species, experts believe that major impacts from changing climatic conditions are unlikely to occur in the next 80 years (2100), unless especially extreme temperatures or significant (frequent or severe) droughts occur.

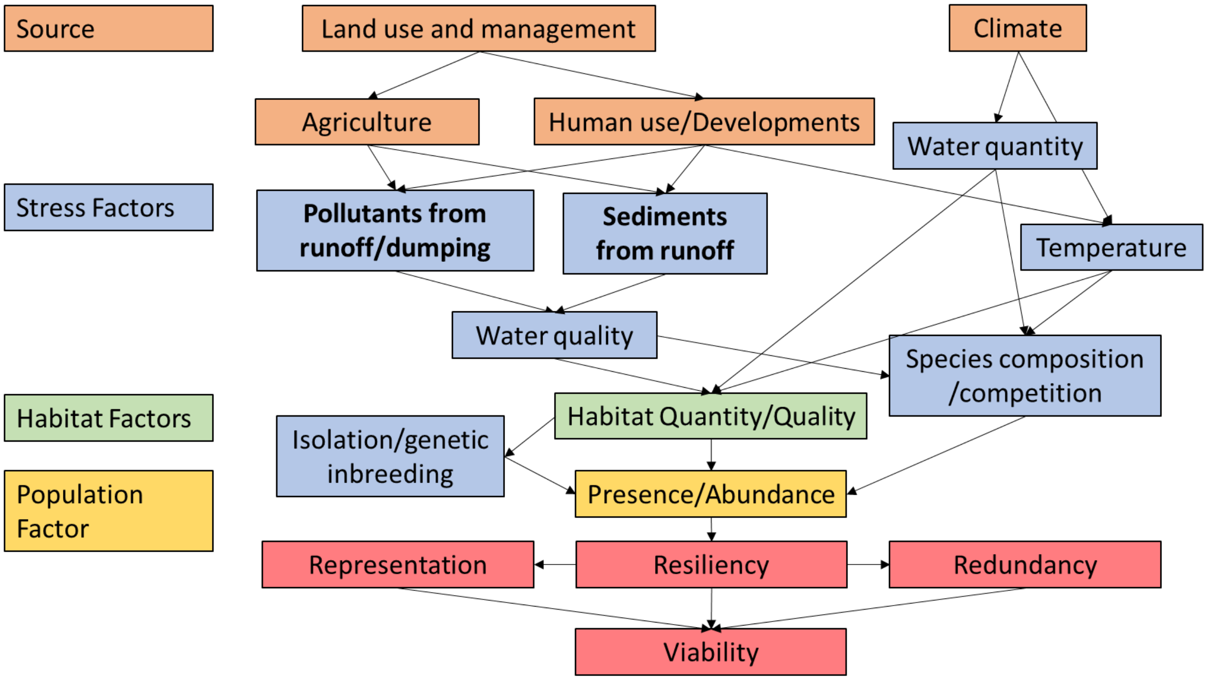

Figure 5. Simplified depiction of the needs of the Rye Cove cave isopod populations for viability.

**Land Use and Management:**

In karst areas such as Rye Cove, surface water is able to quickly leach through the porous substrate into underground channels with little natural filtration, making these areas particularly susceptible to pollution from the surface (Holsinger 1979 in Service 1992, p. 54723). Contaminants can travel downstream for thousands of feet or even miles. Land-clearing, development, and agricultural activities can create runoff that is contaminated by fertilizers, pesticides, herbicides, and sediment. Land development and agricultural activities can also increase the prevalence of chemical spills, faulty septic systems, leaking fuel tanks, and debris and trash dumps on the landscape, which also threaten cave ecosystems. In karst regions, where all water eventually ends up underground (Ulrich 2002, p. 28), sinkholes are sometimes used as places to dump trash, waste, wastewater, sludge, and other contaminants. In addition to runoff and pollutants, sedimentation is also assumed to be detrimental to aquatic cave species (Orndorff 2021b, pers. comm.; Hardwick and Gunn 1990 in Ulrich 2002, p. 16; Buendia et al. 2013, p. 184). Fine sediments change the micro-topography of stream beds by filling interstitial spaces, affecting habitat availability or suitability, and can affect food availability and suffocate animals due to a low oxygen concentration in sediment deposits (Buendia et al. 2013, pp. 184-185).

Rye Cove is largely privately owned with a small area owned by the Virginia Dept. of Conservation and Recreation in Natural Tunnel State Park (Figure 6). Land use in Rye Cove is predominantly agricultural (about 60 percent of the area), another 30 percent of the area is forested, and 7 percent of the area is developed, mostly open, space, with 2 percent of the area developed at low or medium intensity (USGS 2019). While most of Rye Cove is uninhabited or sparsely habited by humans with relatively large parcel sizes, the Bishoptown section of Rye Cove is a more densely populated rural area within the drainage for Conduit 1 (Figure 6). Bishoptown is roughly a half-square mile with about 100 parcels and at least 50 homes, with many lots as small as 0.5 acres or less (Scott County 2021, entire; USFWS 2021, entire). No sanitary sewer serves the area, but public water was recently provided to parts of Rye Cove (Orndorff and Malabad 2016, pp. 8-9). Thus, water is brought in but is not removed from the area after use through a municipal disposal system. Instead, residents rely on septic tanks and leach fields for wastewater disposal. The southwestern-most area of Rye Cove that drains to Conduit 1 is located within Natural Tunnel State Park, representing the only public and protected land within the Rye Cove drainage basin (Figure 5).

Within Rye Cove, 372 mapped sinkholes drain the area that flows into the cave streams occupied by the Rye Cove cave isopod (Figure 6). Because aquatic isopods are sensitive to contaminants, the Rye Cove cave isopod is predominantly threatened by contamination of the groundwater flowing into its habitat. A similar species, the federally listed endangered Lee County Cave isopod (*Lirceus usdagalun*), was extirpated by groundwater pollution in Thompson Cedar Cave, one of the two cave systems it was originally documented in, when a sawmill operation produced a large quantity of sawdust that was piled on the ground surface over the cave and rainwater leached tannins and other toxins from the sawdust into the underlying groundwater (Service 1992, p. 54723). This breakdown of organic carbon in the cave reduced oxygen levels below what is optimal for *Lirceus* sp. isopods (Orndorff and Hanlon 2014, p. 16). While the Lee County Cave isopod has since returned to Thompson Cedar Cave, other caves have similarly seen a loss of species due to pollutants; some were due to major environmental impacts, such as toxic metals and other industrial waste being purposefully discharged into groundwater (Lewis 1995, p. 214), but other extirpations have been due to passive or less catastrophic events, such as wastewater or animal waste contaminants, which was the case of one cave amphipod in Illinois (USFWS 2021, entire).

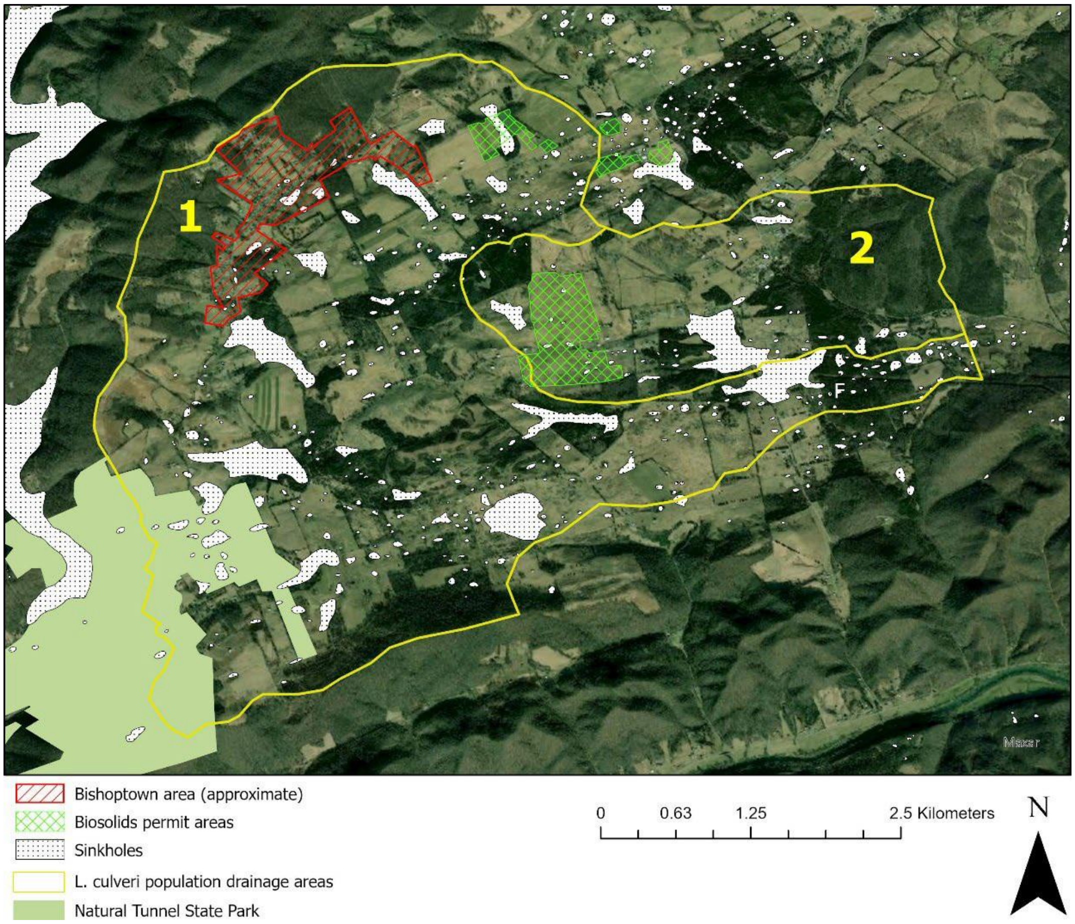

Figure 4. Location of Bishoptown area, Natural Tunnel State Park, biosolids permit areas, and areas that drain each cave conduit within Rye Cove.

Discharge from septic systems within the Bishoptown community poses a significant water quality threat and may explain why the Rye Cove cave isopod is not found in Cave A or Cave B which are both located within 0.5 km of Bishoptown in Conduit 1, although no water quality data exists to confirm this and the current land situation in Bishoptown has persisted for decades (Orndorff and Malabad 2016, pp. 8–9). The Rye Cove cave isopod has persisted in three caves that are located over 2.5 km south of Bishoptown in Cave E and Cave F in Conduit 1, and Cave H in Conduit 2. According to the National Land Cover Dataset (USGS 2019, entire), which categorizes land uses at a 30 m scale, less than 3 percent of the land area within Rye Cove has changed category (categories include several developed classes, two agriculture classes, different forest types, etc.) between 2001 and 2019. Land that has changed in that time has been both forested areas converting to hay/pasture as well as hay/pasture converting to deciduous and mixed forest. Overall, the amount of forested area has increased, and the amount of agricultural land has decreased in that time (USGS 2001, entire; USGS 2019, entire) (Figure 7).

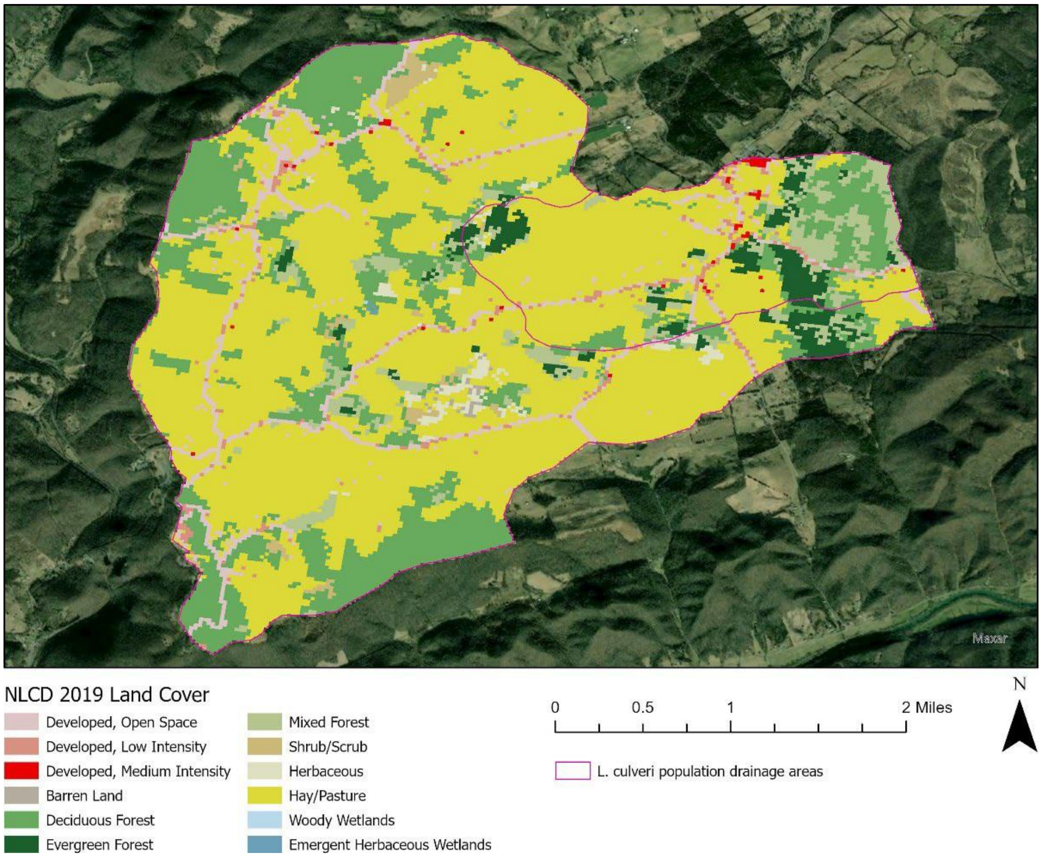

Figure 5. Landcover as of 2019 as classified by the National Land Cover Dataset (NLCD 2019) within the drainage areas for the two populations of Rye Cove cave isopod.

Agricultural land uses in Rye Cove are mostly hay production and cattle grazing (USDA 2017, p. 248). Crops are generally not grown commercially in Rye Cove, perhaps due to inferior soil conditions (USGS 2019, entire). A variety of agricultural activities can negatively affect cave ecology, although the magnitude of each impact will depend on the timing and location of each activity (Hardwick and Gunn 1990 in Ulrich 2002 (p. 16). There is also a negative effect from use of pesticides that target arthropods, as well as some common herbicides, to aquatic isopods. For example, glyphosate-based herbicides can include a surfactant that is toxic to aquatic invertebrates (Langeland 2012, p. 2). However, we do not know the effect of herbicide applications that prepare croplands for seeding on subterranean crustacean populations (Orndorff and Malabad 2016, pp. 8–9).

While runoff from cattle farms, pesticides and other agricultural applications could impact water quality in the karst cave systems, the degree to which most agricultural contaminants affect the Rye Cove cave isopod is unknown. Agricultural related impacts of karst groundwater systems were studied by Drew (1996, entire) in terms of various impact's biological oxygen demand (BOD). High BOD causes water eutrophication and deoxygenation by supplying food for bacteria which then multiply and use up dissolved oxygen, especially in warmer climates

(Sherwood 1992, pp. 7–8). Effluent from silage, or fermented feed (typically corn) for livestock, was found to have a very large BOD (Table 3), but silage production is usually for dairy farms, which do not exist in Rye Cove at this time, and if properly stored, silage should not produce effluent. However, future animal operations such as poultry production or small-scale pig farming are possible in Rye Cove (Sherwood 1992, Table 1 (p. 7). Phosphorus, and to a lesser extent, nitrogen, in water can cause water to be nutrient rich and lead to eutrophication (Sherwood 1992, p. 8). Nitrogen is soluble and moves into caves more easily than phosphorus, which would enter attached to sediment (Ciparis 2021, pers. comm.). A study in eastern West Virginia found that a cave stream that drained a dairy farm and a cave stream that drained a pasture where beef cattle congregate for shade and water were both high in nitrates, with the dairy farm contributing about 60 to 70 percent of the nitrogen load increase (Boyer and Pasquarell 1996, p. 565). Distribution of nitrogen in soils was found to be related to the frequency of animal presence; since karst pastures funnel water to cave streams via sinkholes, management strategies that change livestock grazing behavior in sinkholes and reduce opportunity for water and contaminants to reach sinkhole drains could help control the amount of nitrogen leaching from karst pastures (Boyer and Alloush 2001, p. 809).

Three parcels within Rye Cove have current permits for the application of biosolids (Virginia DEQa 2021, entire) (Figure 6). Biosolids, which are the solid organic matter recovered from a sewage treatment process, can be used as fertilizer or to augment nutrient deficiencies in soil. Permits typically follow a soil sample to authorize application only for the amount of deficiency; however, runoff from treated fields can lead to water rich in nitrogen, as it is soluble, as well as other nutrients and contaminants if soil particles make it to the sinkholes (Ciparis 2021, pers. comm). Nutrient rich water can encourage microbial growth that provides additional resources for non-subterranean animals, the invasion of these organisms from the surface, and thus competitors for food and other resources for troglobitic isopods (Lewis 2021b, pers. comm.; Graening and Brown 2003, pp. 1497–1498).

Additionally, hundreds of chemicals that are incompletely removed or not removed via the sewage treatment process before application could be present in biosolids (Banda 2021, pers. comm.; Kinney et al. 2006, p. 7207). These contaminants include pharmaceuticals, hormones, detergents, fragrances, plasticizers, bacteria, and pesticides and their metabolites. An analysis of 9 different biosolid products from 7 different states found a minimum of 30 and a maximum of 45 different contaminants (of 87 contaminants searched for) in any one biosolid product (Kinney et al. 2006, p. 7207; Ciparis 2021, pers. comm.). The specific chemicals present during any biosolid application, the timing and number of applications, and the effect of these chemicals on the Rye Cove cave isopod is unknown.

Contamination of the cave systems by pesticides, herbicides, or biosolid runoff is primarily due to excessive or improper application, poor timing of application, incorrect choice of chemicals, and improper cleanup and disposal practices (Ulrich 2002, p. 22). Additional information, such as water quality data, could help indicate areas of concern for the Rye Cove area, although no water quality data exists at this time. While these types of runoff are possible throughout Rye

Cove, there are no known high-density cattle, poultry, or pig operations in the area such as concentrated animal feeding operations (CAFOs) or dairy farms or silage storage locations that could create large amounts of pollutants at once (Jerrell 2021, pers. comm.). Grazing and agricultural activities exist in Rye Cove, but on a smaller scale, and the majority of Rye Cove is pasture and hay with a small portion in silage corn production; grazers are mainly beef cattle, with some small-scale sheep producers (Jerrell 2021, pers. comm.). In the broader area of Scott County, of the 654 cattle farms, only 8 are dairy farms; only 28 hog and pig farms exist in the county (USDA 2017, p. 248). Farms, farmland, and production animal numbers have been decreasing in Scott County (Jerrell 2021, pers. comm.).

There is one gas station in the Rye Cove drainage area with both underground and aboveground petroleum storage tanks (Virginia DEQ 2021b, entire). There has also been one reported leak or spill of petroleum products or other contaminants reported to the Virginia Department of Environmental Quality within the Rye Cove drainage area in 1994 within Natural Tunnel State Park (Virginia DEQ 2021c, entire); other leaks or spills may not have been reported.

The human population of Scott County has decreased over the past decade (US Census Bureau 2021, entire). The recent addition of a public water supply to this area may increase housing development in the area, potentially creating a rural/residential suburb to Kingsport, TN, the largest nearby metropolitan area; some Rye Cove residents already commute daily to and from Kingsport (Orndorff 2021a, pers. comm.). Most of Rye Cove is considered to have a moderate vulnerability to development, according to the Virginia Conservation Vision model (Virginia DCR 2015, entire). We analyzed the USGS Forecasting Scenarios of Land Use (FORE-SCE) model, which looks at predicted land use changes given two climate change scenarios. Under the high trajectory for climate impact predictions (consistent with the RCP 8.5 scenario), approximately 30 percent of Rye Cove is modeled as being converted from forests to agricultural uses by 2100 (Sohl et al. 2018, entire). The lower trajectory (consistent with the RCP 4.5 scenario) predicts less than 2 percent of the area will be converted by 2100. Looking at all of Scott County, the higher impact scenario predicts that 20 percent of the county will be converted from forest to developed areas and agriculture by 2100 (Sohl et al. 2018, entire).

### Climate Change:

Downscaled climate projections for Rye Cove predict an increase in temperatures over time but do not predict a decrease in precipitation, even under the higher emissions climate scenario (RCP 8.5) (Hegewisch et al. 2021, entire). Average summer temperatures are expected to increase from a historical average (1971 to 2000) roughly 4.5 to 6 °F by 2040 to 2069, depending on the lower emissions (RCP 4.5) or higher emissions (RCP 8.5) scenario, respectively. Average winter temperatures, likewise, increase 3.5 to 5.5 °F by 2040 to 2069. Annual precipitation is not projected to change as much but will likely increase 1.5 to 2 inches. Looking at the highest emissions scenario out to 2099, we see summers around 10 °F hotter, winters around 7 °F warmer, and anywhere from 1 to 3 additional inches of rainfall annually (Hegewisch et al. 2021, entire) (Table 4).

Table 2. Summer temperatures, winter temperatures, and precipitation for Rye Cove across historical years (1971-2000) and projected at two future timesteps (2040 to 2069 and 2070 to 2099) under two climate change scenarios, RCP 4.5 and RCP 8.5. Data from Hegewisch et al. (2021, entire).

| | **Summer Temp (°F)** | | **Winter Temp (°F)** | **Precipitation (inches)** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **Max** | **Mean** | **Summer** | **Winter** | **Annual** |
| Historical (1971-2000) | 73.2 | 84.6 | 37.2 | 12.8 | 12.1 | 48.5 - 50.3 |
| RCP 4.5 2040-2069 | 77.6 | 89.2 | 40.8 | 12.8 | 12.7 | 50.3 |
| RCP 8.5 2040-2069 | 79.3 | 91 | 41.8 | 13 | 12.8 | 50.8 |
| RCP 8.5 2070-2099 | 82.9 | 94.7 | 44.5 | 13.1 | 13 | 51.4 |

Average air temperatures in cave ecosystems correlate almost exactly with the average annual temperature of the region (outside the cave), as surface temperatures are conducted through the bedrock and external air penetrating the cave is buffered by humidity and eventually reaches equilibrium with the temperature of the rock (Mammola 2019, p. 101). Thus, changes in surface atmospheric temperature will result in changes to the temperature underground. Data indicate that climate change is already modifying microclimates underground; however, deeper caves will experience these impacts later than shallower caves (Mammola 2019, p. 102). While changes in the climate and precipitation patterns globally are certain, the magnitude and rate of change on a local scale is unknown.

Because cave species have evolved in stable, constant conditions (temperature and humidity), they are thought to be less tolerant of shifting climatic conditions and perhaps more prone to local extinction, as they are unable to shift their distributional range (Mammola 2019, p. 98). However, experts do not concur that the Rye Cove cave isopod is at risk of major climate impacts within the next 80 years (2100) (Service 2021, p. 3). While little is known about the ecology of the genus *Lirceus*, it is likely that the Rye Cove cave isopod has existed through climate variations, including both temperature and water quantity (drought conditions, flood conditions), given molecular evidence that points to a time frame of millions of years since the Rye Cove cave isopod diverged from its closest relative, the unnamed epigean species (Lewis 2021a, pers. comm.).

Troglobitic *Lirceus* tend to do well in cave systems that are prone to both floods and droughts, as are the cave systems in the range of the Rye Cove cave isopod. Some troglobitic isopods appear to have adaptations that allow them to outcompete freshwater asellids of the genus *Caecidotea*, including the ability to aestivate on dry surfaces within the stream during drought (observed for the Lee County Cave isopod) and the ability to remain attached to substrate during high flow conditions (Orndorff 2021b, pers. comm.). Based on their presence in these caves, we assume the Rye Cove cave isopod is able to withstand normal flood and drought events despite not knowing the mechanism by which it accomplishes this or specifically whether the Rye Cove cave isopod has either of these adaptations.

**Other factors:**
We do not consider natural predation a major threat to this species. No invasive or nonnative species and/or predators or diseases are known in these cave systems at this time, although these are potential threats given the porosity of the karst area. The epigean *Lirceus* species may pose some competition to the Rye Cove cave isopod, if its presence is a result of increased nutrients drawing it into the caves. However, there is no evidence that this is the case, and this is only speculative (Orndorff 2022, pers. comm.).

Conservation Measures
These caves do not benefit from any conservation actions or protections at this time. Because these caves occur exclusively on private lands, none of them currently receive significant visitation by cavers, and none are known to have a tradition of recreational use (Orndorff 2021b, pers. comm).

## CURRENT CONDITION

The following information is summarized from chapter 5 of the SSA Report (Service 2022, pp. 36-39); see the full chapters for additional details.

To assess current condition, we consider each occupied cave system within the range of the Rye Cove cave isopod as a separate population. These include two confirmed populations, Conduit 1 and Conduit 2, and one potential (but unlikely) population, Conduit 3. Within these populations, we will discuss individual caves as occupied locations not because each cave is a biologically relevant unit, but to give an assessment of the area within the cave system that might be occupied (or the population area/size). Caves where occupancy is possible but unconfirmed due to access constraints are considered potential locations. Thus, we define three extant locations (Cave E and Cave F in Conduit 1, and Cave H in Conduit 2), one potentially extirpated location (Cave G in Conduit 2), and one unknown and unlikely but potential location (Cave I in Conduit 3) (Table 3).

In the absence of other data, we consider population size to be a reasonable indicator of resiliency and therefore to assess current resiliency, we used the most recent survey data and expert input. The most comprehensive and recent surveys for the Rye Cove cave isopod were in 2004 to 2005 (Hobson and Orndorff, entire) and 2015 to 2016 (Orndorff and Malabad 2016, entire). In addition to recording presence data, the 2015–2016 surveys noted relative abundance within each cave and experts familiar with the caves contributed additional details on relative abundance (Orndorff and Malabad 2016, p. 2; USFWS 2021, entire). We assume that populations within caves with relatively more individuals noted are in better condition than populations within caves where fewer individuals are noted. Caves with no survey data due to access are considered unknown.

The current conditions of each survey location (each cave) along the two linear populations (Conduit 1 and Conduit 2) then help inform the current resiliency by using a combination of the known conditions present. We assessed resiliency comparatively between the two populations, and do not attempt to quantify population resiliency in absolute terms. Because we do not know the current stressors on these systems (water quality data) or the status of each population (stable, increasing, decreasing over time), we can only compare apparent abundances of individuals present within each cave.

Censusing of cave invertebrates has indicated that snapshots in time of numbers of individuals present is helpful but that in many cases the number of individuals present can fluctuate greatly depending on stream and habitat conditions at that time (Orndorff and Hanlon 2014, pp. 9–11). Because these caves have been formally surveyed only once and entered only a few times, we include expert input regarding population condition. Still, these metrics are far from ideal. Better information using randomized censusing and noting size-class data would provide better information regarding the health and trajectory of these populations (Lewis 2021a, pers. comm.).

Results:

The Rye Cove cave isopod exists in two populations with unknown current resiliency and inherently low redundancy and representation. Surveys in 2016 noted “many” Rye Cove cave isopod individuals in Cave E and Cave F (Conduit 1) and in Cave H (Conduit 2). While “few” were noted in Cave D (Conduit 1), these were later presumed to be misidentified (Lewis 2021c, entire). While no Rye Cove cave isopods were detected in Cave G (Conduit 2), the species was noted as present in 2004 and 2005; however, as noted previously, these individuals were not verified and may have been misidentified (Orndorff 2021a, pers. comm.). Although relative abundances did not differ among the three caves where the Rye Cove cave isopod was detected in 2016, experts agree from personal experience in the caves that Cave E (Conduit 1) is the only place where the species is abundant. They define “abundant” qualitatively in this case as approximately 10 to 15 individuals per square foot (USFWS 2021, entire).

Population Resiliency

The distribution of this species was found to be mostly unchanged since 2004 and 2005 surveys; however, Rye Cove cave isopods were located in Cave G in 2004 and 2005 (although these records were not taxonomically verified) but were not detected in 2016 (Hobson and Orndorff 2005, entire; Orndorff and Malabad 2016, p. 5). The Cave G portion of the population is considered to be potentially extirpated, although expert opinion posits that this cave may have never actually been inhabited (Orndorff 2021a, pers. comm).

Based on presence and relative abundance data from these surveys and expert experience, we expect that the population in Conduit 1 likely has higher resiliency than the population in Conduit 2. This is because Conduit 1 has two caves with a relative abundance of ‘many’ and a higher condition than Conduit 2 which has only one cave with a relative abundance of ‘many’ and a lower condition (Table 3). We did not assess resiliency for the potential population in Conduit 3, which is unlikely to be inhabited (Table 3).

Table 3. Estimated population resiliency of the two populations of Rye Cove cave isopod (Conduit 1 and Conduit 2) based on observed relative abundance in accessed caves along each system and assumed condition in these caves. Conduit 3 was not assessed for resiliency.

| Population, Conduit | Cave | Relative Abundance | Condition | Resiliency |
|---|---|---|---|---|
| 1 | E | many** | Higher | higher |
|  | F | many | Lower |  |
| 2 | H | many | Lower | lower |
|  | G | none* | extirpated? |  |
| 3 | I | unknown | likely not inhabited | NA |

* Found in 2004/2005, although these records are unverified.

** Expert opinion notes that Cave E has higher relative abundance than any other cave.

Species Representation

Given the small range of this local endemic species, we assume that its representation is inherently low. The species is unlikely to have adaptive capacity to shift its microhabitat use or thermal tolerance over time, and given its limited range in a linear environment, it is also unlikely that it would be able to disperse into new areas with different microhabitats. While we have no evidence of representative units for this species, its potential extirpation from Cave G and potentially other cave streams or systems may mean that some genetic diversity has been lost over the past decade or more.

Species Redundancy

Because the Rye Cove cave isopod is a narrow ranging endemic, we assume that population redundancy has naturally always been low, with likely just two populations having ever existed. With low redundancy, a catastrophic event affecting the water quality or quantity (or both) in one of the two cave stream systems could extirpate half of the species populations. While the species may be at risk of being extirpated by one or more catastrophic impacts, experts indicate it is likely that unmapped tributaries that could serve as refugia for Rye Cove cave isopod are present, and that dye tracing suggests that the water from the two conduits meets underground prior to emerging from Mill Creek Springs, and therefore there is a significant chance the isopods from one branch could recolonize the other in the event of a catastrophic event. Additionally, intense future land uses (animal feeding operations, dairy farms, suburban neighborhoods) are possible but unlikely; trends and models do not predict major land use changes, the terrain and access in Rye Cove may hinder this sort of development, and the human population has declined from the last census. Potential catastrophic impacts are outlined further in the future Condition section below and in Chapter 6 of the SSA.

## FUTURE CONDITION

The following information is summarized from chapter 6 of the SSA Report (Service 2022, pp. 39-45); see the full chapters for additional details.

The major threats to the Rye Cove cave isopod in the future will continue to depend on how humans use the land within Rye Cove, as well as impacts resulting from climate change. While we are uncertain how climate change is likely to affect the Rye Cove cave isopod in the long term (beyond 2100), we do not expect major impacts from climate change in the near term (2040 to 2070; Table 4). However, the way that humans respond to climate change and if or how we choose to combat the progression of climate change has repercussions on how land use will progress in this region and whether land is developed further or converted from forests to agriculture (Sohl et al. 2018, entire).

As discussed, human land use has various potential impacts to water quality in the cave systems it flows into. In Rye Cove, municipal water is brought in, but it is not removed from the area after use through municipal disposal. Thus, all water in Rye Cove that is not up taken or does not evaporate eventually ends up in the cave systems with minimal filtration because of the nature of karst systems. Some of it is used in households and will be cleaned via a septic system before it enters the cave system. Although adequately installed and maintained septic systems and proper agriculture do not pose threats to water quality if used without error, improper maintenance or improper management can lead to contaminants ending up in groundwater. Given human use of the land, there is always an inherent risk of some level of contaminants leaching into caves. Oil leaks from vehicles and machinery, application of herbicides and pesticides or fertilizers to lawns and gardens, and stormwater can pick up traces of anything that ends up on the ground.

These potential contaminants of Rye Cove cave isopod habitat are all linked to land use; some amount of contaminants associated with land use practices are expected to occur on a normal basis; however, these same contaminants, if spilled, applied inappropriately, or if they exist in high concentrations, could have catastrophic impacts on an entire cave system. The Rye Cove cave isopod is likely currently being impacted from the accumulation of these various non-point source pollutants throughout Rye Cove. However, we do not know the impact of these contaminants on the species or if populations have declined or been extirpated from areas in response to current or past contaminant levels. Data do not exist regarding Rye Cove cave isopod population changes over time. It has been speculated that the species may have been extirpated from Cave A and Cave B in Conduit 1 due to the influence of Bishoptown (Orndorff and Malabad 2016, p. 8). It is also possible that the species has been extirpated from Cave G (Conduit 2) or from other unknown tributaries, or that current pollutant levels are responsible for fewer individuals being present in Cave H and Cave F (Table 1). While we can compare estimated resiliency between the two cave systems, we do not know the actual current resiliency of these populations or how much existing stressors are influencing them.

Additionally, regardless of how many individuals are present in these cave systems and how resilient these populations currently are, a catastrophic event could extirpate one or more entire populations. Because these cave systems are linear and it is unknown if there are any additional occupied tributaries, and because the known distribution of Rye Cove cave isopod is limited to these linear habitats, any upstream contaminant could impact the entire downstream area. Unless occupied tributaries exist where the species would be protected from the main flow, the potential remains for an entire population to be impacted from a major spill or incompatible land use; depending on the severity of this catastrophic event, extirpation of a population could result. Potential population extirpation is particularly meaningful to this species given that there are only two known populations, and it is unknown whether a connection exists for one population to "rescue" the other via dispersal to repopulate the extirpated cave stream. While the two parallel populations are likely connected underground near their reemergence at the springs, it is unknown whether the isopod could move from one conduit to the other or how likely this movement might be. Movement between conduits must be underground, as the isopod is not known to disperse across the surface.

While the current contaminant level is unknown, we can reasonably conclude that the future viability of the Rye Cove cave isopod depends on two things:

1) <u>Contaminant levels</u>: Whether typical or existing contaminant concentrations increase, decrease, or stay the same as current. As we do not have a measure of the current level of contaminants (which may be currently low or currently high), we assume that the level of contaminants is related to the human population and land uses in the drainage areas that input to Rye Cove's caves. Factors that we assume are positively related to contaminant increase include: human population size, area of residential developments, area of agricultural use, and land use intensity. For instance, if contaminants are a result of current agricultural practices and we expect these practices to increase in area on the landscape over time, then we would expect contaminants to increase as well.
2) <u>Catastrophic events</u>: Whether the risk of catastrophic contaminant events (spills, dumping, or other incompatible land use practices such as concentrated animal feeding operations) will increase, decrease, or stay the same over time. Currently, the possibility exists that a catastrophic event will occur on the landscape with the ability to eliminate one or more of the existing populations of the Rye Cove cave isopod. We assume that this risk will increase with increased number of or magnitude of risk factors. Risk factors that we assume increase the risk of catastrophic contaminant events include: increased human population size, increased area of residential developments, increased area of agricultural use, and more intense use of the land. Thus, if a threat exists from human developments (household contaminants enter the cave system), and we expect the human population to increase on the landscape, then we expect that the risk of a catastrophic impact will also increase.

While contaminant levels would affect the resiliency of a population, the second item (point source catastrophic contamination) could affect the future redundancy of the species.

The risk of a catastrophic event, even if the daily probability of such an event is very low, will increase as risk factors increase and as the timeframe over which the risk is considered increases. An event having a low probability in the short term can have a high probability of occurring in the longer term. Thus, our future scenario analysis incorporates the risk from both increasing contaminant levels and catastrophic contamination. Due to the species presumed short generation time based on the lifespan of similar isopods (Service 2022, p. 23), the potential immediate effects of changes in human land uses, and the risk of catastrophic events on the species, we project the future scenarios at two timesteps: 2040 (19 years out) and 2070 (49 years out).

Because we do not know where population resiliency is now, but we can link population resiliency to existing or typical contaminants, we model future resiliency as a projected magnitude of effect on resiliency, where more or more intense risk factors that increase the normal contaminants on the landscape are assumed to have a greater potential effect on resiliency. Additionally, because the Rye Cove cave isopod is at particular risk of catastrophic impacts due to its presumed linear habitat, limited dispersal capabilities, and sensitivity to contaminants, we also model future redundancy in terms of the potential for catastrophic impact on the species that could extirpate one or both populations. We assume this risk increases with more or more intense risk factors and over time, as outlined above. In the future scenarios, the risk factors (which are positively related to normal contaminant increase and positively related to the risk of a catastrophic event) are human population size, area of residential developments, area of agricultural use, and land use intensity.

Land use has not changed much in Rye Cove in the past (USGS 2001, entire; USGS 2019, entire), and according to available forecasts, it is not expected to change greatly in the future. Based on the FORE-SCE models, under a B1 climate scenario, less than 2 percent of the land area in both Rye Cove and Scott County is expected to be converted to or from developed areas, forests, and agriculture by both 2040 and 2070 (Table 4). Similarly, under the A2 climate scenario, less than 1.5 percent of the area is expected to change cover types by 2040; by 2070, however, just over 10 percent of land is converted from forest to agriculture in Rye Cove, and within Scott County, about 7 percent of the area converts from forests to development or agriculture (Table 4).

Table 4. Percent of the area projected to change from present (2021) within each of three land cover classes for both Rye Cove (area of interest) and all of Scott County in both 2040 and 2070, according to the FORE-SCE models that forecast according to both a lower impact (B1, based on RCP 4.5) and a higher impact (A2, based on RCP 8.5) climate scenario.

| | **2040** | | **2070** | |
|---|---|---|---|---|
| | **Rye Cove** | **Scott Co.** | **Rye Cove** | **Scott Co.** |
| B1 | | | | |
| Developed | -2.0 | 0.1 | -2.0 | -0.1 |
| Forest | 2.0 | 0.3 | 1.0 | 0.5 |
| Agriculture | 0.0 | -0.5 | 1.0 | -0.4 |
| A2 | | | | |
| Developed | -0.7 | 1.2 | 0.0 | 2.7 |
| Forest | 0.3 | -1.3 | -10.6 | -7.3 |
| Agriculture | 0.3 | 0.1 | 10.6 | 4.6 |

Thus, we defined two scenarios, a lower change in risk factors (low) and a higher change in risk factors (high) at the two timesteps, 2040 and 2070:

2040 low: no increase in risk factors by 2040
2040 high: a slight increase in risk factors by 2040
2070 low: a slight increase in risk factors by 2070
2070 high: a larger increase in risk factors by 2070

Due to the relationship between the level of risk factors and both population resiliency and population redundancy (catastrophic events that can remove one or more populations), we looked at both resiliency and the risk of catastrophic events, both at the timestep as well as over the time leading up to that timestep.

Based on the scenarios and relationships discussed above, the outcome of each scenario is shown in Table 8. Population resiliency is directly related to risk factors, so when risk factors increase, resiliency decreases. Thus, we expect the largest change to resiliency given the highest level of impacts, modeled as 2070 high. While no change in risk factors means that the daily risk of catastrophic event has not changed, the risk of one or more catastrophic events having occurred increases when we look 19 years out to the year 2040. This risk of a catastrophic event having happened would be higher by 2070, given more time, when stressors are likely to have increased, as well. Thus, we can expect that population resiliency has the potential to decrease in the future, for both populations, but even if population resiliency stays constant, the risk of a catastrophic event continues into the future, and the probability of such an event happening increases over time. A catastrophic event has the potential to extirpate an entire population, regardless of how resilient (or not) it is currently. However, experts indicate it is likely that unmapped tributaries that could serve as refugia for Rye Cove cave isopod are present, and that dye tracing suggests that the water from the two conduits meets underground prior to emerging from Mill Creek Springs, and therefore there is a significant chance the isopods from one branch could recolonize the other in the event of a catastrophic event.

Table 5. Outcomes of each scenario at 2040 and 2070, where a horizontal arrow (→) indicates no change, one arrow indicates a slight upward (↑) or downward (↓) change, two arrows indicate a greater upward (↑↑) or downward (↓↓) change, and three arrows (↑↑↑) represent the largest upward change.

| **Scenario** | **Risk factors** | **Stressors on populations** | **Population resiliency** | **Risk of catastrophic event** | **Risk of catastrophic event having occurred** |
|---|---|---|---|---|---|
| 2040 low | no change | → | → | → | ↑ |
| 2040 high | little increase | ↑ | ↓ | ↑ | ↑↑ |
| 2070 low | little increase | ↑ | ↓ | ↑ | ↑↑ |
| 2070 high | larger increase | ↑↑ | ↓↓ | ↑↑ | ↑↑↑ |

While we currently know of two populations, the Conduit 1 population with relatively higher current resiliency, and the Conduit 2 population with relatively lower current resiliency, Conduit 3 was identified as potentially having habitat, but the cave has not been surveyed for Rye Cove cave isopod. Thus, experts believe a third population is possible but unlikely.

As discussed above, the potential for a catastrophic event to extirpate one or both populations of the Rye Cove cave isopod is always present, and this potential will increase if additional land is converted to residential areas, if more land is converted to agricultural uses, if the human population increases, if land is used more intensely, and as the timeframe considered increases. Some land uses are considered incompatible and would increase this risk even more, such as CAFOs, dairy operations or other high-density animal operations. We expect that, under all scenarios, redundancy will decline in the future. While there is no evidence of different representative units or “types” of this species, the loss of one population is likely to decrease the genetic diversity of this species, and thus representation is likely to decline with declines in redundancy.

In summary, the effects of land use and management have likely begun to occur in the current Rye Cove cave isopod range and may have contributed to some habitat degradation. However, these threats appear to have low imminence and magnitude such that they are not affecting the species’ ability to maintain populations within its range. The Rye Cove cave isopod has the best viability into the future with zero to low land use changes, but there is always risk of a catastrophic event. Intense future land uses (animal feeding operations, dairy farms, suburban neighborhoods) in Rye Cove are possible but unlikely; trends and models do not predict major land use changes, the terrain and access in Rye Cove may hinder this sort of development, and the human population has declined from the last census. While the risk of a catastrophic event occurring increases with an increase in the risk factors, all of these risk factors are projected to remain low or decrease based on the geographic location, census, and modeling of human population growth and development in Rye Cove. And, while the Rye Cove cave isopod is at particular risk of catastrophic impacts due to its linear habitat, limited dispersal capabilities, and assumed sensitivity to contaminants, the cave streams likely also contain unmapped blind tributaries and refugia, as well as stream habitat connectivity to provide protection and re-population opportunities if a catastrophic event occurred.

## FINDING

### Regulatory Framework

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

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

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

The Act does not define the term "foreseeable future, which appears in the statutory definition of "threatened species." The regulatory language that is applicable to determinations of the foreseeable future is contained in the regulations at 50 C.F.R. 424.11(d) promulgated in 2019 (In re: Washington Cattlemen's Ass'n, No. 22-70194 (9th Cir. Sept. 21, 2022) (staying the district court's vacatur of the 2019 regulations pending resolution of the motion for reconsideration) (Washington Cattlemen's)). However, those regulations remain the subject of ongoing litigation, and their continued applicability is therefore uncertain. If the litigation results in vacatur of the 2019 regulations, the regulations that were in effect before those 2019 regulations (the pre-2019 regulations) would again become the governing law for listing decisions. Because of the uncertainty surrounding the legal status of the regulations, we undertook two analyses of the foreseeable future: one under the 2019 regulations and one under the pre-2019 regulations, which may be reviewed in the 2018 edition of the Code of Federal Regulations at 50 CFR 424.11(d). Those pre-2019 regulations did not include provisions clarifying the meaning of "foreseeable future," so we applied a 2009 Department of the Interior Solicitor's opinion (M-37021, "The Meaning of 'Foreseeable Future' in Section 3(2) of the Endangered Species Act" (Jan. 16, 2009) (M-37021).

The analyses under both the 2019 regulations and the pre-2019 regulations are included in the decision file for this decision and posted on https://www.regulations.gov. Based on those analyses, we concluded that our determination of the foreseeable future would be the same under the pre-2019 regulations as under the 2019 regulations.

### 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 Rye Cove cave isopod to determine if it meets the definition of an endangered species. The Rye Cove cave isopod inherently has low redundancy and representation due to its being a narrow ranging endemic. The species exists with unknown current resiliency, but the survey data indicate that the species resiliency has remained unchanged over the years. The effects of land use and management have likely begun to occur in the current Rye Cove cave isopod range and may have contributed to some habitat degradation. However, these threats appear to have low imminence and magnitude such that they are not affecting the species' ability to maintain populations within its range and the risk of extinction is currently low. Thus, after assessing the best available information, we conclude that the Rye Cove cave isopod is not in danger of extinction throughout all of its range and does not meet the definition of an endangered species.

Therefore, we proceed with determining whether Rye Cove cave isopod 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 Rue Cove isopod, 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 limited quantity and quality of available data about effects to Rye Cove cave isopod and its response to those effects. The Rye Cove cave isopod is subject to threats from the effects of climate change, the aggregation of pollutants, sediments, and nutrients that occur on the landscape over time that enter into the cave system as runoff, as well as more acute catastrophic events or incompatible land use practices that may occur. While we are uncertain how climate change is likely to affect the Rye Cove cave isopod in the long term (beyond 2100), we do not expect major impacts from climate change in the near term (2040 to 2070; Table 2). However, the way that humans respond to climate change and if or how we choose to combat the progression of climate change has repercussions on how land use will progress in this region and whether land is developed further or converted from forests to agriculture (Sohl et al. 2018, entire). The primary threats affecting the Rye Cove cave isopod are land use and management and risk of catastrophic events. These factors were included in our assessment of the future condition of the Rye Cove cave isopod.

The results of the future scenario analysis describe a range of possible future conditions for the Rye Cove cave isopod. The SSA's analysis of future scenarios incorporates the risk from both increasing contaminant levels and catastrophic contamination. Due to the species assumed short generation time, the potential immediate effects of changes in human land uses, and the risk of catastrophic events on the species, we project the future scenarios at two timesteps: 2040 (19 years out) and 2070 (49 years out). Risk factors that we assume are positively related to contaminant increase and also increase the risk of catastrophic contaminant events include: increased human population size, increased area of residential developments, increased area of agricultural use, and more intense use of the land. When resiliency is very low, populations become more vulnerable to extirpation, in turn, resulting in concurrent losses in representation and redundancy. The Rye Cove cave isopod has the best viability into the future with zero to low land use changes, but there is always risk of a catastrophic event. Intense future land uses (animal feeding operations, dairy farms, suburban neighborhoods) in Rye Cove are possible but unlikely; trends and models do not predict major land use changes, the terrain and access in Rye Cove may hinder this sort of development, and the human population has declined from the last census. While the risk of a catastrophic event occurring increases with an increase in the risk factors, all of these risk factors are projected to remain low or decrease based on the geographic location, census, and modeling of human population growth and development in Rye Cove. And, while the Rye Cove cave isopod is at particular risk of catastrophic impacts due to its linear habitat, limited dispersal capabilities, and assumed sensitivity to contaminants, experts indicate that it is likely that the cave streams contain unmapped blind tributaries and refugia, as well as stream habitat connectivity to provide protection and re-population opportunities if a catastrophic event occurred. After assessing the best available information, we conclude that Rye Cove cave isopod 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 Rye Cove cave isopod is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we evaluated the range of the Rye Cove cave isopod 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 Rye Cove cave isopod is a narrow endemic that occurs within a very small area with only two known extant populations, one in each of two parallel cave systems that drain a relatively small surface area. Thus, the threats that the species faces affect the species comparably throughout its entire range. This means that no portions of the species' range have a different biological status from its rangewide biological status. Therefore, we conclude that there are no portions of the species' range that warrant further consideration, and the species is not in danger of extinction 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. *U.S. Department of the Interior*, 321 F. Supp. 3d 1011, 1070-74 (N.D. Cal. 2018), and *Center for Biological Diversity v. Jewell*, 248 F. Supp. 3d. 946, 959 (D. Ariz. 2017) because, in reaching this conclusion, we did not apply the aspects of the Final Policy on Interpretation of the Phrase "Significant Portion of Its Range" in the Endangered Species Act's Definitions of "Endangered Species" and "Threatened Species" (79 FR 37578; July 1, 2014), including the definition of "significant" that those court decisions held to be invalid.

### *Determination of Status*

Our review of the best available scientific and commercial information indicates that the Rye Cove cave isopod 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 Rye Cove cave isopod is not warranted at this time.

## COORDINATION WITH STATES

While conducting our SSA for the Rye Cove cave isopod, we coordinated and received information from the State within the species' current range of Virginia. A draft of the SSA Report was provided to the State within the species' range, and we received comments from the State of Virginia.

Actions that may benefit the Rye Cove cave isopod by decreasing the probability of impacts to one or both populations include:

- Public education and outreach about how to protect karst areas.
- Initiate voluntary conservation projects with private landowners.
- Assess the need and feasibility of developing a karst contaminant spill response plan for Rye Cove.

- Frequent inspections of septic systems and pump-outs with repair of failing systems.
- Construction of a sanitary sewer system for the area.
- Assessing of the effects of biosolid application to the groundwater system.
- Managing livestock to minimize impacts to surface water and groundwater.
- Limiting the application of potential contaminants like pesticides and herbicides, especially near sinkholes.
- Perform water quality monitoring for parameters specific to land use (nitrogen, dissolved oxygen, ammonia, etc.) to identify acute or chronic issues in the groundwater system.
- Develop sampling methods and systematic monitoring to better understand Rye Cove cave isopod population demographics. Future genetic analysis could focus on assessing genetic diversity within and among the populations of Rye Cove cave isopods and may indicate if the two known populations are connected.

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

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**Martha Williams,**
*Director,*
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