Lee County Cave Isopod
(Lirceus usdagalun)

5-Year Review:
Summary and Evaluation

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

Summer 2008

5-YEAR REVIEW

Species reviewed: Lee County cave isopod (*Lirceus usdagalun*)

TABLE OF CONTENTS

5-YEAR REVIEW
Lee County cave isopod/*Lirceus usdagalun*

1.0 GENERAL INFORMATION

1.1 Reviewers

Technical Reviewers:
Wil Orndorf, Virginia Department of Conservation and Recreation, Division of Natural Heritage, 540-831-4056, wil.orndorff@dcr.virginia.gov
Dr. John Holsinger, Old Dominion University, 757-683-3606, jholsing@odu.edu

Lead Field Office:
Southwestern Virginia Field Office, Mr. Shane Hanlon, 276 -623-1233, shane_hanlon@fws.gov

Lead Regional Office:
Region 5, Ms. Mary Parkin, 617-876-6173, mary_parkin@fws.gov

1.2 Methodology Used to Complete the Review

This 5-year review was conducted as an individual effort by the lead endangered species biologist for the Lee County cave isopod. Because of the limited range of this isopod, the Southwestern Virginia Field Office(SVFO) is the principle lead for the species. Much of the new data and information regarding the species population status and water quality data used in this review originated from internal joint reports between the U.S. Fish and Wildlife Service (USFWS) and the Virginia Department of Conservation and Recreation, Division of Natural Heritage (DNH). All State natural resource agency personnel responsible for the recovery of this species were contacted for up-to-date information on occurrences, threats, and recovery activities. Other academic researchers that have conducted research on this species were also contacted. This review summarizes and evaluates past and current conservation efforts, current threats, and scientific research and surveys related to the species. All pertinent literature and documents on file at the SVFO were used for this review.

1.3 Background

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

Vol. 72, No. 18, January 29, 2007, pages 4018-4019

1.3.2 Listing history:

FR notice: Vol. 57, No. 225, November 20, 1992, pages 54722-54726

Date listed: effective date December 21, 1992
Entity listed: species
Classification: endangered

1.3.3 Associated rulemakings: None

1.3.4 Review history:
Since Federal listing of the Lee County cave isopod in 1992, no status assessment or 5-year review has been conducted for this species.

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

1.3.6 Recovery plan:

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

2.1.1 Is the species under review a vertebrate? No. Because the Lee County cave isopod is an invertebrate, the 1996 DPS policy does not apply.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing recovery 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.

2.2.2.2 Are all relevant listing factors addressed in the recovery criteria (and is there no new information about existing or new threats)? 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:*

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

Species experts have posited that the range of the Lee County cave isopod may extend southwest potentially into northeastern Tennessee. However, no additional work has been initiated to investigate the extent of the *L. usdagalun* distribution and range beyond that described in the current recovery plan. Most land is held in private ownership, and the karst resources in the area are not fully known or understood.

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

A number of dye tracing investigations have been conducted in attempt to better understand the subsurface hydrology throughout the known range of the Lee County cave isopod (Jones 1990, Culver et al. 1992, Ewers et al. 1995, Neely 1996). These tests indicate that groundwater in the Cedars area generally moves southwest and south along geologic strike and fracture zones through four major spring systems (Batie Springs, Flanary Springs, Sim's Spring, and the Surgener-Gallohan Cave resurgence). Further unpublished dye tracing data have been obtained by the DNH (W. Orndorff, DNH, pers. comm.). The DNH has used the culmination of dye tracing data to establish trajectories and a flow model that identify the approximate flow of subterranean water, as well as conservation sites that capture the zone of influence for the 4 known subterranean systems occupied by the Lee County cave isopod. It is believed that enough data have been gathered to sufficiently understand the relationships among the surface and subterranean hydrology within the known range of the Lee County cave isopod.

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.

The Lee County cave isopod has been documented as occurring in two cave systems and two springs (Surgener-Gallohan cave system, Thompson Cedar Cave, Sim's Spring, and the springs near Flanary Bridge). In 1987, the Thompson Cedar Cave population was considered extirpated due to leachate produced from sawdust waste that was generated from a local sawmill operation. Only three populations of the Lee County cave isopod were believed to remain in

existence, until the Thompson Cedar Cave population was "rediscovered" in February 19, 2002, following successful steps taken by the USFWS and its partners to remediate the impacts to the cave system. Since then, the population seems to be recovering, although it is not nearly as robust as previously documented by Estes (1978). The following points address the specific action items listed in recovery criterion C:

1) Baseline water quality data gathering for the Surgener-Gallohan cave system has been initiated, but monitoring is still in its infancy. Additional and perhaps more rigorous data will need to be obtained to correlate habitat condition with population status.
2) To date, sampling techniques have not been finalized, and no attempt been made to monitor the populations known from Sim's Spring or the springs near Flanary Bridge.
3) Although steps are being taken to refine and increase population and water quality monitoring, current available data are insufficient to allow inferences about the isopod's population status in the springs. Habitat in Thompson Cedar Cave has greatly improved since November of 1992 when the Lee County cave isopod was listed as endangered. The Lee County cave isopod was rediscovered in February of 2002, and the population appears to be recovering; however, several uncertainties exist regarding the water quality and full recovery of the isopod in Thompson Cedar Cave. These concerns are as follows:

    a) Although it appears that the remaining sawdust piles have decomposed past their peak of producing leachate, uncertainties persist about the stability of the remaining piles and the threat that they pose to the Thompson Cedar Cave stream fauna. Under certain conditions, leachate production may be increased in pockets of material within the pile during periods of heavy and prolonged precipitation. Large sawdust piles such as these are prone to sub-surface combustion, which may lead to additional water quality problems following precipitation.
    b) The quality and quantity of continued succession of re-vegetation on both the "old" pile and footprint of the "new" pile is questionable. The sawdust may not support certain vegetation past some level of maturity, and the loose nature of the sawdust may lead to blow-down if trees do grow to a mature size. The sawdust may also encourage the establishment of undesirable non-native invasive species.
    c) According to USFWS recent monitoring data, 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 typically occur during periods of drought and extremely low stream flow. This suggests that some level of leachate input still persists, increasing the biological oxygen demand of the cave stream water column. In addition, a layer of fine silt persists on the floor of the cave stream, especially during

periods of low flow. Whether these occurrences are natural or a result of continued decomposition of the "old" pile is currently not well understood. Although the Lee County cave isopod has re-established itself in the cave stream, its numbers have increased only toward the terminus of the passageway where dissolved oxygen levels in the cave stream increase. The numbers of individuals do not appear to have recovered to the levels that have been described prior to the establishment of the sawmill operation (Estes 1978). The USFWS believes the fauna of the cave stream are still in a state of recovery and remain impacted by the sawdust to some degree.

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.

Groundwater monitoring has been initiated at selected sites; however, data are limited to basic water quality parameters. Water quality data have been collected periodically by the SVFO concurrently with population monitoring at Thompson Cedar Cave, Masons Cave, Surgener Cave, and Gallohan Cave. Water quality monitoring has been conducted periodically at Sim's Spring; however, the population has not been monitored because of inaccessibility to the habitat. Neither of the springs near Flanary Bridge has been monitored for water quality or persistence of the isopod. Additional monitoring will need to be conducted at these springs.

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).

Permanent protection from groundwater contamination may be unrealistic given the vulnerability of the karst systems to accidental spills and non-point source contaminants and siltation that may occur at a watershed scale. Nonetheless, significant accomplishments have been made by The Nature Conservancy (TNC) and the DNH to permanently protect lands surrounding the occurrences of the isopod. Currently, over 1,000 acres have been acquired and permanently protected by controlling threats from timber harvesting, development, and livestock grazing. In addition, work has been ongoing to abate both direct impacts and impacts that may be indirect or temporally more remote. Examples of these efforts follow.

Leachate from three massive sawdust piles was identified as the primary cause of extirpation or near-extirpation of the Thompson Cedar Cave population. These three sawdust waste piles were at varying stages of decomposition and were accordingly termed the "ancient", "old", and "new" piles. Late in 1988, the

owner of the sawmill operation removed the sawdust from the Thompson Cedar Cave sinkhole and cave entrance and established a clay berm around the sinkhole to prevent sawdust leachate from entering the cave. Sawdust continued to be stockpiled and the cave stream in Thompson Cedar Cave continued to be impacted. In 1998, the Virginia Department of Environmental Quality (DEQ) issued an order of consent to the sawmill company to remove the "new" and "old" sawdust stockpiles from the site, an estimated total of 176,000 cubic yards of material. Remediation involved removal of almost the entire "new" pile (96,300 cubic yards), and partial removal of the "ancient" and "old" piles. By 2001, most of the "new" pile was removed and disposed of at an industrial incinerator located in Kingsport, Tennessee. An undetermined amount of sawdust from the "old" pile was incorporated into newly generated sawdust that was also transported to Kingsport, Tennessee, for incineration. An estimated 47,520 cubic yards (13,283 tons) of sawdust was removed from the "ancient pile" and used as a soil amendment for mine land reclamation. Currently, the major impacts from the sawdust stockpiles to water quality of the Thompson Cedar Cave stream and Batie Creek appear to be curtailed. All newly generated sawdust continues to be transported to Kingsport, Tennessee, for incineration. With the exception of some residual deposits of sawdust waste, the "new" pile has been removed. Although slow to progress, volunteer vegetation is becoming established on the footprint of the pre-existing "new" pile. The clay berm around the sinkhole of Thompson Cedar Cave appears to be adequate in preventing material from entering the sinkhole and cave entrance. Approximately 25 to 30 percent of the "old" pile has been removed, and volunteer vegetation is starting to become established on the remaining sawdust.

Other efforts have been made to improve water quality in the Cedars karst area. In 2001, the Virginia Department of Transportation (VDOT) constructed a stormwater retention system for its Jonesville maintenance facility, located in the Cedars. Prior to this improvement, the Jonesville VDOT facility discharged runoff directly into a sinkhole. The discharge eroded a channel to bedrock and caused increased subsidence in the receiving sinkhole complex, which is about 100 feet long by 25' feet deep. The channel had petroleum residue deposited on some of the bedrock exposures. The new stormwater retention pond between the facility and the receiving sinkhole reduced stormwater flows to the sink and removed pollutants and sediment through wetland vegetation.

In the fall of 2000, a large sinkhole was cleaned out through a partnership between the Cave Conservancy of the Virginias, DNH, and USFWS. The sinkhole is located within the drainage basin of Batie East Spring, which is likely to contain part of the eastern Cedars population of *Lirceus usdagalun*. Approximately 25 tons of tires and 20 tons of municipal solid waste, which were potentially contaminating groundwater, were removed from the sinkhole.

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.

Although the surface and subterranean hydrology within the known range of the isopod are understood, a thorough delineation of the present and historic distribution for this species has not been completed. As stated above, sampling techniques have not been finalized, nor have any attempts been made to monitor the populations known from Sim's Spring or the springs near Flannery Bridge. Although some data exist, water quality monitoring has not been consistent or rigorous enough to correlate habitat condition with population status or sufficient enough to gauge survival of this species. Permanent protection of ground water for any of the populations may by unrealistic; however, significant accomplishments have been made in protecting in perpetuity the karst landscape of the Cedars. This ensures permanent protection of the immediate landscape surrounding the populations and ameliorates many potential impacts that would likely otherwise occur such as development, logging, and livestock and other agricultural practices.

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:

The final recovery plan contains the most current information on the isopod's biology and life history.

2.3.1.2 Abundance, population trends, demographic features, or demographic trends:

Although the subterranean habitat of *L. usdagalun* at Sim's Spring and the springs near Flanary Bridge is not accessible and abundance estimates of the Lee County cave isopod are therefore not obtainable, occurrence data have been acquired from captures at the resurgent springs during moderate to high flows. Historic density and population estimates have been reported for Thompson Cedar Cave and Gallohan Cave (Estes 1978). The isopod was formerly very abundant in Thompson Cedar Cave (Holsinger and Bowman 1973, Estes 1978). Estes (1978) reported the average density of *L. usdagalun* in the section of Thompson Cedar Cave immediately downstream of the cave entrance to be $109/m^2$. Furthermore, densities in shallow riffles which the isopod prefers averaged over $200/m^2$. Based on available habitat where *L. usdagalun* predominated, the total population was estimated at 100,000 animals. According to recent data collected by the USFWS and DNH, *L. usdagalun* is extremely rare to absent in the section of the cave stream just below the cave entrance, and specimens become more prevalent further downstream as dissolved oxygen levels increase. Quantitative analysis of the cave populations is needed to more accurately evaluate their status.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation:

A study has been proposed and funded to conduct an analysis of the genetic populations among specimens of the Lee County cave isopod from Gallohan, Masons, Surgener and Thompson Cedar caves. The hydrology of the area suggests that these four localities house fewer than four genetically distinct populations, as there is strong evidence indicating that water in Thompson Cedar and Masons caves is connected underground. An effective protection strategy for this isopod requires knowledge of the number of genetic populations at these four locations. This project proposes to analyze genetic differentiation among localities of *L. usdagalun* by comparison of sequence divergence of the mitochondrial gene COI (cytochrome oxydase I). In addition, sequences from specimens of the Rye Cove Isopod, *Lirceus culveri*, will be obtained to compare with *L. usdagalun*, along with sequences obtained from surface forms of *Lirceus* species as an outgroup.

2.3.1.4 Taxonomic classification or changes in nomenclature:

Taxonomic classification and nomenclature remain unchanged for the Lee County cave isopod.

2.3.1.5 Spatial distribution, trends in spatial distribution, or historic range:

Spatial distribution and the historic range of the Lee County cave isopod populations remain as defined in the 1997 recovery plan. However, one additional cave location inhabited by the isopod, Masons Cave, was documented in November of 2002. This cave is within the Thompson Cedar Cave system and is likely an extension of available habitat of the population. Dr. John Holsinger first documented Masons Cave on May 15, 1990 (J. Holsinger, Old Dominion University, in litt. 2007). At that time, no fauna was observed in the stream and the cave stream was determined to be contaminated presumably by leachate produced from the "ancient" sawdust waste pile. Holsinger described the cave stream as "black" in color with a strong "sweet" odor apparently from the decaying tannic acid in the water. Presently, the cave stream appears to have recovered and is of good water quality. Where suitable habitat is accessible, *L. usdagalun* occurs in high densities, greater than $100/m^2$.

2.3.1.6 Habitat or ecosystem conditions:

As a result of successful remediation of sawdust waste, leachate contamination has been abated and, consequently, the cave stream habitat and fauna of Thompson Cedar cave have partially recovered. The Lee County cave isopod was rediscovered in this cave stream in February 19, 2002. Since its rediscovery, the population seems to be stable although not nearly as robust as previously documented. As mentioned in the evaluation of recovery criteria above (section

2.2.3), recent water quality data suggest the cave stream habitat may still be compromised to some level. Primarily, dissolved oxygen levels have been recorded at low levels particularly during periods of low flow conditions. Some level of siltation persists on the floor of the cave stream, potentially further compromising habitat for the Lee County cave isopod.

2.3.2 Five-factor analysis:

The current recovery plan for the Lee County cave isopod does not address threats with regard to the five listing factors. Consequently, the lead biologist conducted an assessment of current threats to the Lee County cave isopod (Attachment 1). The following five-factor analysis is based on known threats and the results of the attached threat assessment.

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

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 depressions or sinkholes, blind valleys, sinking streams, springs, and caverns, reflecting the development of subsurface drainage systems with direct connections to the surface. In contrast to non-karst 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 either no or minimal filtering by soils (Smith 1991). The geochemical, hydrological, and climatic characteristics of the Cedars form an uncommon habitat that is home to 32 State and globally rare plant and animal species. This fragile ecosystem is particularly vulnerable to ground disturbances and stormwater discharges that are concentrated or contaminated.

The primary threat to the Lee County cave isopod is destruction and modification of its habitat. Degradation of water quality, in particular, serves as the greatest stressor to the species over its entire range. Six major threats that contribute to the destruction and modification of habitat have been identified, including: development, logging, industry, agriculture, vandalism, and toxic spills.

Development

Although moderate in its severity, both residential and commercial development contributes sediment and contaminants to groundwater within the Cedars karst area. Several significant infrastructure developments have occurred in the Cedars, the cumulative effects of which have the potential to cause extinction.

An eighteen-hole golf course has been in operation since 1966 within the watershed that feeds the Flanary Bridge springs. The golf course lies directly within a large sinkhole that feeds the system. Maintenance of the golf course with fertilizer and pesticides may pose a significant threat to the isopod population of the Flanary Bridge spring system. Currently, the greens are maintained using Integrated Pest Management (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 fish and invertebrates. A liquid foliar fertilizer is applied as neede,d usually during the spring and fall of each year at a rate of 28 lbs per acre. The toxicity of the foliar to fish and invertebrates is not known.

Over the last 5 years the local municipality has been installing water lines along roads throughout the Jonesville area that includes the Cedars. Actual installation of the waterlines has not been of great concern to the conservation of the Lee County cave isopod; however, the water lines will likely encourage and enable development, the cumulative effects of which could pose a threat to *L. usdagalun* populations.

Between 2001 and 2003, the Lee County municipal airport was constructed within the Sim's Spring watershed. The airport is a general aviation facility with a 5,000-foot runway and full-length taxiway. Over 230 acres were disturbed and seven caves were filled during construction of the airport. Water quality monitoring reports show increased levels of sedimentation in the Sim's Spring system as a result of the construction, primarily from blasting, excavating, and fill activities. Because of the porous karst topography of the Cedars, the airport water retention ponds have thus far failed to retain stormwater. As a result, the Sim's Spring system is more vulnerable to stormwater events and contaminants such as de-icers and hydrocarbons derived from accidental fuel spills. According to a post-construction review of the airport, construction of the airport has caused increased turbidity in the Sim's Spring system as well as increased outflow during storm events (T. Roberts, Virginia Department of Conservation and Recreation, in litt. 2002). How this has impacted the Sim's Spring population of the Lee County cave isopod is not currently known.

Logging

Logging occurs throughout the watersheds that feed into the Cedars karst area. The severity of this threat is moderate over a substantial portion of the range of the Lee County cave isopod; however, it is unlikely that logging would cause extinction. With the exception of lands owned and protected by TNC and the DNH, all forest lands within the watersheds that

feed the Cedars are in private ownership. With the implementation and enforcement of State forestry Best Management Practices (BMPs), there is some potential for managing logging to reduce adverse effects on the Lee County cave isopod, although there is little control as to when and where logging will occur. Land acquisition and conservation easements appear to be the most effective tools in gaining permanent protection of forest lands. Although, no conservation easements have been established to date in the Cedars, TNC and DNH have acquired over 1,000 acres of land to form the Cedars State Natural Area Preserve and plans are underway to expand the preserve.

Industry

Apart from agriculture and logging, industry within the range of the Lee County cave isopod is currently represented by one operation, a local 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 Lee County cave isopod is known to occur. The Thompson Cedar Cave system drains into Batie Creek, which was listed as a TMDL (Total Maximum Daily Load, i.e., impaired waters as designated by the Virginia DEQ) in 1998; the creek was removed from the TMDL list in 2006, as explained below. The sawmill has operated for over twenty years within the karst watershed of Batie Creek, disposing massive amounts of sawdust in piles on its property, with an estimated total volume of 217,000 cubic yards. In 1987, the sinkhole and cave entrance of Thompson Cedar Cave were completely filled with sawdust. Leachate from beneath the piles was extremely high in tannin, lignin, total dissolved solids, and turbidity. The thin soils and well-developed karst landscape at the site allowed the leachate to drain with little or no filtration directly into the underlying aquifer. Decomposition of the leachate produced an intense biochemical oxygen demand, in some locations exceeding that of raw sewage. As a result, the cave fauna of Thompson Cedar Cave was reported to be extirpated in 1988. Concerns from both State and Federal agencies led to action to remediate the impacts. Late in 1988, the sawmill owner volunteered to remove the sawdust from the cave and install a clay berm to curtail drainage from the sawdust pile into the cave entrance. In December 1990, the sawmill owner signed an agreement with the governor-appointed Virginia Cave Board to address the issue; however, sawdust waste continued to be disposed on-site in vast stockpiles until 1998 when the Virginia DEQ issued a Consent order to the sawmill company to remove sawdust from the site.

As a result of the accumulation of decomposing sawdust, the water quality in both the Thompson Cedar Cave system and Batie Springs was extremely poor. In particular, Batie West Spring was marked by the

appearance of the filamentous sewage fungus *Sphaerotilus,* accompanied by a strong sewage odor. The degradation and their juxtaposition made the connection between Thompson Cedar Cave and Batie West Spring obvious. Dissolved oxygen levels at Batie West Spring from the late 1980s through the early 1990s ranged from 1 to 5.5 mg/l. During that period, all but one reading was above the standard of 5.0 mg/l for surface streams.

Since 1998, the USFWS in partnership with the Tennessee Valley Authority, the Upper Tennessee River Roundtable, and DNH has assisted the sawmill owner in removing 47,500 cubic yards of sawdust from existing piles. All newly generated sawdust waste has been transported off-site for incineration. As a result, water quality has improved dramatically since 2000, particularly with regard to dissolved oxygen levels, and Batie Creek was removed from the TMDL list in 2006 (Attachment 2).

Agriculture

Agricultural activities, including livestock operations, pose a moderate threat to the Lee County cave isopod over a substantial portion of its range. Although it is unlikely that agriculture alone would cause extinction, extinction risks could increase if the level of activity increases. BMPs are being initiated in the area; however, most of the livestock operations within the isopod's watersheds do not implement BMPs such as establishing or protecting riparian vegetation or excluding livestock from streams. Because of the nature of the karst terrain in the cedars, groundwater water quality is clearly affected by poorly managed agricultural practices. For example, as a result of nearby livestock activity, high levels of fecal coliform have been recorded in water from the Surgener Cave stream, one of the accessible locations for the Lee County cave isopod.

Vandalism

Because the Lee County cave isopod is confined to cave streams, its habitat is particularly vulnerable to vandalism and/or unintentional disturbance from recreational cavers. The threat is immediate and extends across a substantial portion of the isopod's known range, as the caves that harbor populations of the isopod are not protected from cave traffic. Given the assumption that an undetermined quantity of habitat is inaccessible and therefore protected from vandalism and human foot traffic, the likelihood that this threat will cause extinction is low. Although not currently necessary, barriers to exclude cavers could be installed in cave entrances to manage recreational caving activity and abate vandalism.

Toxic spills

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 (USFWS 1997). Thus, it is apparent that in this type of ecosystem, any single contamination event of land, surface streams, or underground caverns could rapidly contaminate springs and cave streams. Further, as development increases, the probability of unintentional toxic spills also increases. The severity of toxic spills from transport of fuels and chemicals and accidental releases from residents and industries is considered to be moderate and likely to impact a substantial portion of the Lee County cave isopod's range. Given the susceptibility of karst groundwater to contamination, this threat poses some level of extinction risk. In particular, the Sim's Spring population may be at risk because of potential contamination of groundwater from activities and accidents associated with the Lee County municipal airport. Although it is difficult to abate these threats entirely, management practices can be implemented to lower the risk. Such practices may include properly managed septic and sewer systems, tighter stormwater controls, fuel containment and limited use of deicers at the airport, and highway improvements that lower vehicle accident rates.

2.3.2.2 Factor B. Over-utilization for commercial, recreational, scientific, or educational purposes:

At the time of listing, the only potential collection identified was associated with scientific purposes. Currently, the threat of over-utilization for commercial, recreational, scientific, or educational purposes is low in severity and is not likely to cause extinction of the species. Known collections are tightly managed and regulated. No other utilization of specimens has been identified other than scientific collections for recovery efforts.

2.3.2.3 Factor C. Disease or predation:

At the time of listing, neither predation nor disease was considered a threat to the species continued existence. Although disease is likely to persist at some level within and among populations, nothing is known about diseases that affect the Lee County cave isopod. However, the Lee County cave isopod lives among a community of several other cave dwellers that likely prey on isopods as well as other crustaceans and small organisms. Within Thompson Cedar Cave in particular, there is a robust population of spring salamanders (*Gyrinophilus porphyriticus*) that likely prey on the isopod. In addition, crayfish, fish, and flatworms that also live

in the cave stream may consume the isopod. The predatory threat likely persists at some level over a substantial portion of the isopod's range, although the severity of the threat is thought to be low and unlikely to cause extinction.

2.3.2.4 Factor D. Inadequacy of existing regulatory mechanisms:

The protections provided by the Endangered Species Act of 1973 (ESA), as amended, are adequate to prevent a rangewide decline of populations of the Lee County cave isopod as long as it is listed. However, the ESA allows for incidental take, which has resulted in a potential decline of the Sim's Spring population. Further, at the current time, regulatory protections outside the ESA would be insufficient for preventing a rangewide population decline.

Under Section 305(b) of the Clean Water Act, states provide designated uses for streams. Designated use categories include: fish and aquatic life, livestock watering and wildlife, irrigation, navigation, domestic water supply, and industrial water supply, among others. Criteria to support the designated uses are also established and include numerical criteria for water quality parameters (e.g., ammonia, heavy metals, and dissolved oxygen) and narrative criteria for biological parameters (e.g., benthic macroinvertebrates). Streams that do not meet designated uses for certain criteria are placed on a Section 303(d) list of impaired waters. For instance, Batie Creek was listed as impaired in 1998 (and subsequently removed from the list) due to levels of dissolved oxygen that were less than half of that necessary to support aquatic life. An antidegradation policy establishes that all designated uses be maintained and guides the State as to which activities can or cannot be permitted in specific streams and stream reaches.

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

Currently there are no known non-native invasive species within habitat occupied by the Lee County cave isopod, nor have any other additional factors been identified as posing an extinction risk for the isopod. At the time of listing, increased human visits to caves was identified as a potential future threat, however, we now consider this under Factor A.

2.4 Synthesis

The Lee County cave isopod is endemic to The Cedars, a mature karst area located in Lee County, Virginia. This species has been documented from four major cave/spring systems: Thompson Cedar Cave, Flanary Springs, Sim's Spring, and the Surgener-Gallohan cave system.

The Lee County cave isopod was federally listed as endangered in November 1992, in large part because the Thompson Cedar Cave population, one of the two populations known prior to listing, was thought to be extirpated, leaving a single known population. Furthermore, the Lee County cave isopod has an extremely limited range, increasing its susceptibility to a single incident of groundwater pollution that could pose serious threats to the survival of the species.

In February of 2002, the Lee County cave isopod was rediscovered in Thompson Cedar Cave following abatement of contaminants associated with sawdust waste from a nearby sawmill operation. Although the isopod has become re-established in the Thompson Cedar Cave system, its abundance is much lower than estimates reported prior to impacts. Recent data obtained from periodic water quality monitoring indicate that the cave system may still be affected to some degree by residual sawdust waste.

Present or threatened destruction, modification, or curtailment of the Lee County cave isopod's habitat or range is the primary listing factor associated with threats to the species. Threats from development, logging, industry, agriculture, and toxic spills are seen as moderate in severity. Among all threats, development and toxic spills are the most likely to cause extinction, whereas threats from vandalism, scientific collection, predation, and invasive species are thought to be relatively low in severity.

Given the vulnerability of the subterranean habitats in The Cedars, it is recognized that permanent protection from significant groundwater contamination of all four cave and spring systems inhabited by the Lee County cave isopod may be unrealistic. However, continued efforts to protect the surrounding landscape and water quality through land acquisition, conservation easements, education, implementation of BMPs via voluntary cost-share programs, and proper planning of development could lower the risk of extinction to a point where downlisting or even delisting becomes possible. In the meantime, several important data gaps preclude an evaluation and determination of the species' status.

Recovery criteria for the Lee County cave isopod have been only partially met. Although monitoring has been initiated, additional time and effort will be required in order to accurately evaluate the isopod's biological status with any level of confidence. In sum, the Lee County cave isopod is considered to still be in danger of extinction throughout its entire range based upon the best information currently available about threats to the species and its biological status. The following considerations are particularly relevant to assessing the status of the isopod:

1. A thorough delineation of the present and historic distribution for this species has not been fully undertaken.

2. Although in process, baseline data sufficient to correlate habitat conditions with population status have not been obtained.

3. Sampling techniques have not been finalized nor has any attempt been made to monitor the populations known from Sim's Spring or the springs near Flanary Bridge.

4. Although steps are being taken to refine and increase population and water quality

monitoring, current available data are not sufficient to allow inferences about the isopod's population status in the two spring systems.

5. Although the population in Thompson Cedar Cave appears to be stable, abundance is much lower than historically reported, and several uncertainties exist regarding the quality of habitat and full recovery of the isopod in the cave system. Further monitoring will be necessary to evaluate the recovery of this population.

6. A groundwater monitoring program has been established; however, data gathering is in its infancy and available information does not suffice to lead to management that can ensure the survival of the isopod.

3.0 RESULTS

3.1 Recommended Classification: Retain as endangered. No change needed.

Rationale: The species continues to face a moderate degree of threat, and several important information gaps present an obstacle to accurately assessing the species' entire distribution and status of known populations. Additional monitoring of known populations will be necessary to determine their stability.

3.2 Recommended Recovery Priority Number: Retain as 8. No change needed.

Rationale: The listed entity is a species facing a moderate degree of threat and having a high potential for recovery.

3.3 Recommended Listing/Reclassification Priority Number: Not applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Below are recommendations for future actions organized into three categories. For each category, action items are listed in order of priority. Recovery action numbers are indicated for action items that relate to actions identified in the recovery plan for the species.

Recommendation: revise current recovery plan

The 1997 recovery plan for the Lee County cave isopod should be revised for the following reasons: (1) More detailed information has been gathered about threats, habitat, and populations that would inform a revised recovery strategy. (2) The Thompson Cedar Cave population has been re-established and is showing signs of recovery, providing significant information to modify current recovery criteria. (3) Recovery actions need to be adjusted because of new information and accomplishments. (4) Recovery criterion E needs to be re-worded to reflect a more realistic and attainable measure of recovery. (5) The five listing factors are not addressed in the recovery plan.

Recommendations for specific research and data needs

1. Establish and implement a population and water quality monitoring protocol 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. Recovery tasks 2.1, 2.2, 5.1, 5.2, 5.3, 5.4.

2. Conduct an investigation of karst resources southwest of the known populations and survey accessible cave streams to thoroughly delineate the present and historic distribution of this species. Recovery tasks 1.2, 1.3.

3. Conduct a quantitative assessment of the Thompson Cedar Cave and Gallohan Cave populations and compare with historic data to evaluate the current status of the two populations. Recovery tasks 1.1, 2.1, 2.2.

4. Conduct a presence/absence assessment of *L. usdagalun* to verify its continued presence at Sim's Spring and the Flanary Bridge springs. Recovery tasks 2.1, 2.2.

5. Conduct a Geographic Information System analysis to identify and quantify land cover and potential threats within each of the conservation sites identified by the DNH. Recovery tasks 4.1, 4.2.

Recommendations for conservation actions:

1. Continue to assist with and support land acquisition and establishment of conservation easements in The Cedars karst area, particularly with regard to expanding the Cedars State Natural Area Preserve. Recovery task 6.2.

2. Continue to work with partners to abate impacts to the Thompson Cedar Cave population from sawdust waste. Recovery task 6.2.

3. Continue to educate and work with landowners and managers to implement BMPs. Recovery tasks 5.5, 7.1, 7.2.

4. Continue working with the Lee County planning commission to plan development so as to minimize threats to the Lee County cave isopod. Recovery tasks 6.1, 6.2, 6.3.

5.0 REFERENCES

Data and literature are located within the U.S. Fish and Wildlife Service's Southwestern Virginia Field Office, 330 Cummings Street, Abingdon, Virginia 24210.

Culver, D.C.,. Jones, W.K, and Holsinger, J.R. 1992. Biological and hydrological investigation of The Cedars, Lee County, Virginia, an ecologically significant and threatened karst area. *In:* Stanford, J.A. and J.J. Simons. Proceedings of the First International Conference on Ground Water Ecology, pp. 281-290. U.S. Environmental Protection Agency and American Water Resources Association.

Estes, J.A. 1978. The comparative ecology of two populations of the troglobitic isopod crustacean *Lirceus usdagalun* (Asellidae). M.S. Thesis, Old Dominion University, Norfolk, Virginia. 85 pp.

Ewers, R.O., Idstein, P.J., Jacobs, J., and Keith, W. 1995. A hydrogeological investigation of "The Cedars," Lee County, Virginia. Unpublished report prepared for the Virginia Chapter of The Nature Conservancy. 25 pp.

Gilbert, Dale. 2007. Telephone conversation with Shane Hanlon, USFWS Southwestern Virginia Field Office on October 19, 2007, regarding management of Cedar Hill Country Club golf course.

Holsinger, J.R. 2007. E-mail to Shane Hanlon, USFWS Southwestern Virginia Field Office, on October 18, 2007, regarding information on history of Masons Cave.

Holsinger, J.R. and Bowman, T.E. 1973. A new troglobitic isopod of the genus *Lirceus* (Asellidae) from southwestern Virginia, with notes on its ecology and additional cave records for the genus in the Appalachians. International Journal of Speleology 5: 261-271.

Jones, W.K. 1990. Preliminary hydrological investigation of "The Cedars," Lee County, Virginia. Environmental Data Systems, Inc., Charleston, West Virginia. Unpublished report. 8 pp.

Neely, R.A. 1 996. Hydrogeological investigation of the proposed Lee County regional airport site, Lee County, Virginia. Report prepared by Mill Creek Environmental Consultants, Ltd. Hampton, Virginia, for Delta Airport Consultants, Inc. 7 pp.

Roberts, T. 2002. Electronic mail to Wil Orndorff, Virginia Department of Conservation and Recreation, Division of Natural Heritage, on November 25, 2002, regarding the Lee County airport.

Smith, L. 1991. An overview of the natural heritage resources of The Cedars, Lee County, Virginia. Unpublished report of the Division of Natural Heritage, Department of Conservation and Recreation. 8 pp.

U.S. Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants: Determination of endangered status for the Lee County cave isopod (*Lirceus usdagalun*). Federal Register 57 (225): 54722-54726.

U.S. Fish and Wildlife Service. 1997. Lee County cave isopod (*Lirceus usdagalun*) recovery plan. Hadley, Massachusetts. 40 pp.

Reviewers

Dr. John Holsinger, Professor of Biological Sciences, Department of Biological Scieneces, Old Dominion University, provided information for and peer review of this 5-year review.

Wil Orndorff, Karst Protection Coordinator, Virginia Department of Conservation and Recreation, Division of Natural Heritage, provided peer review of this 5-year review. Also provided data and field notes that were incorporated in internal joint reports between the USFWS and DCR-DNH.

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

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X__ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Shane D. Hanlon

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Roberta E. Hylton Date Jan. 25, 2008

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 9/4/08

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. Written concurrence from other regions is required.

Cooperating Regional Director, Fish and Wildlife Service – N/A

_____Concur _____ Do Not Concur

Signature_____ Date_____

ATTACHMENT 1

Threats Assessment for the Lee County cave isopod

Threats Assessment for the Lee County Cave Isopod (*Lirceus usdagalun*)

Coordinated and compiled by:

Shane Hanlon

U.S. Fish and Wildlife Service
Southwestern Virginia Field Office
330 Cummings Street
Abingdon, Virginia 24210
(276) 623-1233 x 25
shane_hanlon@fws.gov

April 12, 2007

This threat assessment was conducted by the FWS national lead biologist for the Lee county cave isopod (*Lirceus usdagalun*) as part of the 5-year review of the species recovery plan. This analysis was conducted assuming current and foreseeable conditions and does not consider stochastic events or unpredictable activities.

Methodology

Twelve species experts, including the lead biologist, were selected to assist in completing this threats assessment. The experts were selected based on their familiarity with the biology, ecology, and current status of *L. usdagalun*. A threats assessment worksheet was sent to each identified expert on March 21, 2007. Each species expert was requested to complete the worksheet independently and submit it back to the lead biologist by March 31, 2007. The lead biologist also completed the worksheet independently and prior to any revision of other worksheets completed by other experts. The worksheet identifies all the major threats associated with the five listing factors. Ten general threats were identified as impacting *L. usdagalun*. These include development, logging, industry, agriculture, vandalism, toxic spills, scientific collection, disease, predation, and invasive species. These threats are cross examined with six measures of threat which include: 1) Severity of the threat, 2) geographic scope of the threat, 3) immediacy of extinction as a result of the threat, 4) likelihood the threat will cause extinction, 5) possibility of abating the threat without ESA, and 6) management potential of the threat. This resulted in 60 fields to be evaluated and ranked based on best professional judgment. Experts were asked to rank each measure of each threat on a 3-level ordinal scale (e.g. 1 = low, 2 = moderate, 3 = high) as well as a nominal binary ranking of "0" if the measure for any particular threat was unknown. The lead biologist compiled the completed worksheets to obtain an average ranking for each field. If any given field received 2 or less ordinal rankings (knowns), the cell was assigned a "0" indicating that the particular parameter is unknown.

Summary of Results

Eight of the twelve experts responded with the completed worksheet. Two of the eight worksheets were excluded from analysis on the bases that these worksheets were either incomplete or completed incorrectly. Therefore, this assessment is based on the opinions of 6 species experts (appendix A).

Of the listing factors, habitat destruction / modification or range curtailment was clearly the dominant factor causing endangerment to the species (appendix B). Threats from developments and toxic spills pose the greatest overall risk to the species among the identified threats. Both ranked moderate in severity over a substantial portion of the species range and somewhat likely to cause extinction within the mid-term future. The threat of agriculture ranked similarly with the exception that it is not likely to cause extinction in the future. Although the threat of industry is moderate in severity, it is localized in geographic scope and is not likely to cause extinction of the species. The threat of logging is considered moderate in severity over a substantial portion of the range of the species; however, it is not likely to cause extinction in the mid-term future. The threat of vandalism could occur over a substantial portion of the species range; however it is considered low in severity and not likely to cause extinction. The threat of scientific collection is low in severity and not likely to cause extinction. Literally nothing is known about the threat of

disease to this species; therefore, all measures of threat were ranked as unknown. The threat of predation is considered low in severity and not likely to cause extinction even though it occurs over a substantial portion of the species range. The threat of invasive species is thought to be low, but not known to occur throughout the species range and therefore not likely to cause extinction.

APPENDIX A. List of contributors

Shane Hanlon
Fish and Wildlife Biologist
U.S. Fish & Wildlife Service
Southwestern Virginia Field Office
330 Cummings Street
Abingdon, Virginia 24210
276-623-1233 extension 25
276-623-1185 (facsimile)
Shane_hanlon@fws.gov

Braven Beaty
Science Specialist II
Clinch Valley Program
The Nature Conservancy
146 East Main Street
Abingdon, Virginia 24210
276-676-2209
276-676-3819 (facsimile)
bbeaty@tnc.org

Dr. David Culver
Biology Department, Hurst Hall 110A
American University
4400 Massachusetts Ave
NW Washington, DC 20016-8007
202-885-2180
202-885-2182 (facsimile)
dculver@american.edu

Larry Smith
Natural Area Protection Manager
DCR Natural Heritage Program
217 Governor Street
Richmond, Virginia 23219
804-371-6205
Larry.Smith@dcr.virginia.gov

Wil Orndorff
Karst Protection Coordinator
Virginia DCR Natural Heritage Program
6245 University Park Drive, Suite B
Radford, Virginia 24141
540-831-4056
540-831-4058 (facsimile)
Wil.orndorff@dcr.virginia.gov

Dr. John Holsinger
Professor of Biological Sciences
Dept. of Biological Sciences
Old Dominion University
Norfolk, Virginia 23529-0266
757- 683-3606
757-683-5283 (facsimile)
jholsing@odu.edu

APPENDIX B

Threat assessment worksheet and tables

Threats assessment worksheet for the Lee County Cave Isopod (*Lirceus usdagalun*) showing frequency distribution of responses.

LISTING FACTOR	THREAT	SEVERITY (intensity of effect where activity occurs) 0 = unknown 1 = low 2 = moderate 3 = high	GEOGRAPHIC SCOPE (extent of threat across species' range) 0 = unknown 1 = localized 2 = substantial portion of range 3 = rangewide	IMMEDIACY (how soon the threat could cause extinction) 0 = unknown 1 = distant future or not at all 2 = mid-term future 3 = near future	LIKELIHOOD (how likely it is that the threat will cause extinction in the future) 0 = unknown 1 = not likely 2 = somewhat likely 3 = very likely	POSSIBILITY OF ABATEMENT WITHOUT ESA 1 = highly possible 2 = to some degree 3 = not possible	MANAGEMENT POTENTIAL 1 = low 2 = moderate 3 = high
Habitat destruction/ modification (including fragmentation) or range curtailment	Development	0,0 1 2,2,2	1 2,2,2,2 3	0 2,2,2,2,2	1 2,2,2,2 3	2,2,2,2,2 3	1 2,2,2,2 3
	Logging	0 1,1 2,2,2	1 2,2,2,2 3	1,1,1,1 2,2	0 1,1,1 2,2	1,1 2,2,2 3	1,1,1 2,2 3
	Industry	0 1,1,1 2 3	0 1,1,1,1 3	0 1,1,1,1,1	1,1,1,1 2,2	1 2 3,3,3,3	1 2,2,2 3,3
	Agriculture	1,1 2,2,2,2	1,1 2 3,3,3	1,1,1 2,2,2	1,1,1,1,1 3	1 2,2,2 3,3	1,1 2,2,2 3
	Vandalism	0 1,1,1,1,1	0 1,1,1 3,3	0,0 1,1,1 3	0 1,1,1,1 2	1 2,2,2,2 3	0 1,1 3,3,3
	Toxic spills	0 1 2 3,3,3	0 1 2,2,2 3	0 1,1 2 3,3	1,1,1 2,2 3	2,2 3,3,3,3	1,1,1,1 2 3
Over-utilization	Scientific collection	1,1,1,1,1,1	1,1,1 2 3,3	1,1,1,1,1 3	1,1,1,1,1,1	1,1,1 2 3,3	1 3,3,3,3,3
Disease & predation	Disease	0,0,0,0,0 1	0,0,0,0,0 3	0,0,0,0 1 2	0,0,0,0 1,1	0,0,0,0 3,3	0,0,0 1,1,1
	Predation	0,0 1,1,1,1	0,0,0 1 3,3	0,0,0,0 1,1	0,0,0 1,1,1	0,0 2,2,2 3	0,0 1,1,1,1
Threats from other natural or man-made factors	Invasive species	0,0 1,1,1,1	0,0,0,0,0 2	0,0,0,0 1,1	0,0,0,0 1,1	0,0,0 2,2,2	0,0,0 1,1,1

Tabulation of responses from threat assessment worksheet for the Lee County Cave Isopod (*Lirceus usdagalun*)

Threat	Respondent	Severity	Geographic Scope	Immediacy	Likelihood	Abatement without ESA	Management Potential
Development	1	2	2	2	2	3	2
	2	0	2	2	2	2	3
	3	1	3	2	2	2	2
	4	0	1	0	2	2	2
	5	2	2	2	1	2	2
	6	2	2	2	3	2	1
	Number of knowns	4	6	5	6	6	6
	Total	7	12	10	12	13	12
	Average	2	2	2	2	2	2
Logging	1	1	2	1	1	1	2
	2	1	1	1	1	3	2
	3	2	3	2	2	1	3
	4	0	2	2	2	2	1
	5	2	2	1	0	2	1
	6	2	2	1	1	2	1
	Number of knowns	5	6	6	5	6	6
	Total	8	12	8	7	11	10
	Average	2	2	1	1	2	2
Industry	1	2	1	1	2	3	3
	2	3	1	1	1	3	3
	3	1	3	1	1	1	2
	4	0	0	0	2	3	2
	5	1	1	1	1	3	2
	6	1	1	1	1	2	1
	Number of knowns	5	5	5	6	6	6
	Total	8	7	5	8	15	13
	Average	2	1	1	1	3	2
Agriculture	1	1	2	1	1	2	1
	2	2	3	2	1	2	3
	3	2	3	2	1	2	2
	4	2	1	2	3	3	2
	5	2	3	1	1	1	2
	6	1	1	1	1	3	1
	Number of knowns	6	6	6	6	6	6
	Total	10	13	9	8	13	11
	Average	2	2	2	1	2	2
Vandalism	1	1	1	1	1	2	3
	2	1	3	1	1	1	1
	3	1	3	0	1	2	0
	4	0	0	3	2	2	3
	5	1	1	1	1	2	3
	6	1	1	0	0	3	1
	Number of knowns	5	5	4	5	6	5
	Total	5	9	6	6	12	11
	Average	1	2	2	1	2	2

Threat	Respondent	Severity	Geographic Scope	Immediacy	Likelihood	Abatement without ESA	Management Potential
Toxic spills	1	3	2	3	2	2	1
	2	3	2	1	1	2	2
	3	1	3	0	1	3	1
	4	0	0	3	3	3	3
	5	2	1	1	1	3	1
	6	3	2	2	2	3	1
	Number of knowns	5	5	5	6	6	6
	Total	12	10	10	10	16	9
	Average	2	2	2	2	3	2
Scientific collection	1	1	1	1	1	3	3
	2	1	3	1	1	1	3
	3	1	3	3	1	1	3
	4	1	1	1	1	1	3
	5	1	1	1	1	2	3
	6	1	2	1	1	3	1
	Number of knowns	6	6	6	6	6	6
	Total	6	11	8	6	11	16
	Average	1	2	1	1	2	3
Disease	1	0	0	0	0	0	1
	2	0	0	0	0	0	0
	3	1	3	2	1	3	1
	4	0	0	0	0	0	0
	5	0	0	1	1	3	1
	6	0	0	0	0	0	0
	Number of knowns	1	1	2	2	2	3
	Total	1	3	3	2	6	3
	Average	1	3	2	1	3	1
Predation	1	1	3	1	1	2	1
	2	0	0	0	0	0	0
	3	1	3	0	1	2	1
	4	0	0	0	0	0	0
	5	1	1	1	1	2	1
	6	1	0	0	0	3	1
	Number of knowns	4	3	2	3	4	4
	Total	4	7	2	3	9	4
	Average	1	2	1	1	2	1
Invasive species	1	0	0	0	0	2	1
	2	1	0	0	0	0	0
	3	1	0	0	0	0	0
	4	0	0	0	0	0	0
	5	1	2	1	1	2	1
	6	1	0	1	1	2	1
	Number of knowns	4	1	2	2	3	3
	Total	4	2	2	2	6	3
	Average	1	2	1	1	2	1

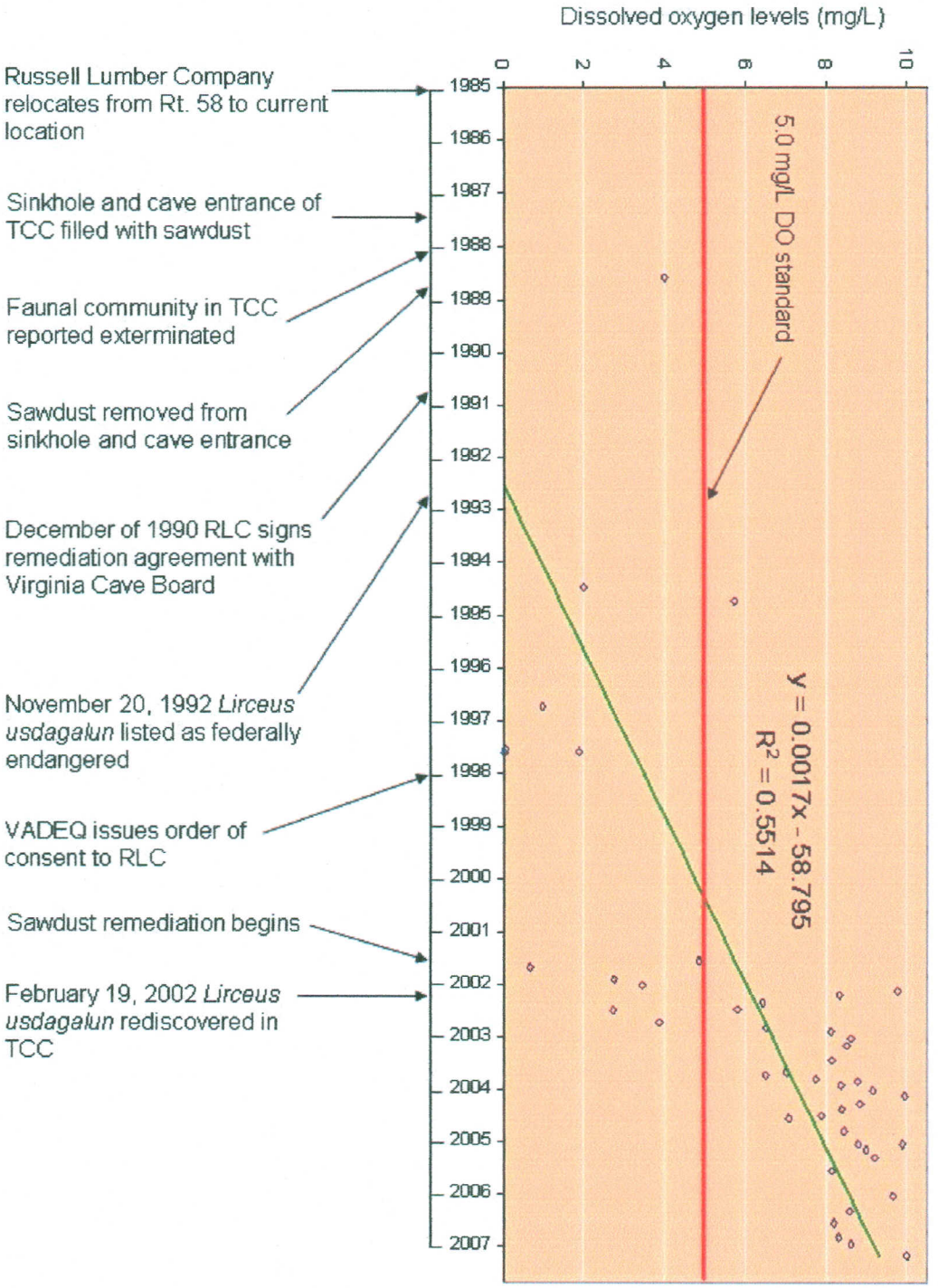
Threat assessment summary of averages from 6 respondents for the Lee County cave isopod (*Lirceus usdagalun*).

LISTING FACTOR	THREAT	SEVERITY (intensity of effect where activity occurs) 0 = unknown 1 = low 2 = moderate 3 = high	GEOGRAPHIC SCOPE (extent of threat across species' range) 0 = unknown 1 = localized 2 = substantial portion of range 3 = rangewide	IMMEDIACY (how soon the threat could cause extinction) 0 = unknown 1 = distant future or not at all 2 = mid-term future 3 = near future	LIKELIHOOD (how likely it is that the threat will cause extinction in the future) 0 = unknown 1 = not likely 2 = somewhat likely 3 = very likely	POSSIBILITY OF ABATEMENT WITHOUT ESA 1 = highly possible 2 = to some degree 3 = not possible	MANAGEMENT POTENTIAL 1 = low 2 = moderate 3 = high
Habitat destruction/ modification (including fragmentation) or range curtailment	Development	2	2	2	2	2	2
	Logging	2	2	1	1	2	2
	Industry	2	1	1	1	3	2
	Agriculture	2	2	2	1	2	2
	Vandalism	1	2	2	1	2	2
	Toxic spills	2	2	2	2	3	2
Over-utilization	Scientific collection	1	2	1	1	2	3
Disease & Predation	Disease	0	0	0	0	0	1
	Predation	1	2	0	1	2	1
other natural or man-made factors	Invasive species	1	0	0	0	2	1

Note: The above rankings are averages based on responses of 6 species experts.
A "known" response is represented as ordinal, non-binary data (e.g. 1 = low, 2 = moderate, 3 = high).
An "unkown" response is represented with "0" and is considered nominal, binary data
Rule: If any given cell receives 2 or less knowns, the cell is assigned a "0" = unknown

ATTACHMENT 2

Time line and dissolved oxygen monitoring of Batie Creek



Time line and dissolved oxygen levels of Batie Creek, Lee County, Virginia.