Redlips Darter (*Etheostoma maydeni*) Species Status Assessment

Version 1.1

Photo courtesy of Dr. David Neely, Tennessee Aquarium Conservation Institute
(East Fork Obey River, Fentress County, Tennessee, December 2017)

U.S Fish and Wildlife Service
Region 4
Atlanta, Georgia

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EXECUTIVE SUMMARY

Background

This species status assessment (SSA) describes the analytical process used by the U.S. Fish and Wildlife Service to assess the viability of the Redlips Darter, *Etheostoma maydeni*. During this process, we evaluated the three conservation biology principles of resiliency, representation, and redundancy (or the "3Rs") as they pertain to the species. The Redlips Darter is a small, colorful, benthic fish native to the Cumberland River system in Kentucky and Tennessee. It can be distinguished from other darters by its pointed snout, red lips, expanded soft dorsal fin, and four horizontal rows of spots along the top and side of the body. The species typically occupies pools of medium to large upland streams, where it is most commonly observed around boulders or large cobble surrounded by relatively silt-free sand or gravel substrates. The species feeds primarily on midge larvae and burrowing mayflies. Spawning occurs from January to April, and the species has a maximum lifespan of 4-5 years.

Methodology

The SSA process can be categorized into three sequential stages. During the first stage, we considered the Redlip Darter's life history and used the conservation biology principles of resiliency, redundancy, and representation to better understand the "needs" of populations and the species to maintain viability. The next stage involved an assessment of the historical and current condition of the species' demographics and habitat characteristics. The final stage of the SSA involved making predictions about future viability while considering the species' responses to anthropogenic and environmental influences that are likely to occur within its range. This process used the best available information to characterize viability as the ability of a species to sustain populations in the wild over time.

We delineated populations of the Redlips Darter using occurrence data obtained from peer-reviewed articles, unpublished survey reports, and survey records (1891 to present) contained in agency databases (i.e., Kentucky Department of Fish and Wildlife Resources (KDFWR), Kentucky State Nature Preserves Commission (KSNPC), Tennessee Department of Environment and Conservation (TDEC), Tennessee Wildlife Resources Agency (TWRA) and Tennessee Valley Authority (TVA)). Based on these sources, we identified seven Redlips Darter populations, each of which occurs in a distinct tributary system of the Cumberland River. .

We made qualitative assessments of the current condition (viability) of each population through evaluations of components describing the species' physical environment (Habitat Elements) or its demographics (Population Elements). Habitat elements included physical habitat, connectivity, and water quality. Population elements included reproduction, occurrence extent (total length of occupied streams compared to historical range), and occurrence complexity. We further defined how each of these components might vary in terms of condition. These metrics were selected because the supporting data were consistent across the range of the species and at a resolution suitable for assessing the species at the population level. The model output was a condition score for each Redlips Darter population that was then used to assess the Redlips Darter's current condition across its range relative to the "3Rs" described below:

Resiliency is assessed at the population level and describes the ability of a species to withstand stochastic disturbance (arising from random factors). Resiliency is positively related to population size, growth rate, and fecundity and may be influenced by connectivity among populations. Generally, populations need sufficient numbers of individuals within habitats of adequate area and quality to maintain survival and reproduction in spite of disturbance. Resilient populations are better able to withstand disturbances, such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

Redundancy describes the ability of a species to withstand catastrophic events (a rare destructive natural event or episode involving many populations). Generally speaking, redundancy is best achieved by having multiple, resilient (connected) populations widely distributed across the species' range. Having multiple populations reduces the likelihood that all populations are affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Therefore, as redundancy increases, species viability also increases.

Representation describes the ability of a species to adapt to changing environmental conditions over time and is characterized by the breadth of genetic and environmental diversity within and among populations. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range and other factors that may be appropriate to the species.

The same methodology was used to assess the species' condition and potential viability under three future scenarios. We chose to model these scenarios at 10, 30, and 50 years because we have data to reasonably predict potential habitat and water quality changes within this timeframe. Scenario 1 modeled the continuation of current trends where we assumed no change in urbanization rate, a moderate atmospheric emission scenario, and no changes in public ownership or conservation actions. Scenario 2 modeled a decreased rate of urbanization, lower emissions, and increased conservation activity across the species' range. Scenario 3 modeled an increased rate of urbanization, higher emissions, and no change in conservation activity across the species' range. Each of these scenarios had a different probability of occurring at different time steps, so probability categories were used to describe the likelihood of each scenario for each time period.

Conclusions

Current Condition

The Redlips Darter currently occupies four tributary systems of the Cumberland River – Obey River, South Fork Cumberland River, Buck Creek, and Rockcastle River. Populations within the Red River, Stones River, and Roaring River are considered to be extirpated. The South Fork Cumberland River and Rockcastle River populations exhibit high resiliency, as evidenced by the species' long-term persistence (over 100 years) in those systems; large population size and widespread distribution in both systems, including the mainstem and multiple tributaries; and the high quality of physical habitat and water quality conditions within both systems. Resiliency is lower in the remaining two populations (Buck Creek and Obey River) due to smaller population size, lower levels of occurrence extent, reduced connectivity caused by impoundments, and continued threats from typical land use. The Redlips Darter continues to occupy both of its historical ecoregions (Interior Plateau and Southwestern Appalachians), but representation is lowered (low-moderate) because of the species' extirpation from three of five Interior Plateau systems and a loss of connectivity caused by dam construction. The species has moderate redundancy based on the presence of two highly resilient populations, one population with low-moderate resilience, and one population with low resilience.

Future Condition

Under Scenario 1, extant populations are expected to persist across all time periods, with no adverse changes in habitat or water quality, no negative trends in population elements, and no changes in resiliency, redundancy, or representation.

Under Scenario 2, habitat threats across the species' range are expected to decrease due to lower urbanization rates, lower emission levels, and increased conservation efforts. Overall resiliency will increase for two populations through improved habitat conditions, increased occupancy extent of extant populations, and reintroduction of the species into one historical system (Roaring River). Representation is expected to improve from low-moderate to moderate, while redundancy is expected to remain at a moderate level.

Under Scenario 3, higher urbanization rates and emission levels lead to adverse changes in physical habitat, water quality, and occupancy extent, causing lower resiliency in one (Buck Creek) of four extant populations. Representation and redundancy are expected to remain the same.

Scenario 1 was considered to be the most likely to occur within the next 10 and 30 years, and it was considered to be "as likely as not" to occur over the course of 50 years. Scenario 2 was considered to be "unlikely" to occur in 10 years, and "as likely as not" to occur in 30 and 50 years. Scenario 3 was considered to be "very unlikely to occur in 10 years, "unlikely" to occur in 30 years, and "as likely as not" to occur in 50 years.

CHAPTER 1. INTRODUCTION

This report summarizes the results of a Species Status Assessment (SSA) conducted for the Redlips Darter (*Etheostoma maydeni*), a small benthic fish native to the Cumberland River system in Kentucky and Tennessee. We, the U.S. Fish and Wildlife Service (Service), were not formally petitioned to list the Redlips Darter as endangered or threatened under the Endangered Species Act (ESA), but on April 20, 2010, we were petitioned to list its closest relative, the Ashy Darter (*E. cinereum*), and 403 other aquatic, riparian, and wetland species (CBD 2010, entire). In 2011, the Service found that this petition presented substantial scientific or commercial information indicating that listing may be warranted for 374 species, including the Ashy Darter (76 FR 59836; 76 FR 62260). In 2012, the Ashy Darter was evaluated by Powers *et al.* (2012, entire), who concluded that populations from the Cumberland River drainage represented a distinct species – the Redlips Darter (*E. maydeni*). Based on these conclusions, the Service decided to conduct an SSA for the Redlips Darter concurrent with the Ashy Darter SSA.

The SSA framework (USFWS 2016, entire; Smith *et al.* 2018, entire) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program, including the cycle from Candidate Assessment to Listing and Recovery, as well as Consultations. As such, the SSA Report will be a living document upon which other decision documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

The SSA will be the biological underpinning of the Service's decision on whether or not to propose to list the species as threatened or endangered and, if so, where to propose designating critical habitat. Importantly, the SSA Report does not result in a decision by the Service on whether the Redlips Darter should be proposed for listing as a threatened or endangered species under the Act. Instead, it provides a review of available information strictly related to the biological status of the species. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of any proposed decision will be announced in the Federal Register, with appropriate opportunities for public review and input.

For the purpose of this assessment, we generally define viability as the ability of the Redlips Darter to sustain natural populations in river and stream systems over time. Using the SSA framework (Figure 1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire).

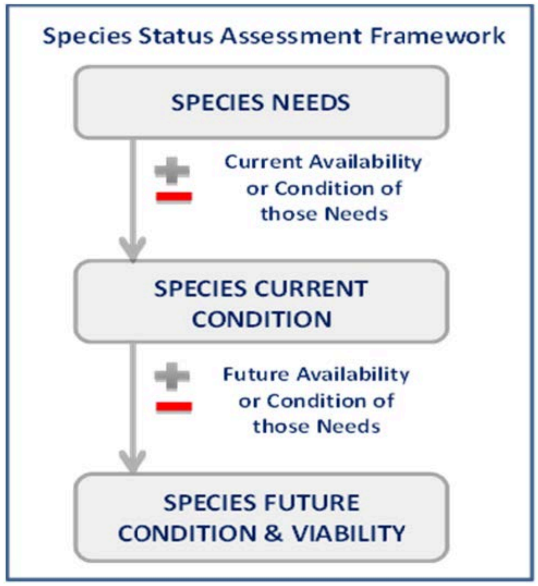

Figure 1. Species Status Assessment Framework

Resiliency

Resiliency describes the ability of a species to withstand stochastic disturbance (arising from random factors). Resiliency is positively related to population size, growth rate, and fecundity and may be influenced by connectivity among populations. Generally, populations need sufficient numbers of individuals within habitats of adequate area and quality to maintain survival and reproduction in spite of disturbance. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

Representation

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To evaluate the biological status of the Redlips Darter both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3Rs). This SSA Report provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species. This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future risk factors to the Redlips Darter.

CHAPTER 2. SPECIES NEEDS AND DISTRIBUTION

Biology and Life History

Taxonomy

The Redlips Darter is a member of the Class Actinopterygii (ray-finned fishes), Order Perciformes, and Family Percidae (perches) (Etnier and Starnes 1993, pp. 18–25). It was described by Powers *et al.* (2012, entire), who evaluated the morphology, genetics, and biogeography of the Ashy Darter (*Etheostoma cinereum*) species complex, concluding that populations of *E. cinereum* from the Cumberland River drainage represented a distinct species, *E. maydeni*. The separation of *E. cinereum* and *E. maydeni* was based on differences in two genes (cytochrome b gene and recombination activation gene), as well as differences in pigmentation and other morphological variables (Powers *et al.* 2012, p. 43). The Redlips Darter can be differentiated from the Ashy Darter based on its distribution (restricted to Cumberland River drainage) and the conspicuous red pigment on the lips (Figure 2). The Redlips Darter's taxonomy and common name have been accepted by the scientific community, as evidenced by the species' inclusion in Page *et al*. (2013, pp. 138, 222) – a list of common and scientific names of fishes from the United States, Canada, and Mexico published by the American Fisheries Society (7^{th} edition).

Physical Description

The Redlips Darter is a small, compressed fish, with a maximum total length of about 115 mm (4.5 in.) (Figure 2) (Powers *et al.* 2012, p. 52). The species is characterized by an elongated, pointed snout; rust to blood red coloration on the lips, margin of the first dorsal fin (first fin along top of body), and interradial membranes (membranous tissue between the fin rays) of both dorsal fins; large and expanded second dorsal fin of males (second fin along top of body); rust to faint red spots in four horizontal rows along the top and side of the body; and iridescent blue coloration on rays of the anal (single belly fin near the tail) and pelvic (paired belly fins near the head) fins of breeding males (Shepard and Burr 1984, p. 696; Powers *et al.* 2012, p. 53). The background body coloration is cream to light brown, with a series of 10-13 dark brown to black lateral blotches that are oval to rectangular in shape and that expand to form faint diagonal bands along the side of the body. The bands typically form an interrupted lateral stripe that extends through the eye to the tip of the snout (Shepard and Burr 1984, p. 696).

Genetics

Powers *et al.* (2012, entire) and Powers *et al.* (2004, entire) examined genetic differences within the *E. cinereum* complex, but no information is available on population genetics of the Redlips Darter.

Figure 2. Left lateral view of a male Redlips Darter from the Rockcastle River, August 2010 (Photo courtesy of Dr. Matthew Thomas, Kentucky Department of Fish and Wildlife Resources).

Habitat

The Redlips Darter is typically observed in clear pools or eddies of medium to large upland streams, with silt-free sand or gravel substrates (Kuehne and Barbour 1983, p. 72; Shepard and Burr 1984, p. 708; Etnier and Starnes 1993, p. 481) (Figure 3). In these habitats, the species is most often associated with large cobble, boulders, stands of water willow (*Justicia americana*), or woody debris at depths ranging from 0.5-1.75 m in areas of slow current adjacent to faster current (Kuehne and Barbour 1983, p. 72; Shepard and Burr 1984, p. 708; Compton and Taylor, 2013, p. 188). Snorkeling observations have revealed that the species spends much of its time beneath or in close proximity to slab-rock boulders (Etnier and Starnes 1993, p. 481). The species' close association with cover makes it difficult to collect with traditional seining techniques and may partially explain why it has often been observed in low numbers (Shepard and Burr 1984, p. 708).

Compton and Taylor (2013, entire) examined habitat associations for Redlips Darter adults and juveniles at two spatial scales (stream reach and microhabitat) within the Rockcastle River system in Kentucky. The distribution and abundance of adults and juveniles differed significantly at each spatial scale, and both groups demonstrated non-random use of the available habitat. At the reach scale, stream size was one of the most important limiting factors affecting the distribution of adult and juvenile darters. Redlips Darters were observed at all fifth order mainstem sites (watershed size > 750 km^2 (290 mi^2)) and in lower fourth order reaches of larger tributaries (watershed size > 100 km^2 (38.6 mi^2)). Within a given stream reach, Compton and Taylor (2013, p. 187) also demonstrated the importance of large boulders and their proportion within a stream reach. The species was always present in reaches when at least 20% of microhabitat plots contained one large boulder (intermediate axis width >0.5 m).

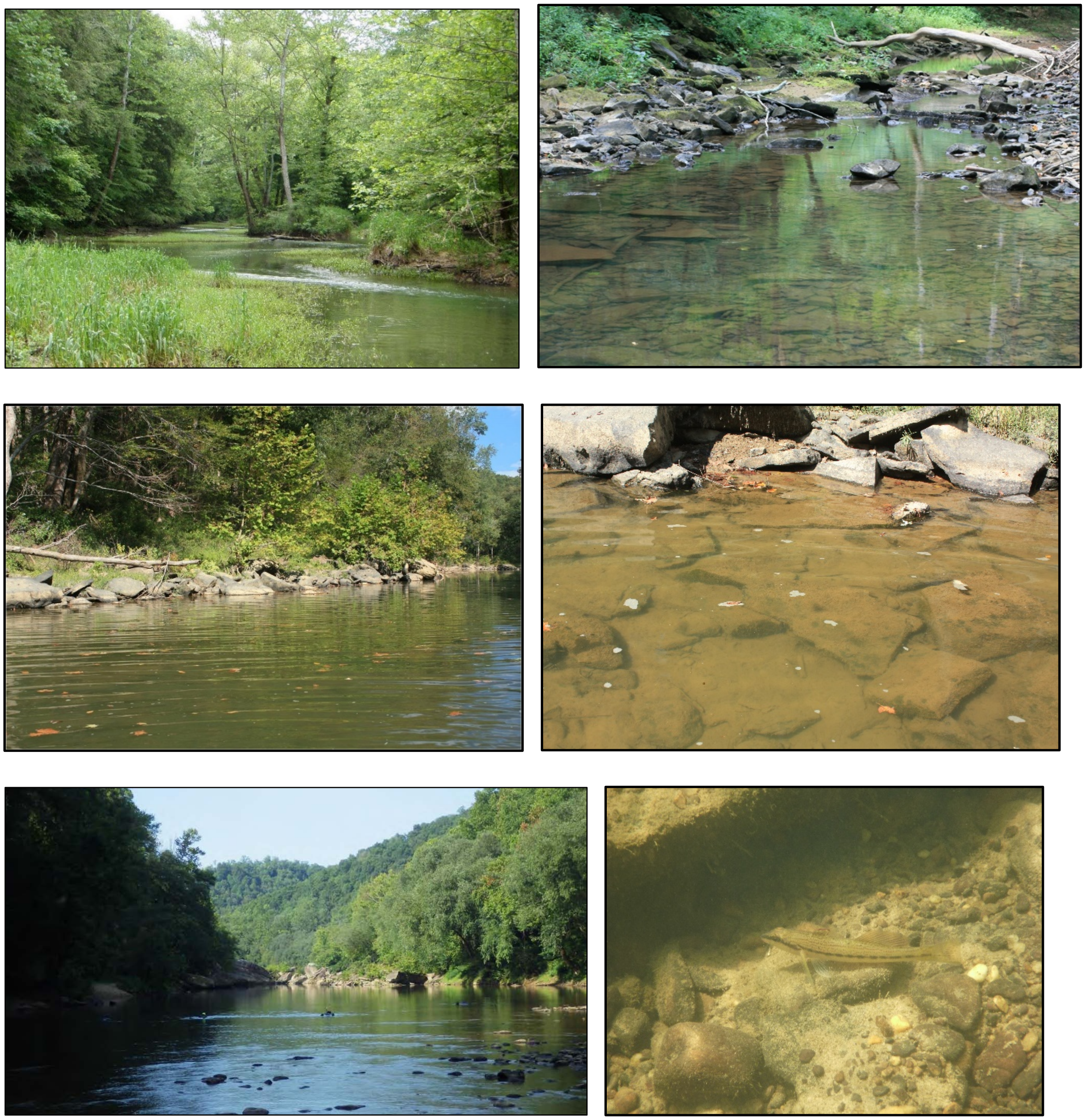

Figure 3. Redlips Darter Habitats: Buck Creek, Pulaski County, Kentucky (top L); Horse Lick Creek (at low flow condition), Rockcastle County, Kentucky (top R); Rockcastle River, Rockcastle County, Kentucky (middle L and R); South Fork Cumberland River, McCreary County, Kentucky (bottom L); Rockcastle River (microhabitat with darter resting on bottom), Rockcastle County, Kentucky (bottom R). (Photos courtesy of Dr. Matthew Thomas, KDFWR (top L and R); Mike Compton, KSNPC (middle L and R, bottom R); and Jeff Simmons, TVA (bottom L)).

At the microhabitat scale, Compton and Taylor (2013, p. 188) provided strong evidence that stable rock substrates, in particular large boulders (>0.5m), minimal silt, pools, and no or slow flow are important habitat variables for the species. Adults occurred more frequently along channel margins, particularly the outside channel bend, and were mostly associated with larger substrates (i.e., boulder and cobble). Juveniles were more evenly distributed within the channel and were associated with smaller substrates. Large woody debris and water willow had been identified previously as important habitat factors for the species (Shepard and Burr 1984, entire), but Compton and Taylor (2013, p. 188) considered these habitat factors to be secondary and of minimal importance to the species. Overall, Compton and Taylor (2013, p. 188) viewed large rock substrates as the primary cover for the species, and they considered excessive silt to be one of the principal factors detrimental to the species.

Feeding Habits

Shepard and Burr (1984, p. 711) identified midge (Chironomidae) larvae, burrowing mayfly larvae (*Ephemera*), and oligochaete worms as the primary prey items of the *E. cinereum* complex; however, Cumberland River populations (i.e., *E. maydeni*) showed a greater reliance on burrowing mayflies and oligochaetes. Smaller individuals (< 40 mm standard length (SL)) of *E. cinereum* and *E. maydeni* fed almost exclusively on midges, while larger individuals (41-60 mm SL) fed on a mixture of mayflies, oligochaetes, and midges (Shepard and Burr 1984, p. 711). Stomachs of the largest individuals (> 60 mm SL) were dominated by larger food items such as mayflies, stoneflies (Plecoptera), and caddisflies (Trichoptera). Other reported food items include amphipods, isopods, mayflies (*Stenonema*), and limpets (*Ferrissia*) (Shepard and Burr 1984, p. 711). The dominance of midge larvae, burrowing mayflies, and aquatic worms reinforced previous observations that the species' principal habitat is sandy-bottomed pools where these prey items occur (Shepard and Burr (1984, p. 711). The species' feeding behavior is unknown, but its elongated snout and papillose lips may be specializations for feeding on burrowing organisms.

Reproduction and Life History

The species' spawning period likely extends from January to early April, with peak spawning in mid-March (Figure 4) (Shepard and Burr 1984, p. 711; Etnier and Starnes 1993, p. 481). Based on laboratory observations of reproductive behavior of *E. cinereum*, Rakes *et al.* (2017, p. 5) hypothesized that adults come into reproductive condition in the wild by early February and begin spawning when water temperatures exceed about 8ºC. If water temperatures stay close to 10ºC or do not rise and stay above 15ºC, spawning may last for one month or more. The maximum lifespan reported by Shepard and Burr (1984, p. 708) was 52 months (5 year classes) (Table 1).

Males and females become sexually mature by year 2 (all males greater than 50 mm SL (standard length) and females greater than 55 mm SL) (Shepard and Burr 1984, p. 709), and females produce 50-250 ova (eggs) per year (Shepard and Burr 1984, p. 710). Spawning habitat and behavior are unknown, but the species' conical-shaped genital papilla of gravid females suggests the species may bury the eggs or attach them to hard substrates (Shepard and Burr 1984, p 711; Powers and Mayden 2002, p. 264). In aquarium settings, females of *E. cinereum* have laid eggs on filter tubes and pleated paper filters (simulating water willow stems/roots or rock crevices) (Etnier and Starnes 1993, p. 481; Rakes *et al.* 2017, p. 5). Laboratory observations by Rakes *et al.* (2017, p. 5) indicated that eggs and larvae cannot successfully develop at temperatures below 15ºC (optimal temperatures for spawning). Consequently, they suspected that a successful hatch and recruitment was dependent upon (1) the critical chance that occurrence and persistence of warmer temperatures overlap with the end of spawning or (2) the placement of eggs and the subsequent development of larvae in microhabitats that are warmer than the rest of the stream or river, such as sun-warmed shallows. Attachment of eggs to water willow stems or other substrates in shallow, warmer marginal habitats along shore would fit this scenario.

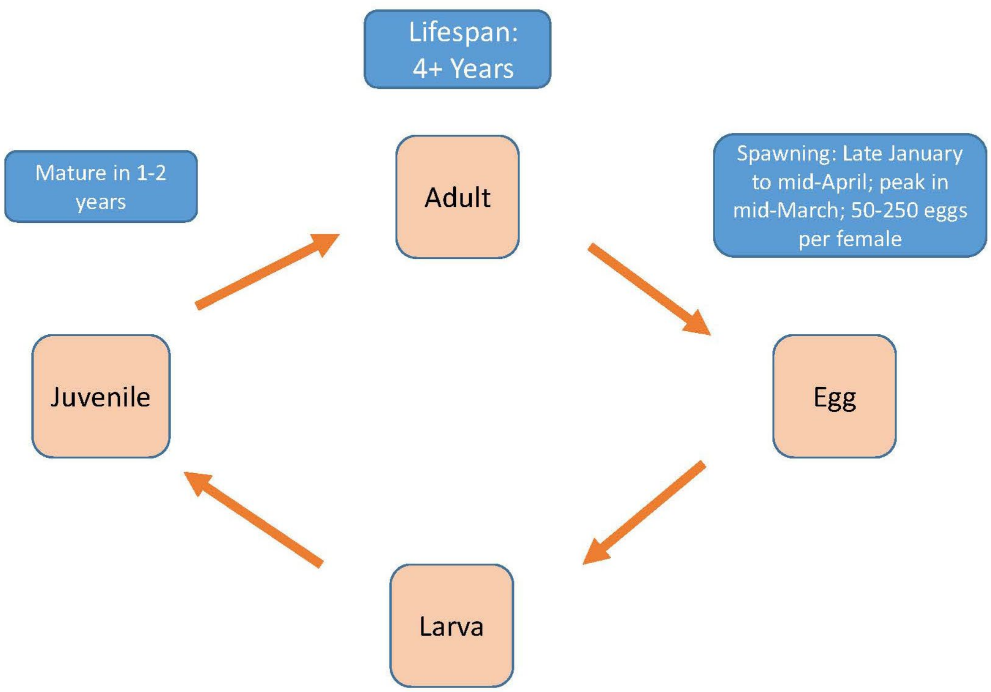

Figure 4. Redlips Darter life cycle.

Table 1. Overview of needs of individual Redlips Darters based on our knowledge of the species' biology, ecology, and life history summarized above.

Life Stage	Resources Needed	Information Source
Fertilized Egg	Water temperatures >15ºC (laboratory setting); Water willow stems/roots or rock crevices in shallow marginal habitats.	Rakes *et al.* 2017, pp. 5-6.
Larval	Water temperatures >15ºC (laboratory setting); Water willow stems/roots or rock crevices in shallow marginal habitats.	Rakes *et al.* 2017, pp. 5-6.
Juveniles	Clear pools, runs, and glides of free-flowing medium to large upland streams and rivers; cobble and boulder substrates throughout the channel; stands of water willow, and woody debris – with low amounts of siltation; food availability - Chironomidae (midge) larvae.	Shepard and Burr 1984, pp. 708-711; Etnier and Starnes 1993, p. 481; Rakes *et al.* 2017, entire.
Adults	Clear pools, runs, and glides of free-flowing medium to large upland streams; large cobble and slab-rock boulders (generally > 0.5 m), especially along stream margins and with minimal embeddedness and siltation; food availability - burrowing mayflies, oligochaetes, midges, stoneflies, and caddisflies; water temperatures of 8-15ºC for successful spawning (typically early February to April).	Shepard and Burr 1984, pp. 708-711; Etnier and Starnes 1993, p. 481; Rakes *et al.* 2017, entire.

Population Needs

Each population of the Redlips Darter needs to be able to withstand, or be resilient to, stochastic events or disturbances. Even though these events may happen infrequently, they are reasonably likely to occur and can drastically alter Redlips Darter habitats where they happen. Classic examples of stochastic events include drought, major floods, fire, and landslides (Chapin *et al.* 2002 p. 285 - 288). To be resilient to stochastic events, populations of Redlips Darters need to have a large number of individuals (abundance), cover a large area (spatial extent), and the area occupied needs to occur in multiple non-linear waterways or watersheds (spatial complexity). Additionally, populations need to exist in locations where environmental conditions provide suitable habitat and water quality such that adequate numbers of individuals can be supported. Without all of these factors, a population has an increased likelihood for localized extirpation.

Species Needs

For a species to persist over time, it must exhibit attributes across its range that relate to either representation or redundancy (Figure 5). *Representation* describes the ability of a species to adapt to changing environmental conditions over time and encompasses the "ecological and evolutionary patterns and processes that not only maintain but also generate species" (Shaffer and Stein 2000, p. 308). It is characterized by the breadth of genetic and environmental diversity within and among populations. For the Redlips Darter to exhibit adequate representation, resilient populations should occur in the ecoregions (Woods *et al.* 2002, entire) to which it is native (Interior Plateau and Southwestern Appalachians); these populations should occur at the widest extent possible across the historical range of the species; and they should occupy multiple tributaries in systems where they are native. The breadth of morphological, genetic, and behavioral variation should be preserved to maintain the evolutionary variation of the species. Finally, natural levels of connectivity should be maintained between representative populations because it allows for the exchange of novel and beneficial adaptations where connectivity is high or is the mechanism for localized adaption and variation where connectivity is lower or the species is naturally more isolated (Figure 5).

Redundancy describes the ability of a species to withstand catastrophic events. It "guards against irreplaceable loss of representation" (Redford *et al.* 2011, p. 42; Tear *et al.* 2005, p. 841) and minimizes the effect of localized extirpation on the range-wide persistence of a species (Shaffer and Stein 2000, p. 308). Redundancy for the Redlips Darter is characterized by having multiple, resilient and representative populations distributed within the species' ecological setting and across its range. For this species to exhibit redundancy, it must have multiple resilient populations with connectivity maintained among them. Connectivity allows for immigration and emigration between populations and increases the likelihood of recolonization should a population become extirpated (Figure 5).

Historical Range and Distribution

To determine the historical and current range of the Redlips Darter, we reviewed all available occurrence data (1891 to present) associated with peer-reviewed research (e.g., Everman 1918, Shepard and Burr 1984, Powers *et al.* 2012), unpublished survey reports (e.g., Thomas and Brandt 2017), university collections (e.g., The University of Tennessee Etnier Ichthyology Collection), and agency databases (i.e., KDFWR), KSNPC, TDEC, TWRA, and TVA).

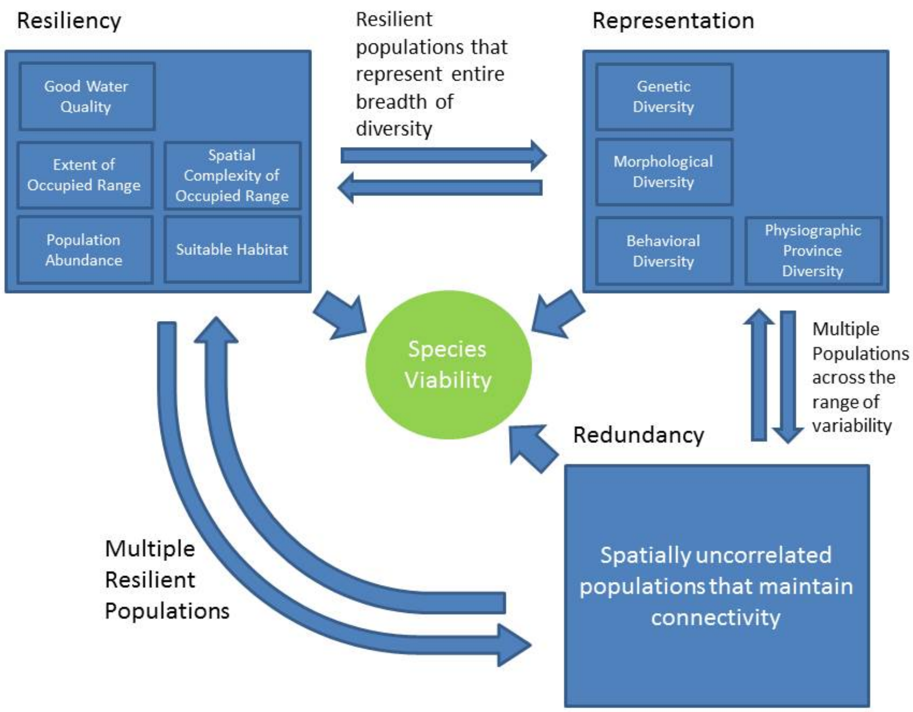

Figure 5. How resiliency, representation, and redundancy are related to species viability.

Additionally, the Service received survey data for the South Fork Cumberland River system (1990-2016) from CFI, a non-profit fish research and propagation facility in Knoxville, Tennessee. The Tennessee Ecological Services Field Office is currently funding a status survey within the Tennessee portion of the species' historical range (Neely 2018, entire). As part of this study, biologists with the TNACI are visiting historical collection localities across the species' range in Kentucky and Tennessee to provide an updated review of the species' distribution, especially in areas with limited survey efforts. All TNACI collection data obtained to present have been incorporated into our assessment to provide an accurate representation of the species' historical and current condition.

Historical Range

The species' historical range (prior to 2006) included seven large tributary systems of the Cumberland River downstream of Cumberland Falls in Kentucky and Tennessee (Figure 6) (Kirsch 1891, p. 264; Carrithers 1971, p. 46; Comiskey and Etnier 1972, p. 143; Shepard and Burr 1984, pp. 701-703; Evans 1998, pp. 34-35; Scott 2007, p. 21; Powers *et al.* 2012, p. 44). Moving upstream through the drainage, these tributary systems included the Red River (Kentucky and Tennessee), Stones River (Tennessee), Roaring River (Tennessee), Obey River (Tennessee), South Fork Cumberland River (Kentucky and Tennessee), Buck Creek (Kentucky), and Rockcastle River (Kentucky). The greatest number of historical occurrences are available from the South Fork Cumberland River and Rockcastle River systems. By the early 1980s, Shepard and Burr (1984, p. 703) noted that populations in the Red River, Stones River, Roaring River, Obey River, and Buck Creek systems had been extirpated or their status was unknown.

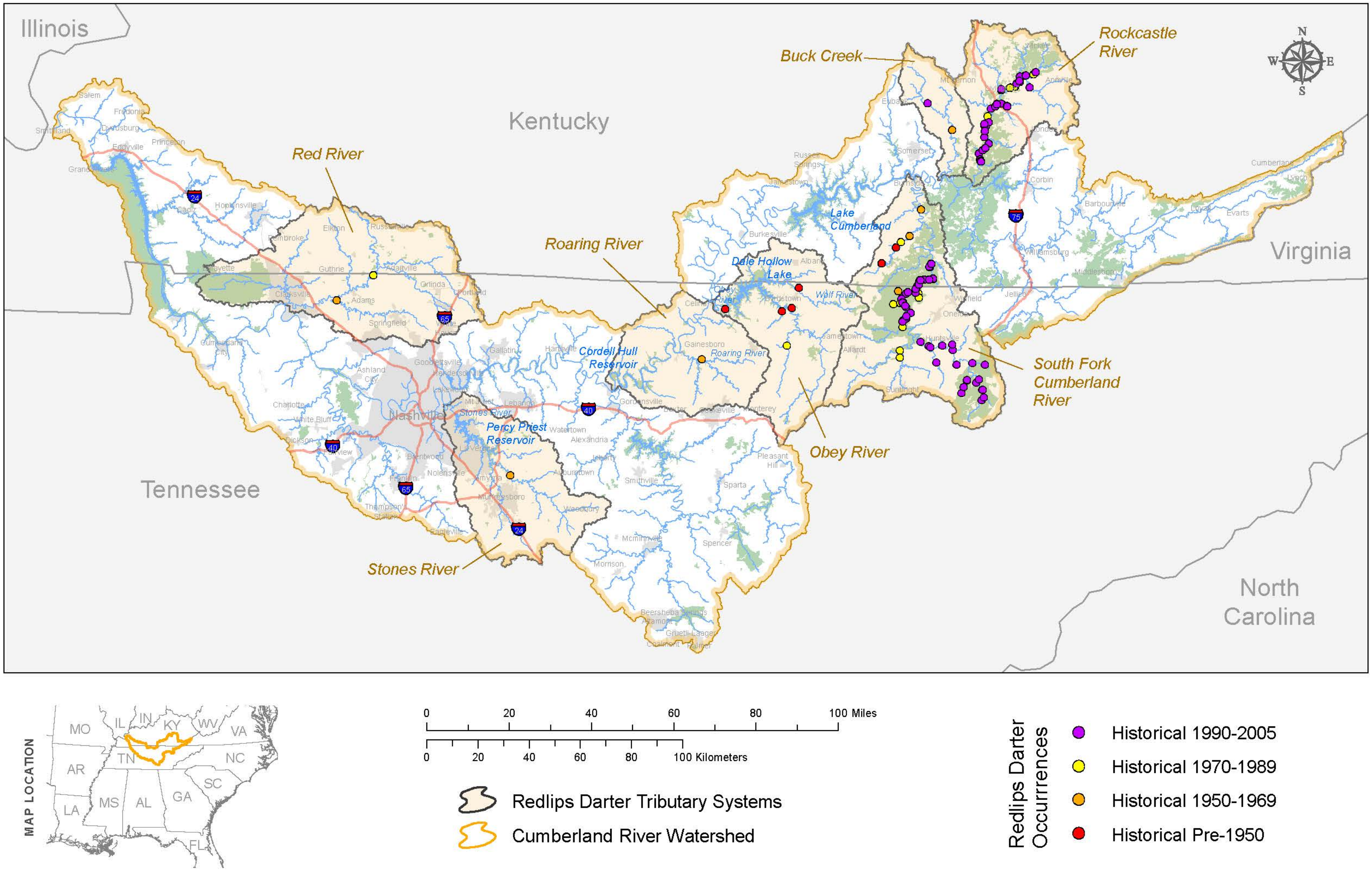

Figure 6. Historical distribution of the Redlips Darter in the Cumberland River drainage, Kentucky and Tennessee, based on positive occurrence records (1891-2005).

Potential stressors identified by Shepard and Burr (1984, p. 703) included impoundments, siltation, coal mining, and domestic and industrial pollution. Reproducing populations showing some recruitment were limited to the South Fork Cumberland River and Rockcastle River systems (Shepard and Burr 1984, p. 703; Evans 1998, pp. 34-35). Some researchers suspect that the Redlips Darter formerly used the Cumberland River mainstem as a migration corridor (for gene flow), and the species may have occupied appropriate habitats in the mainstem (Etnier and Starnes 1993, p. 481; B. Kuhajda, pers. comm., 2017). The species' historical distribution in each tributary system is summarized below.

<u>Red River</u>

Collections of *E. maydeni* in the Red River system are limited to a 1952 record (1 individual) near the confluence of Red River and Sulphur Fork Creek in Montgomery County, Tennessee and a 1957 collection (3 individuals) from the Red River near the KY/Tennessee state line (just south of Keysburg) in Robertson County, Tennessee (Shepard and Burr 1984, p. 702; Thomas and Brandt 2017, p. 10). The species was considered to be extirpated by Shepard and Burr (1984, pp. 702-703); heavy siltation and pesticide pollution were listed as possible reasons for the species' decline within the system.

<u>Stones River</u>

The only record of *E. maydeni* from the Stones River system is a single individual collected in 1961 near the U.S. Highway 231 crossing in Rutherford County, Tennessee (Shepard and Burr 1984, p. 702). Shepard and Burr (1984, pp. 702-703) considered the species to be extirpated from the Stones River system; inundation of potential habitat by J. Percy Priest Lake (established in 1968) was listed as the primary reason for the species' decline within the system.

<u>Roaring River</u>

The only record of the Redlips Darter from the Roaring River system is a single individual collected in 1968 near Gainsboro, Jackson County, Tennessee (Shepard and Burr 1984, p. 702; Crumby *et al.* 1990, p. 890). Creation of Cordell Hull Lake in 1973 and inundation of the lower reaches of Roaring River may have played a role in the species' decline within the system.

<u>Obey River</u>

The Redlips Darter was observed historically at five locations within the Obey River system in Tennessee. These locations included the Wolf River at Pryor Bend, Pickett County (1891); Obey River at Pryor Bend, Pickett County (1930); Obey River at mouth of Horse Creek, Clay County (1939); Obey River at mouth of Eagle Creek, Pickett County (1939), and West Fork Obey River at the Tennessee Highway 52 crossing, Overton County (1973) (Carrithers 1971, p. 46; Shepard and Burr 1984, p. 695; Service unpublished data). Shepard and Burr (1984, p. 702) were unable to locate additional specimens and listed the species' status as unknown. Creation of Dale Hollow Lake in 1943 and inundation of the lower reaches of the Obey River and Wolf Creek were identified by Shepard and Burr (1984, p. 702) as possible reasons for the species' decline within the system.

South Fork Cumberland River

Historical records for this system are available from 36 mainstem sites and 25 tributary sites in Kentucky and Tennessee (Comiskey and Etnier 1972, p. 143; Obara *et al.* 1982, p. 72; Obara and Estes 1984, p. 14; Shepard and Burr 1984, pp. 702-703; Evans 1998, pp. 34-35). The first Redlips Darter record from the system was a September 1891 collection (2 individuals) from Little South Fork Cumberland River (confluence with Kennedy Creek) in Wayne County, Kentucky (Kirsch 1893, entire). Shepard and Burr (1984, p. 703) described the South Fork Cumberland River population as "substantial" and reported it as one of two Kentucky populations with evidence of reproduction and recruitment. The species was reported historically throughout the length of the mainstem, from the confluence of New River and Clear Fork in Scott County, Tennessee, downstream to the mouth of Brush Creek in Pulaski County, Kentucky. The species was also observed at multiple sites in the Clear Fork and New River watersheds in Tennessee. Brazinski (1979, entire) did not observe the Redlips Darter during surveys conducted throughout the New River system in the late 1970s; however, the species was observed at 18 of 42 sites during surveys completed by Evans (1998, pp. 34-35). Evans (1998, pp. 34-35) concluded that improving water quality and habitat conditions within the New River system had allowed the species to reinvade the New River and its tributaries from downstream refugia such as the South Fork Cumberland River mainstem (Evans 1998, pp. 34-35). Tributaries with historical records include Beech Fork, Big Bull Creek, Brimstone Creek, Laurel Fork (of Station Camp Creek), Ligias Fork, Little South Fork Cumberland River, New River, Nicks Creek, No Business Creek, North White Oak Creek, Paint Rock Creek, Phillips Branch, Roaring Paunch Creek, Smoky Creek, White Oak Creek, and Williams Creek.

Buck Creek

The earliest records of the Redlips Darter within the Buck Creek system include a July 1954 collection (1 individual) at the Kentucky Highway 80 crossing in Pulaski County, Kentucky; a September 1955 collection (5 individuals) from the same locality; and an August 1955 collection (2 individuals) at the Brushy Creek confluence in Pulaski County (Shepard and Burr 1984, p. 702; Thomas and Brandt 2013, p. 10). Shepard and Burr (1984, p. 702) and Cicerello and Butler (1985, entire) were unable to locate additional specimens from Buck Creek and considered the species to be extirpated from the system. Acid mine wastes and chemical pollutants (pesticides) from agriculture were listed as possible reasons for the species' decline (Shepard and Burr 1984, p. 702). The species was rediscovered in Buck Creek in 1996 (Compton and Moeykens 2001, pp. 144-145), when a total of four individuals (young-of-year) were observed near the Buck Creek and Lick Fork confluence, an intra-system upstream range extension of approximately 7.5 km (4.7 mi).

Rockcastle River

The first record of the Redlips Darter from the Rockcastle River system was a May 1979 collection (1 individual) from the Rockcastle River mainstem (confluence with Grassy Shoal Branch) at the Laurel and Pulaski County border. Additional historical records are available from 28 mainstem sites and 12 tributary sites in Laurel, Pulaski, and Rockcastle counties, Kentucky. Shepard and Burr (1984, p. 703) considered the Rockcastle River population to be one of two Kentucky populations with evidence of reproduction and recruitment. Tributaries with historical records include Hazel Patch Creek, Horse Lick Creek, Laurel Fork (of Middle Fork Rockcastle River), Little Rockcastle River, Middle Fork Rockcastle River, Roundstone Creek, and South Fork Rockcastle River.

Current Range

The Redlips Darter continues to occupy large tributary systems of the Cumberland River downstream of Cumberland Falls, but it has disappeared or occurs in low densities in tributaries of the middle and lower portions of the drainage (Figure 7) (Powers *et al.* 2012, p. 53; Neely 2018, p. 6). Shepard and Burr (1984, p. 702) considered the species to be extirpated in the Red River and Stones River systems; survey efforts by Powers *et al.* (2012, p. 53), Johansen *et al.* (2017, pp 52-58), Thomas and Brandt (2017, p. 10), and Neely (2018, p. 6) support this conclusion. The species has not been observed within the Roaring River system since 1968, but the presence of suitable habitat and lack of comprehensive surveys within the system suggest the species could still be present in low densities (Powers *et al.* 2012, p. 53). In 2007, the species was rediscovered in the Obey River system – the first observation since 1973 – when a single juvenile was collected near the Tennessee Highway 52 bridge crossing of East Fork Obey River in Fentress County (B. Zimmerman, pers. comm., 2017). The site was revisited by TNACI in December 2017, resulting in the collection of two more individuals during an approximate one-hour survey effort (Neely 2018, p. 6). The mainstem and large tributaries of the South Fork Cumberland River and Rockcastle River continue to support the largest populations, with evidence of reproduction and recruitment (Powers *et al.* 2012, p. 53; Compton and Taylor 2013, pp. 180-182; TVA 2017, p. 40). The species continues to be extant in Buck Creek and has a more extensive distribution (greater occurrence extent) within the system than previously reported (Thomas and Brandt 2013, pp. 9-10; D. Black, pers. comm., 2017). A detailed overview of the species' current range and population resiliency is provided in the **Current Condition and Species Viability** section.

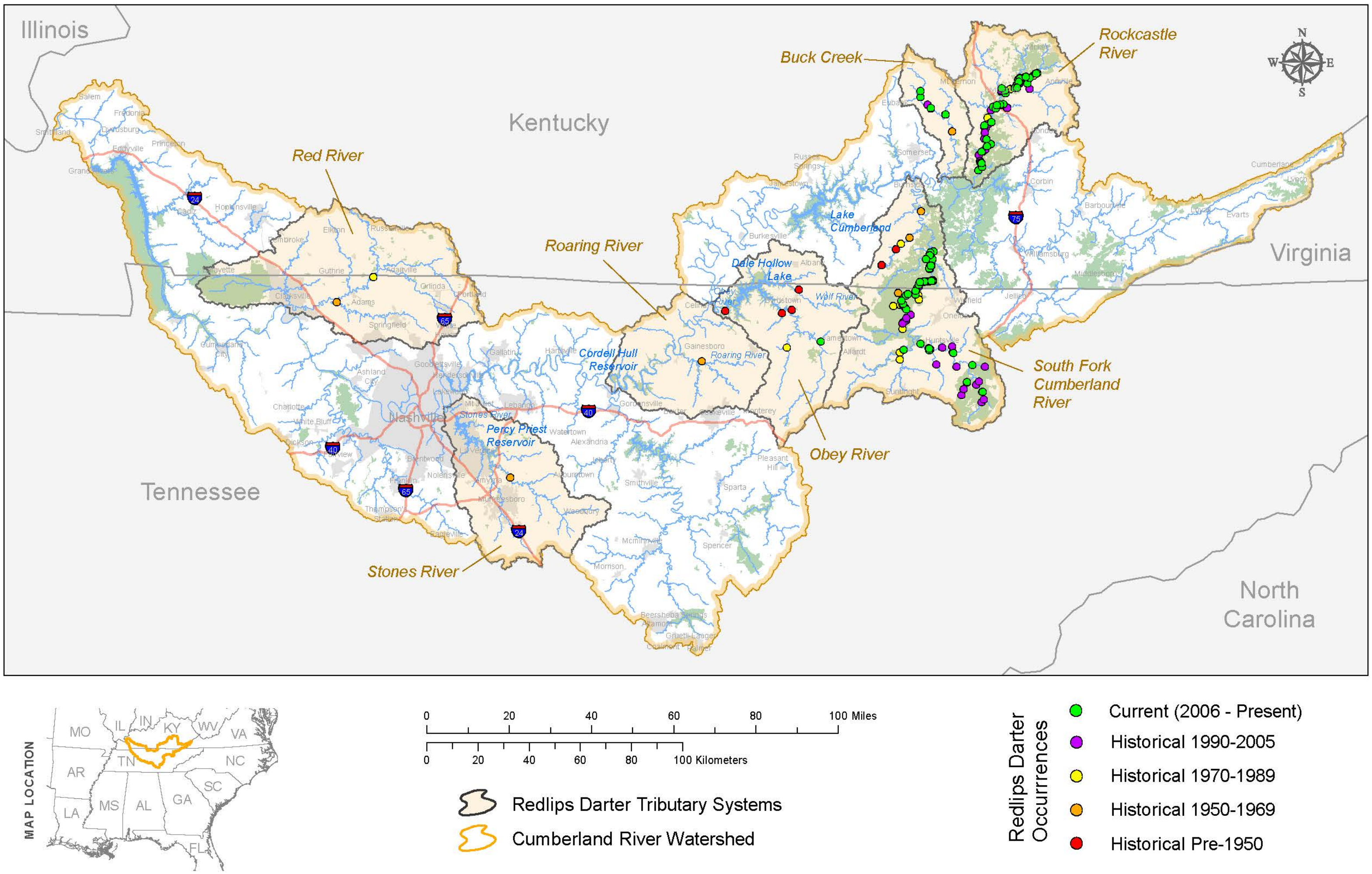

Figure 7. Current (2006-present) and historical distribution of the Redlips Darter in the Cumberland River drainage, Kentucky and Tennessee, based on positive collection records (1891-present).

CHAPTER 3. FACTORS INFLUENCING VIABILITY

In the following discussion, we summarize factors that may affect the viability of the Redlips Darter. We have identified four major factors: habitat loss and degradation (i.e., siltation, water quality degradation, and impoundment impacts), reduced range, climate change, and conservation actions (Figure 8).

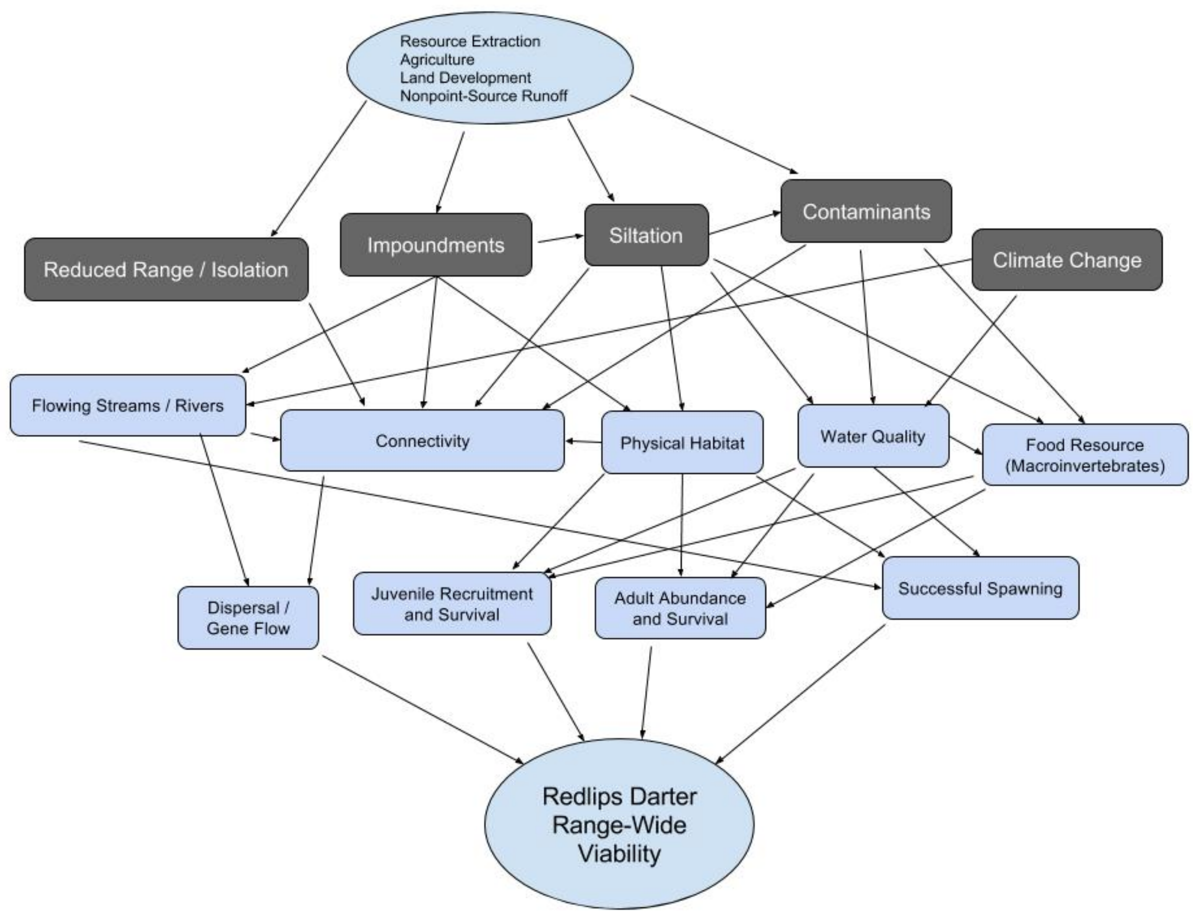

Figure 8. Redlips Darter Stressor Diagram

Habitat Loss and Degradation

Habitat loss and degradation is the principal factor affecting the viability of the Redlips Darter across its range in Kentucky and Tennessee. The primary stressors associated with these habitat alterations are siltation, water quality degradation (pollution), and hydrologic alteration (impoundments) (Carrithers 1971, pp. 51-52; Brazinski 1979, pp. 15-26; Shepard and Burr 1984, pp. 702-703; Powers and Mayden 2002, p. 264; Compton and Taylor 2013, pp. 188-189; KDOW 2013a, pp. 88-94, 107, 121-125).

Siltation

Siltation (excess sediments suspended or deposited in a stream) has been identified as one of the most common and significant stressors of the Redlips Darter (Shepard and Burr 1984, pp. 702-703; Powers and Mayden 2002, p. 264; Compton and Taylor 2013, pp. 188-189). Siltation of streams can be caused by channel instability, instream channel disturbance, or any soil-disturbing activity within the watershed. Siltation has been shown to abrade or suffocate fish gills, eggs, and larvae; reduce disease tolerance; degrade or destroy spawning habitats, affecting egg, larval, and juvenile development; modify migration patterns; reduce food availability through the blockage of primary production; and reduce foraging efficiency (Berkman and Rabeni 1987, pp. 285–294; Waters 1995, pp. 5–7; Wood and Armitage 1997, pp. 211–212; Meyer and Sutherland 2005, pp. 2–3). Shepard and Burr (1984, p. 703) suggested that pool habitats occupied by the Redlips Darter (i.e., areas with less current) may be especially vulnerable to the effects of siltation because these habitats lack the necessary current velocities to remove excessive silt deposits.

Within the Cumberland River drainage, the most commonly reported sources of siltation include loss of riparian habitat, channel disturbance, agriculture, land development, and resource extraction (e.g., surface coal mining, logging, natural gas development) (Shepard and Burr 1984, pp. 702-703; Powers and Mayden 2002, p. 264; Thomas 2007, p. 5; TDEC 2010, pp. 56-65; KDOW 2013a, pp. 88-94, 107, 121-125; KDOW 2013b, pp. 458–475, 502-529; KDOW 2015, pp. 61-70). The reduction or loss of riparian vegetation contributes to siltation through bank destabilization and the removal of submerged root systems that help to hold sediments in place while providing habitat for fish and macroinvertebrates (Barling and Moore 1994, p. 544; Beeson and Doyle 1995, p. 989; Allan 2004, p. 262; Hauer and Lamberti 2006, pp. 721–723; Minshall and Rugenski 2006, pp. 721–723). Removal of riparian vegetation can also reduce the stream's capacity for trapping and removing contaminants and nutrients from runoff; increase solar exposure, resulting in higher water temperatures; increase algal abundance (primary production); and reduce inputs of woody debris and leaf litter, thereby reducing food sources and lowering stream production (Brazier and Grown 1973, p. 4; Karr and Schlosser 1978, p. 231; Peterjohn and Correll 1984, p. 1473; Osborne and Kovacic 1993, p. 255; Barling and Moore 1994, p. 555; Vought *et al.* 1994, p. 346; Allan 1995, pg. 109; Wallace *et al.* 1999, p. 429; Pusey and Arthington 2003, p. 4).

Channelization of streams associated with agriculture and residential development is another common source of sediment within the Cumberland River drainage. Generally, channelization and dredging of streams occurs when channels are relocated to one side of the stream valley to provide space for home sites, livestock, hay production, or row crops. The resulting channelization dramatically alters channel dimensions, gradient, stream flow, and instream habitats, causing channel instability, erosion of bed sediments, and siltation (Allan 2004, p. 262). These modified channels are often managed through vegetation removal and dredging to improve flood conveyance (Allan and Castillo 2007, p. 327) or through placement of quarried stone or gabion baskets to protect against bank erosion. Unrestricted livestock access occurs on many streams and has the potential to cause siltation and other habitat disturbance (Fraley and Ahlstedt 2000, pp. 193–194). Grazing may reduce water infiltration rates and increase stormwater runoff; trampling and vegetation removal increases the probability of erosion and siltation (Brim Box and Mossa 1999, p. 103). Croplands have the potential to contribute large sediment loads during storm events, thereby causing increased siltation and potentially introducing harmful agricultural pollutants such as herbicides and pesticides.

Activities associated with resource extraction (e.g., surface coal mining, oil and gas exploration and drilling, and logging) are major sources of siltation in Kentucky and Tennessee streams (TDEC 2010, pp. 59-65; KDOW 2013a, pp. 88-94, 121-125; KDOW 2013b, pp. 502–529; KDOW 2015, pp. 61-70). These activities (e.g., land clearing, road construction, excavation) can produce new road networks and large areas of bare soil that, if not protected or controlled through erosion control practices, can contribute large amounts of sediment to streams during storm events. Land use practices, such as the placement of valley fills, can affect sediment and water discharges into downstream stream reaches, leading to increased erosion or sedimentation patterns, destruction or modification of in-stream habitat and riparian vegetation, stream bank collapse, and increased water turbidity and temperature (Wiley *et al.* 2001, pp. 1–16; Messinger 2003, pp. 17–20). Similarly, logging activities can adversely affect Redlips Darters through removal of streamside (riparian) vegetation, direct channel disturbance, and sedimentation of instream habitats. During logging activities, sedimentation occurs as soils are disturbed, the overlying leaf or litter layer is removed, and sediment is carried overland from logging roads, stream crossings, skid trails, and riparian zones during storm events. Logging impacts on sediment production can be considerable, but access and haul roads often produce more sediment than the land harvested for timber (Brim Box and Mossa 1999, p. 102).

Siltation of Redlips Darter habitats also occurs due to stream gravel mining and stormwater runoff from unpaved roads. Habitats within Buck Creek, Pulaski County, Kentucky, continue to be degraded by activities associated with illegal, instream gravel removal (M. Thomas, pers. comm. 2017). This practice degrades and destabilizes foraging and spawning substrates and can also lead to downstream bank instability and subsequent siltation. Stormwater runoff from unpaved roads, all-terrain vehicle (ATV) trails, and driveways represents a significant but difficult to quantify source of sediment that impacts streams throughout the Cumberland River drainage. Observations made by Service personnel during field collections suggest that this is a common and widespread problem during storm events.

Water Quality Degradation (Pollution)

Water quality degradation within the range of the Redlips Darter is caused by a variety of nonpoint source pollutants (contaminants from many diffuse and unquantifiable sources) (KDOW 2013a, pp. 88-94, 107, 121-125; KDOW 2013b, pp. 459-475; KDOW 2015, pp. 61-70). Historically, surface coal mining was identified as a significant source of these pollutants in the upper half of the species' range (i.e., Cumberland Plateau), including the Obey River, South Fork Cumberland River, Buck Creek, and Rockcastle River systems (Carrithers 1971, pp. 51-52; Bruzinski 1979, pp. 15-26; Shepard and Burr 1984, pp. 702-703; Powers and Mayden 2002, p. 264; KDOW 2013a, pp. 88-94, 121-125). Acid mine drainage (a mixture of sulfuric acid, iron compounds, acid salts, and other elements released from mined sites) was a significant problem from the 1950s to 1980s (Carrithers 1971, pp. 51-52; Brazinski 1979, pp. 15-26; Etnier and Starnes 1993, p. 481), but protective measures brought on by passage of the 1977 Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (33 U.S.C. 1251 *et seq*.), and the 1977 Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) (33

U.S.C. 1201 *et seq.*) have led to improved water quality conditions in the upper portions of these watersheds. Surface coal mining activity has also decreased in these systems over the last 10 years; a trend that is expected to continue (KEEC 2017, p. 2; KDEDI 2017, p. 18). Currently, there are no active surface mines within the known range of the Redlips Darter (T. Barbour, pers. comm., 2018; M. Moran, pers. comm., 2018).

Surface coal mining also has the potential to contribute high concentrations of dissolved metals and other solids that lower stream pH or lead to elevated levels of stream conductivity (Pond 2004, pp. 6-7; Black *et al.* 2013, pp. 35–46). Conductivity is a measure of electrical conductance in the water column that increases as the concentration of dissolved solids increases. Conductivity is often used as a surrogate of disturbance in mined watersheds, such as the Cumberland River drainage, where baseline conductivity values tend to be low (< 50 µS/cm). These impacts have been shown to negatively impact biological communities, including losses of mayfly and caddisfly taxa (Chambers and Messinger 2001, pp. 34–51, Pond 2004, pp. 6–7; Hartman *et al.* 2005, p. 95; Pond *et al.* 2008, pp. 721–723; Pond 2010, pp. 189–198) and decreases in fish diversity (Kuehne 1962, pp. 608–614; Branson and Batch 1972, pp. 507–512; Branson and Batch 1974, pp. 81–83; Stauffer and Ferreri 2002, pp. 11–21; Fulk *et al.* 2003, pp. 55–64; Mattingly *et al*. 2005, pp. 59–62; Thomas 2008, pp. 1–9; USFWS 2010, pp. 1–4, Black *et al*. 2013, pp. 34–45; Hitt 2014, pp. 11–13; Hitt and Chambers 2014, pp. 919–924). The direct effect of these pollutants on fishes, including the Redlips Darter, is poorly understood, but some listed species, such as Blackside Dace and Kentucky Arrow Darter, have shown declines in abundance over time as conductivity increased in streams affected by mining (Hitt 2014, pp. 11-13; Hitt *et al.* 2016, pp. 46-52), and these species are generally absent when conductivity values exceed 250 µS/cm (Black *et al.* 2013, pp. 34-35; Hitt 2014, pp. 11-14). It is unclear if Redlips Darters are adversely affected by dissolved solids associated with elevated conductivity, but these pollutants have adversely affected fish communities in the Cumberland Plateau region of Kentucky and Tennessee.

Oil and gas exploration and drilling activities represent another source of harmful pollutants on the Cumberland Plateau or eastern half of the species' historical range (KDOW 2013a, pp. 88-94, 121-125; KDOW 2015, p. 67). Alternative methods (i.e., hydraulic fracturing ("fracking") and horizontal drilling) have allowed for the expansion of oil and gas drilling into deposits that were previously inaccessible (KGS 2015, pp. 1–2; Papoulias and Velasco 2013, p. 92). This has led to increased activity within eastern Kentucky and Tennessee, including the Cumberland Plateau region. A variety of chemicals (e.g., hydrochloric acid, surfactants, potassium chloride) are used during the drilling process (Colborn *et al*. 2011, pp. 1040–1042) and can be harmful to aquatic organisms if they leave the drill site and enter nearby waterways (Wiseman 2009, pp. 127–142; Kargbo *et al.* 2010, p. 5680–5681; Osborn *et al.* 2011, pp. 8172–8176; Papoulias and Velasco 2013, pp. 92–111).

Other nonpoint-source pollutants that are common within the Cumberland River drainage and have the potential to affect the Redlips Darter include domestic sewage (through septic tank leakage or straight pipe discharges) and agricultural pollutants, such as animal waste, fertilizers, pesticides, and herbicides (KDOW 2013a, pp. 88-94, 121-125). Nonpoint-source pollutants can cause excess nutrification (increased levels of nitrogen and phosphorus), excessive algal growths, instream oxygen deficiencies, and other changes in water chemistry that can seriously impact aquatic species. Non-point source pollution from land surface runoff can originate from virtually any land use activity and has been correlated with impervious surfaces and storm water runoff (Allan 2004, pp. 266–267). Pollutants may include sediments, fertilizers, herbicides, pesticides, animal wastes, septic tank and gray water leakage, pharmaceuticals, and petroleum products. These pollutants tend to increase concentrations of nutrients and toxins in the water and alter the chemistry of affected streams such that the habitat and food sources for species like the Redlips Darter are negatively impacted.

Impoundments

Impoundments are often cited as a major threat to the Redlips Darter and a major factor influencing the species' current distribution within the Cumberland River drainage (Shepard and Burr 1984, pp. 702-703; Powers and Mayden 2002, p. 264; Compton and Taylor 2013, pp. 188-189). With the exception of the Red River system, all of the species' historical tributary systems have been impacted by large impoundments (Figure 6). These impacts have resulted from the creation of two reservoirs on the Cumberland River mainstem and two reservoirs on large tributaries (Table 2). An approximate 67.6-km (42.0-mi) reach of the Stones River system was impounded by the creation of J. Percy Priest Lake in 1968. This reservoir impounded portions of the Stones River, East Fork Stones River, and West Fork Stones River. The first 4.8 km (3.0 mi) of Roaring River were impounded by the construction of Cordell Hull Lake in 1973. An approximate 98.1-km (61.0-mi) reach of the Obey River system was impounded by the creation of Dale Hollow Lake in 1943, affecting the Obey River, East Fork Obey River, West Fork Obey River, and Wolf River. Extensive reaches of South Fork Cumberland River (45 km), Buck Creek (21 km), and Rockcastle River (14.5 km), were inundated by the creation of Lake Cumberland in 1952. Physical, chemical, and biological changes to these systems have been dramatic, and connectivity of populations within these systems has been diminished and in some cases eliminated.

Table 2. Summary of reservoirs affecting historical habitats of the Redlips Darter.

Reservoir	Construction Date	Dam Location	Length (km/mi)	Affected Redlips Darter Habitats
J. Percy Priest Lake	1968	Stones River	67.6 / 42.0	Stones River system: East Fork Stones River
Cordell Hull Lake	1973	Cumberland River	108.3 / 67.3	Roaring River system: Roaring River
Dale Hollow Lake	1943	Obey River	98.1 / 61.0	Obey River system: Obey River, East Fork Obey River, West Fork Obey River, and Wolf River
Lake Cumberland	1952	Cumberland River	162.5 / 101.0	South Fork Cumberland River, Buck Creek, and Rockcastle River systems

Impoundments cause dramatic changes in riverine habitats, including loss of riffle and shoal habitats; alteration of water flow, leading to increased sedimentation, nutrients, energy inputs, and outputs; increased sediment deposition; modification of flood pulses; increased water depths; decreased levels of habitat heterogeneity; reductions in bottom stability due to subsequent sedimentation; and creation of fish dispersal and migration barriers (Layzer *et al.* 1993, pp. 68-69; Neves *et al.* 1997, pp. 63-64; Watters 1999, pp. 261-262). Dams can also seriously alter downstream water quality and riverine habitat and negatively impact fishes in tailwater habitats (areas immediately downstream of the dam) (Freeman *et al.* 2001, p. 183; Power *et al.* 1996, p. 893). These impacts include changes and fluctuation in flow regime, channel scouring, and bank erosion; reduced dissolved oxygen levels and water temperatures; and changes in resident fish assemblages (Williams *et al.* 1992, p. 7; Layzer *et al.* 1993, p. 69; Neves *et al.* 1997, pp. 63–64; Watters 1999, pp. 265–266).

Reduced Range

The Redlips Darter has a limited geographic range. The existing populations are localized, and geographically isolated from one another due to impoundments, leaving them vulnerable to localized extinctions from intentional or accidental toxic chemical spills, habitat modification, progressive degradation from runoff (non-point source pollutants), natural catastrophic changes to their habitat (e.g., flood scour, drought), other stochastic disturbances, and decreased fitness from reduced genetic diversity. Potential sources of unintentional spills include accidents involving vehicles transporting chemicals over road crossings of streams inhabited by the Redlips Darter, or the accidental or intentional release of chemicals used in agricultural or residential applications into streams.

Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression, decreasing their ability to adapt to environmental changes, and reducing the fitness of individuals (Soulé 1980, pp. 157–158; Hunter 2002, pp. 97–101; Allendorf and Luikart 2007, pp. 117–146). Some small Redlips Darter populations (e.g., Buck Creek) may be below the effective population size required to maintain long-term genetic and population viability (Soulé 1980, pp. 162–164; Hunter 2002, pp. 105–107). The long-term viability of a species depends on the conservation of numerous local populations throughout its geographic range (Harris 1984, pp. 93–104). These separate populations are essential for the species to recover and adapt to environmental change (Harris 1984, pp. 93–104; Noss and Cooperrider 1994, pp. 264–297). The unnatural level of isolation of the Redlips Darter makes repopulation following localized extirpations virtually impossible without human intervention in certain parts of the range.

Climate Change

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) concluded that warming of the climate system is unequivocal (IPCC 2014, p. 3). Numerous long-term climate changes have been observed including changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones (IPCC 2014, p. 4). Species that are dependent on specialized habitat types, limited in distribution, or at the extreme periphery of their range may be most susceptible to the impacts of climate change (75 FR 48896, August 12, 2010, p. 48911); however, while continued change is certain, the magnitude and rate of change is unknown in many cases.

Climate change has the potential to increase the vulnerability of the Redlips Darter to random catastrophic events (McLaughlin *et al.* 2002, pp. 6060–6074; Thomas *et al.* 2004, pp. 145–148). An increase in both severity and variation in climate patterns is expected, with extreme floods, strong storms, and droughts becoming more common (Cook *et al.* 2004, pp. 1015–1018; Ford *et al.* 2011, p. 2065; IPCC 2014, pp. 58–83). Thomas *et al.* (2004, pp. 145–148) report that frequency, duration, and intensity of droughts are likely to increase in the Southeast as a result of global climate change. Predicted impacts of climate change on fishes include disruption to their physiology (such as temperature tolerance, dissolved oxygen needs, and metabolic rates), life history (such as timing of reproduction, growth rate), and distribution (range shifts, migration of new predators) (Jackson and Mandrak 2002, pp. 89–98; Heino *et al.* 2009, pp. 41–51; Strayer and Dudgeon 2010, pp. 350–351; Comte *et al.* 2013, pp. 627–636). According to Kaushal *et al.* (2010, p. 465), stream temperatures in the Southeast have increased roughly 0.2–0.4ºC (0.4–0.7ºF) per decade over the past 30 years, and as air temperature is a strong predictor of water temperature, stream temperatures are expected to continue to rise.

Estimates of the effects of climate change using available climate models typically lack the geographic precision needed to predict the magnitude of effects at a scale small enough to discretely apply to the range of a given species. However, data on recent trends and predicted changes for Kentucky (Girvetz *et al.* 2009, pp. 1–19), and, more specifically, the Cumberland River drainage (Alder and Hostetler 2017, entire) provide some insight for evaluating the potential impacts of climate change to the Redlips Darter. Alder and Hostetler (2017, entire) use different emission scenarios to calculate estimates of average annual increases in maximum and minimum temperature, precipitation, snowfall, and other variables. These scenarios, called "representative concentration pathways" (RCPs) are plausible pathways toward reaching a target radiative forcing (the change in energy in the atmosphere due to greenhouse gases) by the year 2100 (Moss *et al*. 2010, p. 752). Depending on the chosen model and emission scenario (RCP 8.5 (high) vs. 4.5 (moderate)), annual mean maximum temperatures for the Cumberland River drainage are expected to increase by 2.2 to 3.3ºC (3.8 to 5.9ºF) by 2074, while precipitation models predict that the Cumberland River drainage will experience a slight increase in annual mean precipitation (0.5 cm/month (0.2 in/month)) through 2074 (Girvetz *et al.* 2009, pp. 1–19; Alder and Hostetler 2016, pp. 1–9).

The upper thermal limits of the Redlips Darter are unknown, but the species' occurrence in a wide range of stream sizes (large creeks to medium-size rivers) suggests that it may have some tolerance to warmer water conditions. For similar reasons, we also assume the species may be less vulnerable to droughts, compared to species occurring in lower order or headwater streams. Consequently, the effects of climate change on species' viability are largely unknown, but limited information suggests the species may have some resilience to the effects of climate change. A "Climate Change Vulnerability Assessment" of more than 700 species in the Appalachian region ranked the Ashy Darter as "moderately vulnerable" to the effects of climate change (Appalachian Landscape Conservation Cooperative 2017). Moderately vulnerable was defined as "abundance and/or range extent within geographical area assessed likely to decrease by 2050." Even though the Redlips Darter was not identified in the assessment, it was included as part of the Ashy Darter range in Kentucky and Tennessee. Consequently, we conclude that the Redlips Darter likely would also be ranked as "moderately vulnerable" to the effects of climate change.

Conservation Actions

State Listings

The Redlips Darter has been identified as a species of special concern within Kentucky (KSNPC 2014, p. 40), but this state designation conveys no legal protection for the species or its habitat. Kentucky law prohibits the collection of the Redlips Darter (or other fishes) for scientific purposes without a valid state-issued collecting permit (KRS § 150.183). Enforcement of this permit requirement is difficult, but we do not believe that these activities represent a significant threat to the species. Persons who hold a valid Kentucky fishing license (obtained from KDFWR) are allowed to collect up to 500 minnows per day (a minnow is defined as any non-game fish less than 6 inches in length, with the exception of federally listed species) (301 KAR 1:130, § 1(3)). This regulation allows for the capture, holding, and potential use of the Redlips Darter as a bait species; however, we believe these activities are practiced infrequently and do not represent a threat that has substantial impact to the species.

The Redlips Darter has been designated as "Wildlife in Need of Management" (analogous to Special Concern) in Tennessee (TWRA 2000, p. 1; TDEC 2009, p. 53). Under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101-112): "[I]t is unlawful for any person to take, attempt to take, possess, transport, export, process, sell or offer for sale or ship nongame wildlife, or for any common or contract carrier knowingly to transport or receive for shipment nongame wildlife." Further, regulations included in the Tennessee Wildlife Resources Commission Proclamation 00-14 (Wildlife in Need of Management) (1) prohibits the knowing destruction of habitat of designated species without authorization and (2) provides circumstances for which permits can be given to take, posses, transport, export, ship, remove, capture, or destroy a designated species.

State Wildlife Action Plans

The Redlips Darter was identified as a Species of Greatest Conservation Need (SGCN) in both the Kentucky (KDFWR 2013, entire) and Tennessee (TWRA 2015, p. 48) State Wildlife Action Plans. The Kentucky plan identifies conservation issues (threats), conservation actions, and monitoring strategies for 251 animal species belonging to one of 20 terrestrial and aquatic habitat guilds (collection of species that occur in the same habitat). The Redlips Darter belongs to the "upland headwater streams in pools" guild. To fully understand these conservation issues, the KDFWR developed a priority list of research and survey needs for Kentucky's SGCN. Seven conservation actions were developed for the species' habitat guild (upland headwaters streams in pools): (1) the creation of financial incentives to protect riparian corridors and watersheds, (2) acquisition and conservation easements of critical aquatic habitat, (3) encouragement and assistance in developing and implementing best management practices, (4) restoration of degraded habitats, (5) coordination and implementation of existing Farm Bill programs or other

Federal incentive programs, (6) education of user groups on significance and importance of riparian corridors and watersheds, and (7) development and initiation of local watershed improvement projects. Other appropriate conservation actions for the Redlips Darter identified in KDFWR's plan include the removal of migration barriers (dams) and reductions in siltation and increased turbidity.

Tennessee's first comprehensive wildlife strategy (TWRA 2005, entire) involved the development of an integrated regional database and geographic information system (GIS) model based on the best available wildlife distribution data and comprehensive habitat classification systems and maps. It identified sources of stress, conservation priorities, and conservation actions for 664 animal species in one of three tiers (based on status) and in three general environments (aquatic, subterranean, and terrestrial). The plan was revised for the first time in 2015 (TWRA 2015, entire). Key attributes of the revised plan include an expansion of statewide mapping efforts to include priority problems affecting habitats; the identification of conservation opportunity areas; integration of climate change vulnerability assessments; the revision of Tennessee's SGCN list, including the addition of plants (as Tier 4); and the targeting of priority conservation actions with both government agency and non-governmental organization partners. The Redlips Darter is identified as a Tier 1 species in the aquatic environment (Cumberland River drainage). Tier 1 species are those defined as "wildlife" under Tennessee Code Annotated 70–8–101 (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans, and mollusks). Tier 2 includes all other fauna not defined as "wildlife" under Tennessee State law (i.e., insects and other arthropods), Tier 3 includes federally listed species or game species with alternate funding sources, and Tier 4 includes plants.

Existing Regulatory Mechanisms

The Redlips Darter and its habitats are afforded some protection from water quality and habitat degradation under the Clean Water Act, SMCRA, Kentucky's Forest Conservation Act of 1998 (KRS §§149.330–355), Kentucky's Agriculture Water Quality Act of 1994 (KRS §§ 224.71–140), Kentucky Wild Rivers Act (KRS §§146.200-360), additional Kentucky statutes and regulations regarding natural resources and environmental protection (KRS § 224; 401 KAR §§ 5:026, 5:031), Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974, and Tennessee's Water Quality Control Act of 1977 (T.C.A. 69–3–101). While it is clear that the protections afforded by these statutes and regulations have not prevented the degradation of some habitats used by the Redlips Darter, the species has undoubtedly benefited from improvements in water quality and habitat conditions stemming from these regulatory mechanisms.

Incidental Protections Provided by the Endangered Species Act

The Redlips Darter receives incidental protection under the Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 *et seq.*), because populations in the Buck Creek, Rockcastle River, and South Fork Cumberland River systems share habitats with multiple federally listed species: Cumberland Bean (*Villosa trabilis*), Cumberland Elktoe (*Alasmidonta atropurpurea*), Cumberlandian Combshell (*Epioblasma brevidens*), Fluted Kidneyshell (*Ptychobranchus subtentum*), Littlewing Pearlymussel (*Pegias fabula*), Oyster Mussel (*Epioblasma capsaeformis*), Spectaclecase (*Cumberlandia monodonta*), Tan Riffleshell (*Epioblasma florentina walkeri*), and Duskytail (=Tuxedo) Darter (*Etheostoma percnurum* (=*lemniscatum*) (Table 4, Appendix A). Section 7 of the Act requires Federal agencies to consult with the Service on any action that may affect a listed species or any action that may destroy or adversely modify critical habitat. Section 9 of the Act also provides protection against "take" of the species ("take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct). In Kentucky, streams supporting federally threatened or endangered species receive additional protection under Kentucky's water quality standards. Pursuant to 401 KAR §§ 10:031, Section 8, the existing water quality and habitat of these Outstanding State Resource Waters (OSRWs) shall be maintained and protected, unless it can be demonstrated that lowering of water quality or a habitat modification will not have a harmful effect on the threatened or endangered species that the water supports. Kentucky Pollutant Discharge Elimination System (KPDES) permits associated with OSRWs typically contain additional requirements (e.g., biological surveys) designed to protect waters supporting listed species. Because of these regulations, surface coal mining and other significant development activities with a Federal nexus have been excluded from, or severely limited in, Redlips Darter watersheds that support listed species.

CHAPTER 4. CURRENT CONDITION AND SPECIES VIABILITY

Current habitat and population conditions are described below. This section details specific stressors acting within each tributary system occupied by the species. Additionally, collection history and qualitative abundance is provided. Current resilience is assessed for each population, followed by a summary of range-wide redundancy and representation.

To qualitatively assess current viability, we considered 6 components that broadly relate to the species' physical environment ("Habitat Elements") or its populations ("Population Elements"). Habitat elements consisted of an evaluation of physical habitat, connectivity, and water quality. Population elements consisted of an estimation of reproduction, occurrence extent (total length of occupied streams compared to historical range), and occurrence complexity. We further defined how each of these components might vary in terms of condition (see Table 3).

For our analysis, we divided the species range into seven populations: Red River, Stones River, Roaring River, Obey River, South Fork Cumberland River, Buck Creek, and Rockcastle River (Figure 7). Information on population genetics and movement behavior is lacking for the Redlips Darter; however, we proposed these divisions based on our knowledge of the species' current distribution within the Cumberland River drainage and the level of geographic isolation observed among tributary systems. The seven historical tributary systems are separated from each other by long distances, and they have been further isolated by the construction of several impoundments on the Cumberland River mainstem and its tributaries.

Habitat Elements

The quality of physical habitat was evaluated by determining if it suited the needs of the Redlips Darter. Suitable habitat consisted of pools with stable rock substrates, in particular large slab rocks or boulders (>0.5m), minimal silt (low embeddedness), and no or slow flow. We also considered any known threat to the species' physical habitat, such as habitat disturbance from activities associated with agriculture, resource extraction, or development.

Connectivity was determined using documentation of fish passage barriers within each tributary system. The ability for species to move upstream and downstream is important for feeding, spawning migration, seasonal movements, refuge from extreme high or low water events and predators, as well as the exchange of genetic material. The quality of connectivity was evaluated based on the amount of known impact to the species' life history needs.

We evaluated water quality by determining how many impacts were identified, their severity, and if measures have been taken toward removing the issues. Kentucky's and Tennessee's Clean Water Act Section 303(d) and Total Maximum Daily Loads (TMDLs) programs (KDOW 2015, pp. 61-70, 180-185; TDEC 2017, pp. 12-18, 34-39) and watershed reports by various groups were used to identify impaired stream reaches and potential pollutants that could be impacting the species.

For the Redlips Darter to exhibit high representation, its populations should exhibit high resiliency and should occur in the ecoregion where they are native (e.g., Southwestern

Appalachians); these occupied populations should occur at the widest extent possible across the historical range of the species; and they should occupy multiple tributaries in addition to the core population within the mainstem of a river. Finally, connectivity should be maintained between representative populations because it allows for the exchange of novel and beneficial adaptations where connectivity is high or is the mechanism for localized adaption and variation where connectivity is lower and the species is naturally more isolated. It is helpful to consider representation in terms of how much it is reduced if a population is extirpated.

High redundancy for the Redlips Darter is characterized by having resilient and representative populations distributed within the species' ecological setting and across its range. For this species to exhibit high redundancy it must have highly resilient populations with connectivity maintained among them. Connectivity allows for immigration and emigration between populations and increases the likelihood of recolonization if a population becomes extirpated. Additionally, populations should have a low likelihood of extirpation due to catastrophic events.

Population Elements

Collection records were used to evaluate population elements, and these records were compiled from a variety of sources as described in Chapter 2 (Historical Range and Distribution). The dataset used in this analysis is not considered to be exhaustive but represents the best data accessible in the public domain. Each collection record is georeferenced with geographic coordinates. These records were considered recent if they represented a collection since 2006 and historical if they represented a collection prior to 2006.

Evidence of reproduction and recruitment was indicated by species persistence and the presence of one or more age classes (recorded field measurements of total length). Condition categories consisted of high (persistence and multiple age classes), low (persistence but no direct evidence of reproduction – no age class data), and extirpated (none observed).

Occurrence extent for the Redlips Darter was evaluated by measuring the distance between the most upstream record and the most downstream record. Historical and current records were assessed separately to determine and quantify any range reduction or expansion that may have occurred. As stated previously, the historical range of the Redlips Darter consisted of seven tributary systems of the Cumberland River in Kentucky and Tennessee. Within each tributary system, the historical range was calculated from the furthest upstream collection point within each tributary to its confluence with the nearest downstream river or stream. To determine the current range, we used all records obtained between 2006 and 2017 and evaluated how those records compared to historical collections. Not all historical streams within a specific tributary system were visited over the last 10 years, but we made the decision to include some of these streams as part of the species' current range. We decided to include these streams as part of the species' current range if available information indicated that habitat or water quality conditions had not changed significantly since the species' historical collection and recent collection records were available from the receiving stream (in some cases habitat and/or water quality conditions had improved). Alternatively, if available information suggested that habitat and water quality conditions were poor and no recent collections were available, these streams were not included as part of the species' current range.

Occurrence complexity is a measure of the spatial complexity of the occupied habitat. For aquatic species that inhabit large streams or rivers, complex spatial occurrence relates to a species occupying multiple tributaries and the river mainstem as opposed to only inhabiting the river mainstem. If connectivity is sufficient, then the more complex and dendritic (tree-like) spatial arrangement of occupied habitat will be more resilient against extinction (Fagan 2002, p. 3244). We considered high occurrence complexity to exist when individuals occupied the river mainstem and three or more major tributaries. Low occurrence complexity would exist if a species only inhabited the river mainstem and two or fewer tributaries.

Current Population Status

For the Redlips Darter to exhibit high representation, all tributary systems (populations) should have high resilience and occur at a wide extent across the Cumberland River drainage where the species is native. Within each population, the species should occupy multiple tributaries in addition to the core population within the mainstem.

High redundancy for the Redlips Darter is characterized by having multiple resilient and representative populations distributed within the species' ecological setting and across its range. Increased connectivity would further improve redundancy by reinforcing existing populations and increase the likelihood for reestablishment of lost populations. The current status of each population is summarized below.

Red River

The Redlips Darter appears to be extirpated from the Red River system. Despite surveys of historical habitats by Shepard and Burr (1984, p. 702), Powers *et al.* (2012, p. 53), Neely (2018, p. 6), and Thomas and Brandt (2017, p. 10), the species has not been observed in the Red River system since 1957 (Figure 9). Thomas and Brandt (2017, p. 10) observed what appeared to be suitable depth, flow, and cover at the 1957 capture locality (near the Kentucky/Tennessee state line), but bottom substrates were laden with silt. This agrees with the observations of Shepard and Burr (1984, p. 702), who identified heavy siltation as an important factor in the species' decline within the system.

Table 3. Component conditions used to assess current condition for populations of the Redlips Darter.

Component	**Condition**			
	High	**Moderate**	**Low**	**0**
Physical Habitat	No significant habitat alterations; extensive areas with suitable habitat	Low to moderate habitat alterations; some areas with suitable habitat	Habitat heavily altered and recognized as impacting species	Habitat unsuitable (species absent)
Connectivity	No known barriers to fish passage	Passage barriers known but do not impact species	Passage barriers identified as negatively impacting species	No connectivity (unable to support survival)
Water Quality	Minimal or no known water quality (WQ) issues (i.e., no 303(d) streams impacting the species, area sparsely populated, few roads)	WQ issues recognized and may impact species (i.e., some 303(d) streams, unpaved roads more common, moderate housing amounts)	WQ issues prevalent within system, likely impacting populations (i.e., numerous 303(d) streams)	Habitat unsuitable (species absent)
Reproduction	Species persisting over time; clear evidence of reproduction (multiple age classes present)	N/A	Species persisting over time but no direct evidence of reproduction	Extirpated
Occurrence Extent	<10% decline from known range	10-50% decline from known range	>50% decline in known range	Extirpated
Occurrence Complexity	Occupies main channel and numerous tributaries	Occupies main channel and maximum of 3 tributaries	Occupies main channel and mouths of a maximum of 2 tributaries	Extirpated

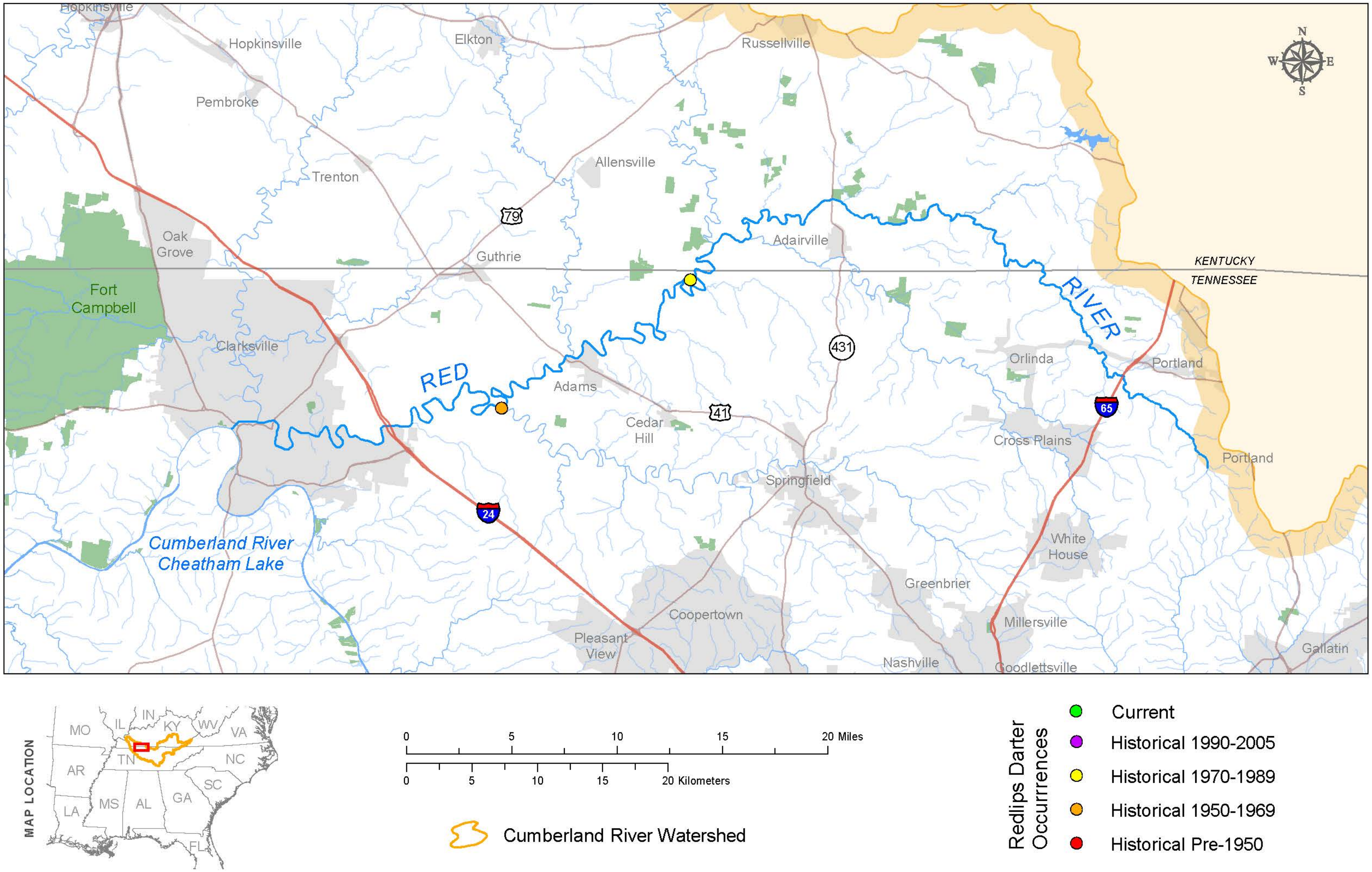

Figure 9. Current and historical distribution of the Redlips Darter in the Red River system, Tennessee, based on positive occurrence records (1952 – present).

Suitable habitat conditions for the Redlips Darter (i.e., large slab rock boulders with minimal silt, adequate water quality) may occur in limited reaches within the Red River system (Neely 2017, p. 6), but we consider overall physical habitat quality and water quality to be low. Forest cover is sparse, and agriculture is the dominant land use (73 percent), consisting of extensive crop lands (55 percent) and pasture (18 percent) (NRCS 2017). Pollutants such as nutrients, bacteria, and sediment are widespread within the system, resulting in a total of 448.2 stream km (278.6 stream mi) being listed as impaired in Kentucky and Tennessee (KDOW 2013b, pp. 458–474; 2015, pp. 180-185; 2016, pers. comm.; TDEC 2017, pp. 34-39). The primary sources of impairment include agricultural practices (non-irrigated crop production, pasture grazing, and unrestricted cattle access), sewage treatment plant discharges, and urban stormwater runoff. No large reservoirs have been constructed within the system, so connectivity does not appear to be a major issue with respect to fish spawning movements, seasonal movements, refuge from extreme high or low water events, feeding behavior, or the exchange of genetic material. A low-head dam near the KY 591 bridge in Logan County, Kentucky, could represent a significant barrier for small, benthic fishes (Thomas, pers. comm., 2018), but the impact of this barrier is unknown. This dam is located upstream of all historical locations for the species within the Red River system.

Due to the species' absence from the system over the past 60 years and continued impacts to physical habitat and water quality from agriculture and other pollutant sources, the Red River population is considered to be **Extirpated**.

Stones River

The species has not been observed in the Stones River system since 1961 and is now considered extirpated (Shepard and Burr 1984, p. 702; Powers *et al.* (2012, p. 53; Johansen *et al.* 2017, pp 52-58; Neely 2017, p. 6)) (Figure 10). The species' only historical location (East Fork Stones River) continues to be influenced seasonally by the backwaters of J. Percy Priest Lake, resulting in reduced flows and altered temperature and dissolved oxygen levels. The site is also influenced by Walter Hill Dam, an approximate 100 year old structure (and migration barrier) located just upstream of the species' historical location. Suitable habitat conditions for the Redlips Darter (i.e., pools with large slab rock boulders, minimal silt, and adequate water quality) occur in limited reaches upstream of Walter Hill Dam (Neely 2017, p. 6), but the East Fork Stones River continues to be impacted by nutrients, siltation, and high levels of bacteria (TDEC 2017, pp. 34-39). Identified sources of impairment include agriculture (unrestricted cattle access, pasture/grazing), municipal point source discharges, septic discharge/releases, land development, highway/road runoff, and channelization. J. Percy Priest Lake and Walter Hill Dam restrict fish passage within the East Fork Stones River, so connectivity between upstream and downstream reaches is low, affecting seasonal movements and limiting the exchange of genetic material.

Due to the species' absence from the system over the past 57 years, the presence of barriers to fish passage, and continued impacts to physical habitat and water quality from agriculture and other pollutant sources, the Stones River population is considered to be **Extirpated**.

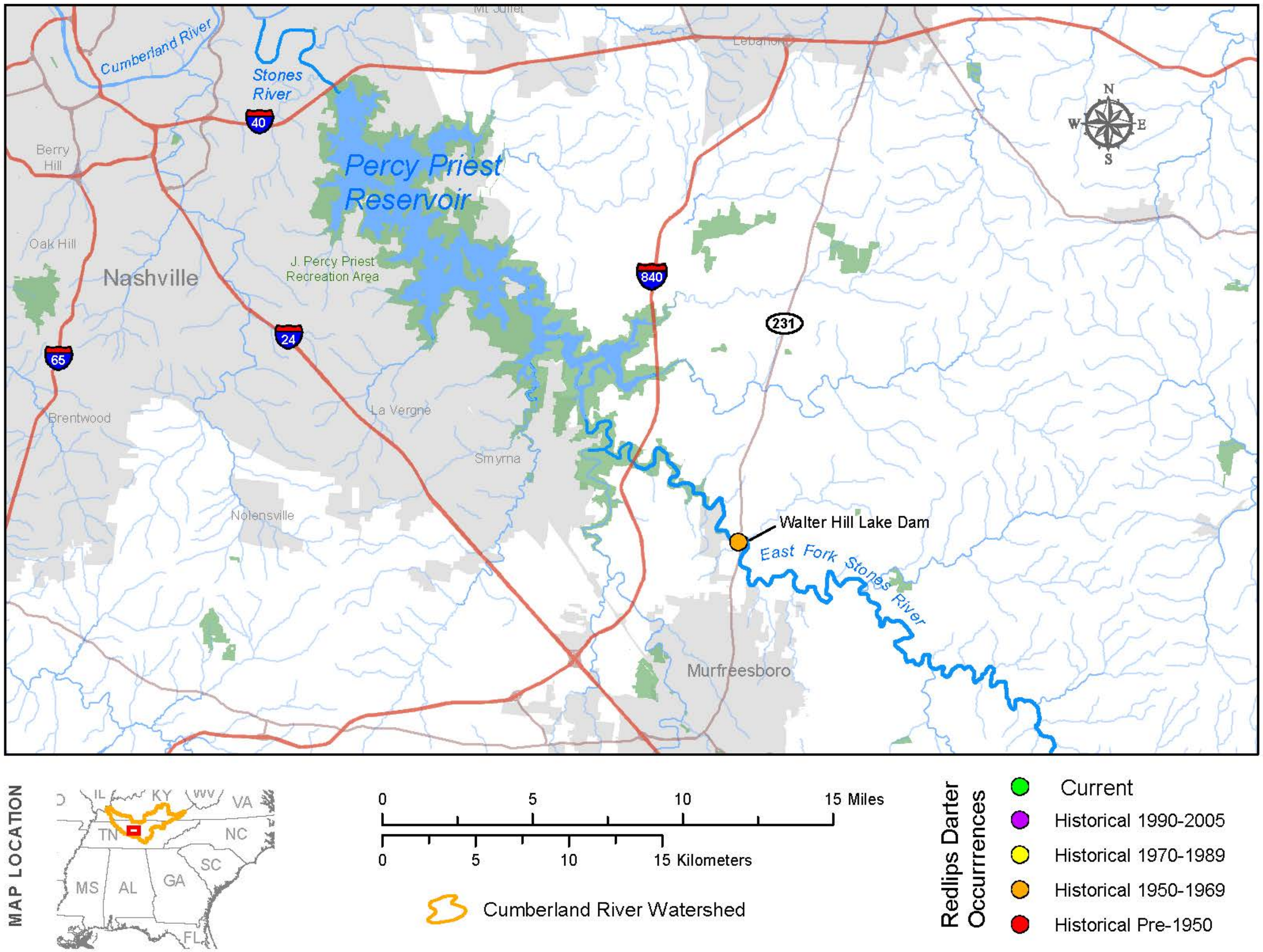

Figure 10. Current and historical distribution of the Redlips Darter in the Stones River system, Tennessee, based on positive occurrence records (1961 – present).

Roaring River

The species has not been observed in the Roaring River system since 1968 (Figure 11). Shepard and Burr (1984, p. 702) and Powers *et al.* (2012, p. 53) listed the species' status within the Roaring River as "unknown" due to the presence of suitable habitat within the Roaring Fork mainstem (i.e., pools with large slab rock boulders, minimal silt, and adequate water quality). Shepard and Burr (1984, p. 702) listed no specific threat for the Roaring River, but recent assessments by TDEC (2017, pp. 17-18) indicate that at least 114 km (71 mi) of the system are impacted by sediment runoff and/or high levels of nutrients and bacteria due to agriculture (pasture/grazing) and urban runoff. Connectivity is reduced within the system due to the creation of Cordell Hull Lake and subsequent inundation of approximately 4.8 km (3 mi) of the lower Roaring River mainstem. This affects seasonal fish movements and limits the exchange of genetic material with adjacent Cumberland River tributaries.

Due to the species' absence from the system over the past 50 years and continued impacts to physical habitat and water quality from agriculture and other pollutant sources, we consider the Roaring River population to be **Extirpated.**

Obey River

The Redlips Darter was rediscovered in the Obey River system in April 2007 (Figure 12), the first observation of the species in over 34 years. A single individual was observed during a brief survey of the East Fork Obey River near the State Route 52 bridge crossing, approximately 5.4 km (3.4 mi) west of Jamestown (B. Zimmerman, pers. comm., 2017). The record was confirmed by the Service through discussions with the collector (Brian Zimmerman, Ohio State University) and our review of associated field notes and a photo voucher. The site was revisited by TNACI in December 2017, resulting in the collection of two individuals during an approximate one-hour survey effort (Neely 2018, p. 6). These collections demonstrate the species' persistence within the Obey River system, but the species' current abundance and distribution within the system remain unknown.

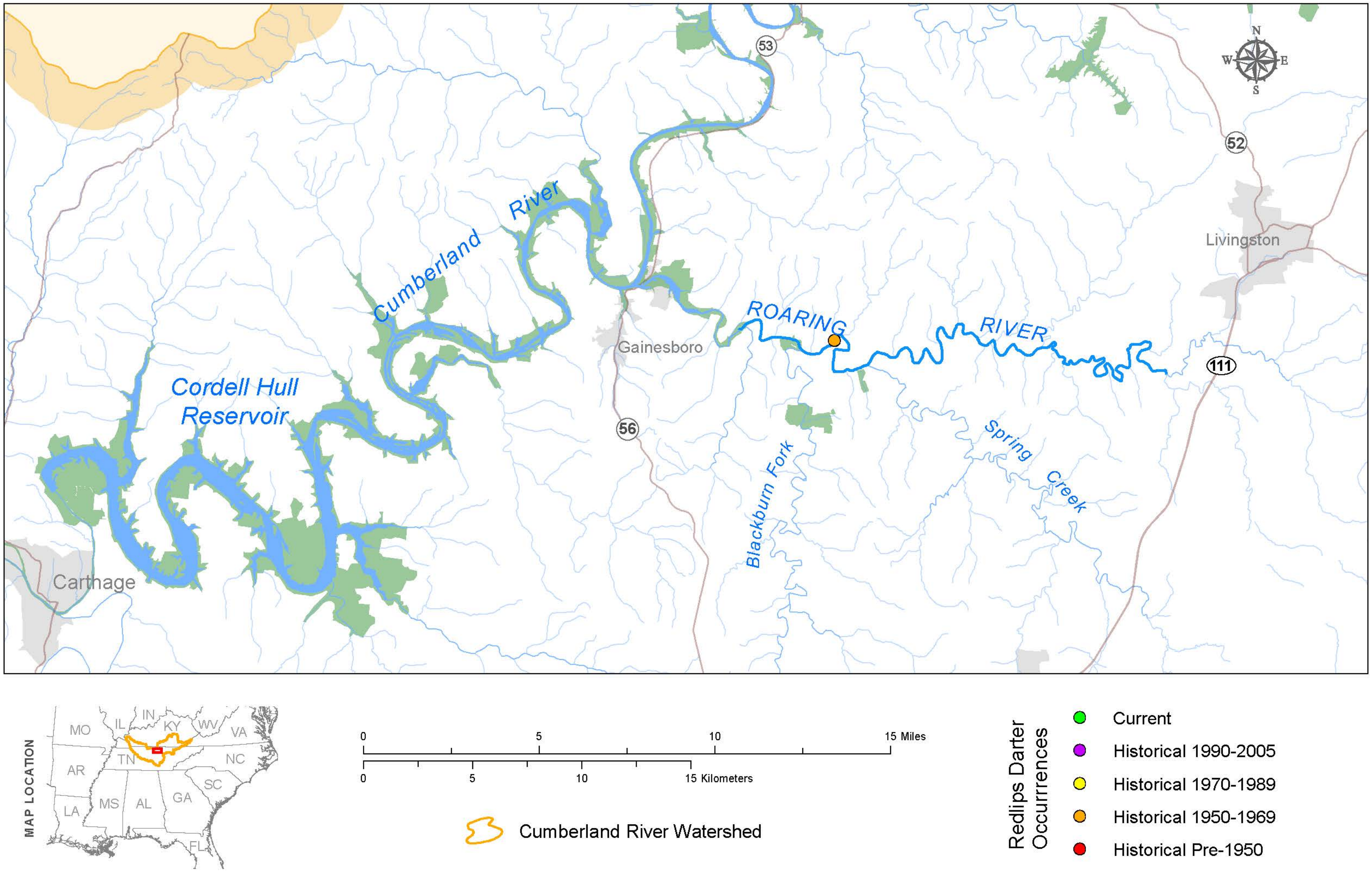

Figure 11. Distribution of the Redlips Darter in the Roaring River system, Tennessee, based on positive occurrence records (1968 – present).

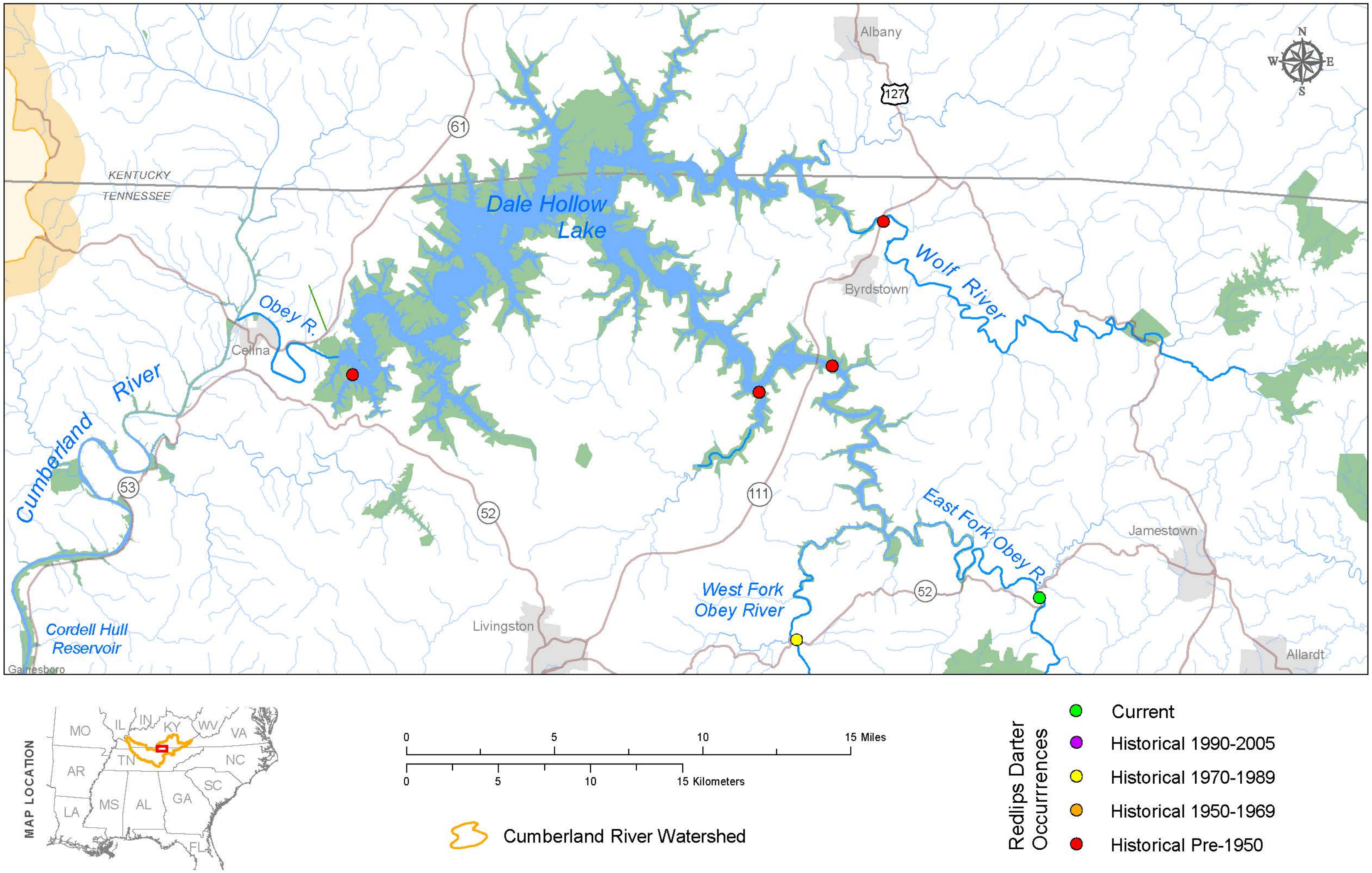

Figure 12. Distribution of the Redlips Darter in the Obey River system, Tennessee, based on positive occurrence records (1891 – present).

Habitats within the entire Obey River mainstem, and large portions of the East Fork Obey River, West Fork Obey River, and Wolf River are no longer suitable for the species due to the creation of Dale Hollow Lake in 1943 (Figure 12; Table 2). Upstream of the reservoir, portions of the system continue to be impacted by siltation, low pH, and dissolved solids associated with legacy coal mining (TDEC 2017, pp. 15-17), but the species' recent discovery in the East Fork Obey River demonstrates that suitable physical habitat and water quality conditions are present within selected reaches of the system. Physical habitat quality within the East Fork Obey River was described as excellent by TNACI during surveys in December 2017 (Neely 2018, p. 6). The survey reach contained an abundance of large slab rocks and minimal siltation. In contrast, habitat quality within the West Fork Obey River (State Route 52 Bridge) was described as poor (Neely 2018, pp. 6-8). Substrates were covered by a thick, silty flocculent or biofilm; a sheen was visible on the water's surface; and sludge-like, oily deposits were present in areas of slow current (e.g., eddies and stream margins).

We consider the Obey River population to have a **low** resilience to stochastic events (Table 4). The population's resilience is reduced by the species' continued absence from the Obey River mainstem, West Fork Obey River, and Wolf River; continued degradation of physical habitat and water quality from pollutants associated with legacy land use practices; and low connectivity caused by the creation of Dale Hollow Lake. As additional surveys are completed within the East Fork Obey River and new information is gathered on the species' distribution and abundance within the system, our estimate of the species' resilience may increase.

South Fork Cumberland River

The Redlips Darter continues to be commonly observed within the free-flowing portion of the South Fork Cumberland River mainstem (upstream of Lake Cumberland), with evidence of reproduction and recruitment (Figure 13) (Powers *et al.* 2012, p. 53; TVA 2017, entire; Service unpublished data). Since 2005, the species has been reported from 28 mainstem sites, and at many of these localities, the species has been observed repeatedly in high numbers (10-30 individuals per sampling event). Most of these collections have been associated with routine agency surveys or agency monitoring and propagation efforts for the Duskytail Darter (TVA 2017, entire; P. Rakes, pers. comm. 2017). No population estimate is available for the mainstem; however, we arrived at an estimate using a density estimate calculated for the Rockcastle River system by Compton and Taylor (2013, entire). If we assume similar densities within each system and apply the Rockcastle River mean density estimate of 1 darter / 2.12 m across the approximate 50.5-km (31.4-mi) reach of the South Fork Cumberland River mainstem, we arrive at an estimated population size of 23,821 darters (1 darter / 2.12 linear meters * 50,500 m = 23,821 darters). This is likely a conservative estimate because it does not account for the larger width (size) of the South Fork Cumberland River or for areas upstream of the New River and Clear Fork confluence.

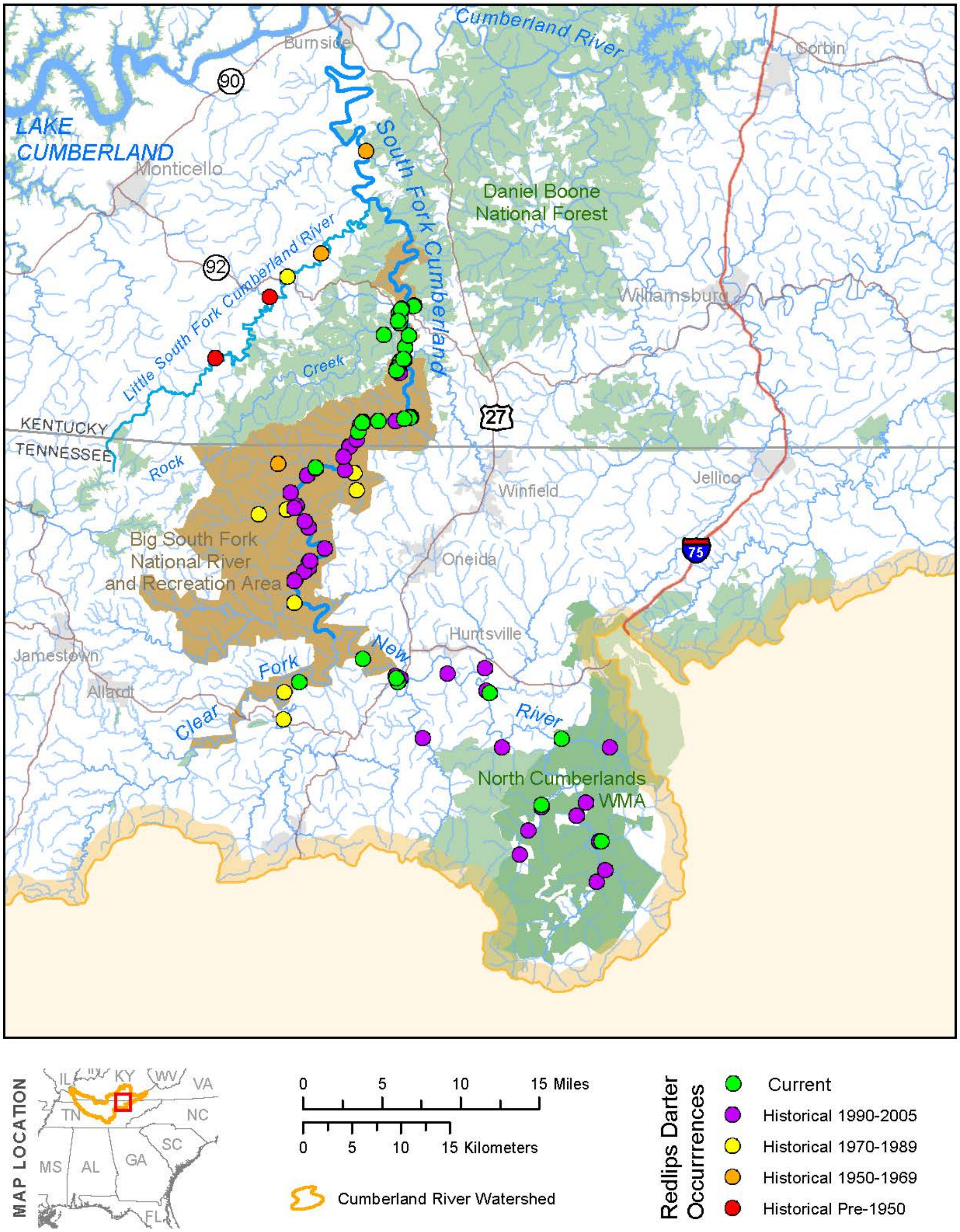

Figure 13. Distribution of the Redlips Darter in the South Fork Cumberland River system, Kentucky and Tennessee, based on positive occurrence records (1891 – present).

The most recent comprehensive survey effort within the system has involved annual fish surveys of the lower South Fork Cumberland mainstem by TVA, the U.S. Army Corps of Engineers (USACE), and CFI. From 2007-2013, water levels in Lake Cumberland were lowered gradually during the first year (elevation reduced approximately 12 meters (40 feet)) to allow for repairs to Wolf Creek Dam. During the draw-down period, free-flowing conditions returned to an approximate 11-km (7-mile) reach of the lower South Fork Cumberland River, creating a series of 14 shoal complexes just upstream of Lake Cumberland. Prior to the return of Lake Cumberland to pre-drawdown levels, snorkeling surveys (supplemented by electrofishing and seining) were initiated by TVA, USACE, and CFI to determine if rare species (e.g., Tuxedo Darter) were present in the affected reach and to assess any potential impacts on these species as lake elevations returned to normal (TVA 2017, entire). A total of 69 Redlips Darters were observed at 8 survey reaches during the first survey effort (2014), including 26 individuals at the most downstream sampling reach. During subsequent surveys (2015-2017), the species continued to be observed in relatively high numbers (64, 38, and 35 individuals, respectively) (TVA 2017, p. 40; J. Simmons, pers. comm., 2017).

Since 2006, collection records from South Fork Cumberland River tributaries (5) have been limited to sites on Beech Fork (Tennessee), Buffalo Creek (Tennessee), Montgomery Creek (Tennessee), New River (Tennessee), Rock Creek (Kentucky), and Smoky Creek (Tennessee). The species had been reported previously from Montgomery Creek and Smoky Creek, but the species' occurrence in Rock Creek represented a new distributional record for the South Fork Cumberland River system. A total of 17 individuals were observed in lower Rock Creek during surveys completed in 2008, 2009, and 2013 by Brandt (2009, pp. 18, 28, 45) and KDFWR (unpublished data). The species was last recorded from the Little South Fork Cumberland River in 1980 (Branson and Schuster 1982, p. 68), and subsequent fish surveys have failed to produce additional specimens, despite the presence of suitable habitat conditions (Henry *et al.* 1999, entire; Jenkins 2007, entire; KSNPC unpublished data). Other tributary systems have not been searched since 2005, but we expect the species to be present in all of these streams (e.g., New River) based on improving water quality and habitat trends within the system.

Portions of the system continue to be impacted by siltation, low pH levels, and elevated levels of dissolved solids associated with legacy coal mining (TDEC 2017, pp. 12-15); however, the magnitude and scope of these threats have diminished over the last 20 years, with an overall improving water quality and habitat trend (Evans 1998, pp. 74-75; Scott 2006, p. 19), coupled with an expansion of the species' range within the system (Evans 1998, pp. 74-75). The best physical habitat and water quality conditions are found in the South Fork Cumberland mainstem, but suitable habitat is also found in the Clear Fork, New River, and numerous smaller tributaries. The level of public ownership within the system is high (about 42 percent), and many stream segments receive additional protections through national or state designations (Table 10, Appendix A). The entire free-flowing length of the South Fork Cumberland River mainstem (an approximate 50.7-km (31.5-mi) reach) is located within the Big South Fork National River and Recreation Area (Figure 13), which encompasses approximately 50,711 hectares (ha) (125,310 acres (ac)) of the system in Kentucky and Tennessee (about 17 percent of the total watershed). Another 46,417 ha (114,700 ac) are located within the North Cumberland Wildlife Management Area in Tennessee (about 16 percent of the total watershed). Within Kentucky, 25,984 ha (64,207 ac) of the system are located within the Daniel Boone National Forest in McCreary and

Wayne counties (about 9 percent of the total watershed). Habitat quality within the system is further substantiated by the continued presence of several federally threatened and endangered species within the South Fork Cumberland River mainstem and several of its tributaries (Table 10, Appendix A).

Based on all these factors, we consider the South Fork Cumberland River population to have a **high** resilience to stochastic events (Table 4). The population's resilience is substantiated by its persistence within the system for over 100 years, its current high abundance and widespread distribution within the South Fork Cumberland River mainstem and several of its tributaries, and the high quality of physical habitat and water quality conditions within the system. The population is isolated from other Cumberland River tributaries due to Lake Cumberland, but connectivity within occupied reaches of the system is relatively high.

Buck Creek

Since 2006, surveys within the Buck Creek system have yielded multiple new observations of the Redlips Darter (Figure 14). Thomas and Brandt (2013, entire) completed a comprehensive survey of the Buck Creek system during 2011-2012, observing five Redlips Darters from a total of three localities. One of these collections extended the species' range within Buck Creek approximately 8.0 stream km (5.0 mi) upstream of the 1996 record by Compton and Moeykens (2001, p. 144-145). In 2017, a sixth individual was observed at the Goochtown Road crossing in Pulaski County, extending the species' range upstream another 1.8 stream km (1.1 mi) (D. Black, pers. comm., 2017). Based on these observations, the species has persisted within Buck Creek for over 60 years and continues to occur in low densities where suitable habitat exists (Thomas and Brandt 2013, p. 10). Recent collections also demonstrate that the species has a more extensive distribution within the Buck Creek mainstem than previous records indicated. The species now occupies an approximate 35.4-km (22-mi) reach, an increase of over 25.7 km (16 mi) since the species' first observation during the 1950s (Thomas and Brandt 2013, p. 10; D. Black, pers. comm., 2017).

Portions of the Buck Creek system continue to be impacted by siltation and nutrient inputs associated with channelization, gravel dredging, and agricultural practices (KDOW 2013b, pp. 502–529; KDOW 2015, pp. 61-70; KDOW 2016, pers. comm.); however, the species' persistence and greater occurrence extent within the system suggest that these threats are having only a low to moderate impact on the species. Physical habitat and water quality conditions within the Buck Creek mainstem have been sufficient for the species to persist in low densities in portions of the mainstem. Habitat and water quality within the system is further evidenced by the continued presence of several federally threatened and endangered species within the Buck Creek mainstem and several of its tributaries (Table 10, Appendix A). The population's resilience is demonstrated by its persistence within the system for over 63 years, its more extensive distribution within the Buck Creek mainstem compared to historical reports, and the suitable physical habitat and water quality conditions within the mainstem. The population is isolated from other Cumberland River tributaries due to Lake Cumberland, but connectivity within occupied reaches of the system is relatively high. Based on all these factors, we consider the Buck Creek population to have a **low-moderate** resilience to stochastic events (Table 4). Several resiliency measures (e.g., physical habitat, water quality, connectivity, occurrence extent) indicate a moderate level of resiliency for the Buck Creek population, while the low number of observations over the past 12 years and the species' occurrence complexity is more indicative of low level of resiliency to stochastic events. Considering all these factors, we arrived at an overall resiliency estimate of low-moderate.

Rockcastle River

Since 2006, the species has been reported from 25 separate localities within the Rockcastle River system, including 15 mainstem sites and 10 tributary sites (Figure 14). A few of these collections were associated with routine agency surveys, but the majority of records were obtained by Compton and Taylor (2013, pp. 180-182), who completed a comprehensive survey and ecological study of the Redlips Darter in the Rockcastle River system from 2009-2010. Collections by Compton and Taylor (2013, entire) produced a total of 322 Redlip Darters during 39 sampling events. The species was observed at all 12 mainstem sites and 6 major tributaries; new distributional records were obtained for Roundstone Creek and Sinking Creek. During quantitative surveys at 123 microhabitat plots ($30m^2$ in each plot), Compton and Taylor (2013, entire) observed a total of 227 individuals, including 89 juveniles from 62 plots and 138 adults from 80 plots. Juvenile and adult abundance ranged from 0-4 individuals and 0-6 individuals per plot, respectively. Based on their quantitative sampling results and estimates of available habitat, Compton and Taylor (2013, entire) estimated the mean population size within the Rockcastle River system at 34,308 individuals (95% confidence interval: 19,992 – 48,624).

Streams within the Rockcastle River system continue to be impacted by siltation, elevated levels of dissolved solids, low dissolved oxygen levels, and nutrient inputs associated with agriculture, legacy mining, urban runoff, and development (KDOW 2013b, pp. 502–529; KDOW 2015, pp. 61-70; KDOW unpublished data); however, the species' persistence and high abundance within the Rockcastle River mainstem and several tributaries suggest that these threats are not having a significant impact on the species within these habitats. Physical habitat and water quality conditions in the Rockcastle River mainstem and several tributaries have been sufficient for the species to persist over time and in high numbers. Levels of public ownership along the Rockcastle River mainstem are high (Figure 14), and portions of the mainstem and tributaries receive additional protections through national or state designations (Table 10, Appendix A). Habitat quality within the system is further evidenced by the continued presence of several federally threatened and endangered species within the Rockcastle River and several of its tributaries (Table 4, Appendix A).

Based on all these factors, we consider the Rockcastle River population to have a **high** resilience to stochastic events (Table 4). The population's resilience is evidenced by its persistence within the system for over 38 years, its large population size and widespread distribution within the Rockcastle River mainstem and several of its tributaries, and the high quality of physical habitat and water quality conditions within the system. The population is isolated from other Cumberland River tributaries due to Lake Cumberland, but connectivity within occupied reaches of the system is relatively high.

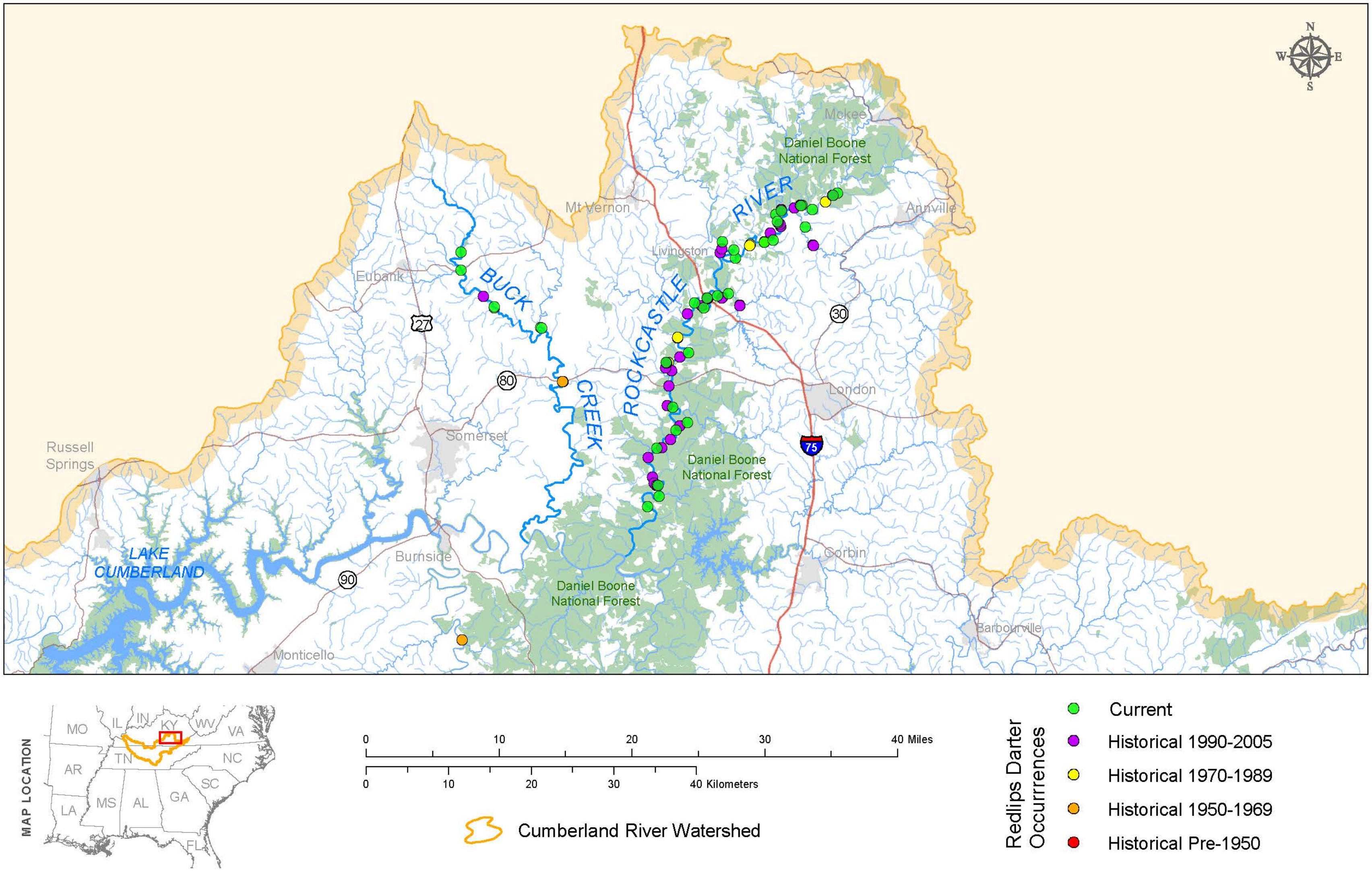

Figure 14. Current and historical distribution of the Redlips Darter in the Buck Creek and Rockcastle River systems, Kentucky, based on positive occurrence records (1954 – present).

Table 4. Current resilience estimates for Redlips Darter populations.

Population	Physical Habitat	Connectivity	Water Quality	Reproduction	Occurrence Extent	Occurrence Complexity	Current Condition
Red River	Low	Moderate-High	Low	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Moderate-High	Low	0	0	0	**Extirpated**
Obey River	Low/Moderate	Low	Low-Moderate	Low	Low	Low	**Low**
South Fork Cumberland River	High	Moderate-High	High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate/High	Moderate	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	Moderate/High	High	High	High	High	**High**

Current Species Representation

Representation describes the ability of a species to adapt to changing environmental conditions over time and encompasses the "ecological and evolutionary patterns and processes that not only maintain but also generate species" (Shaffer and Stein 2000, p. 308). As mentioned previously, no species-specific genetic information is available for populations of the Redlips Darter, so our evaluation of the species' representation is based on the extent and variability of environmental diversity (habitat diversity) across the species' geographical range.

Currently, we consider the Redlips Darter to exhibit **low to moderate** representation. The species no longer occupies all of its historical tributary systems, so there has likely been a reduction in the species' genetic and environmental diversity over time. Historically, the species occupied tributary systems in two ecoregions – Interior Plateau and Southwestern Appalachians (Griffith *et al.* 1998, entire). The species can still be found in both ecoregions, but the number of Interior Plateau stream systems has decreased from five to two. The remaining two Interior Plateau systems, Buck Creek and Obey River, are located in both ecoregions, thereby potentially preserving some of the genetic and environmental diversity that has been lost due to extirpations in the western half of the species' range.

The species has also suffered a loss of connectivity due to dam construction. The species' four extant populations are now isolated, preventing the exchange of novel or beneficial adaptations and reducing the species' ability to migrate to more suitable habitats when necessary. Despite these limitations, the species' representation has been strengthened by its rediscovery in the Obey River system; its persistence, expanding range, and moderate resiliency within the Buck Creek system; and its relatively high abundance, widespread occurrence, and high resiliency within the Rockcastle River and South Fork Cumberland River systems. Even though there has been a loss of connectivity between these populations due to dam construction, there are no movement barriers within these systems to prevent the exchange of genetic material between the mainstem and tributaries. This has allowed individual Redlips Darters to move freely within each system, thereby maintaining some level of genetic exchange and diversity within each system.

Current Species Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. High redundancy "guards against irreplaceable loss of representation" (Redford *et al.* 2011 p. 42; Tear *et al.* 2005 p. 841) and minimizes the effect of localized extirpation on the range-wide persistence of a species (Shaffer and Stein 2000, p. 308). For a species to exhibit greater redundancy, the populations should not be completely isolated and immigration and emigration between populations should be achievable.

Redundancy for the Redlips Darter is characterized by having multiple, resilient and representative populations distributed across the species' range. Currently, the species is represented by two populations with high resilience, one population with moderate resilience, and one population with low resilience. Two Redlips Darter populations have been extirpated, and another is likely extirpated; however, the species' redundancy and representation has been strengthened by its rediscovery in the Obey River system and its persistence, expanding range, and moderate resiliency within the Buck Creek system. The species' redundancy and representation has also been strengthened by its high abundance, widespread distribution, and high resiliency within the South Fork Cumberland River and Rockcastle River systems. The likelihood that a catastrophic event, such as an extreme drought or chemical spill, would cause the loss of a population is higher within the Buck Creek and Obey River systems because the species' distribution within those systems is limited to a single, continuous stream reach. The likelihood of extirpation is much lower in the South Fork Cumberland River and Rockcastle River systems due to the species' widespread occurrence, which includes both the mainstem and multiple tributaries.

Connectivity between extant populations has been reduced, or likely eliminated, by the construction of dams (e.g., Lake Cumberland), but the species is widely distributed within these systems, with no dispersal barriers preventing movement between the mainstem and multiple tributaries. The connectivity within these systems decreases the effect of localized stochastic events that could be detrimental to these populations and lead to extirpation. Based on all these factors, we consider the species to have **low to moderate** redundancy.

CHAPTER 5. FUTURE SCENARIOS AND SPECIES VIABILITY

In this chapter, we describe how current viability of the Redlips Darter may change over time periods of 10, 30 and 50 years. Similar to our current condition discussion, we evaluate species viability in terms of resilience at the population scale, and representation and redundancy at the species scale (3 Rs). Here we describe three plausible future scenarios and whether there will be a change from current conditions for any of the 3 Rs under each scenario. Our future scenarios differ by considering variations that are predicted in three main elements of change: urbanization (development), climate, and conservation activity. These scenarios capture the range of plausible viability outcomes that the Redlips Darter will exhibit by 2070. For each scenario, we provide a summary of resilience for each population at 10, 30, and 50 years in the future (Tables 7-9). Individual components used to characterize future conditions in each scenario are summarized in Appendix B (Tables 11-19).

Conservation of the Redlips Darter has been aided by its occupancy of stream systems with high amounts of public land (South Fork Cumberland River and Rockcastle River systems), its co-occurrence with multiple listed species in three tributary systems (Table 10, Appendix A), and its inclusion as a species of conservation interest in wildlife conservation strategies in Kentucky and Tennessee (KDFWR 2013, entire; TWRA 2005, entire). Over the next 30-50 years, we expect no change in public ownership, and we expect state resource agencies to continue to consider the Redlips Darter as a species of management concern.

The human population in the southeastern United States has grown at an average rate of 36.7% since 2000, making it the fastest growing region in the country (U.S. Census 2016). Within the range of the Redlips Darter, the Stones River population appears to be most impacted by urbanization. Through 2070, development and urban sprawl is expected to expand and influence areas that previously were unaffected by urbanization. Further, we assess how this increase in developed areas affects populations and the species as a whole.

To forecast future development or urbanization, we consider future scenarios that incorporate the SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model, which simulates patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks, including the sprawling, fragmented, “leapfrog” development that has been dominant in the southeastern United States (Terando *et al.* 2014, p. 2). The extent of urbanized areas has been predicted to increase across the southeastern United States by approximately 100 - 192 % based on the “business-as-usual” (BAU) scenario that expects future development to match current development rates (Terando *et al.* 2014, p. 1). We use this range of percent change in urbanization to develop our future scenarios described below. With increased urbanization, forest cover is expected to decrease and water quality and habitat quality are expected to be degraded through increased inputs of point source and non-point source pollutants (e.g., siltation, organic enrichment).

The Fifth Assessment Report (AR5) by IPCC found that “continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems” (IPCC 2014, entire). Therefore, we expect climate change to be a driver of change that should be addressed when evaluating the future viability of the Redlips Darter. As described in Chapter 4, the IPCC utilized a suite of alternative emission scenarios (RCPs) in the AR5 to make near-term and long-term climate projections. These scenarios are plausible pathways toward reaching a target radiative forcing. In this assessment, we used a climate change model developed by Alder and Hostetler (2016) to help understand how climate may change in the future and what effects may be observed that impact the Redlips Darter in the Cumberland River drainage. We attempt to capture the range of plausible climate outcomes by considering that the frequency and probability of extreme climate scenarios will be greatest under RCP8.5 and intermediate under RCP4.5.

Scenarios

Scenario 1

In this scenario, public ownership across the Redlips Darter's range remains at current levels and actions under state wildlife conservation strategies continue to be implemented. As predicted by the SLEUTH model, small increases in urbanization are expected by 2070 within all extant populations (Figures 15-18), but associated impacts on habitat and population elements are expected to be minimal. The current trend in climate continues (moderate RCP of 4.5), and within the next 10 years, a few populations are impacted by either drought or floods, with slightly warmer temperatures. Over the long term (30 – 50 years), drought affects all populations but at intervals and severity levels similar to what has occurred over the last 10 years. Considering all these factors, all extant populations are expected to persist, with potential expansion of the Buck Creek and East Fork Obey River populations. Since 2006, the Redlips Darter has been observed in several new locations of the Buck Creek mainstem, and we expect this trend to continue. The species was rediscovered within the East Fork Obey River system in 2007, and a brief (one hour) survey effort at the same locality in December 2017 produced two additional individuals. Habitat conditions at this site and other reaches of the East Fork Obey River appear to be ideal for the species (D. Neely, pers. comm., 2018), so we expect that additional surveys will expand the species' known range within this portion of the system. For all extant populations, we expect no change in resiliency (Table 5).

Table 5. Resiliency of the Redlips Darter under Scenario 1.

Population	**Current Condition**	**Predicted Condition - Scenario 1**		
		10 Years	**30 Years**	**50 Years**
Red River	Extirpated	Extirpated	Extirpated	Extirpated
Stones River	Extirpated	Extirpated	Extirpated	Extirpated
Roaring River	Extirpated	Extirpated	Extirpated	Extirpated
Obey River	Low	Low	Low	Low
South Fork Cumberland	High	High	High	High
Buck Creek	Low-Moderate	Low-Moderate	Low-Moderate	Low-Moderate
Rockcastle River	High	High	High	High

Representation

Under Scenario 1, representation of the Redlips Darter is expected to remain at **low to moderate** levels. The species has been extirpated from three streams within the Interior Plateau ecoregion, but the species continues to persist in both of its historical ecoregions, Interior Plateau and Southwestern Appalachians, and we expect the species to persist in these systems into the future. These populations help to preserve some of the genetic and environmental diversity that has been lost due to extirpations in the western half of the species' range.

Redundancy

Under Scenario 1, redundancy of the Redlips Darter is expected to remain at a **low-moderate** level. The species continues to have two populations with high resilience, one population with moderate resilience, and one population with low resilience, and we expect these populations to persist within these systems with no decrease in resiliency. The likelihood that a catastrophic event, such as an extreme drought or chemical spill, would cause the loss of a population is higher within the Buck Creek and Obey River systems because the species' distribution within those systems is limited to a single, continuous stream reach. The likelihood of extirpation is much lower in the South Fork Cumberland River and Rockcastle River systems due to the species' widespread occurrence, which includes both the mainstem and multiple tributaries.

Connectivity between extant populations has been reduced, or likely eliminated, by the construction of dams (e.g., Lake Cumberland). No future dams are anticipated under this scenario, leaving the species widely distributed within these systems, with no dispersal barriers preventing movement between the mainstem and multiple tributaries. The connectivity within these systems decreases the effect of localized stochastic events that could be detrimental to these populations and lead to extirpation.

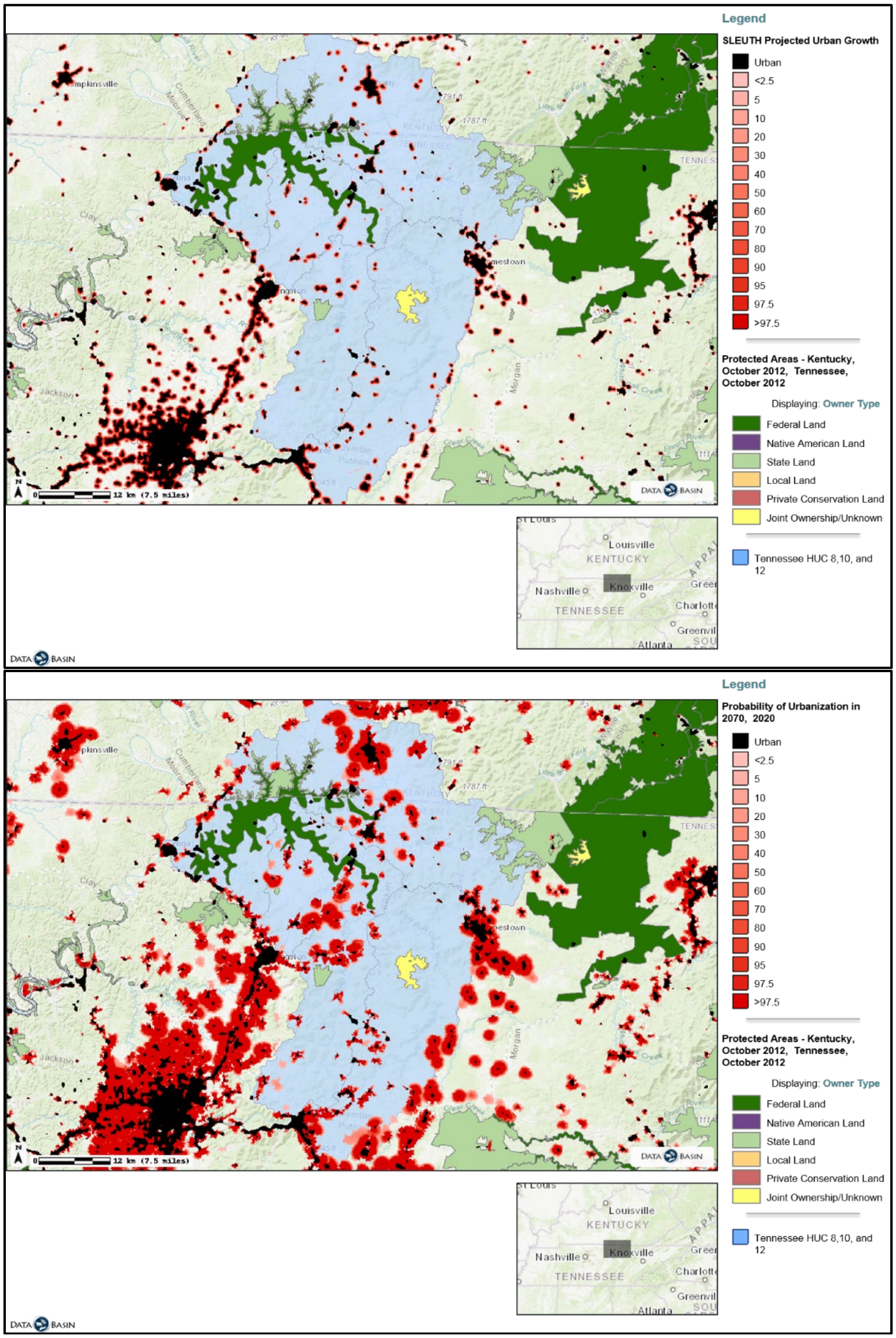

Figure 15. Predicted urbanization levels in the Obey River system (highlighted in blue), 2020 (top) and 2070 (bottom).

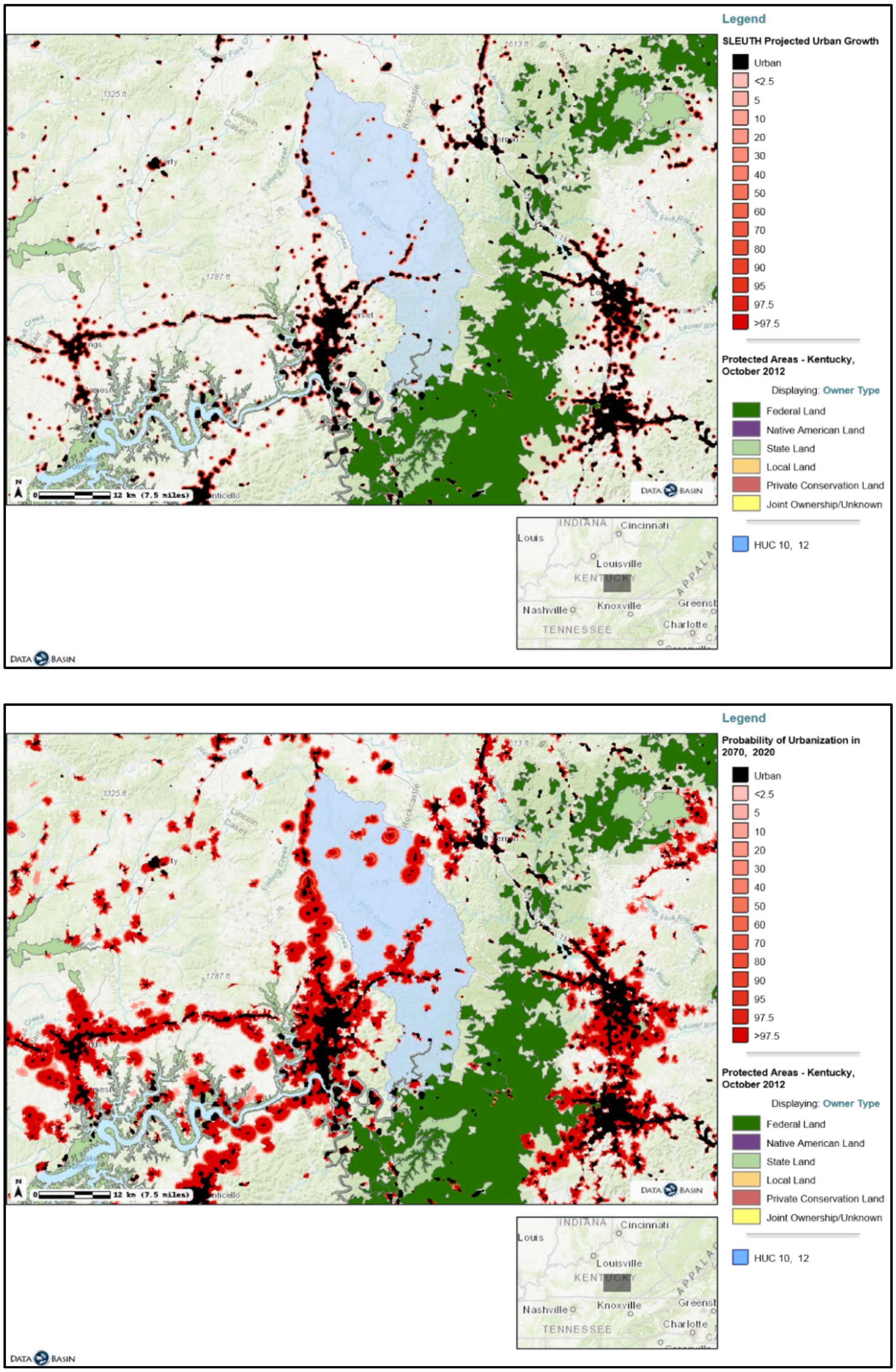

Figure 16. Predicted urbanization levels in the Buck Creek system (highlighted in blue), 2020 (top) and 2070 (bottom).

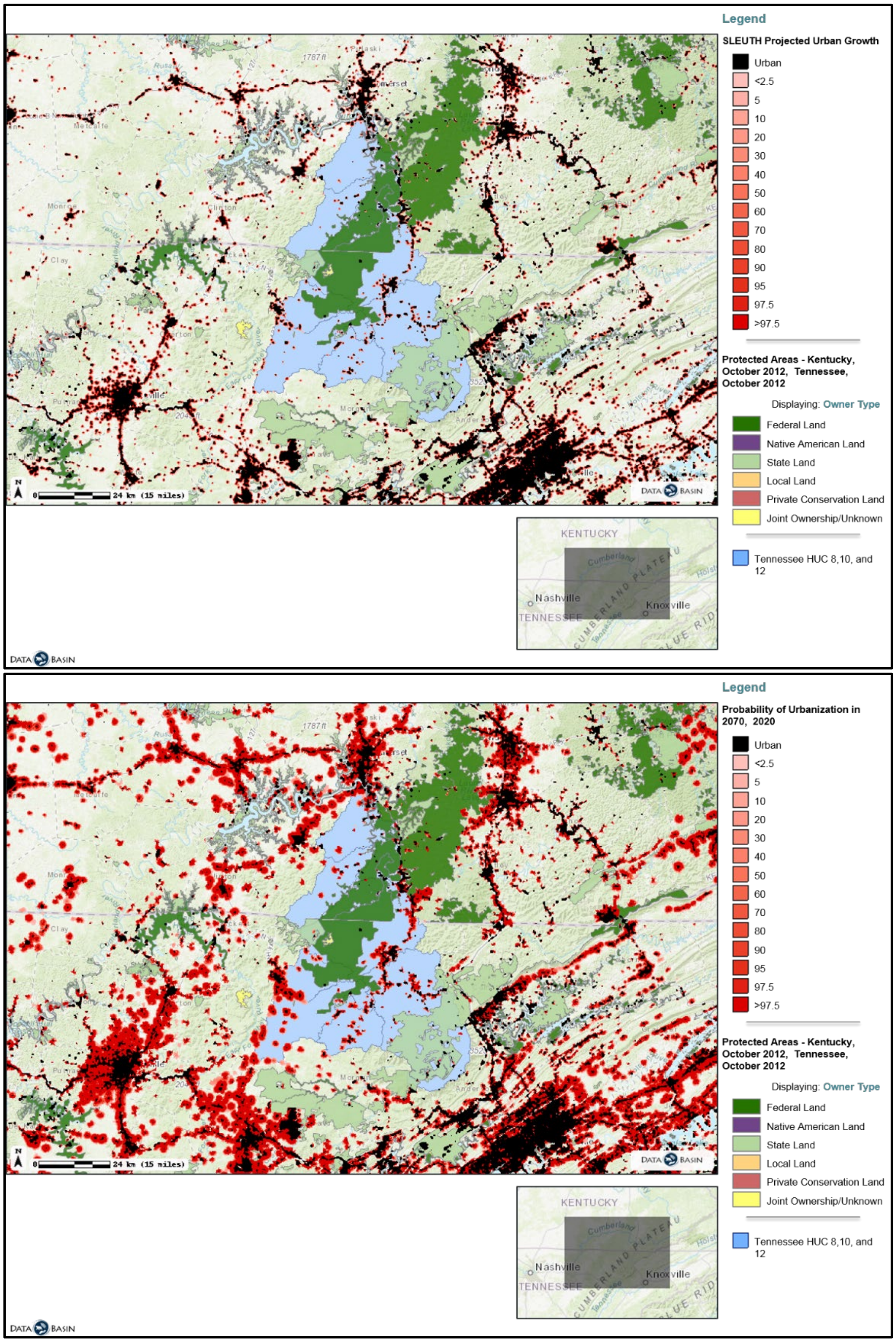

Figure 17. Predicted urbanization levels in the South Fork Cumberland River system (highlighted in blue), 2020 (top) and 2070 (bottom).

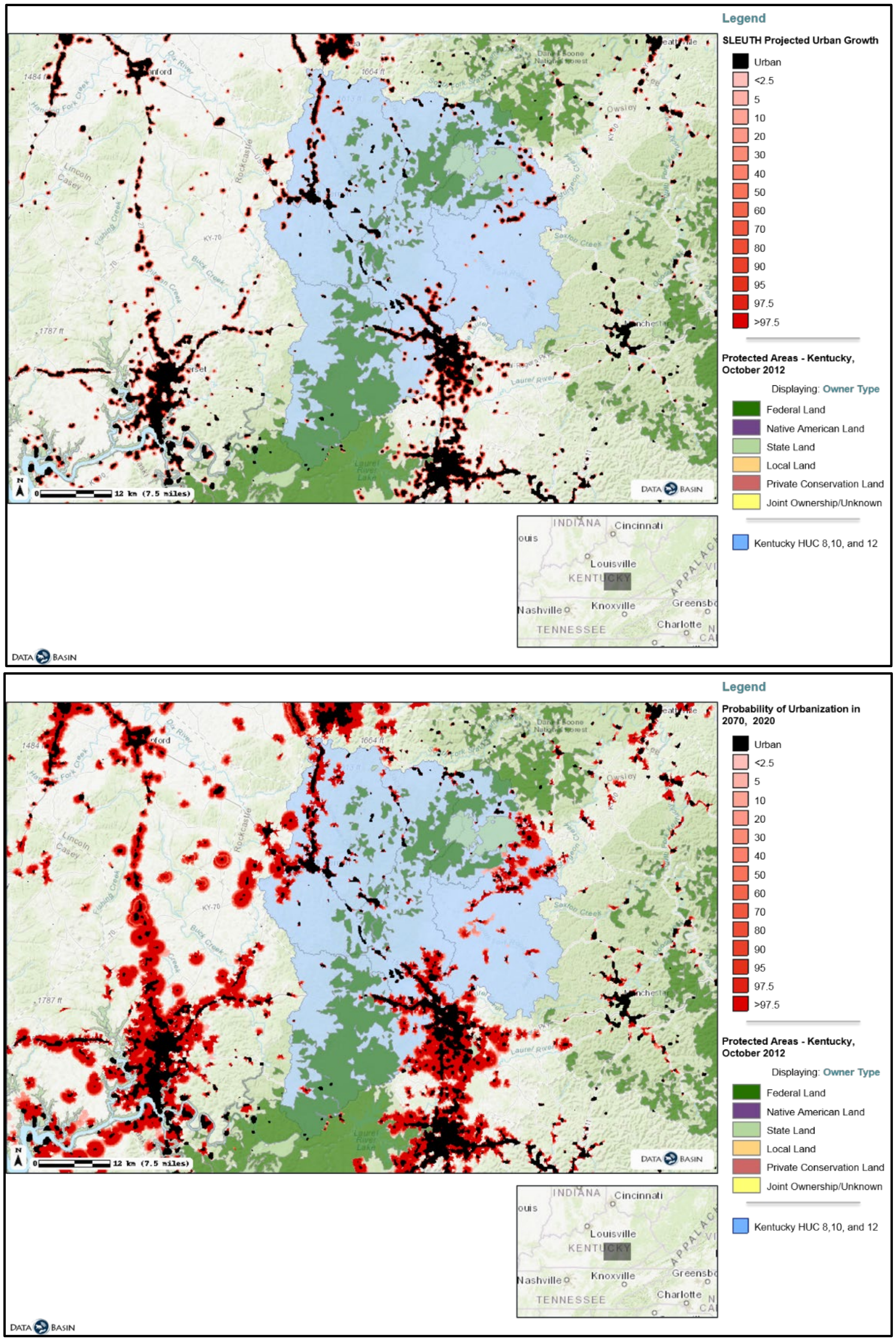

Figure 18. Predicted urbanization levels in the Rockcastle River system (highlighted in blue), 2020 (top) and 2070 (bottom).

Scenario 2

In this scenario, we predict a number of improved conditions and positive outcomes that lead to overall greater resiliency, representation, and redundancy of the Redlips Darter. This scenario assumes no changes in public ownership, but we predict that urbanization rates will be reduced from those predicted by the SLUETH model. The current trend in climate improves, with lower annual increases in temperature and less severe droughts or floods in the short term (RCP < 4.5). Over the long term (30 – 50 years), drought affects all populations but at intervals and severity levels lower than what has occurred over the last 10 years. Conservation efforts will increase through state wildlife action plans, and other partnerships with federal, state, and non-governmental partners. These actions will contribute to improved water quality conditions, increases in forest and riparian cover, and reductions in point source and non-point source pollutants in all historical tributary systems. Within the next 10-30 years, we anticipate the rediscovery or reintroduction of the species to the Roaring River system and portions of the Obey River system (e.g., Wolf River) where the species has not been observed since the 1970s. All of these actions and conditions will lead to increased reproduction and occurrence extent scores for several systems, resulting in increased resiliency for the Roaring River and Obey River populations.

Table 6. Resiliency of the Redlips Darter under Scenario 2 (green text indicates a positive change in resiliency).

Population	Current Condition	Predicted Condition – Scenario 2		
		10 Years	30 Years	50 Years
Red River	Extirpated	Extirpated	Extirpated	Extirpated
Stones River	Extirpated	Extirpated	Extirpated	Extirpated
Roaring River	Extirpated	**Low**	**Low-Moderate**	**Low-Moderate**
Obey River	Low	Low	**Low-Moderate**	**Low-Moderate**
South Fork Cumberland	High	High	High	High
Buck Creek	Low-Moderate	Low-Moderate	**Moderate**	**Moderate**
Rockcastle River	High	High	High	High

Representation

Under Scenario 2, representation of the Redlips Darter is expected to increase to a **moderate** level. Reintroduction of the species to the Roaring River system, and expansion of the species within the Obey River and Buck Creek systems will bolster the species' genetic and ecological diversity across its two historical ecoregions, Interior Plateau and Southwestern Appalachians.

Redundancy

Under Scenario 2, redundancy of the Redlips Darter will increase due to the species' reintroduction to the Roaring River system, and its expansion within the Obey River and Buck Creek systems. This increased redundancy will decrease the likelihood that a catastrophic event, such as an extreme drought or pollution event, would lead to the species' extinction.

Connectivity between extant populations has been reduced, or likely eliminated, by the construction of dams (e.g., Lake Cumberland). No future dams are anticipated under this scenario, leaving the species widely distributed within these systems, with no dispersal barriers preventing movement between the mainstem and multiple tributaries. The connectivity within these systems decreases the effect of localized stochastic events that could be detrimental to these populations and lead to extirpation.

Under Scenario 2, we expect the Redlips Darter to continue to exhibit low-**moderate** redundancy.

Scenario 3

In this scenario, public ownership across the Redlips Darter's range remains at current levels and actions under state wildlife conservation strategies continue to be implemented. Urbanization rates are higher than those predicted by the SLEUTH model, especially in systems with less public ownership (e.g., Buck Creek and Obey River). Decreasing habitat and water quality conditions within these systems lead to reductions in physical habitat, water quality, and occurrence extent. The current trend in climate worsens (high RCP of 8.5), and within the next 10 years, populations are impacted by either drought or flood, with warmer stream temperatures. Over the long term (30 – 50 years), drought affects all populations at slightly higher intervals and severity levels than those observed over the last 10 years. All extant populations are expected to persist, but increased urbanization and agricultural activity within the Buck Creek and Obey River systems lead to reduced resiliency for these systems. We predict no change in resiliency for the South Fork Cumberland and Rockcastle River populations (Table 7).

Representation

Under Scenario 3, representation of the Redlips Darter is expected to remain at **low to moderate** levels. The species has been extirpated from three streams within the Interior Plateau ecoregion; however, the species will continue to persist in both of its historical ecoregions, Interior Plateau and Southwestern Appalachians, and we expect the species to persist in these systems into the future. These populations help to preserve some of the genetic and environmental diversity that has been lost due to extirpations in the western half of the species' range.

Table 7. Resiliency of the Redlips Darter under Scenario 3 (red text indicates a negative change in resiliency).

Population	**Current Condition**	**Predicted Condition - Scenario 3**		
		10 Years	**30 Years**	**50 Years**
Red River	Extirpated	Extirpated	Extirpated	Extirpated
Stones River	Extirpated	Extirpated	Extirpated	Extirpated
Roaring River	Extirpated	Extirpated	Extirpated	Extirpated
Obey River	Low	Low	Low	Low
South Fork Cumberland	High	High	High	High
Buck Creek	Low-Moderate	Low-Moderate	**Low**	**Low**
Rockcastle River	High	High	High	High

Redundancy

Under Scenario 3, redundancy of the Redlips Darter is expected to decrease to a **low** level. The South Fork Cumberland River and Rockcastle River populations will continue to exhibit high resilience, but we expect a decrease in resilience for the Buck Creek and Obey River populations. The likelihood that a catastrophic event, such as an extreme drought or chemical spill, would cause the loss of a population is higher within the Buck Creek and Obey River systems because the species' distribution within those systems is limited to a much smaller, continuous stream reach. The likelihood of extirpation is much lower in the South Fork Cumberland River and Rockcastle River systems due to the species' widespread occurrence, which includes both the mainstem and multiple tributaries.

Connectivity between extant populations has been reduced, or likely eliminated, by the construction of dams (e.g., Lake Cumberland). No future dams are anticipated under this scenario, leaving the species widely distributed within these systems, with no dispersal barriers preventing movement between the mainstem and multiple tributaries. The connectivity within these systems decreases the effect of localized stochastic events that could be detrimental to these populations and lead to extirpation.

Future Viability

The future scenario assessment was developed to understand how viability of the Redlips Darter may change over the course of 10, 30 and 50 years in the terms of resilience, representation, and redundancy. To account for considerable uncertainty associated with future projections, we defined three scenarios that would capture the breadth of changes likely to be observed in the Cumberland River drainage and those changes that have the potential to impact the Redlips Darter. These scenarios considered three elements of change: urbanization, climate, and conservation activity. While we consider these scenarios plausible, we acknowledge that each scenario has a different probability of occurring at different time steps. To account for this difference in probability, probability categories were used to describe the likelihood of each scenario (Tables 8-9).

Table 8**.** Explanation of confidence terminologies used to estimate the likelihood of a scenario (after IPCC guidance, Mastrandrea *et al.* 2011)

Confidence Terminology	Explanation
Very likely	Greater than 90% certain
Likely	70-90% certain
As likely as not	40-70% certain
Unlikely	10-40% certain
Very unlikely	Less than 10% certain

Table 9. Likelihood of Scenarios 1-3 occurring at 10, 30, and 50 years.

	Scenario 1	Scenario 2	Scenario 3
10 years	Very Likely	Unlikely	Very unlikely
30 years	Likely	As Likely as not	Unlikely
50 years	As likely as not	As likely as not	As likely as not

In Scenario 1, all extant populations are expected to persist with an increase in resiliency for the Obey River population but no changes in redundancy, or representation. With respect to likelihood, we consider this scenario to be “very likely”, “likely”, and “likely” to occur within 10, 30, and 50 years, respectively (Table 9).

Scenario 2 predicts a reduction in habitat threats across the species’ range due to reduced urbanization rates and increased conservation efforts. Overall resiliency will increase through improved habitat conditions, increased occupancy extent of extant populations, and reintroduction of the species into one historical system (Red River). Representation is expected to improve from low-moderate to moderate, while redundancy is expected to remain at a moderate level. With respect to likelihood, we consider this scenario to be unlikely" to occur in 10 years and "as likely as not" to occur within 30 and 50 years (Table 9).

Scenario 3 predicts continued conservation efforts under state wildlife action plans, but urbanization rates are predicted to be higher than those predicted by the SLEUTH model, and the likelihood of extreme climate events increase as greenhouse gas emissions continue to increase. As a result, resiliency is reduced in two of four extant populations, while representation and redundancy remain the same. We consider this scenario to be "very unlikely" to occur in 10 years, "unlikely" to occur in 30 years, and "as likely as not" to occur within 50 years (Table 9).

Uncertainty

Through the course of this analysis, it was necessary to make certain assumptions to assess current and future conditions. These assumptions introduce some uncertainty to our estimates of species viability, and our future scenarios are projections based only on current trends and predictive models. The following are uncertainties recognized in this assessment report:

- We assumed that the species' historical range is represented by known collection records. The actual historical range prior to European colonization is unknown and may have included other Cumberland River tributaries or portions of the Cumberland River mainstem.
- To determine the species' current range, we used all records obtained between 2006 and 2017 and evaluated how those records compared to historical collections. Not all historical streams or sites within a specific tributary system were visited over the last 12 years, but we made the decision to include some of these streams as part of the species' current range. Streams were included if available information indicated that habitat or water quality conditions had not changed significantly within these systems since the species' historical collection, and recent collection records were available from the receiving stream or other throughout the system (in some cases habitat and/or water quality conditions had improved). Alternatively, if available information suggested that habitat and water quality conditions were poor and no recent collections were available, these streams were not included as part of the species' current range.
- In order to calculate a population estimate for the South Fork Cumberland River mainstem, we assumed that Redlips Darter densities in the South Fork Cumberland River mainstem were comparable to those recorded from the Rockcastle River system by Compton and Taylor (2013, entire). We limited our estimate to an approximate 50.5-km (31.4-mi) reach of the South Fork Cumberland River from the confluence of Clear Fork and New River downstream to Lake Cumberland (at Blue Heron).
- We assumed that levels of public ownership within extant populations will not change over time.
- Future conservation efforts are dependent on funding availability, available conservation opportunities, and the willing cooperation of our partners, so only a portion of actions may be undertaken in the future.
- We used an available urbanization (development) model (SLEUTH) to predict how future urbanization could impact habitats used by the Redlips Darter. This model uses spatial observations of past urban growth and transportation networks to make

predictions about future urbanization rates. We acknowledge that this model does not account for other potential sources of habitat disturbance or water quality impairment (e.g. agriculture, surface coal mining) that could impact the species in the future. Currently, we are unaware of models that could evaluate future threats associated with these activities.

Overall Summary

Currently, the Redlips Darter is known from four tributary systems of the Cumberland River – Obey River, South Fork Cumberland River, Buck Creek, and Rockcastle River. Populations within the Red River, Stones River, and Roaring River are now considered to be extirpated. The South Fork Cumberland River and Rockcastle River populations exhibit high resiliency, as evidenced by the species' documented persistence within these systems for over 100 years; the large population size estimated for both systems (23,800 – 34,300 individuals); the species' widespread distribution in both systems, including the mainstem and multiple tributaries; and the high quality of physical habitat and water quality conditions within both systems. Resiliency is lower in the remaining two populations (Buck Creek and Obey River) due to smaller population size, lower levels of occurrence extent, reduced connectivity caused by impoundments, and continued threats from agriculture and legacy land use. Representation is currently low-moderate based on the species' extirpation from three of five Interior Plateau systems and a loss of connectivity caused by dam construction. The species has moderate redundancy based on the presence of two highly resilient populations, one population with low-moderate resilience, and one population with low resilience. The Redlips Darter's redundancy and representation have been strengthened by its rediscovery in the Obey River system; its persistence, greater occurrence extent, and low-moderate resiliency within the Buck Creek system; and its high abundance, widespread distribution, and high resiliency within the South Fork Cumberland River and Rockcastle River systems.

Our future scenarios assessment used three elements of change (urbanization, climate change, and conservation activity) to assess the viability of the species over three time periods – 10, 30, and 50 years. These scenarios captured the range of likely viability outcomes that the Redlips Darter will exhibit by 2070. The species persisted in each population and in all scenarios. Resiliency, redundancy, and representation remained constant or increased under Scenarios 1 and 2 and decreased slightly under Scenario 3. Scenario 1 was considered to be the most likely to occur within the next 10 and 30 years, and it was considered to be "as likely as not" to occur over the course of 50 years. Scenario 2 was considered to be "unlikely" to occur in 10 years, and "as likely as not" to occur in 30 and 50 years. Scenario 3 was considered to be "very unlikely to occur in 10 years, "unlikely" to occur in 30 years, and "as likely as not" to occur in 50 years.

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APPENDIX A

Table 10. Summary of public ownership, special use waters, listed species, and designated critical habitat within the Buck Creek, Rockcastle River, and South Fork Cumberland River systems.

Stream	Public Ownership	Special Designation(s)	Listed Species
South Fork Cumberland River – mainstem (KY/TN)	• Big South Fork NRRA (KY/TN) • DBNF (KY)	(RM 54.8-44.3) • KY Wild River • Outstanding National Resource Water (KY) • Outstanding State Resource Water (KY)	Cumberland Bean Cumberland Elktoe* Cumberlandian Combshell* Dromedary Mussel Fluted Kidneyshell* Littlewing Pearlymussel Oyster Mussel* Spectaclecase Tan Riffleshell Tuxedo Darter
Clear Fork and tributaries (TN)	• Big South Fork NRRA (TN)		
New River and tributaries (TN)	• Big South Fork NRRA (TN) • North Cumberland WMA (TN)		
Little South Fork Cumberland River (KY)	• DBNF (KY)	(RM 10.1-4.4) • KY Wild River • Outstanding State Resource Water (KY) (RM 31.1-10.1) • Outstanding State Resource Water (KY)	Cumberland Bean Fluted Kidneyshell* Littlewing Pearlymussel Oyster Mussel Snuffbox Palezone Shiner
Rock Creek (KY/TN)	• Big South Fork NRRA (KY) • DBNF (KY) • Pickett State Park (TN)	(RM 17.6-3.9) • KY Wild River • Outstanding State Resource Water (KY)	Cumberland Elktoe* Fluted Kidneyshell*

Buck Creek (KY)		(RM 55-11.7) • Outstanding State Resource Water (KY)	Cumberland Bean Cumberlandian Combshell* Fluted Kidneyshell* Oyster Mussel* Snuffbox
Rockcastle River (KY)	• DBNF (KY)	(RM 24.4-8.5) • KY Wild River • Outstanding State Resource Water (KY) (RM 53.3-24.4) • Outstanding State Resource Water (KY) (RM 22.4-8.9) • Outstanding National Resource Water (KY)	Cumberland Bean Cumberlandian Combshell Fluted Kidneyshell* Littlewing Pearlymussel Oyster Mussel
Horse Lick Creek (KY)	• DBNF (KY)	(RM 12.3-0.0) • Outstanding State Resource Water (KY)	Cumberland Bean Fluted Kidneyshell* Littlewing Pearlymussel
Middle Fork Rockcastle River (KY)	• DBNF (KY)	(RM 7.9-0.0) • Outstanding State Resource Water (KY)	Cumberland Bean Fluted Kidneyshell*
Laurel Fork of Middle Fork Rockcastle River (KY)	• DBNF (KY)	(RM 12.3-0.0) • Outstanding State Resource Water (KY)	Cumberland Bean
Roundstone Creek (KY)	• DBNF (KY)	(RM 26.4-13.5) • Outstanding State Resource Water (KY)	Cumberland Bean
Sinking Creek (KY)	• DBNF (KY)	(RM 20.3-0.0) • Outstanding State Resource Water (KY)	Cumberland Bean
South Fork Rockcastle River (KY)	• DBNF (KY)	(RM 5.8-0.0) • Outstanding State Resource Water (KY)	Cumberland Bean

Abbreviations: Big South Fork National River and Recreation Area (Big South Fork NRRA), Daniel Boone National Forest (DBNF), Kentucky (KY), North Cumberland Wildlife Management Area (WMA), river mile (RM), and Tennessee (TN); Critical Habitat has been designated for the species (*).

Appendix B

Tables 11-13. Future resilience estimates (10-year, 30-Year, and 50-Year) for the Redlips Darter – Scenario 1.

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	10-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low-Moderate	Low-Moderate	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	30-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low-Moderate	Low-Moderate	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	50-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low-Moderate	Low-Moderate	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Tables 14-16. Future resilience estimates (10-year, 30-Year, and 50-Year) for the Redlips Darter – Scenario 2 (green text indicates a positive change in resiliency).

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	10-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Moderate	Moderate-High	Low	Low	Low	**Low**
Obey River	Low-Moderate	Low-Moderate	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	30-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Moderate	Moderate-High	Low	Low	Low	**Low-Moderate**
Obey River	Low-Moderate	Low-Moderate	Low	High	Low	Low	**Low-Moderate**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Moderate	High	Low	**Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	50-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Moderate	Moderate-High	Low	Low	Low	**Low-Moderate**
Obey River	Low-Moderate	Low-Moderate	Low	High	Low	Low	**Low-Moderate**
South Fork Cumberland River	High	High	Moderate-High	High	High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Moderate	High	Low	**Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Tables 17-19. Future resilience estimates (10-year, 30-Year, and 50-Year) for the Redlips Darter – Scenario 3 (red text indicates a negative change in resiliency).

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	10-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low-Moderate	Low-Moderate	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Moderate	Moderate	Moderate-High	Low	Moderate	Low	**Low-Moderate**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	30-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low	Low	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Low	Low	Moderate-High	Low	Low	Low	**Low**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**

Population	Physical Habitat	Water Quality	Connectivity	Reproduction	Occurrence Extent	Occurrence Complexity	50-Year Future Condition
Red River	Low	Low	Moderate-High	0	0	0	**Extirpated**
Stones River	Low	Low	Low	0	0	0	**Extirpated**
Roaring River	Moderate	Low	Moderate-High	0	0	0	**Extirpated**
Obey River	Low	Low	Low	Low	Low	Low	**Low**
South Fork Cumberland River	High	High	Moderate-High	High	Moderate-High	High	**High**
Buck Creek	Low	Low	Moderate-High	Low	Low	Low	**Low**
Rockcastle River	High	High	Moderate-High	High	High	High	**High**