United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 Westgate Center Drive
Hadley, MA 01035-9589

In Reply Refer To:
FWS/Region5/ES-TE

Memorandum

To: Assistant Regional Director, Ecological Services

From: Coordinator, Endangered Species

Subject: Lee County Cave Isopod 5-Year Review

Attached for your concurrence and signature is the subject review. The review was prepared by the Southwestern Virginia Field Office in coordination with the Virginia Field Office. Our regional office endangered species program has reviewed this document and concurs with its status assessment and recommendation to reclassify this species from Endangered to Threatened.

If you have any questions or need further assistance, please feel free to contact Mary Parkin, at 617-417-3331, or Martin Miller at 413-253-8615.

Attachment

Lee County Cave Isopod
(Lirceus usdagalun)

5-Year Review:
2013 Summary and Evaluation

U.S. Fish and Wildlife Service
Southwestern Virginia Field Office
Abingdon, VA

March 2014

5-YEAR REVIEW
Lee County cave isopod (*Lirceus usdagalun*)

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5-YEAR REVIEW
Lee County cave isopod (*Lirceus usdagalun*)

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Field Office: Shane Hanlon, Southwestern Virginia Field Office, (276) 623-1233, ext. 25, shane_hanlon@fws.gov
Lead Region: Mary Parkin, Northeast Region, (617) 876-6173, mary_parkin@fws.gov
Technical Reviewer: Wil Orndorff, Virginia Department of Conservation and Recreation, Division of Natural Heritage, (540) 831-4056, wil.orndorff@dcr.virginia.gov

1.2 Methodology used to complete the review: This 5-year review was conducted primarily by the lead recovery biologist for the Lee County cave isopod (LCCI), with significant review by the Karst Protection Coordinator for the Virginia Department of Conservation and Recreation, Division of Natural Heritage (DNH). State natural resource agency personnel responsible for the recovery of this species and individuals who have conducted studies and research on this species were contacted for up-to-date information on occurrences, threats, and recovery activities. This review summarizes and evaluates new information relevant to the listing status of the species. All pertinent literature and documents on file at the U.S. Fish and Wildlife Service (Service) Southwestern Virginia Field Office were used for this review.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review: 77 FR 13251-13253, March 6, 2012

1.3.2 Listing history:
FR notice: 57 FR 54722-54726, November 20, 1992
Date listed: December 21, 1992
Entity listed: Species
Classification: Endangered

1.3.3 Associated rulemakings: None

1.3.4 Review History:
Previous 5-Year Review
Initiated: 72 FR 4018-4019, January 29, 2007
Date Finalized: September 4, 2008
Results: No change in status

1.3.5 Species Recovery Priority Number at start of 5-year review: 8

1.3.6 Recovery Plan or Outline:
Name of plan: Lee County Cave Isopod (*Lirceus usdagalun*) Recovery Plan
Date issued: September 30, 1997

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy: The LCCI is an invertebrate; therefore, it is not covered by the DPS policy.

2.2 Recovery Criteria

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

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? No.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

Delisting may be considered when the following criteria are met:

<u>A. Inventory work leads to a thorough delineation of the present and historic distribution for this species.</u>

This criterion has been met.

The LCCI is endemic to extreme southwestern Virginia in the Powell River Valley of the central Lee County karst region, part of which is known locally as the Cedars (Holsinger 1985). Known occurrences of the LCCI are restricted to shallow riffles and rock dam faces in vadose streams (subterranean streams that flow above the phreatic zone or water table) that flow through caves beneath the surface outcrop area of the Hurricane Bridge limestone, which is exposed in the core of the Cedars Syncline. Host caves are developed in the Hurricane Bridge and Martins Creek limestones, both of middle-Ordovician age.

In considering surface and subsurface areas that lie within or drain to the current and historical range of the LCCI, Hanlon and Orndorff (2013) delineated allogenic and autogenic zones, which are defined by their level of hydrological influence on LCCI habitat. The autogenic zone is defined as the topographical area that overlies LCCI habitat and potential habitat. This corresponds to the surface outcrop area of the Hurricane Bridge limestone in the Cedars Syncline structure. Within the autogenic zone, hydrology is predominantly sub-surface and there is little to no perennial surface flow. Instead, intermittent overflow channels are briefly active following heavy precipitation events, when runoff exceeds the capacity of the subsurface drainage network. The allogenic zones, by contrast, do not contain LCCI habitat but instead drain to the LCCI habitat. Generally defined by topographic watershed boundary, allogenic zones contain both perennial and intermittent surface streams that either sink or lose portions of their flow into vadose streams that flow beneath the Cedars intersecting LCCI habitat. Unlike autogenic zones, allogenic zones do not harbor LCCI populations; nonetheless, these zones may be important to LCCI conservation.

The rangewide population of the LCCI occurs entirely within autogenic zones and includes eight known site occurrences: (1) Thompson Cedar Cave; (2) Masons Cave; (3) a spring along Sims Creek; (4) two springs located near Flanary Bridge, which will be referred to as Flanary Bridge Springs; (5) Golf Course Cave No. 3; (6) Gallohan Cave No. 1; (7) Gallohan Cave No. 2; and (8) Surgener Cave. The spatial distribution of the LCCI population is geographically separated by Hardy Creek, dividing the rangewide population into the Cedars population (eastern half), and Surgener-Gallohan cave system population (western half). This separation is further supported by Fong (2009), who identified two corresponding genetic clades of the LCCI. Geologically, all sites fall within the Cedars syncline structure. Numerous other cave streams have been investigated on the periphery of the Cedars syncline and throughout Lee County, but with negative results on presence of the LCCI (Orndorff and Hanlon 2010, 2011). Based on this information, along with substantial data on the subterranean stream flows and the unique geological conditions of the area of known habitat, we are confident that the LCCI is endemic to the autogenic zone, as delineated by Hanlon and Orndorff (2013). There are no biological or geological data to suggest that the species is likely to occur outside of the currently known range.

<u>B. The surface and subterranean hydrology within the known range of the isopod are understood sufficiently to monitor and manage the species</u>.

This criterion has been met.

As mentioned previously, LCCI habitat is confined to caves in streams underlying the outcrop area of the Hurricane Bridge limestone along the west-southwest plunging Cedars syncline. Dissolution of limestone bedrock over geologic time has resulted in a landscape characterized by sinkholes, blind valleys, sinking streams, springs, and caverns, resulting in a close connection between surface and subsurface aquatic habitat. In contrast to nonkarst regions, where rainwater filters very slowly through soil and bedrock before reaching groundwater, the sinkholes, fissures, and crevices that are characteristic of karst regions offer accelerated routes for surface water to enter groundwater systems, with minimal filtering by soils (Smith 1991). Consequently, seemingly benign activities can pose a serious threat to the quality of both ground and surface waters.

A number of dye- tracing investigations have been conducted to better understand the subsurface hydrology throughout the known range of the LCCI (Jones 1990, Culver et al. 1992, Ewers et al. 1995, Neely 1996). These tests indicate that groundwater in the Cedars generally moves southwest along geologic strike and south along fracture zones through four major spring systems (Baṭie Springs, Flanary Springs, Sims Spring, and the Surgener-Gallohan Cave resurgence). The DNH has developed a subterranean flow model based on dye-tracing investigations and water quality parameters.

Based on these flow models in combination with topographic and geomorphic data, Hanlon and Orndorff (2013) describe the hydrological dynamics of the surface and subterranean landscape that provides LCCI habitat. They delineated seven conservation zones covering 8,564 hectares that potentially influence LCCI habitat. The Surgener-Gallohan Cave and Cedars autogenic zones encompass 1,420 hectares and comprise the geographic extent of habitat for the LCCI. These two areas are geographically separated from each other by Hardy Creek and correspond to two separate genetic clades of the LCCI (Fong 2009).

Dye tracing and hydrogeologic modeling suggest the Cedars, which support the eastern population of the LCCI, is highly interconnected. The complex subterranean voids with constricted outflow act as reservoirs during precipitation events, impounding water and slowing water releases to the Powell River. The subterranean hydrology of the Cedars is at least superficially divided into three subterranean drainages that terminate as springs that feed the Powell River: Batie West Spring, Flanary Bridge Spring, and Sims Spring. Batie West Spring captures subterranean water flows associated with the Thompson Cedar Cave and Masons Cave populations. The Flanary Bridge Spring captures subterranean water flows associated with the Golf Course Cave No. 3 population. There are currently no known accessible stream caves that represent the Sims Spring population.

The western population of the LCCI resides within the Surgener-Gallohan Cave subterranean system and is influenced by a perennial spring-fed stream that sinks into Surgener Cave at the Southern terminus of a topographically discrete ravine known locally as Long Hollow. Several autogenic cave streams are tributaries to Long Hollow and flow together to form the Surgener Cave stream, which exits the mouth of the cave at the flood plain of the Powell River. The Gallohan Cave No.1 stream is the most notable tributary to this system as it hosts the type locality of the LCCI.

C. Populations of the Lee County cave isopod, in at least four subterranean systems, are shown to be stable and persistent over a 10-year (minimal) monitoring period. For the three known extant populations, this monitoring period would begin when the following actions are completed: (1) baseline data correlating habitat conditions with population status are gathered for the Surgener-Gallohan Cave system, (2) sampling techniques are finalized for the two springs at Flanary Bridge and Sims Creek, and (3) a monitoring protocol is established that provides for consistency among populations and allows inferences, if necessary, about the isopod's population status in the springs based upon comparative analysis of habitat conditions among the various cave systems. For the fourth population, the 10-year (minimal) monitoring period would begin when criteria A and B are met and either a new population is found or habitat restoration/return of a Thompson Cedar Cave population is achieved.

This criterion has been partially met.

The LCCI has been documented in four discrete subterranean basins (and associated caves) that flow to four resurgence springs. For consistency with the recovery plan and other related documentation, we refer to these subterranean basins as:

1. Surgener-Gallohan Cave system – culminates at Surgener cave spring and includes Surgener Cave and Gallohan Caves No.1 and No.2
2. Thompson Cedar Cave system – culminates at Batie West Spring and includes Thompson Cedar and Mason caves
3. Sims Creek system – includes Little Sims Spring and Sims Spring
4. Flanary Bridge Springs system – includes Golf Course Cave No.3

Although 10 years of regular monitoring has not occurred for all monitoring sites, we believe populations of the LCCI have persisted and have been stable over a 10-year period in all but one of the four subterranean systems. Persistence of the population in the Sims Creek system has not been verified since initially reported in 1996.

The only specimens of the LCCI collected from the Sims Creek system were exoskeletal remains captured from a small lateral spring, hereinafter referred to a Little Sims Spring. Extensive population monitoring of the Little Sims Spring system is unrealistic since the likely recharge area for Little Sims Spring was rendered inaccessible following earth moving and paving during construction of the Lee County Municipal Airport (LCMA). However, limited water quality data gathered at Little Sims Spring, which flows intermittently, have not demonstrated degradation.

The species is almost certainly present in blind subterranean tributaries to the main underground stream that ultimately resurges at Sims Spring. Most of the resurging water at Sims Spring originates from water lost to the subterranean system from Dry Creek. Although water quality has been monitored at Sims Spring, the data merely demonstrate the dominance of surface water influence on Sims Spring and may not necessarily represent LCCI habitat within the system. Numerous dye traces from karst features (caves, sinkholes, sinking streams) to the east and northeast of Sims Spring verify the presence of these blind tributaries. The overlying topography (Cedars Karren) is contiguous with and virtually identical to that which overlies known populations of LCCI. Furthermore, some of the karst features trace not only to Sims Spring but Batie West Spring and Flanary Bridge Springs as well, demonstrating subterranean connectivity and ill-defined watershed boundaries. In addition to those subterranean sites where the LCCI is known to be present, it is also highly likely to be present throughout other shallow cave streams beneath the Cedars.

The following address the specific items listed in recovery criterion C as they apply to the Surgener-Gallohan Cave, Flanary Bridge Springs, and Little Sims Creek systems:

(1) Data gathering to characterize water quality in the Surgener-Gallohan Cave system was initiated in 2003. It has continued and has provided a baseline water quality data set (table 1) that can be used to characterize the natural variation in water quality over time as a measure of habitat condition. Key parameters including dissolved oxygen, pH, temperature, conductivity, and turbidity have been correlated with habitat condition.

The cave stream hydrology of the Surgener-Gallohan Cave system has also been monitored to characterize habitat condition.

(2) Sampling techniques have been finalized for the population associated with Flanary Bridge Springs, but have not been finalized for the population associated with Sims Creek. The LCCI has only been confirmed at Little Sims Spring, and not Sims Spring or Sims Creek. The existence of the LCCI in the Little Sims Spring system is based on exoskeletal remains, and no living animals have been documented from the system. No attempts have been made to confirm continued persistence of the LCCI in the Little Sims Spring system, which flows only intermittently. Since there are no known accessible caves within the Sims Spring system (now covered by the LCMA), any assumptions about the Little Sims Spring population rely on captured individuals at springs and water quality measurements as a measure of habitat condition. Key water quality parameters are regularly measured at Sims Spring and Little Sims Spring, which is located lateral to Sims Creek.

(3) Through a cooperative agreement between the Service and the DNH, a monitoring protocol has been established that provides for consistency among populations and allows inferences, if necessary, about the isopod's population status in the springs. Based upon comparative analysis of habitat conditions among the various cave systems, current available data are adequate to allow conclusions about the isopod's population status in the springs.

Table 1. Summary of monitoring effort implemented by the Service and DNH among the four subterranean systems inhabited by the LCCI. Monitoring Initiation = date each site was first monitored, Monitoring Duration = number of years site has been monitored (given date of January 30, 2014). Data Collected During Monitoring: W = water quality, P = LCCI population, H = hydrologic.

Subterranean System	**Monitoring Site**	**Monitoring Initiation**	**Monitoring Duration (years)**	**Data Collected During Monitoring**		
				W	**P**	**H**
Thompson Cedar Cave System	Flanary Swallet	Sep-2003	10.4	X		
	Batie East Spring	Feb-2002	12	X		
	Batie West Spring	Feb-2002	12	X		
	Masons Cave	Sep-2003	10.4	X	X	X
	Thompson Cedar Cave	Feb-2002	12	X	X	X
	Warner Window	Sep-2010	3.4	X		
Surgener-Gallohan Cave System	Surgener Cave	Nov-2003	10.3	X	X	X
	Gallohan Cave	Mar-2007	6.9	X	X	X
Flanary Bridge Springs System	Flanary Bridge Springs	Feb-2008	6.0	X		
	Golf Course Cave No. 3	May-2011	2.8	X	X	
Sims Creek System	Little Sims Spring	Feb-2010	4	X		
	Sims Spring	Feb-2002	12	X		

Habitat in Thompson Cedar Cave has greatly improved since November 1992 when the LCCI was listed as endangered. The LCCI was "rediscovered" in Thompson Cedar Cave in February 2002, and the population appears to be recovering. However, several uncertainties exist regarding water quality and full recovery of the LCCI in Thompson

Cedar Cave. A sawmill operation lies directly adjacent to Thompson Cedar Cave. Leachate derived from disposal of sawdust waste was the primary stressor to the species and a principle reason the species was listed. Most of the impacts resulting from sawdust waste have been remediated. However, water quality data show some residual impacts remain. Although it appears that the remaining sawdust piles have decomposed past their peak of producing leachate, a low level of leachate continues to enter the cave stream. During low flows, tannins and lignins have been measured as high as 0.9 milligrams/liter (mg/L) above the normal background level of 0.1 mg/L in the Thomson Cedar Cave stream. Chronic persistence of tannin is visually evident by yellow-orange stains on LCCI exoskeletons and monitoring equipment left submerged in the cave stream. The presence of higher tannin and lignin levels in the stream cause a higher biological oxygen demand; dissolved oxygen levels have been recorded as low as 3.5 mg/L within the Thompson Cedar Cave stream. Slightly lower pH readings were recorded concurrently with lower dissolved oxygen readings. Low dissolved oxygen readings expectedly occur during periods of drought and extremely low stream flow conditions when concentrations of tannin and lignin are higher within the water column. Although the LCCI has reestablished itself in the cave stream, the numbers of individuals do not appear to have recovered to levels that have been described prior to the establishment of the sawmill operation (Estes 1978). Despite this, the existing population has continued to be stable, persistent and in a state of recovery for over 10 years.

Criterion C states, "For the fourth population, the 10-year (minimal) monitoring period would begin when criteria A and B are met and either a new population is found or habitat restoration/return of a Thompson Cedar Cave population is achieved." Although the Thompson Cedar Cave population has now been monitored and documented as recovering since 2002, which is more than 10 years, it has not been monitored for a full 10 years subsequent to meeting criteria A and B. Although it is logical that criteria A and B precede 10 years of monitoring, monitoring data exist that meet the intent of criteria C. Therefore, we believe the intent of the condition has been fully met.

D. A groundwater monitoring program is established in systems known to contain the Lee County cave isopod, with 10-year results demonstrating that groundwater quality and quantity are sufficient to ensure the survival of this species. For each system, groundwater monitoring would be conducted concurrently with the population monitoring period.

This criterion has been partially met.

A groundwater monitoring program has been established in systems known to contain the LCCI. Ten years of data demonstrating that groundwater quality and quantity are sufficient to ensure the survival of this species has been acquired for all but the Flanary Bridge Springs system. The limited data collected from the Flanary Bridge Springs system indicate that sufficient groundwater quality and quantity exist to ensure survival of its LCCI population.

Groundwater monitoring was initiated in February 2002 at selected sites among three systems known to contain the LCCI (table 1). The monitoring program has expanded to include sites representing all four subterranean systems. Monitoring of the Flanary Bridge Springs commenced in February 2008. Water quality data have been collected concurrently with population monitoring at Thompson Cedar Cave, Masons Cave, Surgener Cave, Gallohan Cave, and recently Golf Course Cave No. 3. Water quality monitoring has been conducted at Sims Spring since 2002; however, the population has not been monitored because of inaccessibility to the habitat.

E. Measures have been secured for the permanent protection from significant groundwater contamination of all four cave systems for the Lee County cave isopod (see criterion C).

This criterion has been partially met.

Permanent protection of groundwater for any of the populations may by unrealistic; however, significant accomplishments have been made in protecting in perpetuity the karst landscape of the Cedars. Key lands have been acquired by The Nature Conservancy (TNC) and DNH to protect the LCCI, particularly in the Surgener-Gallohan Cave and Thompson Cedar Cave systems. This ensures permanent protection of the immediate landscape surrounding the populations, and eliminates or reduces threats from activities such as development, logging, and livestock operations and other agricultural practices. However, this does not preclude impacts to groundwater that originate outside of these acquired lands. Of the four subterranean systems, the Surgener-Gallohan Cave system has the most potential for protection and is near a level of protection that would ensure long-term persistence of the LCCI. The Thompson Cedar Cave system also has significant potential for protection, with prospects for full abatement of impacts from the sawmill operation. Efforts to acquire additional land in the watershed of Golf Course Cave No.3 (Flanary Bridge Springs System) are underway.

Reclassification to threatened may be considered when A and B above are completed, when the monitoring programs in C and D have been underway for all four cave systems for at least 5 years with positive results, and when E is accomplished for at least two sites.

Criteria A and B - completed, as previously described.

Criteria C and D - Populations of the LCCI are stable and have persisted over a 5-year monitoring period in three of the four spring basins. Persistence of the population in the Sims Creek system has not been recently verified with collected specimens, although water quality values have not indicated any deleterious effects to Little Sims Spring or Sims Spring. Any meaningful population monitoring of the Sims Creek system may be unrealistic given the inability to access the subterranean system. However, there are likely additional extant populations within blind subterranean infeeders to the major Sims Creek drainage. Verification of one or more of these populations is necessary to meet criterion C.

Criterion E - A groundwater monitoring program has been established in systems known to contain the LCCI. Data collected over 5 years demonstrate groundwater quality and quantity are sufficient to ensure the survival of this species in all four identified subterranean systems, as previously described.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species biology and life history: No new substantive information regarding the species biology or life history has been published in peer-reviewed journals since the last status review for the LCCI (Service 2008).

The LCCI inhabits fast flowing water and prefers velocity to depth ratios above 0.67. This microhabitat fidelity of the LCCI appears to be very strong. Hanlon (2007) observed that during drought conditions when there is little to no flow in cave streams, LCCI, tended to avoid pooled water and congregated on the damp surface of substrates that would otherwise be submerged under high velocity flows. Specimens appear to be in a dormant state under these conditions, presumably waiting for normal base flow conditions to return. This behavior probably serves three adaptive purposes: (1) reduce metabolic processes when resources are unavailable or unattainable, (2) increase efficiencies in the acquisition of oxygen when dissolved oxygen in stagnant pooled water is generally low, and (3) avoid predation by other cave fauna, particularly by spring salamanders (*Gyrinophilus porphyriticus*), which are common in LCCI cave streams and will be concentrated in pooled areas during drought conditions.

Little is known about natural predators of the LCCI. In August 2013, Hanlon (Service, pers. obs. 2013) observed an Appalachian Valley cave amphipod (*Crangonyx antennatus*) pursue, capture, and consume a LCCI. Previous to this observation, *C. antennatus* was considered only a possible competitor.

2.3.1.2 Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends: Within the extant range of the LCCI, cave entrances provide access to sections of underground streams, where LCCI habitat and populations can be directly observed. However, it is unclear what suitable underground stream habitat exists, beyond that which is accessible for monitoring. Given the extent of surface karst, the limited extent of accessible underground streams, and the results of dye- tracing investigations, it is likely that the size of the LCCI population cannot be predicted with high accuracy at the landscape level. Estimates of LCCI population estimates at specific sites may be more reliably predicted.

Thompson Cedar Cave system - The subterranean stream within the Thomson Cedar Cave system has two known cave entrances that provide access to the LCCI population, Thompson Cedar Cave and Masons Cave. Specimens of the LCCI from these two caves are considered of the same population.

Estes (1978) reported the average density of the LCCI in the section of Thompson Cedar Cave immediately downstream of the cave entrance to be $109/m^2$. Furthermore, densities in shallow riffles that the isopod prefers averaged over $200/m^2$. Based on available habitat where the LCCI predominated, total population was estimated at 100,000 animals. The LCCI is rare to not present in the section of the cave stream just below the Thompson Cedar Cave entrance (Hanlon, Service, pers. obs. 2013). The population has reestablished farther downstream where dissolved oxygen levels are higher and more stable. Population monitoring from a designated monitoring station in Thompson Cedar Cave shows variable densities ranging from 81 to 556 individuals/m^2 over multiple sampling occasions (table 2). Within the observable habitat in Thompson Cedar Cave, there are an estimated 1,296 to 8,896 individuals, based on recent population monitoring data (Orndorff and Hanlon 2011, 2012, 2013). The population is well represented by a variety of size classes, clearly indicating successful recruitment.

To date, no density or population estimates have been made for Masons Cave; however, the population is robust and of relatively high density with a full range of size classes. To calculate a gross estimate of population size for Masons Cave, Thompson Cedar Cave density data were used. Accordingly, an estimated 2,268 to 15,568 individuals persist within observable habitat of Masons Cave. Together, the Thompson Cedar Cave and Masons Cave populations total an estimated 3,564 to 24,464 individuals inhabiting observable habitat.

Table 2. Density and population estimates of LCCI within observable habitat. Density estimates are based on Orndorff and Hanlon (2011, 2012, 2013).

	Range of Population Density (individuals/m^2)		Area of Monitored	Population Estimate for Monitored Habitat	
Monitoring Site	**Low**	**High**	**Habitat (m^2)**	**Low**	**High**
Thompson Cedar Cave	81	556	16	1,296	8,896
Masons Cave*	81	556	28	2,268	15,568
Surgener Cave	90	1,180	72	6,480	84,960
Gallohan No. 1	150	700	30.5	4,575	21,350
Golf Course No. 3*	81	556	3	243	1,668
Gallohan No. 2	NA	NA	NA	NA	NA
Total			149.5	14,862	132,442

* = density data are not available; a density estimate from Thompson Cedar Cave was assumed.

Flanary Bridge Springs system - John Holsinger commonly found the LCCI in the gravel substrate of the spring channels at the Flanary Bridge Springs under base flow condition (Orndorff and Hanlon 2010). Holsinger collected eight specimens from these lateral springs in November of 1994. In May 2009, following a significant thunderstorm, one specimen of the LCCI was captured at the eastern spring, confirming its persistence within the subterranean system (Orndorff and Hanlon 2010).

As previously noted, the Golf Course Cave No. 3 population was discovered in May 2011, and represents the Flanary Bridge Springs subterranean system. Observable habitat is limited to a 10-m-long section within the approximately 91-m-long passageway (Orndorff and Hanlon 2011). Specimens are commonly found, but with a sparse distribution, concentrated in the shallow riffles. What habitat that lies upstream and downstream of this point as well as any associated subterranean stream conduits is unknown but possibly extensive. We estimate that the population within the observable habitat within Golf Course Cave No. 3 is approximately 243 to 1,668 individuals, assuming densities are similar to Thompson Cedar Cave.

Sims Spring system - The subterranean habitat of Sims Spring is not accessible; therefore, data on abundance of the LCCI are not attainable. Exoskeletal remains of three specimens were retrieved from nets set at resurgences of lateral springs (Little Sims Spring) in December 1996, during moderate to high flows (Orndorff and Hanlon 2010). The occurrence at Little Sims Spring has not been confirmed since then, as the lateral springs flow only during significant rain events and it is difficult to coordinate monitoring efforts during such infrequent events. As described above (2.2.3 C), there are likely multiple blind infeeders to the main Sims Spring conduit that house populations of LCCI.

Surgener-Gallohan Cave system - Estes (1978) reported the average density of the LCCI in the section of Gallohan Cave No. 1 to be 79/m^2, while areas with higher velocity to depth ratio (shallow riffles) had densities as high as 296/m^2. A designated population monitoring station in Gallohan Cave No. 1 and Surgener Cave shows variable densities ranging from 150 to 700 individuals/m^2 and 90 to 1,180 individuals/m^2, respectively, over multiple sampling occasions (table 2). Within the observable habitat in Gallohan Cave No. 1, there are an estimated 4,575 to 21,350 individuals based on population monitoring data (Orndorff and Hanlon 2011, 2012, 2013). An estimated 6,480 to 84,960 individuals occur within observable habitat in Surgener Cave. The populations in both caves are recruiting and well represented by a variety of size classes. The population in Gallohan Cave No. 2 has not been monitored, therefore, the status and extent of this site has not been determined.

The total estimated population size of the LCCI in observable habitat ranges from 14,862 to 132,442 individuals/m^2. This broad range represents the variability in population density as it is influenced by flood events that dislodge and flush individuals from the cave system into surface streams. Recruitment is likely rapid to counteract losses from the population during flood events. An actual estimate of population is difficult to determine since unobservable habitat likely occurs throughout the subterranean system. Observable habitat probably accounts for a small percentage of actual occupied habitat. Because individuals cannot be observed or counted in inaccessible habitat, the total population size cannot be reliably determined. Assuming much of the habitat that cannot be observed is occupied, the total population likely consists of millions of individuals. Rather, evidence of recruitment, persistence, densities, site-specific distribution, and habitat quality (mainly water quality) serve as more meaningful measures of population status.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding.): Fong (2009) completed a study to analyze the genetic population structure among specimens of the LCCI, from Gallohan, Masons, Surgener, and Thompson Cedar caves, based on analysis of variations in the mitochondrial CO1 gene). Results showed that the Thompson Cedar Cave system and the Surgener Gallohan system harbor two genetically distinct populations of the LCCI.

Results from the Fong (2009) study suggest that the hydrologic connectivity between Masons Cave and Thompson Cedar Cave is complicated, and that migration of isopods between the two sites occurs only in the direction from Masons Cave towards Thompson Cedar Cave, possibly during localized flood events. These two subclades are genetically very similar and have been isolated from each other for only a short amount of time. Masons Cave lies upstream of Thompson Cedar Cave, and the stream in Masons Cave was dye traced to and has approximately the same flow as the Thompson Cedar Cave stream. In the recent geological past, substantial passage likely connected the two caves. However, recent collapse of the cave roof has created a large pooled area acting as a barrier to upstream migration of the LCCI, which are easily washed downstream through the pool during flood events.

The study further provided some evidence that limited migration occurs from the Thompson Cedar Cave system towards the Surgener-Gallohan Cave system, about 10 kilometers west. Although specimens from Little Sims Spring and Flanary Bridge Springs were not analyzed in the study, dye-tracing results show connectivity between the Thompson Cedar Cave system and both springs (Hanlon and Orndorff 2013). Although these cave and spring systems are recognized as three separate subbasins, Hanlon and Orndorff (2013) consider them interconnected hydrologically within an autogenic zone referred to as the "Cedars Lirceus autogen." This connectivity presumably allows westward migration between subterranean basins, decreasing the distance that separates the two genetic clades identified between the Thompson Cedar Cave and Surgener-Gallohan Cave systems. Further, surface stream flow from northeast to southwest is consistent with the direction of this potential migration.

To date, there has been no evidence of subterranean hydrological connection between the Cedars Lirceus autogen and Surgener-Gallohan Cave autogen (which represents a second autogenic zone with distinct hydrologic interconnectedness) to confirm further westward migration. The two autogens are associated with two different blocks of exposed limestone separated by Hardy Creek and its associated alluvium. Hardy Creek is a deeply incised, perennial stream that receives spring discharge from limestone bedrock on both banks, and is on grade with the Powell River. Subterranean hydrologic connectivity between the two cave systems, even during occasional high-flow events, is also unlikely. Migration through surface streams is one possible explanation. Alternatively, the migration may no longer occur, with the common haplotype pre-dating the modern incision of Hardy Creek. From physiographic and hydrological perspectives, the latter is the more likely explanation.

Although Estes and Holsinger (1982) reported that specimens in Gallohan Cave were significantly larger and showed less seasonal variation in body size than specimens in Thompson Cedar Cave, these differences are confounded by varying environmental conditions between the two caves. Fong (2009) concludes that the genetic difference between populations from the two cave systems (at below 5 percent sequence divergence) is insufficient to indicate taxonomic division at the species level, especially coupled with the lack of morphological differences.

2.3.1.4 Taxonomic classification or changes in nomenclature: Taxonomic classification and nomenclature remain unchanged for the LCCI.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g., corrections to the historical range, change in distribution of the species within its historical range.): Two additional cave locations, Masons Cave and Golf Course No. 3, inhabited by the LCCI have been documented since the recovery plan (Service 1997) was written. Masons Cave was documented in November 2002 and is part of the Thompson Cedar Cave system or sub-basin. The Golf Course Cave No. 3 population was discovered in May 2011 and belongs to the Flanary Bridge Springs subterranean system. Despite these recent discoveries, spatial distribution and the historical range of the LCCI populations remain as defined in the recovery plan (Service 1997).

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem): Basic water quality parameters have been measured at fixed monitoring stations since 2002 to characterize key habitat constituents (table 3). The LCCI persists in cave streams that are highly oxygenated and have mean temperatures around 12.6° C, with very little variation. Habitat is further characterized by neutral to slightly basic pH and specific conductance around 400 microsiemens per centimeter (uS/cm). The LCCI tends to congregate in areas where water depth is low (<1 centimeter) and water velocity is moderate to fast (Estes 1978). The LCCI prefers damp to dry surfaces over still pools during periods of low flow.

Table 3. Suggested water quality limits characterizing habitat for the LCCI based on monitoring data presented in Orndorff and Hanlon (2010). Ppt = parts per trillion.

Parameter	Limits
Dissolved Oxygen	≥ 8 mg/L
Specific Conductivity	250 - 550 uS/cm
pH	7.0 - 8.5
Temperature	11.5 – 13.9° C
Salinity	≤ 0.27 ppt

Thompson Cedar Cave system - As a result of successful removal and remediation of sawdust waste, leachate contamination has been significantly abated, and the cave stream habitat and fauna of Thompson Cedar cave have partially recovered. The LCCI was rediscovered in this cave stream in February 2002. Since its rediscovery, the population seems to be stable, although not nearly as robust as previously documented. The LCCI has successfully recolonized the lower 60 m of the cave stream. The majority (170 m) of the cave stream has not been recolonized by the LCCI; this may reflect compromised water quality.

As mentioned in the evaluation of recovery criteria above (section 2.2.3, criterion C), recent water quality data suggest the cave stream habitat may still be compromised to some level. Some level of siltation persists on the floor of the cave stream, potentially compromising habitat, but it is likely low dissolved oxygen (DO) levels that limit full recolonization of the species. Two monitoring stations have been designated in Thompson Cedar Cave, one just below the cave entrance in the upper reach of the cave stream and the other at the terminal end of the cave stream.

The DO levels in the upper reaches of the cave stream are depressed, with levels being measured as low as 3.6 mg/L (Orndorff and Hanlon 2010, 2011, 2012, 2013) during periods of low flow conditions (figure 1). The lower DO values are attributed to a biological oxygen demand from the decaying lignin and tannin that entered the cave stream from sawdust waste that remains at the surface. Filamentous bacterial coatings (probably *Sphaerotilus sp.*) still appear on substrate intermittently at the upstream end of Thompson Cedar Cave, which lies directly beneath the largest remaining accumulation of sawdust. The cave stream mixes with other infeeding groundwater sources in the lower end of the cave stream where the LCCI is now reestablished. The DO levels in this lower reach are significantly higher and have not been reported below 7.3 mg/L. Full recovery of the LCCI in Thompson Cedar Cave will be recognized upon upstream reestablishment.

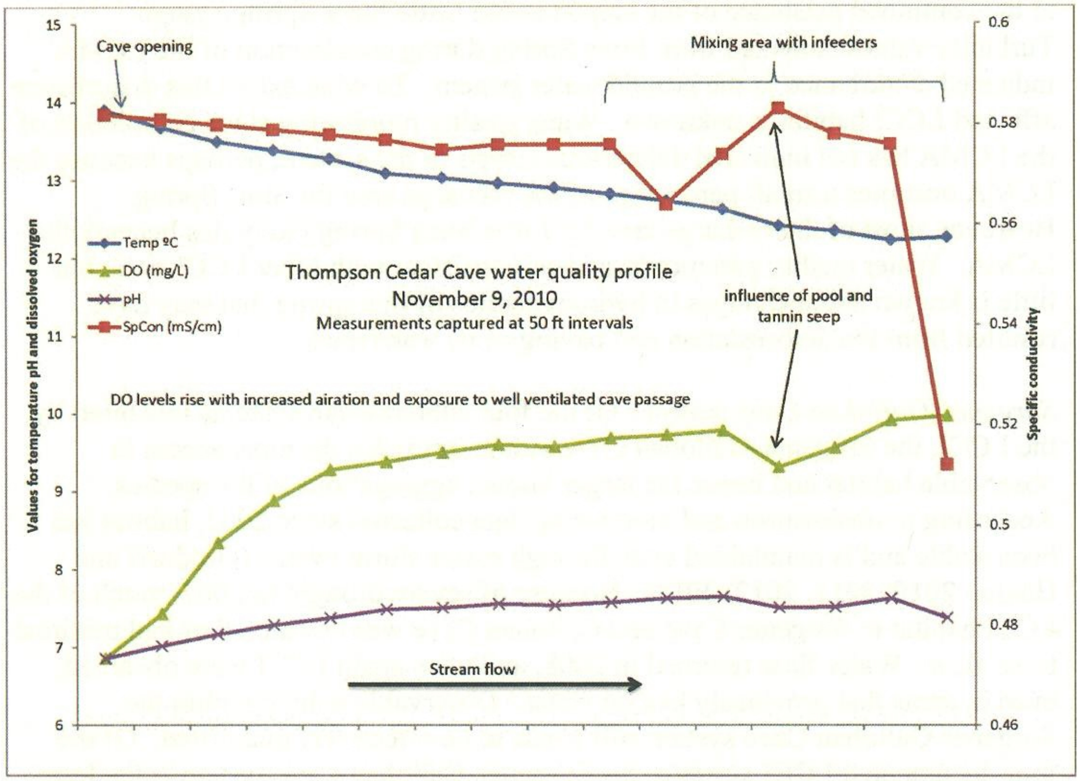

Figure 1. Linear water quality profile for the stream in Thompson Cedar Cave during base flow conditions.

Flanary Bridge Springs system - As previously mentioned, occurrence of the LCCI in the Flanary Bridge Springs subterranean basin was confirmed by specimens collected at the springs in November 1994 and again in May 2009. Based on the DNH flow models derived from dye tracings, the Flanary Springs receive drainage from the central portion of the Cedars Lirceus autogen and the Flanary Cemetery allogen (Hanlon and Orndorff 2013). Indicated by a series of apparent sinkholes, the central line of this system flows in a southwesterly direction through an area demarcated by the Cedar Hills Country Club. The 2011 discovery of the LCCI in Golf Course Cave No. 3 further confirms occurrence within the system. Presumably habitat exists downstream of this cave to the resurgent springs. Water quality data collected from the Flanary Bridge Spring and the stream in Golf Course Cave No. 3 indicate water conditions are suitable for the LCCI. Despite the potential for chemical contamination from fertilizer and pesticide use from the golf course, there has been no evidence of any deterioration to the karst water quality or eradication of the LCCI from the subterranean system.

Sims Creek system - Little is known about what habitat for the LCCI may exist within the Sims Creek subterranean basin. The LCCI was confirmed from exoskeletal remains collected from Little Sims Spring, a lateral spring to Sims Creek downstream and to the northwest of Sims Spring proper. No other evidence has indicated the extent of the population within the system. Construction of the LCMA directly over the subterranean basin has given concern to the continued existence of the isopod in the Little Sims Spring system. Turbidity values collected from Sims Spring during construction of the LCMA indicated disturbance to the ground water system. To what extent this disturbance affected LCCI habitat is unknown. Water quality monitoring since completion of the LCMA has not indicated deleterious effects to the system, perhaps because the LCMA occupies a small percentage of the recharge area for Sims Spring. However, most of the recharge area for Little Sims Spring likely lies beneath the LCMA. Water quality parameters appear consistent with other LCCI sites, but little is known about changes in hydrodynamics of this spring that may have resulted from the deforestation and paving of its watershed.

Surgener-Gallohan Cave system - Of the four subterranean systems inhabited by the LCCI, the Surgener-Gallohan Cave system provides the most access to observable habitat and hence the larger known aggregations of the species. According to observation and monitoring data collected since 2002, habitat has been stable and is maintained even through major storm events (Orndorff and Hanlon 2010, 2011, 2012, 2013). Because of severe drought in 2007, much of the LCCI habitat in Surgener Cave and Gallohan Cave was dewatered or had minimal to no flow. Water flow returned in 2008, and once again LCCI were observed, even in areas that previously had no water. Observable habitat within the Surgener-Gallohan Cave system still needs to be effectively quantified. Of the four documented LCCI systems, the Surgener-Gallohan Cave system is the least likely to be impacted by land development, making it a top priority for maximizing species persistence.

2.3.2 Five-Factor Analysis

The LCCI recovery plan (Service 1997) does not address threats with regard to the five listing factors. A threat assessment of the LCCI was included in the first LCCI 5-year review (Service 2008). A revised threats assessment (appendix A) was completed for the current 5-year review and is included to support the following 5-factor analysis.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range: The primary threat to the LCCI is destruction and modification of its habitat. The LCCI was initially listed due to extirpation as the result of point source discharge of high tannin and lignin leachate from accumulated sawdust waste at a sawmill located in close proximity to Thompson Cedar Cave. Degradation of water quality, in particular, serves as the greatest stressor to the species over its entire range. Specific water quality impacts of concern are sedimentation, pesticide contamination, chemical spills, nutrient contamination, and point source discharges.

The karst topography of the Cedars is formed in areas underlain by limestone bedrock, the dissolving of which, over geologic time, produces a landscape characterized by sinkholes, blind valleys, sinking streams, springs, and caverns. Precipitation enters the karst system both by infiltration and downward movement through soil and weathered bedrock (autogenic recharge) and through direct channelized flow into karst features, termed sinking or losing streams (allogenic recharge). Because of these characteristics, LCCI habitat is particularly vulnerable to water quality degradation and contamination.

Seven sources of stress that contribute to the destruction and modification of habitat have been identified (appendix A) and are discussed in detail below. Although climate change and invasive species are discussed in section 2.3.2.5 below, they also contribute to destruction and modification of LCCI habitat.

Residential activity - represents the common and somewhat routine activities associated with use and maintenance of residential dwellings. Maintenance of lawn and landscape, pesticide use, small-scale land disturbance, auto and home maintenance that utilizes chemicals (hydrocarbon based or otherwise), and onsite waste disposal (septic systems) activities influence hydrology and water quality through existence of impervious surfaces. All four delineated subterranean systems (representing the LCCI subpopulations) underlie a sparsely human-populated rural landscape.

Possibilities to manage residential activity exist, particularly with lands associated with the Surgener-Gallohan Cave system, followed by the Thompson Cedar Cave and Flanary Bridge Springs systems. Feasibility of managing residential activity within the Sims Spring system is low since the system is influenced by a large watershed. Feasibility of managing residential activity within the Little Sims Spring system is high, because the recharge area lies either within or immediately adjacent to the LCMA. Blind tributaries to the main Sims Spring flow, especially to the east, are likely to contain populations of the LCCI, and have a high degree of feasibility for managing residential activity since much of these systems are likely to underlie the Cedars Natural Area Preserve (owned by DNH). Exposure to residential activity is ongoing (chronic) but moderate to low in spatial extent (see appendix A for details on magnitude and severity of threats).

Land development/construction - represents large-scale land disturbance activities including commercial and residential construction and sewer and water projects. This source of stress includes impacts derived from the construction process and does not represent impacts from post-construction operation or existing facilities. Land development/construction activities impact hydrology, water quality, and physical habitat mainly through excessive sediment entrainment and deposition within LCCI habitat. Groundwater can also be contaminated with chemicals used on the construction site, including hydrocarbons. Excavation and surface land-moving operations can disturb and alter the karst geology and consequently physical LCCI habitat.

The LCMA was constructed from 2001 to 2003 within the Sims Creek watershed. Over 93 hectares were disturbed and seven caves were filled during construction. Water quality monitoring reports revealed increased levels of sedimentation in the Sims Spring system as a result of the construction. The degree of resulting impact to the Little Sims Spring LCCI subpopulation and any LCCI populations in blind tributaries to the main Sims Spring flow is difficult to assess due to a lack of access to monitoring points.

The Thompson Cedar Cave system (Batie West Spring basin) may be subject to some level of land development/construction in the future since it is close to Jonesville and receives runoff from the State Route 58 corridor, which Lee County has designated as a key area for business development. Runoff from the State Route 58 corridor could also impact blind tributaries to the main Sims Spring drainage from the east. Over the last 10 years, the local municipality has been installing waterlines along roads throughout the Jonesville area which includes the Cedars. Installation of the waterlines has not been of concern to LCCI conservation. However, waterline installation will enable further development that may pose threats to LCCI populations.

The human population in Lee County decreased 0.4 percent between 2010 and 2012 (U.S. Census Bureau 2013). The current population of about 25,500 is little more than half of the high of approximately 40,000 reported in the 1940 census. Assuming historic trends continue, significant population growth in Lee County is unlikely in the foreseeable future. To some extent, stressors related to land development and construction can be managed, particularly with lands associated with the Surgener-Gallohan Cave system. The feasibility of managing threats is low within the Sims Spring system because of the influence of the larger watershed; however, within watersheds of blind tributaries to the east the feasibility of managing threats is high. Management of construction in the Little Sims spring basin is largely irrelevant, since the recharge area has already experienced the construction of the LCMA. With the exception of the Thompson Cedar Cave system, current and future exposure of LCCI sub-populations to land development and construction is low. This source of stress has a relatively low severity and threat level among all four LCCI subpopulations (see appendix A for details on magnitude and severity of threats).

Logging - is a source of stress which includes timber harvest activities and impacts of land conversion from forest. Logging activities can cause excessive sedimentation that affects water quality and physical habitat. Large-scale logging can alter hydrology as a result of culvert and road building, and temporary and permanent removal of forest attributes. Logging occurs sparsely throughout the watersheds that feed into the Cedars karst area, although significant logging has and continues to occur within the Dry Creek watershed (which influences the Sims Creek system). Because it occurs on private lands, management of this source of stress is largely dependent on land protection. Feasibility to manage logging as a source of stress is moderate given land protection efforts that protect LCCI habitat. Direct acquisition of land or easements for conservation appears to be the most effective tool in gaining permanent protection of forestlands. To date, conservation organizations have acquired over 600 hectares of protected lands that aid in recovery of the LCCI, mostly in the form of a dedicated state natural area preserve managed by DNH and TNC. Severity and threat level of this source of stress is considered low among all LCCI sub-populations (see appendix A for details on magnitude and severity of threats).

Commercial and industrial operations - include activities and operations of retail, manufacturing, mining, and service businesses. Impervious surfaces associated with commercial and industrial facilities and operations can influence hydrology by increasing the rate and amount of surface runoff to karst features, as well as altering and concentrating flow paths. These facilities can be a source of surface and groundwater contamination as well, with a wide range of potential contaminants depending on the specific activities of each business. Exclusive of agriculture and logging, commercial and industrial activity within the range of the LCCI is currently represented by three operations: a local sawmill, a golf course, and LCMA. Commercial and industrial operations are ranked highest for threat level and management priority (appendix A), particularly for the Thompson Cedar Cave system (see appendix A for details on magnitude and severity of threats), relative to other sources of stress that contribute to the destruction and modification of LCCI habitat.

Sawmill - Although the footprint of the sawmill is relatively small, the operation is located on top of the Thompson Cedar Cave system, one of only four subterranean systems where the LCCI is known. The Thompson Cedar Cave system drains into Batie Creek, a creek put on the 303(d) (Clean Water Act) list of impaired waters in 1998. The sawmill has operated for over 20 years within the karst watershed of Batie Creek, resulting in the disposal and storage of an estimated 165,908 m^3 of sawdust. The sawdust produced toxic leachate that drained into the underlying aquifer and exterminated the cave fauna. Sawdust was stored on site in vast stockpiles until 1998 when the Virginia Department of Environmental Quality issued a consent order to the sawmill company to remove sawdust from the site.

Since 1998, the Service, Tennessee Valley Authority, Upper Tennessee River Roundtable, and DNH have assisted the sawmill owner in removing 36,316 m^3 of sawdust from existing piles. All newly generated sawdust waste has been transported offsite for incineration. As a result Batie creek was removed from the Virginia Department of Environmental Quality's Total Maximum Daily Load list in 2006 because water quality improved dramatically since 2000 (figure 2).

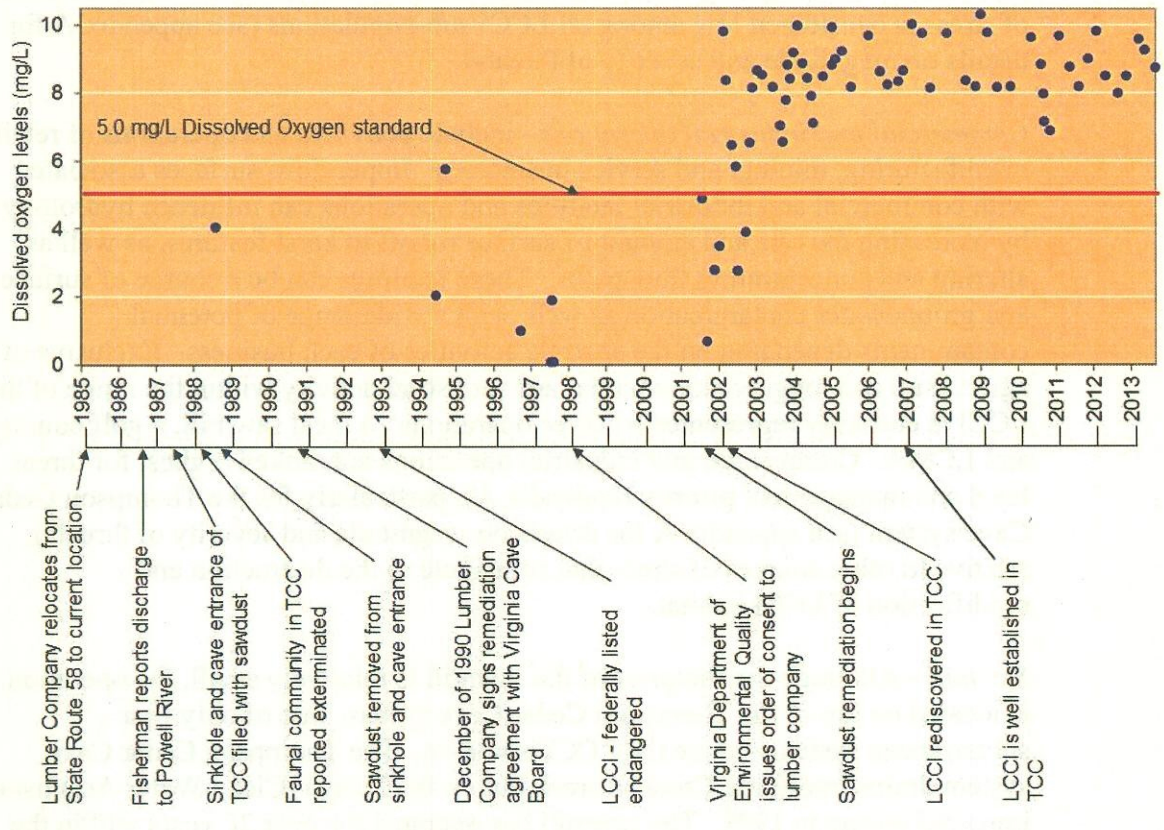

Figure 2. Dissolved oxygen levels over time in Batie West Spring, resurgence for the Thompson Cedar cave (TCC) subterranean system.

As previously discussed in sections 2.3.1.2 and 2.3.1.6, the cave fauna in Thompson Cedar Cave has partially recovered, but some level of stress from sawdust leachate still persists. The sawmill currently poses other threats for contamination, including abandoned heavy equipment, vehicles, and storage tanks. Conservation organizations (TNC, DNH) are working with the sawmill owner to further remediate existing and prevent future impacts, and implement long-term protection measures. Accomplishing this task will significantly improve the status of the LCCI.

Golf course - An 18-hole golf course has been in operation since 1966 within the watershed that feeds Flanary Bridge Springs. The golf course lies directly within a large sinkhole that drains to the system. Maintenance of the golf course with fertilizer and pesticide use may pose a significant threat to the LCCI population of the Flanary Bridge Springs system. The greens are maintained using Integrated Pest Management methods (D. Gilbert, Cedar Hill Country Club, pers. comm. 2007). Deconil 2787 (Tetracholoroisophthalonitrile) a chlorinated benzonitrile fungicide is commonly used and is known to be toxic to invertebrates. A liquid foliar fertilizer is applied as needed usually during the spring and fall of each year at a rate of 28 pounds per acre. The toxicity of the foliar fertilizer to invertebrates is not known.

Despite potential contamination of the subterranean cave stream, the LCCI persists (Orndorff and Hanlon 2010, 2012, 2013). However, quantitative measure of the population is difficult given limited access to the subterranean stream, as previously discussed in 2.3.1.2 and 2.3.1.6. Some level of chemical contamination probably occurs intermittently in the cave stream during rain events that follow fertilizer or pesticide application. Even in these instances, there likely are refugia that allow for natural reestablishment of the LCCI if the population is impaired. For example, Golf Course Cave No. 3 (where occurrence of the LCCI has been confirmed) is located upstream of most of the treated greens. Therefore, impacts from the golf course are not likely to cause extirpation of the LCCI from the Flanary Bridge Springs system.

LCMA - Because of the porous karst topography of the Cedars, the LCMA stormwater retention ponds do not appear to function as designed to retain stormwater. As a result, the Sims Creek system is vulnerable to storm water carrying contaminants such as deicers and hydrocarbons derived from accidental fuel spills. In particular, the Little Sims Spring population and any LCCI populations in blind tributaries to the main Sims Creek (flowing from the western [airport] side) may be at greatest risk to contamination of groundwater from activities and accidents associated with LCMA operations.

Transportation corridors - such as roads, highways, and railways can be a significant source of surface and groundwater contamination from accidental chemical and fuel spills, right-of-way pesticide use, hydrocarbons, other chemicals from leaking vehicles, and residues from road maintenance and resurfacing. Hardened and impervious surfaces and stormwater infrastructure alter hydrology and create ports of entry for contaminated runoff and entrained sediment.

An evaluation of U.S. Geological Survey water budget studies in mature karst terrains suggests that at least 75 percent of the average precipitation falling in the Cedars reaches the Powell River as groundwater (Service 1997). Thus, in this type of ecosystem, any single contamination of land, surface streams, or underground caverns could rapidly contaminate springs and cave streams. Transportation corridors provide the most probable and accelerated route of entry for contaminants because of their level of activity, frequent exposure to contaminants, impervious nature, and established stormwater infrastructure.

Although it is difficult to abate this source of stress entirely, management practices can be implemented to lower the risk. Such practices may include highway improvements that lower vehicle accident rates, establishment of low salt zones, and reduction or elimination of roadside application of pesticides. According to LCCI population monitoring data (Orndorff and Hanlon 2010, 2011, 2012, 2013), there is no indication that past or current highway activity has affected the LCCI. With the exception of the Thompson Cedar Cave system and any blind tributaries to Sims Spring, there are few roads and no major transportation corridors within the documented watersheds of the other subterranean LCCI systems.

It is not likely that stressors related to transportation corridors would eliminate or severely impact the LCCI across its range because (1) there is no indication that past or current highway activities have significantly impacted the LCCI, (2) the species is widespread enough among four sub-populations that any given accidental spill would not affect all populations, (3) subterranean refugia and interconnectivity likely exist to allow recolonization of habitat of potentially extirpated aggregations of the LCCI (such as occurred following the Thompson Cedar Cave extirpation due to the sawdust leachate), and (4) road infrastructure is unlikely to increase or change in the foreseeable future. Across all LCCI subpopulations, transportation corridors pose a moderate threat that is low in severity (see appendix A for details on magnitude and severity of threats).

Agriculture - including pasture and rowcrop lands and associated activities expose highly erodible soils that can inundate LCCI habitat with sediment. Unlike forest lands, agricultural lands have a lower ability to regulate water through retention and natural filtration. Contaminants such as fertilizers and pesticide often accompany sediment that enters surface streams and groundwater. Because of the nature of the karst terrain, subsurface water quality is impacted by poor agricultural practices. For example, as a result of nearby livestock activity, high levels of fecal coliform have been recorded from the stream in Surgener Cave, one of the locations of the LCCI.

A shift toward more chemically intensive operations and/or confined animal feeding operations, particularly within autogenic zones of the LCCI, could impact the species. Although some best management practices (BMPs) are being implemented in the area, most livestock operations within the influencing watersheds do not implement BMPs such as establishing or protecting riparian vegetation or excluding livestock from surface streams or sinkholes. Through acquisition and incorporation of lands into the Cedars Natural Area Preserve, the threat from agriculture has been permanently abated for some key parcels that significantly influence LCCI habitat.

With the exception of the Sims Spring sub-population, feasibility to manage agriculture as a source of stress is moderate, given LCCI habitat protection efforts. Because of the relatively restricted range of the LCCI, surface-to-groundwater dynamics, and the limited geographic bounds by which most of the range of the species is influenced, establishing protected conservation lands appears to be the most effective tool in gaining permanent protection from agricultural impacts. This provides either full control of establishing agricultural BMPs or removing lands out of agricultural production in perpetuity. Agricultural activities, including livestock operations and row crops, pose a moderate level of threat to the LCCI over most of its range. Given current conditions and projections, the potential that agriculture alone would have a significant impact on the LCCI across its range is unlikely (see appendix A for details on magnitude and severity of threats).

Vandalism - and unintentional disturbance from recreational cavers can be in the form of foot traffic, intentional elimination of the LCCI, or habitat destruction. LCCI habitat is confined to cave streams, which often is the main route of passage for cavers. Although not currently necessary, barriers to exclude cavers can be installed in cave entrances to manage recreational caving activity and abate vandalism. Currently, recreational use of caves that provide access to LCCI habitat is low. Caves of the Surgener-Gallohan Cave system and Masons Cave are within the Cedars Natural Area Preserve, where access is limited and managed by DNH. Thompson Cedar and Golf Course Cave No.3 are privately owned and not open to general visitation. There has been no evidence to date that suggests recreational caving or vandalism has impacted the LCCI. Given this and the assumption that an undetermined but likely significant quantity of habitat is inaccessible, and therefore protected from human foot traffic, the threat level from vandalism is low (see appendix A for details on magnitude and severity of threats).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes: Utilization is principally in the form of scientific collection and includes disturbance to individuals and mortality of specimens related to research and monitoring. Known scientific collections are carefully managed and regulated. No measurable effects to populations have been documented as a result of scientific collection. No other utilization of specimens is recognized other than scientific collections for recovery efforts. Overutilization for commercial, recreational, scientific, or educational purposes is not a threat to the species (see appendix A for details on magnitude and severity of threats).

2.3.2.3 Disease or predation: Although disease may persist at some level within and among populations, nothing is known about diseases that affect the LCCI. The species lives in a community of several other cave-dwelling species that likely prey on isopods and other small organisms. Particularly within Thompson Cedar Cave, there occurs a robust population of spring salamanders (*Gyrinophilus porphyriticus*) that probably prey on the LCCI. In addition, crayfish, fish, crangonyctid amphipods, and flatworms in the cave stream may consume the LCCI. The predatory threat likely persists at some level over the range of the LCCI. The threat level from predation is low (see appendix A for details on magnitude and severity of threats).

2.3.2.4 Inadequacy of existing regulatory mechanisms: The Endangered Species Act of 1973, as amended, Clean Water Act, and Virginia state wildlife law (Virginia Code Annotated §§ 29.1-563-570) adequately support LCCI protection and recovery only as far as they are enforced. Current laws to prevent sediment and non-point source-related contaminants from entering waterways are poorly enforced, and BMPs are rarely implemented despite cost share programs.

There are no regulatory mechanisms to maintain stream buffers to adequately protect streams from contaminated runoff or livestock access and loss of functional riparian vegetation. Stewardship is being achieved in the absence of regulations and enforcement for key parcels via land acquisition and incorporation of lands into the Cedars Natural Area Preserve. Inadequate regulatory mechanisms are not expected to become a significant threat for the LCCI (see appendix A for details on magnitude and severity of threats).

2.3.2.5 Other natural or manmade factors affecting its continued existence: Climate change and invasive species are two potential sources of stress to the LCCI. Both sources of stress have the potential to affect habitat and could also be included in 2.3.2.1 above. Climate change may alter hydrology as a result of changes to a drier or wetter region or more extremes in flooding and drought. Using dynamic downscaling to predict climate change in Virginia, Kane et al. (2013) predict more intense precipitation event but decreased soil moisture over time. Effects to the LCCI from climate change are not fully known but will likely to be minimal since the species is adapted to variations in hydrology. The subterranean environment provides consistent temperatures, buffering highly varied diurnal and seasonal temperatures at the surface. The subterranean environment of the LCCI is not expected to change in the face of climate change. Threat level and severity from climate change is anticipated to be low among all LCCI subpopulations (see appendix A for details on magnitude and severity of threats).

Invasive species could change niche and habitat characteristic and/or result in direct effects to the LCCI in the form of predation or competition. Currently, there are no known invasive species within habitat occupied by the LCCI. Introduction of invasive species into the subterranean systems inhabited by the LCCI is not likely due to the adaptations necessary for survival in the cave environment. Threat level and severity from invasive species is anticipated to be low among all LCCI subpopulations (see appendix A for details on magnitude and severity of threats).

2.4 Synthesis: The LCCI is endemic to the Cedars, a mature karst area located in Lee County, VA. This species has been documented from four major subterranean systems: Thompson Cedar Cave, Flanary Bridge Springs, Sims Creek, and Surgener-Gallohan Cave. Two genetic clades of the LCCI have been identified, explained by the spatial distribution of the LCCI population being geographically separated by Hardy Creek, dividing the rangewide population into an eastern half and a western half. The Thompson Cedar Cave, Flanary Bridge Springs, and Sims Creek systems represent the eastern half and are thought to be superficial subterranean basins interconnected during high flows from storm events. Occurrence of the species has been reported from access points to habitat such as caves and washout locations (springs). Beyond what is observable, the actual distribution and amount of habitat may be quite extensive beneath the Cedars - the "autogenic" area that approximately delineates the range of the species.

Present or threatened destruction, modification, or curtailment of the LCCI's habitat or range is the primary factor associated with threats to the species. Threats from commercial/industrial operations, agriculture, and transportation corridors are viewed as the primary sources of stress that threaten the species. Threats from vandalism, scientific collection, predation, climate change, and invasive species are thought to be low in severity.

In the previous 5-year review (Service 2008), the restricted range of the species led the Service to deem the LCCI susceptible to a single incident of groundwater pollution, which could pose serious threats to the survival of the species. New information about the LCCI recovery and distribution and a greater understanding of the subterranean hydrology and extent of the species habitat has lessened, though not eliminated, concern for stochastic events such as accidental spills.

Commercial and industrial operations are ranked highest for threat level and management priority, particularly for the Thompson Cedar Cave system. Commercial and industrial operations are currently limited to three operations - a local sawmill, a golf course, and a municipal airport (LCMA). The sawmill continues to pose some level of stress to the Thompson Cedar Cave sub-population through persistent leachate contamination. However, the population is recovering, and long-term protections and further remediation of sawmill related impacts serve as the greatest conservation gain toward species recovery and ultimately delisting. The discovery of the LCCI in Golf Course Cave No. 3 has shed new light on the persistence, distribution, and security of the species in the Flanary Bridge Springs system. Although the golf course may impact the system via acute episodes of chemical contamination, there has been no evidence that this has occurred. Impacts to the Sims Spring subpopulation from the LCMA are difficult to quantify because of the inability to access the subterranean system. Sub-population persistence will be based largely on captures of the LCCI at springs lateral to Sims Spring.

Because of the relatively restricted range of the LCCI, surface-to-groundwater dynamics, and the limited geographic bounds by which most of the species' range is influenced, establishing protected conservation lands appears to be the most effective tool in gaining permanent protection from impacts associated with agriculture, land development and construction, logging, commercial and industrial operations, and vandalism. Land protection will be most effective if implemented around cave entrances in the Thompson Cedar Cave, Flanary Bridge Springs, and Surgener-Gallohan Cave systems.

Since the last 5-year review (Service 2008), many of the recovery criteria for the LCCI have been met or partially met (table 4). Delisting criteria C, D, and E are partially met. Confirming persistence of the species at Little Sims Spring (lateral to Sims Spring) will enable criterion C to be met. Criterion D is largely met with the exception of additional water quality monitoring within the Flanary Bridge Springs systems. While sufficient protection can be achieved for all four cave systems, we believe permanent protection may be an unrealistic objective of criterion E, given uncertainties of contamination from accidental spills and non-point source pollutants from a landscape dominated by private lands and operations. Our ability to manage sources of stress within the Sims Spring system is particularly low because of the size of the contributing watershed and footprint of the LCMA within the autogenic zone. However, our ability to manage sources of stress in portions of the Cedars draining to blind tributaries of the main Sims Spring flow, likely to house the LCCI, is moderate to high due to direct land protection efforts.

Table 4. Status of progress toward meeting recovery criteria with needs listed for meeting those criteria. Y = criterion has been met, P = criterion has been partially met. Numbers within parenthesis correspond to downlisting (reclassification to threatened criteria).

Recovery Criteria	Conditions	Has Criterion Been Met for Delisting	Has Criterion Been Met for Downlisting	Needs
A	delineate distribution	Y	Y	
B	know hydrology	Y	Y	
C	10(5)-year species persistence	P	P	confirmation at Sims Spring
C-1	baseline data—habitat with populations	Y	Y	
C-2	sampling protocol for springs	Y	Y	
C-3	monitoring protocol established	Y	Y	
C-4	4th population found	Y*	Y*	
D	10(5)-year water quality monitoring program	P	Y	additional monitoring for Flanary Bridge Springs
E	4(2) sites permanently protected	P	P	land protection of key parcels

*Meets the intent of the criterion but not necessarily the literal written condition.

Based on the five factor analysis, the LCCI does not meet the definition of endangered. Although not all downlisting criteria have been fully met, the protection achieved warrants reclassification of LCCI from endangered to threatened. Substantial strides have been made that address recovery actions outlined in the species recovery plan (appendix B). Of the 21 recovery actions outlined, 8 have been completed, and 4 more are scheduled for completion in 2014. Also, two actions were discontinued because their completion would not add significantly to recovery. The six ongoing recovery actions focused on partnership efforts to protect the LCCI and its habitat will continue until or, in some cases, after delisting.

Delisting will be contingent on further monitoring and abatement of key stressors. The species may be considered for delisting upon completion of the following:

1. Confirm persistence of the LCCI within the Sims Spring subterranean system.
2. Sufficiently abate continuing impacts within Thompson Cedar Cave.
3. Obtain sufficient protection for key autogenic areas, particularly to protect areas surrounding caves associated with the Thompson Cedar Cave, Flanary Bridge Springs and Surgener-Gallohan Cave LCCI subpopulations.
4. Determine a stable and persistent LCCI population within the Flanary Bridge Springs subterranean system based on continuation of water quality and population monitoring through 2014.

3.0 RESULTS

3.1 Recommended Classification: Downlist to Threatened
__X__ **Downlist to Threatened**

3.2 New Recovery Priority Number: 14

3.3 Listing and Reclassification Priority Number: 6

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Below are recommendations for future actions, not provided in any order of priority. Recovery action numbers correspond to those identified in the species recovery plan.

1. Continue implementing recovery actions 1.1, 2.2, and 5.4 to monitor water quality and populations of the LCCI, with additional focus on the following:
   - Conduct a presence/absence assessment of the LCCI to verify continued presence at Little Sims Spring, or develop a method to test for presence in blind tributaries to Sims Spring proper. *Recovery action 2.2*
   - Monitor water quality and the LCCI population at Flanary Bridge Springs and Golf Course Cave No. 3 annually through 2014. *Recovery actions 2.2 and 5.4*
   - Determine population status and extent of observable habitat in Gallohan Cave No. 2.
   - Quantify observable habitat within all accessible occurrence locations of the LCCI.
2. Pursue permanent land protection for key autogenic areas. *Recovery action 6.2*
3. Continue to work with partners to abate impacts to Thompson Cedar Cave population from sawmill operations and sawdust waste. *Recovery action 6.2*

5.0 REFERENCES

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Lee County cave isopod (*Lirceus usdagalun*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

__X_ Reclassify to Threatened
____ Reclassify to Endangered
____ Delist
____ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: 14

Review Conducted By: Shane D. Hanlon, Southwestern Virginia Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Cynthia A. Schulz Date 3/17/2014

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

Approve [signature] Date 6-10-14
Martin Miller
Acting ARD, ES

Appendix A. Threats Assessment for the Lee County Cave Isopod.

Approach

This threats assessment was conducted by the Service's lead recovery biologist for the Lee County cave isopod (*Lirceus usdagalun*) (LCCI) and the Virginia State Karst Protection Coordinator as the primary investigators most familiar with the species biology and ecology, progress toward recovery, and threats facing the species. This assessment was conducted to effectively evaluate current and foreseeable threats to the species and accompanies the 5-year review of the species. Stressors to the LCCI are in four primary forms: hydrologic alteration, water quality degradation, direct impacts to physical habitat, and direct impacts to individuals. Twelve general sources of stress were identified as potentially impacting the LCCI. These sources of stress were partitioned and grouped based on type of activity, common stressor mechanisms, and prevalence on the landscape; they are listed and described as follows:

1) **Residential activity** - Residential activity can mainly influence hydrology and water quality through activities such as lawn and landscape maintenance, pesticide use, and auto and home maintenance that utilizes chemicals, hydrocarbon-based or otherwise.
2) **Land development and construction** - Land disturbance activities include commercial and residential construction and sewer and water projects. This source of stress includes impacts derived from the construction process and does not represent impacts from subsequent operation or existence of postconstruction facilities. These activities impact hydrology, water quality, and physical habitat mainly through excessive sediment entrainment and deposition within LCCI habitat. Groundwater can also be contaminated with chemical or hydrocarbons used in construction. Physical habitat can be disturbed and altered via excavation and surface land-moving operations.
3) **Logging** - Logging can cause excessive sedimentation that affects water quality and physical habitat. Large-scale logging can alter hydrology as a result of culvert and road building, and temporary and permanent removal of beneficial forest attributes.
4) **Commercial and industrial operations** - These include activities and operations of commercial facilities such as auto-repair shops, golf courses, sawmills, and airports but not include construction of such facilities. Impervious surfaces associated with commercial and industrial facilities can influence hydrology. These facilities can be a source of surface and groundwater contamination.
5) **Transportation corridors** - Roads, highways, and railways are a significant source of surface and groundwater contamination from accidental chemical and fuel spills, right-of-way pesticide use, hydrocarbons and other chemicals from leaking vehicles, and residues from road maintenance and resurfacing. Hardened and impervious surfaces and stormwater infrastructure alter hydrology and create ports of entry for contaminated runoff and entrained sediment.
6) **Agriculture** - Agricultural land use can alter hydrology by conversion from forest to land cover that has lower ability to regulate water through retention and natural filtration. Pasture and rowcrop lands and associated activities expose highly erodible soils that can inundate LCCI habitat. Contaminants such as fertilizers and pesticides often accompany sediment that enters surface stream and groundwater.
7) **Vandalism** - Recreational cavers could cause intentional or unintentional harm to LCCIs and their habitat by way of mainly foot traffic or intentional destruction by directly

targeting individuals and or habitat. Cave stream substrates inhibited by the LCCI can be easily disturbed and altered. Specimens of the LCCI are delicate and can be crushed or dislodged under foot.

8) **Scientific collection** – Scientific collection can disturb habitat and individuals, and involves euthanasia of specimens to conduct research and monitoring efforts.
9) **Disease** - Diseases of the LCCI are unknown but would have potential to affect individuals of populations.
10) **Predation** - Individuals of the LCCI could be preyed on by spring salamanders, crayfish, and other invertebrates that inhabit cave streams and springs.
11) **Climate change** - Alteration of hydrology may result from changes to a drier or wetter region or more extremes in flooding and drought.
12) **Invasive species** – Invasive species could change niche and habitat characteristic and/or direct effects to individuals of the LCCI in the form of predation or competition.

Each of these sources of stress corresponds to one of the five listing factors. Residential activity, land development and construction, logging, commercial and industrial operations, transportation corridors, agriculture, and vandalism all potentially contribute to Factor A - the present or threatened destruction, modification, or curtailment of the species habitat or range. Scientific collection fits appropriately under Factor B - overutilization for commercial, recreational, scientific, or educational purposes. Disease and predation defines Factor C. Climate change and invasive species are categorized under Factor E - other natural or man-made factors affecting the species' continued existence. Factor D - (the inadequacy of existing regulatory mechanisms) was not included in this threat assessment as it is not a stressor, but a means to influence sources of stressors.

The general approach of this assessment serves to evaluate threat level of any given source of stress against managing that source of stress—our ability to remediate threats. The framework of this assessment was developed to allow evaluation at the subpopulation level as well as the rangewide level.

Threat analysis

For each identified subterranean basin (each of which represent a LCCI subpopulation), the 12 sources of stress were examined against exposure and severity of each source of stress as measures of threat level (see attached matrix). For the purposes of this assessment, the following terms and definitions apply:

Level of exposure – how much of the population is exposed to a particular source of stress. Each subpopulation was assigned a value from 0 to 3 for each source of stress.
0 = unknown level of exposure or no exposure
1 = low level of exposure
2 = moderate level of exposure
3 = High level of exposure

The subpopulation values were then summed to obtain a rangewide level of exposure for each source of stress.

Temporal extent of exposure – the duration LCCI is exposed to a given stressor. For example: continuously vs. intermittent. For each source of stress, a value from 0 to 3 was assigned to quantify the temporal extent of the exposure.
0 = unknown
1 = episodic
2 = intermittent
3 = continuous

The sums of subpopulation level of exposure values were multiplied by temporal extent of exposure to obtain a rangewide exposure score.

Severity - a function of three components, which are as follows:

- Intensity of impact - where occurring, what is the level of effect
- Immediacy of impact - if the threat continues, how soon will the source of stress cause extinction
- Likelihood of impact - how likely will the source of stress cause extinction

To quantify severity, values were assigned for intensity of impact, immediacy, and likelihood and then summed for each source of stress. The following measures were used:

Intensity: 0 = unknown, 1= low, 2 = moderate, 3 = high
Immediacy: 0 = unknown, 1 = distant future or not at all, 2 = foreseeable future, 3 = near future
Likelihood: 0 = unknown, 1 = not likely, 2 = somewhat likely, 3 = very likely

Threat level was calculated as (rangewide exposure score) x (severity).

The sum of threat level values for each subpopulation was then obtained to identify the subpopulations with the highest level of threat.

Management Priority

For each subpopulation a value from 1 to 3 was assigned to quantify the feasibility of remediating any particular source of stress (management potential). Values of 1, 2, and 3 respectively represent low, moderate, and high abilities to manage those sources of stress. Management priority was then calculated as (threat level) x (management potential) for each sub-population against each source of stress.

A priority score was then calculated by summing management priority for each source of stress to identify what sources of stress were the most prominent obstacles to recovery. Summing management priority for each sub-population identified which subpopulations were most important to focus efforts for the largest conservation gain.

Summary of Results

Of the listing factors, habitat destruction/modification or range curtailment was clearly the most significant factor. Stressors derived from commercial/industrial operations, transportation corridors, and agriculture pose the greatest overall risk to the LCCI among the identified sources of stress. Of these three primary sources of stress, commercial/industrial operations ranked highest for management priority, followed by agriculture, and then transportation corridors. The Thompson Cedar Cave and Sims Spring subpopulations received the higher threat level among the four subpopulations. Considering management potential, the Thompson Cedar Cave sub-population ranked highest for management priority, followed by the Surgener-Gallohan Cave subpopulation. To achieve full recovery and delisting, activities need to focus on abating stressors related to commercial/industrial operations within the Thompson Cedar Cave system and agriculture within the Surgener-Gallohan Cave system.

Threat assessment and management priority matrix; a = hydrologic alteration, b = water quality degradation, c = direct habitat impacts, d = direct impacts to individuals. Colored cells indicate level of importance or relevance to the species status and recovery: red = highest, orange = moderate, yellow = lowest.

			Level of Exposure							Severity				Threat level				
Listing Factor	Stressor	Source	Thompson Cedar Cave	Flanary Bridge Springs	Sims Spring	Surgener-Gallohan Cave	Rangewide Exposure	Temporal Extent	Rangewide exposure score	Intensity of Impact	Immediacy	Likelihood	Severity score	Thompson Cedar Cave	Flanary Bridge Springs	Sims Spring	Surgener-Gallohan Cave	Rangewide Threat score
Present or threatened habitat or range destruction/ modification/curtailment	a, b	Residential activity	1	1	1	1	4	3	12	2	1	1	3	9	9	9	9	36
	a, b, c	Land development/construction	2	1	1	1	5	1	5	2	1	1	3	6	3	3	3	15
	a, b, c	Logging	1	1	1	1	4	2	8	1	1	1	2	4	4	4	4	16
	a, b	Commercial/Industry operation	3	2	3	1	9	3	27	3	2	2	10	90	60	90	30	270
	a, b, c	Transportation corridors	3	1	1	1	6	3	18	2	2	1	4	36	12	12	12	72
	a, b, c	Agriculture	2	1	2	3	8	3	24	2	2	1	4	24	12	24	36	96
	c, d	Vandalism	1	1	0	1	4	1	4	3	1	1	4	4	4	0	4	12
Overutilization	d	Scientific collection	1	1	0	1	4	1	4	1	1	1	2	2	2	0	2	6
Disease or predation	d	Disease	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	d	Predation	2	1	1	1	4	3	12	2	1	1	3	18	9	9	9	45
Other natural or man-made factors	a	Climate Change	1	1	1	1	4	3	12	1	1	1	2	6	6	6	6	24
	c, d	Invasive species	1	1	1	1	4	3	12	0	0	0	0	0	0	0	0	0
Totals			18	12	13	13								199	121	161	115	596

Listing Factor	Stressor	Source	Management Feasibility: Thompson Cedar Cave	Management Feasibility: Flanary Bridge Springs	Management Feasibility: Sims Spring	Management Feasibility: Surgener-Gallohan Cave	Management Priority by Population: Thompson Cedar Cave	Management Priority by Population: Flanary Bridge Springs	Management Priority by Population: Sims Spring	Management Priority by Population: Surgener-Gallohan Cave	Management Priority by Population: Priority score
Present or threatened habitat or range destruction/ modification/curtailment	a, b	Residential activity	2	2	1	3	18	18	9	27	72
	a, b, c	Land development/construction	2	2	1	3	12	6	3	9	30
	a, b, c	Logging	2	2	1	2	8	8	8	8	32
	a, b	Commercial/Industry operation	3	1	1	3	270	60	90	90	510
	a, b, c	Transportation corridors	1	1	1	2	36	12	12	24	84
	a, b, c	Agriculture	2	2	1	2	48	24	24	**72**	168
	c, d	Vandalism	3	3	1	3	12	12	0	12	36
Overutilization	d	Scientific collection	3	3	3	3	6	6	0	6	18
Disease or predation	d	Disease	1	1	1	1	0	0	0	0	0
	d	Predation	1	1	1	1	18	9	9	9	45
Other natural or man-made factors	a	Climate Change	1	1	1	1	6	6	6	6	24
	c, d	Invasive species	1	1	1	1	0	0	0	0	0
Totals			22	20	14	25	426	149	158	259	

Appendix B. Status of recovery actions from the Lee County Cave isopod recovery plan. ND = Not Determined, UD = Until Delisting.

Action Number	Abbreviated Action Description (see recovery plan for full descriptions)	Priority	Action Status	Completion Date
1.1	Survey the Thompson Cedar cave system at least annually	3	Partially complete	12/31/2014*
1.2	Inventory potential sampling sites	2	Complete	10/7/2010
1.3	Search for additional cave systems containing the Lee County cave isopod	3	Complete	12/31/2011
2.1	Select appropriate sites for population monitoring	2	Complete	10/7/2010
2.2	Implement monitoring of Lee County cave isopod populations for ten years.	2	Partially complete	12/31/2014*
3.1	Conduct research on biology and ecology	3	Discontinue	
3.2	Determine population viability and stability	3	Ongoing	12/31/2014*
4.1	Map drainage systems and indicate sites where pollution may enter	2	Complete	6/18/2013
4.2	Delineate drainages and determine the temporal relationship between them	3	Complete	6/18/2013
5.1	Determine the effects of water pollution on this species	2	Ongoing current	ND
5.2	Locate appropriate sites for monitoring pollution	2	Complete	10/7/2010
5.3	Establish permanent monitoring stations if needed	2	Complete	12/31/2009
5.4	Track impacts of pollution and changes in natural water levels.	2	Partially complete	12/31/2014*
5.5	Work with partners to minimize negative impacts to the water quality and quantity	2	Ongoing current	UD
6.1	Develop protection and restoration plans for groundwater recharge areas	2	Discontinue	
6.2	Protect and restore Lee County cave isopod habitat	1	Ongoing current	UD
6.3	Enforce existing laws and regulations to protect the LCCI and its habitat.	2	Ongoing current	UD
7.1	Enlist landowners to assistance in protecting LCCI habitat.	3	Ongoing current	UD
7.2	Public outreach	3	Ongoing	UD
8	Restore populations of LCCI to habitat within its historical range.	3	Complete	2/19/2002
9	Implement a program to monitor recovery progress.	3	Ongoing current	UD

*Anticipated completion date.