Species Status Assessment (SSA) Report

for the

Longhead Darter

(*Percina macrocephala*)

Version 1.0

Longhead darter (Photo credit: Robert Criswell)

October 2018
U.S. Fish and Wildlife Service
Northeast Region
Hadley, MA

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Contents

EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the longhead darter (*Percina macrocephala*). This report is intended to provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered under the Endangered Species Act (Act) of 1973, as amended. The process and this SSA report do not represent a decision by the U.S. Fish and Wildlife Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the longhead darter.

Background

The longhead darter is a small fish endemic to predominantly 3rd order and larger streams and rivers in New York, Pennsylvania, Ohio, Kentucky, Tennessee, and West Virginia. Longhead darters are found in streams and rivers with clean, clear water and a range of substrates (*e.g.*, silt, cobble, gravel, and detritus) and are typically observed suspended in the water column, indicating good swimming ability, pelagic habits, and an ability to migrate. Males and females are sexually mature after their first year and spawning likely occurs from March to May. Longhead darters feed on benthic macroinvertebrates and are believed to live a minimum of 3 to 4 years. See Chapter 2 for more details.

Longhead darter populations are widespread but geographically isolated. Historically, longhead darters likely had a more continuous distribution, but now populations, although widespread, are geographically isolated from each other as a result of dams and other barriers, resulting in limited connectivity among populations. Stressors to water quality, particularly increased turbidity and siltation resulting from agricultural, industrial, and municipal development, have also likely influenced the longhead darter's current distribution. The longhead darter has been extirpated from several watersheds but is stable and/or increasing in distribution within several others, likely due to local improvements in water quality coupled with improved survey techniques. See Chapter 3 for more details.

Methodology

To assess the biological status of the longhead darter across its range, we used the best available information, including peer reviewed scientific literature and first-hand accounts and survey data provided by State agencies and academic institutions from New York, Pennsylvania, Ohio, Kentucky, Tennessee, and West Virginia. Fundamental to our analysis of the longhead darter was the determination of analytical units (*i.e.*, populations) at a scale useful for assessing the species. We defined longhead darter populations based primarily on known occurrence locations and the amount of geographic isolation between watersheds, identifying a total of 10 individual longhead darter populations with which to conduct our assessment. See Chapter 4 - Methodology for more details.

To qualitatively assess the current condition of populations we considered components describing characteristics about each population's demography (occupancy, occurrence extent, and occurrence complexity) and physical environment (water quality). 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 longhead darter population that was then used to assess the longhead darter's current condition across its range under the conservation biology principles of resiliency, redundancy, and representation (together the 3Rs). See Chapter 4 – Current Conditions – 3Rs for more details.

The same methodology was used to assess the species' condition and potential viability under three plausible future scenarios. We chose to model these scenarios at 10, 25, and 50 years because we have data to reasonably predict changes in land cover (*e.g.*, conversion of forest to urban development) and concomitant (naturally accompanying) changes in water quality within this timeframe. We chose multiple future scenarios to try to capture the full breadth of plausible future scenarios. Scenario 1 modeled the continuation of current trends where we assumed similar rates of forest loss and urban development and maintenance of water quality under Federal regulations. Scenario 2 modeled an optimistic scenario where we assumed a reduced rate of forest loss and urban development, improved water quality, and an increase in occupancy, occurrence extent, and occurrence complexity from reintroducing longhead darters into a watershed where they are currently believed to be extirpated. Lastly, Scenario 3 modeled the pessimistic scenario where we assumed an increased rate of forest loss and urban development and decreasing water quality with concomitant decreases in occurrence extent. See Chapter 5 for more details.

Conclusions

Current Condition

The longhead darter is currently distributed in 5 (50 percent) of 10 historical populations, 2 are unknown, and 3 are extirpated (representing a complete loss of resiliency in those populations). The longhead darter is present within both physiographic provinces from which it is historically known (Appalachian Plateaus and Interior Low Plateaus) and survey data suggest the species is expanding (as a result of increased abundance or improved survey techniques) in three populations. We qualitatively assessed the five extant populations, placing them in "low," "moderate," or "high" categories that represent the populations' potential to bounce back after stochastic events. Of the 5 known extant populations, 3 (60 percent) have a current score of high resiliency, and 2 (40 percent) have moderate to high resiliency. Therefore, we conclude extant longhead darter populations currently range between moderate to high resiliency.

The longhead darter currently occurs in at least 50 percent of its historical range (5 of 10 known populations). Therefore, redundancy has declined since its historical state. Redundancy for the longhead darter, however, is currently evidenced by multiple extant populations distributed across two physiographic provinces (*i.e.*, four populations in the Appalachian Plateaus and one population in the Interior Low Plateaus). More recently, the species' redundancy has been strengthened by its expanding range (within and outside of its historical range) and high resiliency within three populations and persistence in all other extant populations. Therefore, we conclude that the longhead darter currently has moderate redundancy.

The longhead darter currently maintains representation in multiple watersheds within both physiographic provinces from which it is historically known. As related to the species' diversity of environmental settings, the longhead darter is widely distributed; however, the species no longer occupies all of its historical tributary systems, so there has potentially been a reduction in the species' genetic and environmental diversity over time. Given the longhead darter retains representation in two physiographic provinces and is persisting and/or expanding in at least 50 percent of its historical range, we conclude that the species' representation is moderate.

Future Condition

Under Scenario 1 (continuation of current trend), the condition of all 10 longhead darter populations is predicted to remain relatively unchanged from the current condition within 50 years. Under Scenario 1, the species' redundancy and representation remained unchanged (*e.g.*, all current populations remained extant), and the resiliency of the five extant populations is predicted to remain unchanged.

Under Scenario 2 (optimistic scenario), the condition of nine longhead darter populations is predicted to remain relatively unchanged from the current condition, and the condition of one population is predicted to have improved within 50 years. Under Scenario 2, the species' redundancy would improve (the addition of a single population), representation would remain unchanged, and the resiliency of the one improved population is predicted to increase.

Under Scenario 3 (pessimistic scenario), the condition of eight longhead darter populations is predicted to remain relatively unchanged from their current condition, and the conditions of two populations are predicted to decrease within 50 years. Under Scenario 3, the species' redundancy and representation remained unchanged (*e.g.*, all current populations remained extant), although the resiliencies of two populations are predicted to decrease.

Summary

We considered what the longhead darter needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation. For the purpose of this assessment, we generally define viability as the ability of the longhead darter to sustain populations in natural river ecosystems over time. Based on the longhead darter's life history and habitat needs, we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' viability. We evaluated how potential influences may be currently affecting the species and whether, and to what extent, they would affect the species in the future. Dams currently influence the species' distribution and connectedness over its range, particularly where those structures have eliminated habitat or led to isolated populations. We identified numerous stressors to water quality that have occurred and to some extent continue to occur within the species' range; however, longhead darters are predicted to persist within all currently extant (5 of 10) populations in the future under each of the future scenarios assessed.

CHAPTER 1 – INTRODUCTION

Background

This report summarizes the results of a species status assessment (SSA) conducted for the longhead darter (*Percina macrocephala*). We, the U.S. Fish and Wildlife Service (Service), were petitioned to list 404 aquatic, riparian, and wetland species, including the longhead darter, as endangered or threatened under the Endangered Species Act of 1973, as amended (Act) on April 20, 2010, by the Center for Biological Diversity, Alabama River Alliance, Clinch Coalition, Dogwood Alliance, Gulf Restoration Network, Tennessee Forests Council, West Virginia Highlands Conservancy, Tierra Curry, and Noah Greenwald. In September of 2011, the Service found that the petition presented substantial scientific or commercial information indicating that the listing of 374 species, including the longhead darter, may be warranted. Thus, we conducted an SSA to compile the best scientific and commercial data available regarding the species' biology and factors that influence the species' viability.

Analytical Framework

The SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, 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. As such, the SSA report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA report for the longhead darter is intended to provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered and, if so, whether or not to propose designating critical habitat. The process and this SSA report do not represent a decision by the Service whether or not to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the longhead darter. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and a decision will be announced in the Federal Register.

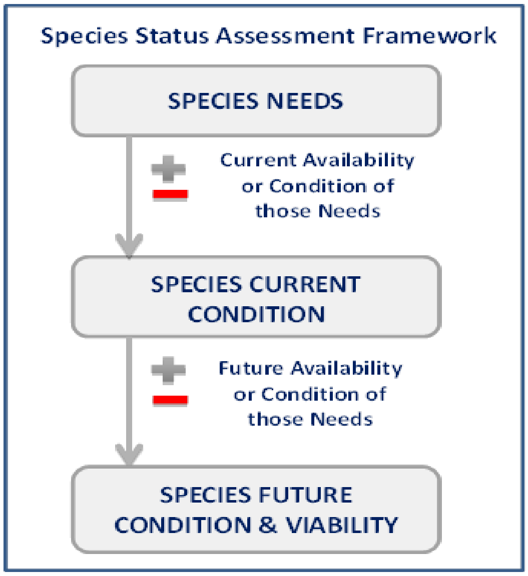

Figure 1. Species Status Assessment Framework

Using the SSA framework (figure 1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Service 2016, entire; Smith *et al*. 2018, entire). For the purpose of this assessment, we generally define viability as the ability of the longhead darter to sustain populations in natural river ecosystems over time. Resiliency, redundancy, and representation are defined as follows:

• **Resiliency** means having sufficiently large populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, birth versus death rates and population size, if that information exists. 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 human activities.

• **Redundancy** means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

• **Representation** means having the breadth of genetic makeup of the species to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. 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 the species' morphology, habitat characteristics within the geographical range, or both.

The decision whether to list a species is based not on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the longhead darter by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of resiliency, redundancy, and representation (together, the 3Rs). We then evaluate the future biological status of the longhead darter by describing a range of plausible future scenarios representing a range of conditions for the primary factors affecting the species and forecasting the most likely future condition for each scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to individually describe and analyze. These scenarios do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures. This SSA report provides a thorough assessment of longhead darter biology and natural history and assesses demographic factors and stressors in the context of determining the viability and risk of extinction for the species.

CHAPTER 2 – SPECIES INFORMATION

Taxonomy and Genetics

The longhead darter (*Percina macrocephala*, figure 2) belongs to the perch family of fishes (Percidae) and was first described by Cope (1869, pp. 400–401; *Etheostoma macrocephalum*) based on three specimens collected from the Youghiogheny River, Pennsylvania. The longhead darter is recognized as a valid taxon and is listed as such in the California Academy of Sciences *Catalog of Fishes: Genera, Species, References* (Fricke *et al*. 2018). We accept this taxonomy.

The longhead darter is a member of the subgenus *Alvordius* (Page 1974, p. 83); however, in an analysis of mitochondrial cytochrome b DNA sequences, Near (2002, pp. 8–10) found no support for the monophyly of *Alvordius* and found no species (described at the time) to be closely related to the longhead darter. Morphological traits used to diagnose *Alvordius* were likely independently derived among species assigned to the subgenus (Page and Near 2007, p. 610). Updated 2007 information suggests the most closely related species is the sickle darter (*Percina williamsi*) (Page and Near 2007, entire). Once recognized as longhead darter, the sickle darter was separated from the longhead darter in 2007. The sickle darter is distinguished from the longhead darter by having larger scales and a shorter snout; mitochondrial DNA sequences also confirm two distinct species (Page and Near 2007, pp. 606 and 610). The sickle darter is geographically restricted to the upper Tennessee River drainage of Tennessee, Virginia, and North Carolina; longhead darters do not occur in these locations (Page and Near 2007, pp. 608–609). Hybridization between darters, including *Percina* species, has been observed in a variety of unique crosses, and may occur more frequently than previously reported (Keck and Near 2009, p. 765). Hybrid crosses between longhead darters and logperch (*Percina caprodes*) are documented in several specimens held in collections at the University of Tennessee (Etnier and Starnes 1993, p. 576) and the Pennsylvania State University (Stauffer 2018); however, we have no information to suggest hybridization is negatively affecting longhead darter viability.

Cytochrome b DNA sequences were collected for seven specimens of longhead darter from the Allegheny River, Pennsylvania; Elk River, West Virginia; and Barren River, Kentucky (Page and Near 2007, p. 611). Page and Near (2007, p. 610) found low genetic variation among individuals from this wide geographic sampling area. We are unaware of additional genetic studies that analyze longhead darter population genetics in greater depth.

Species Description

The longhead darter is elongate, reaching 102 millimeters (mm) (4.02 inches (in)) standard length (SL; the length measured from the tip of the snout to the last vertebra, which excludes the length of the caudal fin (tail)) (Page 1978, p. 656). In the Green River, Kentucky, young of the year ranged from 34 to 52 mm (1.34 to 2.05 in) SL, longhead darters at 2 years of age averaged 75 mm (2.95 in), and 3 to 4 year olds exceeded 90 mm (3.54 in) (Page 1978, p. 663). The snout is sharply pointed, and there is a developed series of 10 or more specialized scales along the ventral midline (Stauffer *et al.* 2016a, p. 468). The back and upper sides are brown, tan, olive, or straw while that of the lower sides and underside are white or light yellow (Stauffer *et al.* 2016a, p. 468). Black ovate and/or square blotches fuse to form a wide mid-lateral stripe (Stauffer *et al.* 2016a, p. 468) whereas younger individuals have more distinct barely touching mid-lateral blotches (Page 1978, p. 659). Page 1978 (p. 658–659) noted morphological variations in body shape, mid-lateral blotches/stripe, and scale counts between specimens from the Green River system, Kentucky, and the upper Ohio River system, Pennsylvania.

Figure 2. Longhead darter (*Percina macrocephala*) (photo courtesy of: Robert Criswell).

Life History

Longevity—Longhead darters collected between May and October from the Green River, Kentucky, were likely 3 to 4 years in age (Page 1978, p. 663). Scale annuli were not discernible; therefore, the exact ages of larger individuals were uncertain (Page 1978, p. 663).

Sheltering—Longhead darters inhabit warm rivers and larger streams, where they occupy a wide range of habitats. The species requires clean, unpolluted water and has been found in riffles and runs over a variety of substrates including gravel, cobble, boulders, and rubble. The longhead darter also occurs in pools with gravel, detritus, or silt bottoms and may be found near macrophytes such as water willow (*Justicia* sp.) (Stauffer *et al.* 2016a, p. 469). Longhead darters are most often encountered hovering in the water column a few centimeters above the bottom near the cover of boulders, vegetation, or brush (Etnier and Starnes 1993, p. 576). In riffle/pool transition areas of the Birch and Elk rivers, West Virginia, longhead darters used areas of slower current (Welsh and Perry 1998, p. 417).

***Feeding*—**Longhead darters have been observed feeding by swimming methodically from rock to rock and delicately picking macroinvertebrates from crevices and stone surfaces (Stauffer *et al*. 2016a, p. 469). Foraging individuals often pause for several seconds at each rock; a feeding style that would be difficult in high water velocities and may partially explain the habitat partitioning according to water velocity observed between longhead darters and logperch (Welsh and Perry 1998, p. 418). Stomach contents of 10 longhead darter specimens from the Green River system, Kentucky, consisted of small crayfishes and mayfly nymphs (Page 1978, p. 663). A long snout and large mouth facilitates ingestion of larger food items (Page and Near 2007, p. 609).

***Reproduction*—**Longhead darters are not sexually mature until after one year of age (Page 1978, p. 663). We are unaware of any literature (or other evidence) that states the age of sexual maturation. Breeding males darken in coloration enough to obscure their body pattern, while breeding females may darken without obscuring body pattern. Young of the year probably develop from eggs laid in March, April, or May in the Green River, Kentucky. The sex ratio among Green River specimens was 1.5 male: 1.0 female, although this ratio may be an artifact of sampling bias (Page 1978, p. 663).

We are unaware of any longhead darter-specific reproduction studies, however, in the Little River, Tennessee, the closely related sickle darter has been observed to move into deep pools during winter months and migrate to shallow gravel shoal areas to spawn in the spring. Sickle darter eggs in this system hatched in 27 days at an average water temperature of 10 degrees Celsius (50 degrees Fahrenheit), with larvae emerging at a length of 10 mm (0.4 in). Larvae are very active and presumably feed on macroinvertebrates after depleting yolk sac nutrients (Etnier and Starnes 1993, p. 576).

***Movement/Dispersal*—**Some longhead darter populations may migrate seasonally. A multi-year study in Kinniconick Creek, Kentucky, found individuals at two sites in August 2007 but not in June 2007 or September 2009. It is suspected that immigration from downstream areas is needed for recolonization of upstream areas during periodic severe droughts that may cause local extirpations or poor recruitment (Eisenhour *et al*. 2011, p. 15). Evidence of capacity for migration and dispersal is supported by the lack of divergence in mitochondrial DNA found in specimens spanning a geographic range from Kentucky to Pennsylvania (Page and Near 2007, p. 610). A longer pelagic larval duration (PLD), or the time an aquatic larva spends in the water column, is thought to be advantageous for dispersal and population connectivity. Some darters have no pelagic stage, while others have lengthy PLDs lasting more than a month that are more characteristic of marine species (Douglas *et al*. 2013, pp. 2–3). While we are unaware of specific studies that examine longhead darter PLD, longhead darters are typically observed suspended in the water column, indicating good swimming ability and pelagic habits (Eisenhour *et al*. 2011, p. 15). This evidence supports the assumption that longhead darters have some ability to disperse and/or migrate.

Table 1. Summary of longhead darter life history information by life stage based on best available information.

Life Stage	Resource and/or circumstance needs and related information
Eggs	• Spawning likely occurs from March to May • Eggs are laid in gravel substrates
Larvae	• Larvae hatch at around 27 days at a length of 10 mm (0.4 in)
Juveniles	• Occupies same habitat as adults • Feed on macroinvertebrates
Adults	• Males and females are sexually mature after their first year • Minimum 3 to 4 year life expectancy • Found in large streams and rivers with clean, clear water and a range of substrates (*e.g.*, silt, cobble, gravel, detritus) • Found hovering in water column near cover (*e.g.*, plants, logs, boulders) • Feed on macroinvertebrates such as crayfish and mayflies

Environmental Settings

Longhead darters are known from six States (New York, Pennsylvania, Ohio, West Virginia, Kentucky and Tennessee) and two physiographic provinces (Appalachian Plateaus and Interior Low Plateaus; Fenneman and Johnson 1946) (figure 3).

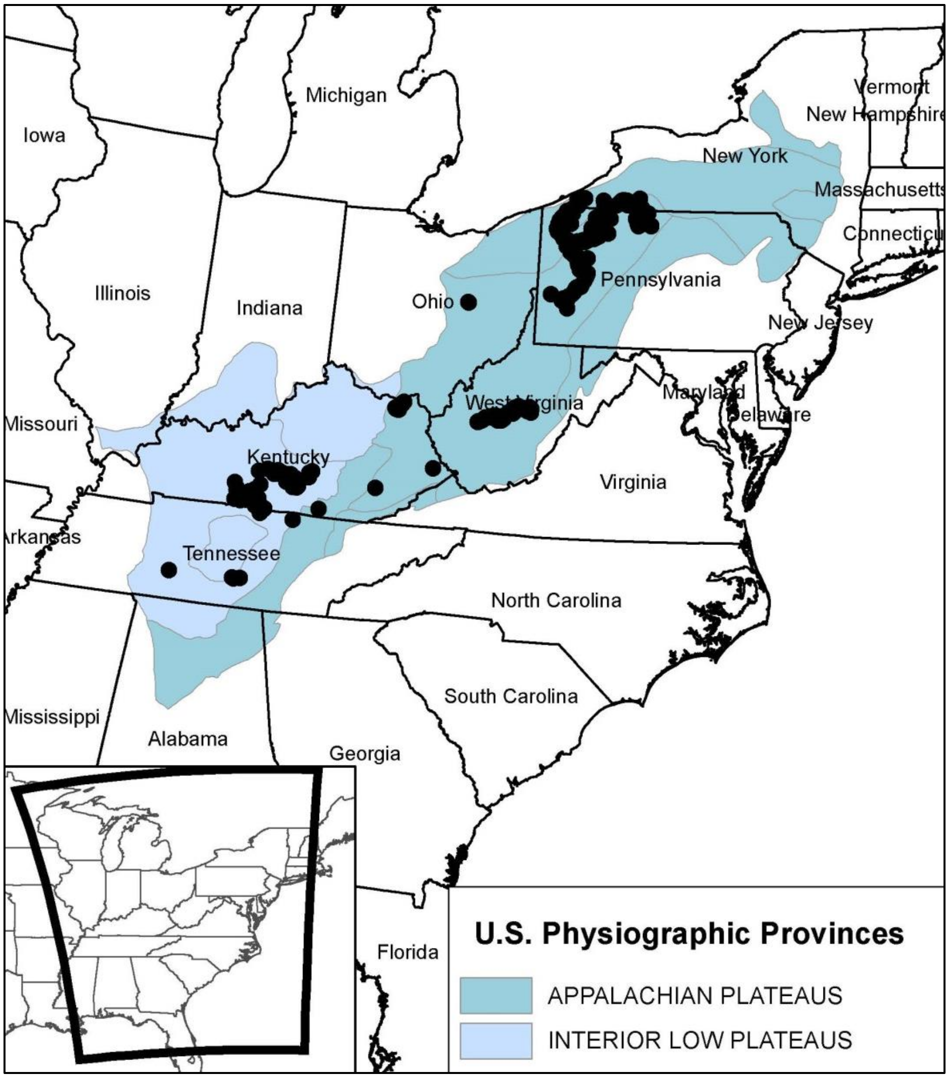

Figure 3. Localities (dots) where the longhead darter has been collected.

The Appalachian Plateaus physiographic province is composed of sedimentary rocks including sandstones, conglomerates, and shales that exist largely as horizontal beds that have been cut by streams to form mountainous terrain. In addition to these sedimentary rocks, beds of coal are locally significant throughout the Appalachian Plateaus, making this area the heart of the American coal industry. In the recent geologic past, the northern portion of the Appalachian Plateaus has been subject to the effects of glaciation (National Park Service (NPS) 2017a). The rolling hills of the Appalachian Plateaus contain rich and diverse broadleaf forests of oaks, hickories, maples, and poplars in the valleys and birch-maple-hemlock forests at higher elevations (White *et al*. 2005, p. 377).

The Interior Low Plateaus physiographic province is composed almost completely of horizontal beds of sandstone, shale, and limestone. The limestone of the province is marked by well-developed karst topography, including Mammoth Cave National Park, Kentucky. The Interior

Low Plateaus are home to widespread but small-scale coal, petroleum, and natural gas mineral resources (NPS 2017b). Soils are primarily red and yellow podzols (*i.e*., forested soils) (White *et al*. 2005, p. 377).

Rivers within the longhead darter range are ecologically diverse. River gradients range from low to high, with variable substrate (*e.g*., rocky, sandy with cobble, sandy with glacial till) and variable alkalinity (White *et al*. 2005, p. 378). Climate is temperate with cool moist winters and warm humid summers. Average monthly precipitation is fairly uniform throughout the year, with significant accumulations of snow in the Appalachians. Land cover is predominantly forested.

Habitat Needs

The longhead darter is known predominantly from 3rd order and larger streams and rivers, where it occupies a wide range of habitats. The longhead darter inhabits pools with current (Trautman 1981, p. 626; Page and Near 2007, p. 609), often upstream or downstream of riffles in clear, mid-sized rivers with moderate to steep gradients (Page 1978, p. 662; Kuehne and Barbour 1983, p. 37). Compared to other species such as logperch, the longhead darter used areas of lower water velocity in West Virginia, likely facilitating its methodical foraging habits (Welsh and Perry 1998, p. 417).

Substrate type varies widely where longhead darters have been found, but water is usually clear with low siltation and low to medium flow. In Kentucky, longhead darters were found most often in areas above riffles (*i.e*., glides) with low flow (0 to 0.22 meters (m)/second (sec) (0.7 foot (ft)/sec), mean = 0.027 m/sec (0.09 ft/sec)), with substrates of boulders and cobble, and low to moderate silt accumulation (less than 1 mm (0.04 in) on rocks). Occasionally, longhead darters were also encountered in shallow sections of larger pools (Eisenhour *et al*. 2011, p. 14). In Pennsylvania, longhead darters were observed in riffles and runs over substrates of clean gravel, rubble, cobble, and boulders at the interface of strong current and backwaters. Longhead darters were also observed in pools with clean substrates of gravel and rubble, or covered in silt or detritus (Stauffer *et al*. 2016a, p. 469). In the middle and lower Allegheny River, Pennsylvania, longhead darters were found in typical channel habitat within pools of the lock and dam navigational system, but were not captured from the mouths of wadeable tributaries within these sections of the Allegheny River system (Koryak *et al*. 2008, p. 493; Koryak *et al*. 2009, p. 514).

Longhead darters are regularly observed suspended in the water column, often near cover (Etnier and Starnes 1993, p. 576). In New York, longhead darters were most frequently encountered in protected areas where woody debris, vegetation, and other types of large cover were available along the river's edge. Longhead darters were also encountered in the main channel in areas with slower flow, often near vegetation (Brewer 2018a). In Pennsylvania, longhead darters have been observed sheltering among plants such as water willow (*Justicia* sp.) (Stauffer *et al*. 2016a, p. 469).

Specific water quality parameters tolerated or preferred by the longhead darter are not well described; however, we assume that the longhead darter requires pH levels close to neutral and contaminant levels below those which would negatively impact native aquatic fauna. Poor water quality, including an increased sediment load, may negatively impact longhead darters by causing direct mortality, stress to individuals, or reduced spawning success.

Connectivity, for the purpose of this assessment, considers a longhead darter's ability to immigrate or emigrate between populations and the likelihood of recolonization should a population become extirpated. Although little is known regarding the minimal habitat patch size or degree of habitat connectivity necessary to support persistent longhead darter populations, it is generally understood in the field of conservation biology that larger and more-connected populations contribute to the long-term viability of a species (*i.e*., higher population resiliency) and that smaller isolated populations are more at risk of decline or extirpation (*e.g*., lower population resiliency) as a result of genetic drift, demographic or environmental stochasticity, and catastrophic events (Gilpin and Soulé 1986, pp. 32–34; Angermeier 1995, entire; Fagan 2002, p. 3248; Wiegand *et al*. 2005, entire; Letcher *et al*. 2007, 5–6; Peterson *et al*. 2014, pp. 564–565).

Range, Distribution, and Abundance

The species was first recorded in 1869 from the Youghiogheny River, Pennsylvania (Cope 1869, pp. 400–401). Surveys conducted before 1940 documented the longhead darter in every major waterway from which it is known today, except for the Duck and Buffalo rivers, Tennessee (figure 4a). Surveys between 1940 and 1989 documented the longhead darter for the first and last time in the Duck and Buffalo rivers (figure 4b). Historical and recent surveys have documented the species' persistence within the Allegheny River/French Creek drainage (New York and Pennsylvania), Elk River watershed (West Virginia), Kinniconick Creek (northeastern Kentucky), and the Green and Barren river watersheds (southcentral Kentucky) (figures 4a, 4b, 4c, and 4d). It is likely that the longhead darter had a broader and more connected distribution than historical and current records indicate (Jelks 2018; Johansen 2018).

Longhead darter distribution has been expanding in New York, Pennsylvania, and West Virginia (Criswell 2006, p. 2; Carlson *et al*. 2016, p. 318; Carlson 2018; Cincotta 2018) likely due to improved water quality coupled with improved survey techniques (Herzog *et al*. 2005, entire; Koryak *et al*. 2008, entire; Freedman *et al*. 2009, entire; Honick *et al*. 2017, p. 222). In New York, longhead darter is relatively common in the areas it is caught (Carlson *et al*. 2016, p. 318) and in 2015, the New York State Department of Environmental Conservation (NYDEC) removed longhead darter from the State's Wildlife Action Plan's list of species of greatest conservation need because their population was determined to be secure in New York (NYDEC 2018a). In Pennsylvania, the longhead darter occurs in every watershed with historical records except the Youghiogheny River, where it is likely extirpated (Stauffer *et al*. 2016a, p. 469). In 2008, the longhead darter was removed from Pennsylvania's State-threatened list (Criswell 2006, pp. 1–2). "Although historically represented by limited, widely scattered collections consisting of only a single or few individuals, recent research has documented a more or less continuous distribution throughout French Creek, from the New York state line in Erie County to its mouth in Venango County, and the Allegheny River, from Potter County downstream to Allegheny County, as well as in the lower sections of a number of larger tributaries to both" (Criswell 2006, p. 1). In West Virginia, the longhead darter is maintaining its historical distribution in the Elk River and has expanded into the lower portions of several tributaries that had no prior historical records (Cincotta 2018; Welsh 2018). Longhead darter distribution in the Green and Barren rivers, Kentucky/Tennessee, has likely been reduced because of the construction of large dams and associated reservoirs; however, data suggest the species is persisting within these watersheds. Longhead darters are believed to be extirpated from the Cumberland River and Kentucky River watersheds in Kentucky and Tennessee, and from the Walhonding River, Ohio (figure 5; Burr and Warren 1986, p. 336; Zimmerman 2018a). Longhead darter status in the Duck and Buffalo rivers, Tennessee, and eastern Kentucky (*e.g.*, Johns Creek) is unknown.

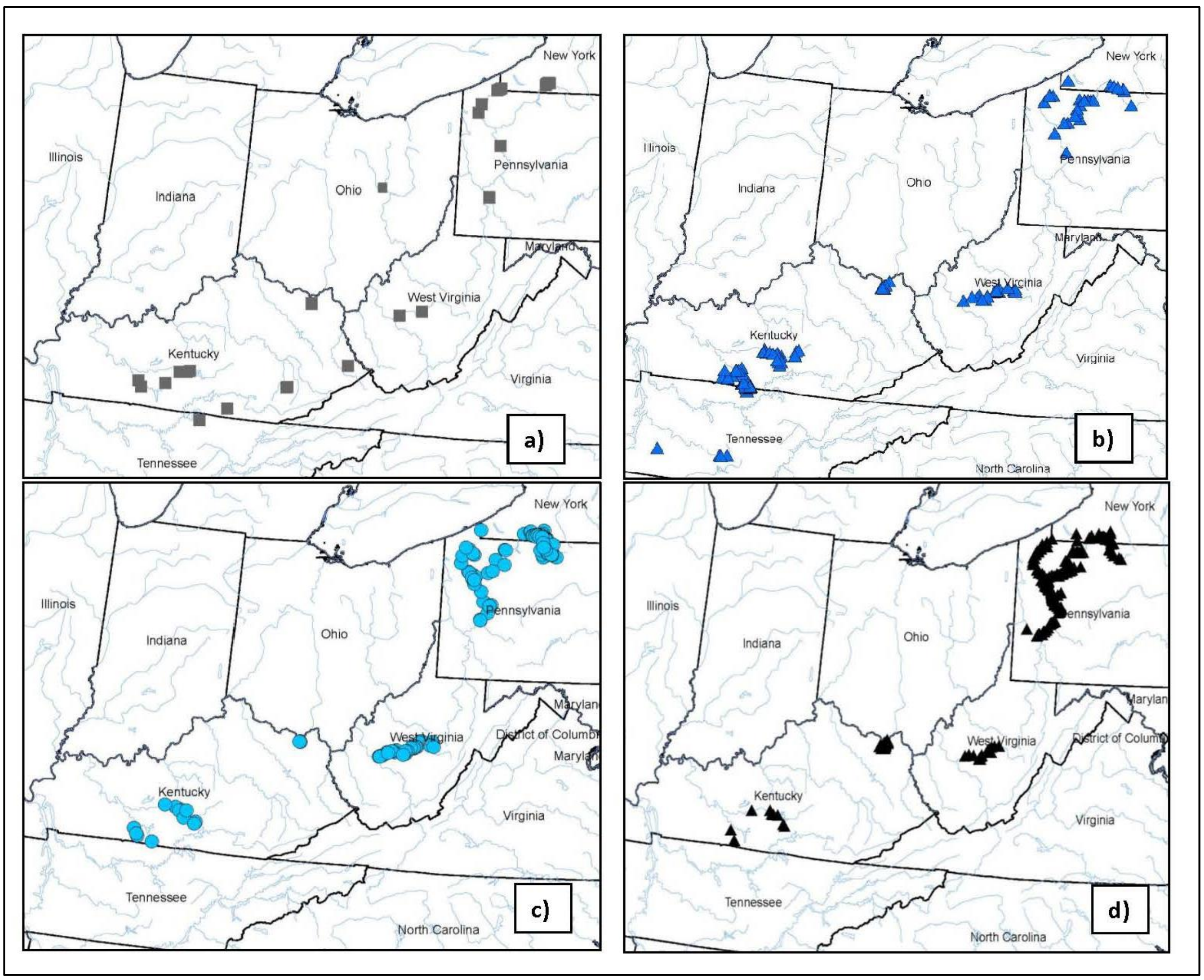

Figure 4a, 4b, 4c and 4d. Longhead darter occurrence records a) pre-1940 (gray squares), b) between 1940 and 1989 (blue triangles), c) between 1990 and 2006 (blue circles), and d) between 2007 and 2017 (black triangles).

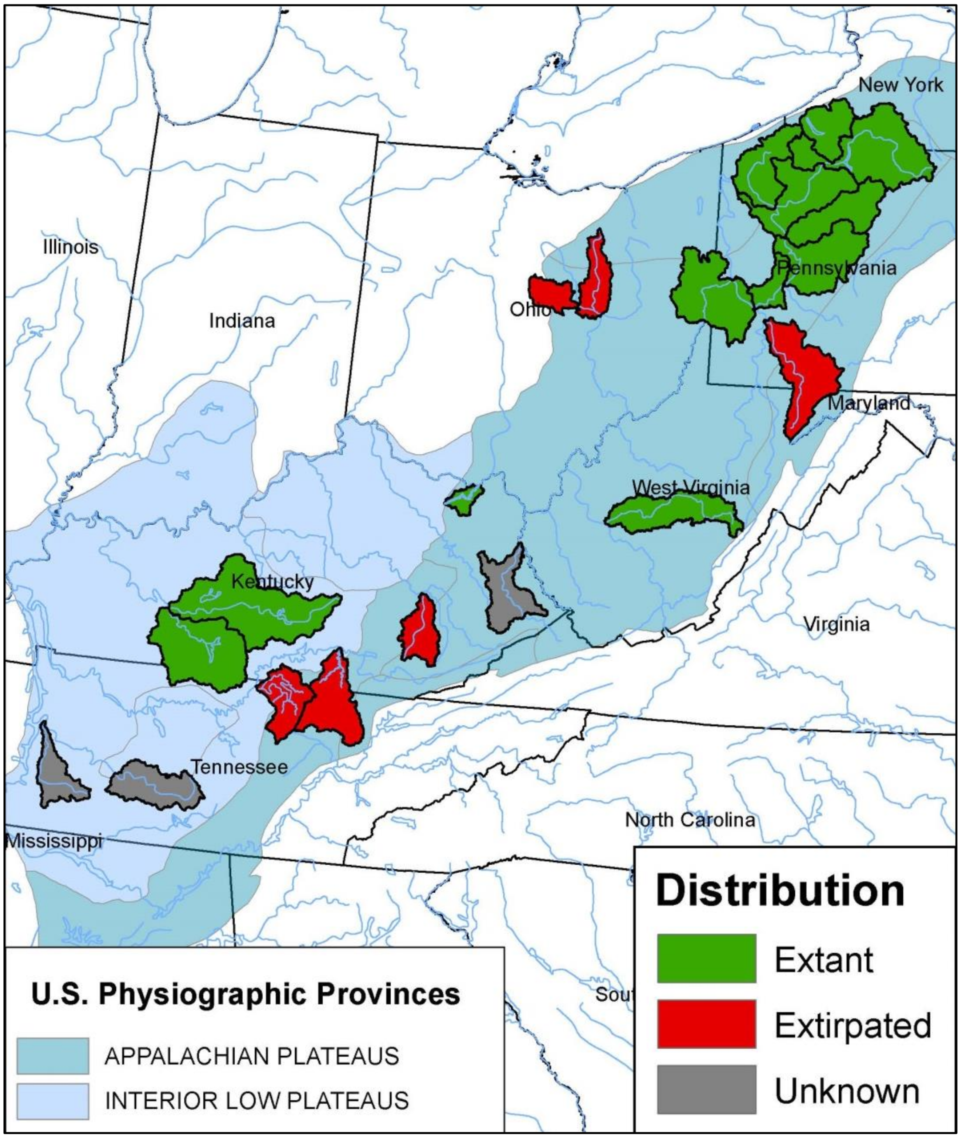

Figure 5. Current longhead darter distribution illustrated by hydrologic unit code (HUC) 8 watersheds.[1]

[1] Kinniconick Creek (northeastern Kentucky) is represented by the smaller HUC 10 watershed because it is encompasses the entire population and is therefore most representative.

CHAPTER 3 – FACTORS INFLUENCING VIABILITY

Based on the longhead darter's life history and habitat needs, we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' viability.

Sedimentation

Excessive stream siltation (or sedimentation) results from soil erosion associated with upland activities (*e.g.*, agriculture, forestry, mining, unpaved roads, road or pipeline construction, and general urbanization), as well as from activities that can destabilize stream channels themselves (*e.g.*, dredging or channelization, construction of dams, culverts, pipeline crossings, or other instream structures) (West Virginia Department of Environmental Protection (WVDEP) 2012, p.12). The negative effects of increased sedimentation are well understood for aquatic species (Newcombe and MacDonald 1991, p.72; Burkhead *et al*. 1997, p 411; Burkhead and Jelks 2001, p. 964). Excessive sediments can cover the stream bottom and fill the interstitial spaces between bottom substrate particles (*i.e.*, sand, gravel, and cobble) and in severe cases also cause stream bottoms to become "embedded," in which case substrate features including larger cobbles, rocks, and boulders are surrounded by, or buried in, sediment. This can affect fish species directly by limiting sheltering or breeding habitat and/or by causing shifts in the benthic community structure that alter the prey base (Berkman and Rabeni 1987, 291–293; Messinger and Chambers 2001, p. 50–51; Sutherland *et al*. 2002, entire; McGinley *et al*. 2013, pp. 223–226). Excessive turbidity can affect the ability of fishes to successfully spawn. Burkhead and Jelks (2001, p. 963) found that crevice-spawning shiners did not lay eggs in higher turbidity situations, greatly reducing egg production. Longhead darters could behave similarly (Jelks 2018). Increased turbidity as a result of sedimentation can also reduce foraging efficiency through reduced visibility; abrade or suffocate fish gills, eggs, and larvae; and reduce disease tolerance (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; Eisenhour *et al*. 2009, p. 11).

Since enactment of various state and Federal regulations (*e.g.*, Federal Clean Water Act of 1977 (33 U.S.C. 1251 et seq.), Surface Mining Control and Reclamation Act of 1977 (30 U.S.C. 1234–1328)) and the increased implementation of forestry and construction best management practices designed to reduce erosion and sedimentation, levels of stream sedimentation have likely improved from historical levels. Based on information obtained from the Environmental Protection Agency's (EPA) Clean Water Act Section 303(d) and Total Maximum Daily Loads (TMDLs) program (EPA 2017a), impairment from sedimentation is listed within four streams where the longhead darter occurs: Dodge Creek, New York; and Glens Fork, Middle Fork Drakes Creek, and Bays Fork, Kentucky (EPA 2017a). Increased siltation resulting from industrial, agricultural, and municipal development has been identified as a principal threat to longhead darter (Page and Near 2007, p. 610). Gravel mining (on a local scale) continues to occur in the Green River system, Kentucky, and Allegheny River, Pennsylvania. Sedimentation continues to be one of the primary stressors in streams in Kentucky (Kentucky Division of Water (KDOW) 2013a, 2013b, and 2015). Sedimentation has likely played a role in the longhead darter's current distribution, as the pools and slow raceways occupied by this species would be impacted by sediment deposition earlier than habitats with faster moving water (*e.g*., riffles) (Eisenhour *et al*. 2009, p. 11).

Water Quality

There is little information regarding the longhead darter's tolerance of specific water quality parameters. Coliform bacteria (likely from sewage or septic releases, or livestock wastes) are a common water contaminant across the range of the longhead darter. Although fish are generally not sensitive to coliform bacteria (unless concentrations are significant enough to cause a decrease in dissolved oxygen), the presence may be an indicator of degraded conditions and/or the presence of other pollutants of concern such as ammonia (Patnode 2017).

Like coliform bacteria, ammonia can enter streams not only via municipal effluent discharges but also via indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands (EPA 2013a, entire). Ammonia causes direct toxic effects on aquatic life when it is present at levels high enough to make it difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic buildup in internal tissues and blood, and potentially death (EPA 2013a, entire). EPA has published national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia. EPA's Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013 is the most recent recommendation from EPA and serves as an update to EPA's previous recommendations from 1999. The 2013 ammonia criteria recommendations take into account the best available freshwater toxicity information for ammonia, including toxicity studies for sensitive unionid mussels and gill-breathing snails. The updated criteria are more stringent than the previously recommended 1999 criteria (EPA 2013a, entire). EPA's recommended water quality criteria are not rules, nor do they automatically become part of a state's water quality standards. Currently, no states within the range of longhead darter have fully adopted the 2013 ammonia criteria. Aquatic toxicity has been reported from streams receiving municipal discharges in Olean Creek and Tunungwant Creek, New York; and Bays Fork and Johns Creek, Kentucky (EPA 2017a). Longhead darters, like most aquatic organisms, have likely been impacted when ammonia has exceeded safe levels (EPA 2013a, entire). Ammonia concentrations have improved, however, with the implementation of each revision of the EPA Freshwater Aquatic Life Ambient Water Quality Criteria (EPA 2013b, p. *x*). Longhead darter exposure to ammonia will likely continue to decrease further if/when states adopt the 2013 criteria, which impose lower limits in waters occupied by longhead darters (Patnode 2017).

Urbanization refers to a change in land cover and land use from forests or agriculture to increased density of residential and commercial infrastructure. Streams affected by urbanization have been described to exhibit an "urban stream syndrome" (Walsh *et al*. 2005, p. 207; Wenger *et al*. 2009, entire; Matthaei and Lang 2016, p. 180). The urban stream syndrome consistently includes "a flashier hydrograph, elevated concentrations of nutrients and contaminants, altered channel morphology and stability, and reduced biotic richness, with an increased dominance of species tolerant to poor water quality and variably includes reduced baseflow and increased suspended solids" (Paul and Meyer 2001, entire; Walsh *et al*. 2005, p. 207). Between 2001 and 2011, development increased approximately 1.7 percent, 0.6 percent, and 0.5 percent within the Lower Allegheny (Pennsylvania), Upper Duck (Tennessee), and Barren (Kentucky/Tennessee) watersheds, respectively (Homer *et al*. 2015). Changes in the amount of development were less evident (*i.e*., 0.2 percent or less) in the remaining watersheds across the longhead darter's range; consequently, while development is a potential stressor, we expect impacts from urbanization to be localized.

Combined sewer overflows (combined overflows), are remnants of the country's early infrastructure. In the past, communities built sewer systems to collect both stormwater runoff and sanitary sewage in the same pipe. During dry weather, these "combined sewer systems (combined systems)," transport wastewater directly to sewage treatment plants. In periods of rainfall or snowmelt, however, the wastewater volume in a combined system can exceed the capacity of the sewer system or treatment plant. For this reason, combined systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or lakes. Combined overflows contain not only stormwater, but also untreated human and industrial waste and toxic materials that could be hazardous to aquatic systems. This is a major water pollution concern for cities with combined systems (EPA 2017b). The EPA's 1994 Combined Sewer Overflows Control Policy (59 FR 18688) is the national framework for control of combined overflows. The policy provides guidance on how communities with combined systems can meet Clean Water Act goals in as flexible and cost-effective a manner as possible including phased implementation. Although some larger cities may have problems with combined overflows, most communities with combined overflow problems have fewer than 10,000 people (EPA 2017c). Elevated levels of fecal coliform (*e.g*., *Escherichia coli*) have been reported in the Elk River, West Virginia; and Johns Creek, Green River, Glens Fork, and Barren River, Kentucky (EPA 2017a). Although combined overflows are a potential stressor, given the wide distribution of longhead darters, we assume potential impacts from combined overflows will be localized.

Agricultural activities that cause non-point source pollution include poorly located or managed animal feeding operations (*e.g*., concentrated animal feeding operation); overgrazing; plowing too often or at the wrong time; and improper, excessive, or poorly timed application of pesticides, irrigation water, and fertilizer. Pollutants that result from farming and ranching include sediment, nutrients, pathogens, pesticides, metals, and salts. Insecticides, herbicides, and fungicides are used to kill agricultural pests. These chemicals can enter and contaminate water through direct application, runoff, and atmospheric deposition (EPA 2005, entire). They can poison fish and wildlife, contaminate food sources, and destroy the habitat that animals use for protective cover. Better agricultural practices have reduced runoff throughout the Ohio Region watershed; however, soil erosion along with fertilizer and pesticide pollution continue to be documented (White *et al*. 2005, p. 378). The amount of agriculture over the longhead darter's range remained stable or decreased slightly between 2001 and 2011 (Homer *et al*. 2015); consequently, we do not anticipate much change in potential effects from agricultural activities from current levels in the near future. However, while impacts from agricultural activities are comparatively localized within populations, sedimentation from agricultural runoff is still one of the most pervasive stressors in agricultural landscapes.

Abandoned coal mines and active strip mining with resultant acid mine drainage and/or elevated conductivity levels continue to be documented throughout the Appalachians (White *et al*. 2005, p. 396), and mountaintop mining has occurred throughout eastern Kentucky and West Virginia

(Palmer *et al*. 2010, p. 148). The EPA's Clean Water Act Section 303(d) and TMDLs program (EPA 2017a) identified iron as an impairment in several sections of the Elk River and tributaries, West Virginia. Iron is likely entering streams via acid mine drainage from coal mining. Operation and maintenance of water discharges and slurry ponds associated with coal mining are also a concern in West Virginia (Johansen 2018). "Two existing impoundments in the middle of the [Elk River] drainage have more than seven times the amount of slurry stored then what was accidently released into Wolf Creek of the Big Sandy River in 2001; this event effectively killed over 40 miles [64 kilometers (km)] of the Tug Fork River" (Johansen 2018). Valley fills from mountaintop mining result in burial of headwater streams which can cause permanent loss of aquatic habitat and decreases in water quality (Palmer *et al*. 2010, p. 148). Longhead darters are found in larger streams and rivers; therefore, burial of the darter's stream habitat is unlikely, but potential impacts include contaminants entering streams and sedimentation from upstream activities. Although widespread impacts from acid mine drainage continue, the effects of coal mining on water quality have generally improved since the implementation of the Surface Mining Control and Reclamation Act of 1977 (Office of Surface Mining 2003, entire).

Natural gas extraction increased between 2008 and 2012 in Pennsylvania and West Virginia as a result of technological advances in drilling. In Pennsylvania alone, 12,151 new unconventional (*e.g.,* Marcelles Shale gas extraction) drilling permits were issued between 2008 and 2012 compared to only 18 between 2000 and 2004 (Pennsylvania Department of Environmental Protection [PADEP] 2018); however, the number of new unconventional well drilling permits decreased 59 percent in 2016 compared to 2014 (PADEP 2016). Wastewater from Marcellus hydraulic fracturing flowback fluids is characterized by high chloride, bromide, iodide, and ammonium (Harkness *et al*. 2015, pp. 1957–1958). Extraction of natural gas produces high salinity water that flows to the surface in advance of the gas. This solution is more concentrated than seawater and is produced by more than 95 percent of Pennsylvania's oil and gas wells (Dresel and Rose 2010, p. 42). "Water quality impacts can result from inadequate management of water and fracturing chemicals on the surface, both before injection and after as flowback and produced water" (Zammerilli *et al*. 2014, p. 74). "Management and disposal of wastewaters increasingly includes efforts to minimize water use and recycling and re-use of fracturing fluids. [Lastly], drilling and hydraulically fracturing a shale gas well can consume between 2 and 6 million gallons of water and local and seasonal shortages can be an issue, even though water consumption for natural gas production generally represents less than 1 percent of regional water demand" (Zammerilli *et al*. 2014, p. 74). Although natural gas extraction has been rapidly developing in Pennsylvania and West Virginia, we are uncertain how impacts to water quality and/or water consumption may be influencing longhead darter viability.

Habitat Fragmentation

There are over 700 dams across the longhead darter's historical range (White *et al*. 2005, p. 413), including navigational locks and dams, small flood control dams, and large hydroelectric power generation dams. Major dams influencing the longhead darter's current condition are identified in Chapter 4. Historically, longhead darters likely had a more continuous distribution, but now populations, although widespread, are geographically isolated from each other as a result of dams and other barriers, resulting in limited connectivity between populations. Dams likely eliminated populations that were never discovered and have influenced longhead darter's ability to recolonize streams and rivers where water quality has improved. Several dams on the lower Muskingum River, Ohio, are likely limiting the potential for longhead darter to recolonize the upper Muskingum River basin (*e.g.*, Walhonding River) which is believed to be extirpated (Zimmerman 2016; Zimmerman 2018a). Longhead darters occupying the Allegheny River in New York and Pennsylvania are separated by the Kinzua Dam and its associated reservoir, essentially isolating the upper Allegheny River and tributaries. The Sutton Dam located on the Elk River, West Virginia, and the Green River Lake Dam located on the Green River, Kentucky, have led to reduced connectivity within longhead darter habitat. Lastly, culverts have led to restricted fish passage during low flows on the Kinniconick Creek, Kentucky (Eisenhour *et al*. 2011, p. 53). Although dam construction has likely influenced the species' current distribution and viability, we do not anticipate future decreases in connectivity as a result of dam creation because the construction of new, large scale dams is unlikely given changing public perceptions regarding dams (Lieb 2015).

Other Factors Considered

The introduction of nonnative species may stress indigenous fish populations via increased predation, competitive interactions, transmission of pathogens, or hybridization (Mills *et al*. 2004, pp. 719–720; Cucherousset and Olden 2011, pp. 216–221). Reproducing populations of round goby (*Neogobius melanostomus*), an introduced nonnative species, were discovered in LeBoef Creek, a tributary of French Creek, in 2014, and by 2015, they had spread to the main channel of French Creek (Stauffer *et al*. 2016b, p. 405; Mueller *et al*. 2017, entire). The presence of round goby has been associated with dietary shifts of rainbow darter (*Etheostoma caeruleum*) (Stauffer *et al*. 2016b, pp. 401–402). While interactions with nonnative species may be affecting individuals, we have no information to suggest that introduction of nonnative species, disease, or predation are affecting longhead darter viability now or may in the future.

The Fifth Assessment Report by the Intergovernmental Panel on Climate Change (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, p. 56). According to state climate summaries released by the National Oceanic and Atmospheric Administration National Centers for Environmental Information (Kunkel *et al*. 2017, entire), historically unprecedented warming is projected by the end of the 21st century across the range of the longhead darter, leading to increases in heat wave intensity, decreases in cold wave intensity, increases in extreme precipitation (with resultant increases in the frequency and intensity of floods), and increases in the intensity of naturally occurring droughts.

The U.S. Army Corps of Engineers and the Ohio River Basin Alliance prepared a pilot study to address the effects of climate change within the Ohio River Basin, which consequently, includes most of the longhead darter's range except for the Upper Duck and Buffalo watersheds, Tennessee (Drum *et al*. 2017, entire). Modeling results indicate a gradual increase in annual mean temperatures over time but substantial variability in hydrologic flow. Subwatersheds located northeast, east, and south of the Ohio River are expected to experience greater precipitation and thus higher stream flows (Drum *et al*. 2017, p. 1). Conversely, those subwatersheds located north and west of the Ohio River are expected to experience ever-decreasing precipitation resulting in decreased in-stream flows. Reduced streamflow coupled with the prospect of rising air temperatures that can result in higher water temperatures may lead to some aquatic species being at risk of extirpation in impacted watersheds; however, seasonal management of reservoir discharge volumes and water temperature may offset some of these anticipated impacts (Drum *et al*. 2017, p. 2).

"The key stressors to aquatic ecosystems that arise from climate change are changes in water temperature and changes in precipitation patterns and flow regimes. Higher temperature will decrease dissolved oxygen and will increase the uptake of toxins by some fish. With these changes, the biotic communities will change as limits of tolerance for some species are exceeded, and the changed conditions become acceptable to invading species" (Drum *et al*. 2017, p. 54). We do not know the upper thermal limits of longhead darter tolerance. However, given the species' broad range and occurrence in 3rd order or greater streams and rivers, we assume longhead darters are relatively tolerant of warmer water conditions. For similar reasons, we also assume they will be less vulnerable to droughts, compared to species occurring in lower order (*i.e*., smaller rivers) or headwater streams. Consequently, the effects of climate change on the longhead darter's viability are largely unknown, but limited information suggests the species may not be particularly vulnerable. A "Climate Change Vulnerability Assessment" of more than 700 species in the Appalachian region ranked the longhead darter as "presumed stable" to the effects of climate change (Appalachian Landscape Conservation Cooperative 2017).

Lastly, there are several conservation efforts in progress that will likely benefit longhead darter viability. Ohio State University is currently collaborating with the Ohio Division of Wildlife and Pennsylvania Fish and Boat Commission on plans for reintroducing longhead darters into four streams in Ohio (Fischer 2018a; Zimmerman 2018a; Zimmerman 2018b; Zimmerman 2018c). The Pennsylvania Fish and Boat Commission has initiated a "trap and transport" project, whereby they are collecting a subset of longhead darters from Pennsylvania streams and relocating them into stream habitats currently blocked by dams (Fischer 2018a). Pennsylvania State biologists are also assessing the Youghiogheny River for potential reintroduction efforts. "Much like many other drainages, water quality in the Yough has recovered significantly, so we hope to identify areas of habitat that will support the establishment of translocated populations" (Fischer 2018b). In addition, the Tennessee Aquarium Conservation Institute conducted surveys in 2018 within the Duck River, Tennessee (where the population status is currently unknown) (Raines and Kuhajda 2017, entire) and additional surveys are planned (Neely 2018).

Summary

Current longhead darter populations are widespread but geographically isolated. Water pollution, including sedimentation, and dams have likely influenced the current distribution and species' viability. Dams have eliminated habitat and led to isolated populations. We identified numerous stressors to water quality that have occurred and likely led to several extirpations; however, water quality has improved in some areas, and longhead darter distribution appears to be stable and/or increasing within multiple populations, likely as a result of water quality improvements coupled with improved survey techniques. Sedimentation, like dams, likely continues to influence longhead darter distribution and abundance.

CHAPTER 4 – CURRENT CONDITIONS

Methodology

To assess the biological status of the longhead darter across its range, we used the best available information, including peer reviewed scientific literature, academic reports, and survey data provided by State agencies and academic institutions. Fundamental to our analysis of the longhead darter was the determination of analytical units (*i.e*., populations) at a scale useful for assessing the species. In this report, we defined longhead darter populations based primarily on known occurrence locations and the amount of geographic isolation between watersheds. Most longhead darter populations are separated from each other by long distances (see Chapter 2), and many are further isolated by dams and impoundments (see Chapter 3).

To qualitatively assess the current condition of populations we considered components describing characteristics about each population's demography and physical environment. Components describing population demography included occupancy, occurrence extent, and occurrence complexity. The population's physical environment was assessed by averaging two subcomponents describing water quality. Parameters for each component's condition category were established by evaluating the range of existing data and separating those data into "high" category (H), "moderate" category (M), "low" category (L), "unknown" category (UNK), or "presumed extirpated" (0), based on our understanding of the species' demography and physical environment (table 2). Using the demographic and physical component parameters defined in table 2, we categorized each population as being in "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UNK), or "presumed extirpated" (0). To aid in the comparison of populations (with each other and under the future scenarios outlined in chapter 5) and assessment of the species' current viability using the 3Rs, we weighted each of the four components equally and determined the average score to describe each population's current condition (table 3).

Table 2. Parameters used to define categories for each component used to assess longhead darter population condition.

		High	Moderate	Low	Unknown	0
Occupancy		Currently occupied (*i.e.*, documented between 2007 and 2017).	N/A	N/A	Unknown occupancy.	Presumed extirpated.
Occurrence Extent		<10% decline from known range.	10 to 50% decline from known range.	>50% decline in known range.	Unknown occurrence extent.	Presumed extirpated.
Occurrence Complexity		Occupies main channel and ≥ 4 tributaries.	Occupies main channel and 1 to 3 tributaries.	Occupies main channel only.	Unknown occurrence complexity.	Presumed extirpated.
Water Quality	**303(d) Streams**	Minimal or no known water quality impairments **or** impairments present but low toxicity **or** impairments present but highly localized.	Water quality impairments present with moderate toxicity.	Water quality impairments known to impact populations.	N/A	Extensive water quality impairments precluding occupancy.
	Land Cover	>80% forest cover	50 to 80% forest cover	<50% forest cover	N/A	N/A

Occupancy

To assess population occupancy, occurrence records provided by State agencies and academic institutions were evaluated. Longhead darter occurrence records came from multiple sources and represented a diversity of sampling techniques and methods, and therefore did not exhibit standardization. The number of individuals collected was inconsistently recorded, and sampling methods varied among records. Although assessing abundance and growth rate would be preferred, the data were not sufficient for this type of analysis; therefore, we used occupancy as a surrogate. A population was considered "occupied" if it included an occurrence record within the last 10 years (2007 or more recent).

Occurrence extent

Occurrence extent for the longhead darter was evaluated by measuring the distance between the most upstream record and the most downstream record using ArcMap 10.3.1. Historical and current records were assessed separately to determine and quantify any range reduction or expansion that may have occurred. To determine the current range, we used all records obtained between 2007 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 if available information indicated that habitat or water quality conditions had not changed significantly since the species' historical collection. 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. A population was considered to have high occurrence extent if it had declined less than 10 percent from its historical range. More significant reductions in range (*i.e.*, 10 to 50 percent or greater than 50 percent) scored lower.

Occurrence complexity

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 not only the river's main channel, but multiple tributaries. Complex and dendritic (*i.e.*, tree-like) spatial arrangement of occupied habitat will be more resilient against extinction (Fagan 2002, p. 3244). A population was considered to have high occurrence complexity when individuals occupied the river's main channel and four or more tributaries, moderate occurrence complexity when individuals occupied the river's main channel and three or fewer tributaries and low occurrence complexity if individuals occupied only the river's main channel.

Water quality

Water quality is a component used to describe the relative health of a stream and its presumed habitability for longhead darters. Water quality conditions within populations were determined by analyzing two subcomponents: 1) known and reported water quality issues from the Environmental Protection Agency's (EPA) Clean Water Act Section 303(d) and Total Maximum

Daily Loads program (EPA 2017a); and 2) assessing land cover using the National Land Cover Database 2011 land cover data within hydrologic unit code (HUC) 8 watersheds[2] (Homer *et al*. 2015, entire). Water quality was considered high when watersheds had few or highly localized impairments and high amounts of forest cover, which we assume equates to lower amounts of sedimentation (see Chapter 3).

Current Condition—3Rs

The results of the longhead darter population condition model provide the basis for our analyses of the species' current status using the 3Rs. The population condition score is a measure of each population's resiliency (table 3, figure 6), and these scores form the basis of our analyses of the species' redundancy (among the various populations) and representation (across its environmental settings).

[2] For the Kinniconick Creek population, we analyzed land cover within the smaller Kinniconick Creek HUC 10 watershed because it is encompasses the entire population and is therefore most representative.

Table 3. Current condition of longhead darter populations. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	H	H
2	Allegheny River, NY/PA	H	H	H	M	M	H
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	0	0	0	H	L	0
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	H	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	M	UKN

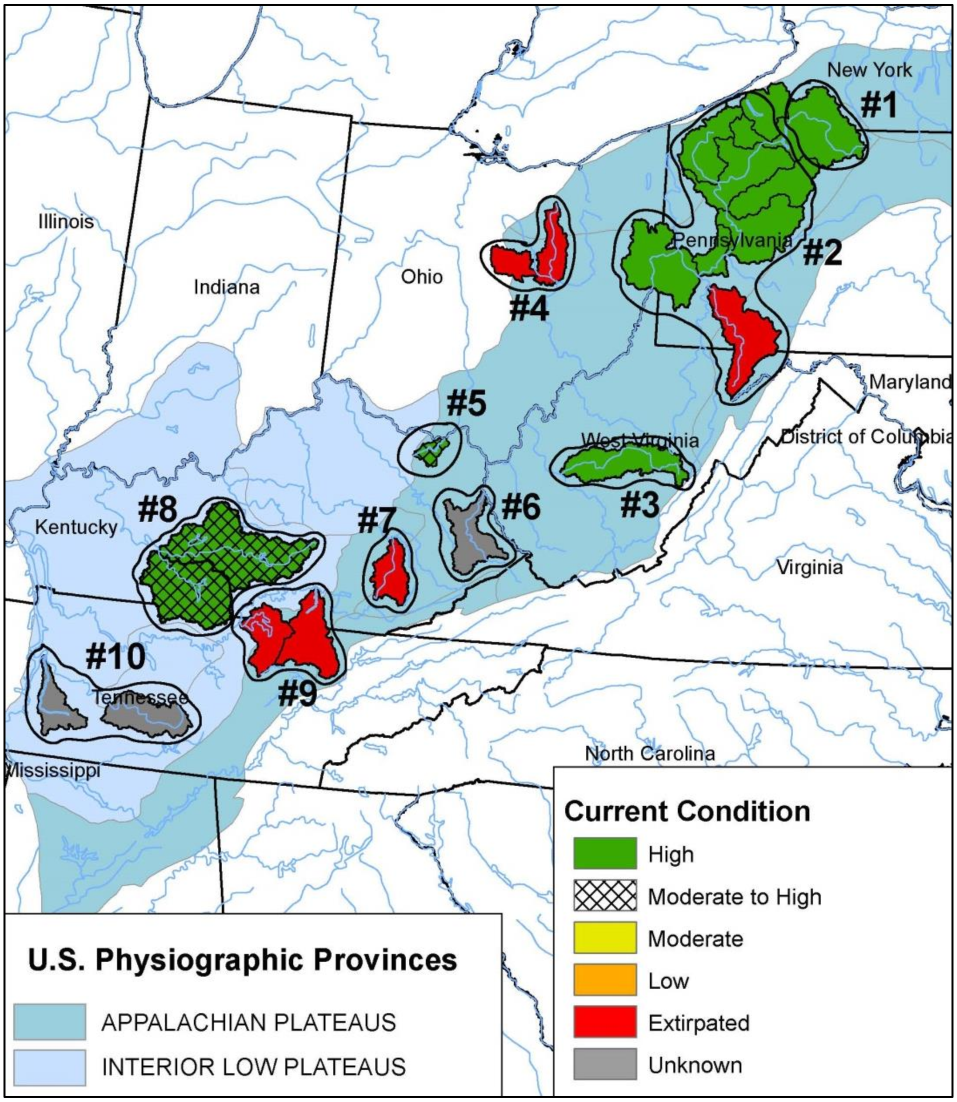

Figure 6. Current condition of longhead darter populations illustrated by HUC 8 watersheds.[3]

Resiliency—Resiliency describes the ability of a population to withstand environmental or demographic stochastic disturbance and is positively related to population size and growth rate, patch size, and connectivity to other populations. The population characteristic components from the longhead darter model, which incorporate estimates of occupancy, occurrence extent, and occurrence complexity, are used in conjunction with water quality to assess longhead darter population resiliency.

#1 Upper Allegheny, New York/Pennsylvania

The Upper Allegheny population includes the upper Allegheny River in Pennsylvania and New York and tributaries in southwest New York (Oswayo Creek, Dodge Creek, Ischua Creek,

[3] #5 Kinniconick Creek population illustrated by HUC 10 watershed.

Tunungwant Creek, Olean Creek, and Great Valley Creek) and northwestern Pennsylvania (Indian Creek, Cole Creek, Fishing Creek, Potato Creek, and Oswayo Creek). The Upper Allegheny population is located upstream of a large hydroelectric power dam, Kinzua Dam, and associated Allegheny Reservoir. The Allegheny Reservoir spans approximately 32 km (20 miles) on the border between Pennsylvania and New York, essentially isolating this population from all other longhead darter populations. The first record of the longhead darter within this population was documented in 1937 and it has been observed as recently as 2018 (Carlson *et al*. 2016, p. 318; Brewer 2018a; Brewer 2018b; NYDEC 2018b, unpublished data; Pennsylvania Fish and Boat Commission (PAFBC) 2018, unpublished data). Occurrence records suggest longhead darters occupy most of their historical range within this population (figure 7), and the population is expanding (Carlson *et al*. 2016, p. 318; Carlson 2018). Longhead darter is relatively common in the areas where it is caught (Carlson *et al*. 2016, p. 318) and high numbers of juvenile longhead darters were observed during 2018 surveys (Brewer 2018b). Land cover within the Upper Allegheny HUC 8 watershed is approximately 83 percent forest, 12 percent agriculture and 4 percent development. "Other" land cover types (*e.g*., open water, emergent wetlands, and grasslands) account for the remaining 1 percent of land cover. Although this watershed is predominantly forested, there are several localized water quality impairments that include nutrients, agricultural runoff, and municipal sewage discharges; therefore, water quality is ranked as moderate to high. Overall, we conclude the Upper Allegheny population currently has high resiliency.

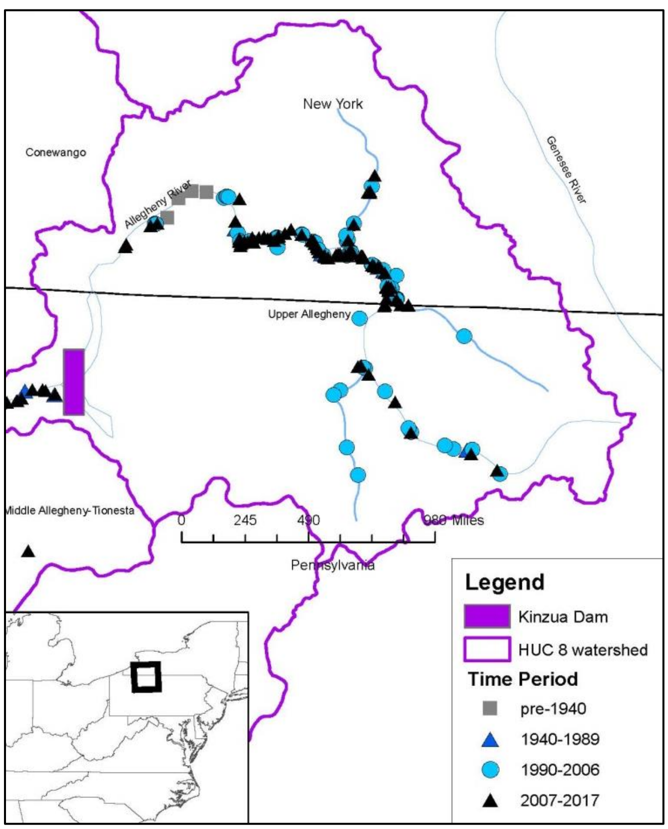

Figure 7. Distribution of the longhead darter in the #1 Upper Allegheny population, Pennsylvania and New York, based on positive occurrence records (1937 – present).

#2 Allegheny River, New York/Pennsylvania

Of all the populations, the Allegheny River population is the largest with a more or less continuous distribution throughout French Creek and the Allegheny River, as well as in the lower reaches of numerous tributaries (figure 8). This population includes Chadakoin River, Conewango Creek, and French Creek in New York; and Allegheny River, Brokenstraw Creek, Clarion River, Conneauttee Creek, Cussewago Creek, East Hickory Creek, French Creek, Hemlock Creek, LeBoeuf Creek, Little Conneauttee Creek, Little Sugar Creek, Mahoning Creek, Muddy Creek, Ohio River, Oil Creek, Sandy Creek, South Branch French Creek, Sugar Creek, Tionesta Creek, West Branch French Creek, Woodcock Creek, and Youghiogheny River in Pennsylvania. Land cover within currently occupied HUC 8 watersheds encompassing this population ranges from 50 to 80 percent forest, 11 to 33 percent agriculture, and 4 to 31 percent developed, and includes the major city of Pittsburgh, Pennsylvania. Water quality has improved since the 1970s, but cities (*e.g*., Pittsburgh) remain point sources for nutrients and industrial waste. Agricultural runoff dominates most tributary inputs, and abandoned mines still exude acid (White *et al*. 2005, p. 381). This unit includes free-flowing rivers (*e.g.*, French Creek and upper Allegheny River) and navigation locks and dam systems (*e.g*., lower Allegheny River and Ohio River). Prior to European contact, the Allegheny River was clear and constantly flowing and contained clean beds of gravel, rock, and sand. Today, the Allegheny River and Ohio River are impounded with deep navigation channels. To maintain the navigational channels, the U.S. Army Corps of Engineers dredges an average of 500,000 cubic meters of silt, sand, and gravel each year (White *et al*. 2005, p. 384). Occurrence records suggest longhead darters occupy most of their historical range with the exception of the Youghiogheny River, Pennsylvania (figure 6; Carlson *et al*. 2016, p. 318; NYDEC 2018b, unpublished data; PAFBC 2018, unpublished data). The earliest longhead darter records within this population (and within the range of the species) are from 1869, and include three specimens from the Youghiogheny River (Cope 1869, pp. 400–401); however, there have been no additional collections from the Youghiogheny River and it is likely extirpated from this waterway (Stauffer *et al*. 2016a, p. 469). Surveys conducted in Pennsylvania since 1985 have documented many records from localities from which it was not previously known and an increase in abundance compared to pre-1985 surveys (Criswell 2006, p. 1). Lastly, the Pennsylvania Fish and Boat Commission has initiated a “trap and transport” project, whereby they are collecting a subset of longhead darters from Pennsylvania streams and relocating them into stream habitats currently blocked by dams (Fischer 2018a). The project is already underway in the Clarion River drainage.

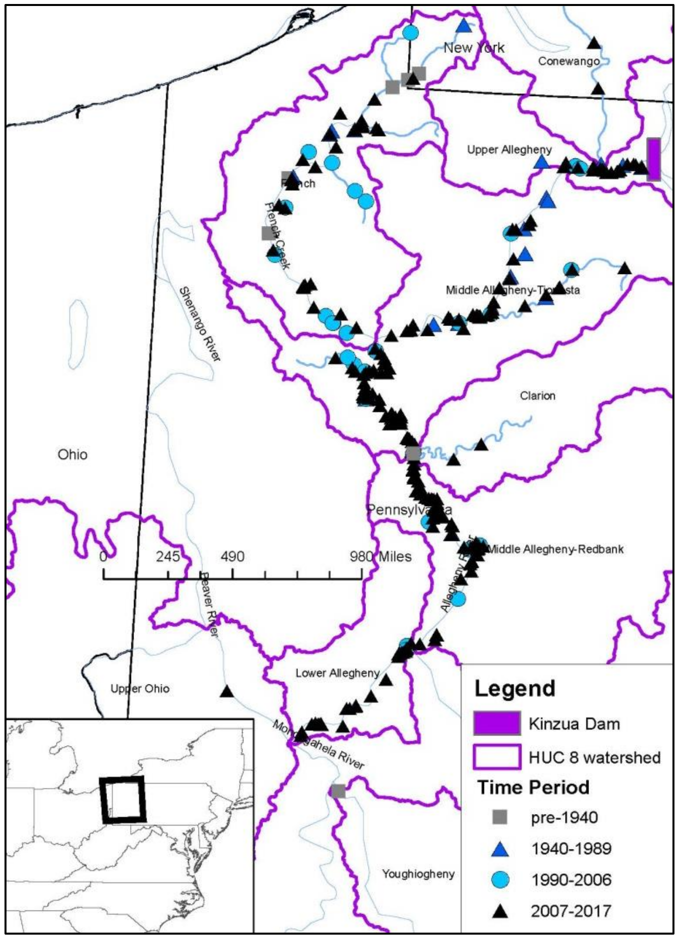

Figure 8. Distribution of the longhead darter in the #2 Allegheny River population, Pennsylvania and New York, based on positive occurrence records (1869 – present).

<u>#3 Elk River, West Virginia</u>

The Elk River population is located in West Virginia and includes the mainstem Elk River and tributaries (Groves Creek, Porter Creek, Leatherwood Creek, Little Otter Creek, Left Fork Holly River, Right Fork Holly River, Strange Creek, Buffalo Creek, and Birch River). The watershed is fairly undeveloped; as towns and businesses are infrequent with the exception of the lower reaches in Kanawha County, West Virginia (Cincotta 2018). Land cover is 91 percent forest, 5 percent development, 2 percent agriculture, and 2 percent "other" within the Elk HUC 8 watershed. The Elk River is one of the most ecologically diverse in the State of West Virginia, supporting over 100 fish species and 30 mussel species, and it is home to the only extant population of the federally endangered diamond darter (*Crystallaria cincotta*). The Elk River watershed has had a long history of coal mining, timbering, oil and gas activities, and high coliform counts due to a lack of municipal sewage treatment (particularly in the lower reaches near Charleston, West Virginia); however, many of these issues have been mitigated in recent years (Cincotta 2017; Cincotta 2018). The water quality has improved markedly in the last 30 years, and several species have recovered dramatically, such as the river redhorse (*Moxostoma carinatum*), popeye shiner (*Notropis ariommus*), spotted darter (*Etheostoma maculatum*), bluebreast darter (*Etheostoma camurum*), Tippecanoe darter (*Etheostoma tippecanoe*), and longhead darter (Cincotta 2018). Some water quality impairments (*e.g*., fecal coliform, selenium, and iron) are still present within the Elk River and its tributaries. The first longhead darter record within this population was documented in 1936, and it has been documented as recently as 2017 (Cincotta 2018; West Virginia Division of Natural Resources (WVDNR) 2018, unpublished data). Occurrence records and personal communications suggest longhead darters occupy most of their historical range within this population (figure 9; Cincotta 2018; Welsh 2018). Longhead darters have repopulated the lower portions of several tributaries that had no prior historical records and the population is considered stable or increasing (Cincotta 2018). Although some other darter species (*e.g*., Tippecanoe darter and bluebreast darter) have recently expanded downstream into the Kanawha River, for unknown reasons, the longhead darter has not, suggesting the Kanawha River may be serving as a "formidable barrier" (Johansen 2018). Connectivity within the population is likely influenced by the presence of the Sutton Dam (figure 9). The Sutton Dam is a 64 m (210 ft) high concrete dam that forms a 22.5 km (14 mile) long lake in the Elk River. There is likely little interaction between longhead darters located upstream and downstream of the Sutton Dam; however, species experts fully expect that longhead darters still occupy habitat above the Sutton Dam (Cincotta 2018; Welsh 2018). Overall, we conclude that the Elk River population currently has high resiliency.

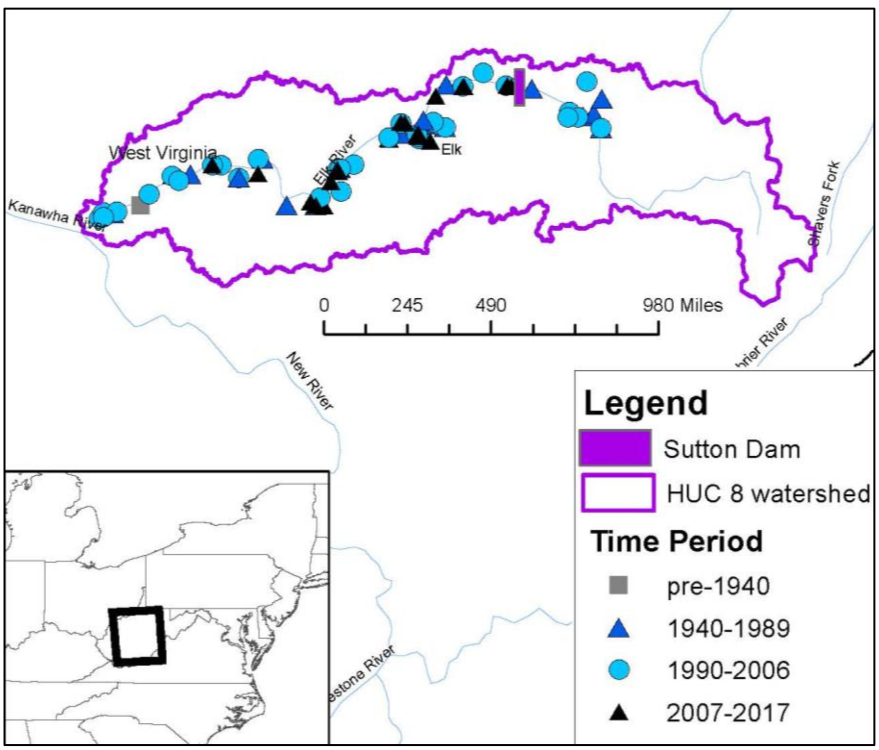

Figure 9. Distribution of the longhead darter in the #3 Elk River population, West Virginia, based on positive occurrence records (1936 – present).

#4 Walhonding River, Ohio

There are only two longhead darter records from Ohio, both of which were collected in 1939 from the Walhonding River (figure 10; Ohio State University (OSU) 2018, unpublished data). Successive surveys have not documented longhead darters in the Walhonding River or upper Muskingum basin; therefore, the species is considered extirpated from this watershed. A significant number of dams on the mainstem Muskingum River prevent longhead darters from returning to this area on their own (Zimmerman 2016); therefore, reintroduction plans are in progress (Zimmerman 2018b). Although only documented from a single watershed, it is plausible that longhead darters once occurred in other Ohio rivers (Zimmerman 2018a). Suitable habitat occurs in Turkey Creek and Scioto Brush Creek and there is potential that longhead darters could expand into these waters on their own given their close proximity to the Allegheny River and Kinniconick Creek populations (Zimmerman 2018a). Currently, however, the longhead darter is considered extirpated in Ohio.

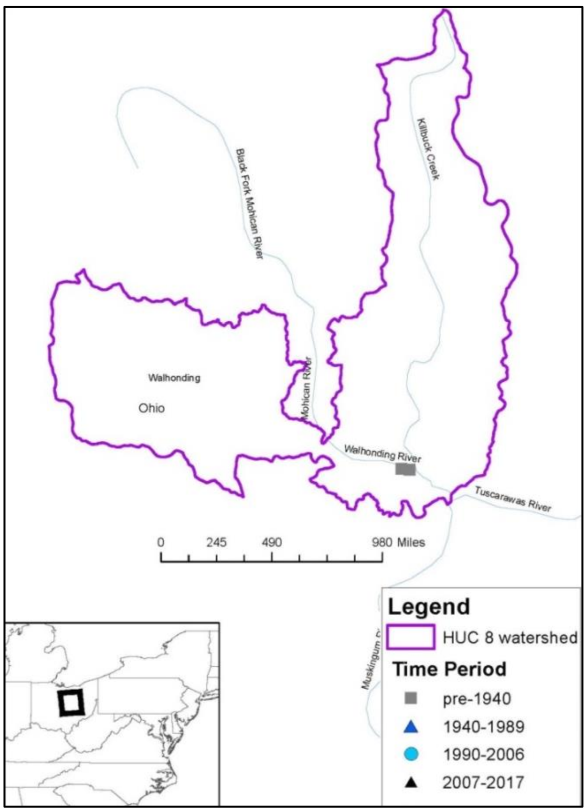

Figure 10. Distribution of the longhead darter in the #4 Walhonding River population, Ohio, based on positive occurrence records (1939 – present).

#5 Kinniconick Creek, Kentucky

The Kinniconick Creek population includes only the mainstem of Kinniconick Creek and is not known from any other tributaries; therefore, occurrence complexity is ranked as low. Water is "fairly clear" with substrates primarily of boulder, cobble, and gravel (Eisenhour *et al*. 2011, p. 14). The first record of the longhead darter within this population was documented in 1938 and it has been observed as recently as 2014 (Eisenhour *et al*. 2011, pp. 17–18; Kentucky Department of Fish and Wildlife Resources (KDFWR) 2018, unpublished data; OSU 2018, unpublished data). Occurrence records suggest the longhead darter occupies most of its historical range within this population (figure 11). Eisenhour *et al*. 2011 (p. 15) concluded that the longhead darter population in Kinniconick Creek may be one of the most robust in Kentucky and estimated between 2,000 and 5,000 longhead darters occupy the 54 km (34 mile) survey area. Land cover within the Kinniconick Creek HUC 10 watershed is approximately 85 percent forest, 6 percent agriculture and 4 percent development. "Other" land cover types account for the remaining 5 percent of land cover. Because the watershed is predominantly forested with no known water quality impairments, water quality is ranked as high. Overall, we conclude the Kinniconick Creek population currently has high resiliency.

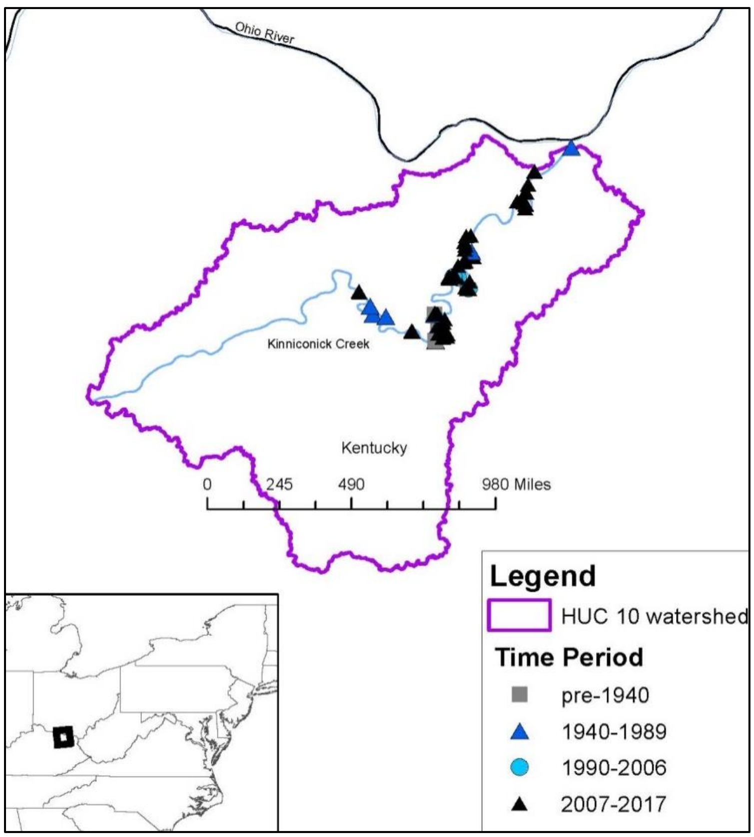

Figure 11. Distribution of the longhead darter in the #5 Kinniconick Creek population, Kentucky, based on positive occurrence records (1938 – present).

<u>#6 Johns Creek, Kentucky</u>

Longhead darter is represented by a single 1937 record from Johns Creek, Pike County, Kentucky (figure 12; Eisenhour *et al*. 2011, p. 13; KDFWR 2018, unpublished data). Land cover within the Lower Levisa HUC 8 watershed is approximately 78 percent forest, 7 percent development, and 3 percent agriculture. Approximately 2 percent land cover is barren and 9 percent is grassland, representing current and historical mining activities, respectively. Surface mining (including mountaintop mining) has led to high amounts of sedimentation/siltation in

Johns Creek (KDOW 2013b). We are aware of a single survey in 1999 that did not result in the capture of longhead darter (KDFWR 2018, unpublished data); however, current population status is considered unknown (Eisenhour *et al*. 2011, p. 13).

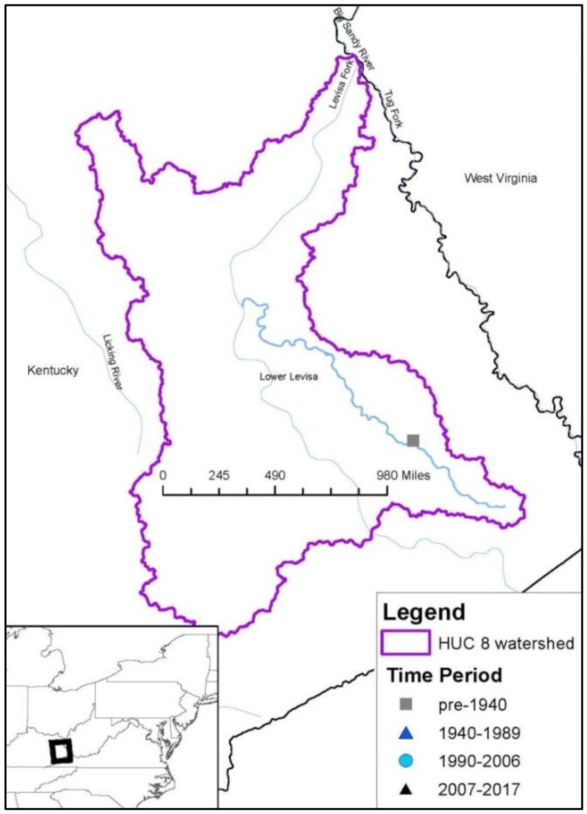

Figure 12. Distribution of the longhead darter in the #6 Johns Creek population, Kentucky, based on positive occurrence records (1937 – present).

<u>#7 Redbird Creek, Kentucky</u>

Longhead darter in the Redbird Creek, Kentucky, population is represented by two specimens[4] collected by A. J. Woolman in August 1890 (figure 13; Page 1978, p. 662; National Museum of Natural History (USNM) 2018). Longhead darter is considered extirpated from the Redbird Creek/Kentucky River drainage (Burr and Warren 1986, p. 336). Land cover is 82 percent forest, 6 percent development, 5 percent agriculture, and 7 percent "other" within the South Fork

[4] Page 1978 (p. 662) referenced Woolman's longhead darter specimens with the catalog number USNM 144267. In addition, Bailey and Gosline 1955 (p. 35) referenced an undated longhead darter specimen from Redbird Creek at the town of Big Creek, under catalog number USNM 63778. Upon further inspection of information available from USNM's online Fish Collection database, which includes all relevant information for each cataloged specimen, Woolman's specimens are listed under catalog number USNM 144267 from Redbird Creek at the town of Big Creek. Within the *Notes* section is the following statement: "*One spec. out as usnm 208594. out of usnm 63778*." Consequently, our interpretation is that Bailey and Gosline 1955 were referencing one of the specimens collected by Woolman (*i.e*., the specimens are one and the same).

Kentucky HUC 8 watershed. Water quality is ranked as high and appropriate longhead darter habitat still persists in the South Fork Kentucky River and Red Bird River, Kentucky (Campbell *et al*. 1993, p. 51).

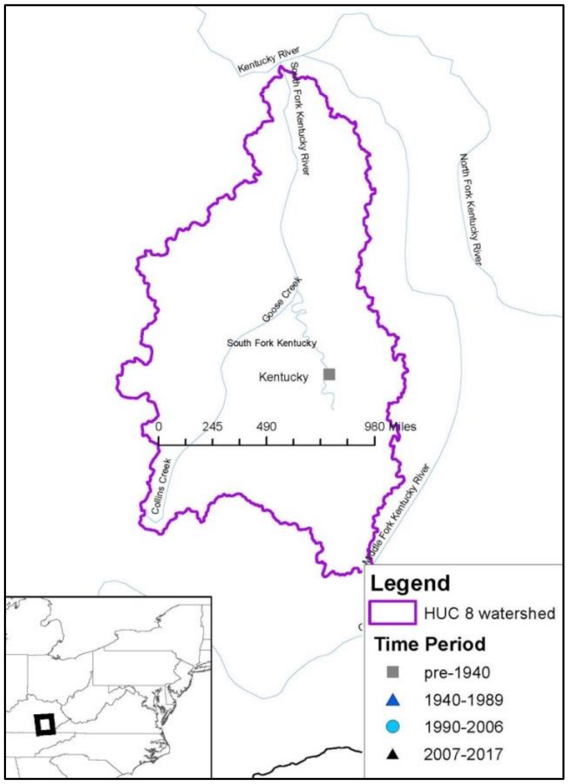

Figure 13. Distribution of the longhead darter in the #7 Redbird Creek population, Kentucky, based on positive occurrence records (1890 – present).

#8 Green River, Kentucky/Tennessee

The first longhead darter record from this population was documented in 1890, and it has been documented as recently as 2018 (Cicerello 2003, pp. 25–26; KDFWR 2018, unpublished data; Morehead State University 2018, unpublished data). The Green River population includes the upper Green River and tributaries (Glens Fork, Sulphur Creek, Little Barren River, and Russell Creek) and the Barren River and tributaries (Bays Fork, Difficult Creek, Beaver Creek, East Fork Barren River, Indian Creek, Peter Creek, Salt Lick Creek, Line Creek, Middle Fork Drakes Creek, Trammel Creek, and Drakes Creek) (figure 14). Land cover is 45 percent forest, 44 percent agriculture, 7 percent developed, and 4 percent "other" within the Upper Green and Barren HUC 8 watersheds. The Barren watershed saw a 0.4 percent increase in development between 2001 and 2011, primarily from urban development in and around the city of Bowling Green, Kentucky.

There are several longhead darter records from above the Green River Lake Dam (figure 14) but the most recent record is from 1962 (KDFWR 2018, unpublished data). We know a survey was conducted in 1978 above the dam that documented other darter species (*e.g*., Tippecanoe darter), but we do not have any information about the extent of the survey or any information about successive surveys; therefore, longhead darter occupancy above the dam is unknown. The Green River Lake Dam stands 44 m (144 ft) high and was completed in 1969. We assume there is no connectivity between longhead darters above and below the dam. Below the Green River Lake Dam, occurrence records suggest longhead darters occupy most of their historical range within the Upper Green watershed (figure 14). Between 2012 and 2015, the Kentucky Department of Fish and Wildlife Resources collected longhead darter at 2 of 41 sites distributed throughout a 153 km (95 mile) reach of the mainstem Green River between Mammoth Cave National Park and the Green River Lake Dam using a benthic trawl (Thomas and Brandt 2016, p. 53). Thomas and Brandt (2016, p. 58) concluded that longhead darter distribution was "sporadic" within that river reach. The longhead darter is likely more abundant and widespread in the Barren and Green River basins than surveys suggest (Cicerello 2003, p. 13). Although the Barren and Green River basins were sampled extensively, longhead darters were seldom captured because they were not targeted and standard survey methods were inadequate. The longhead darter lives in relatively deep water that is difficult to survey and where net avoidance is possible (Cicerello 2003, p. 13). Regardless, within the Barren River watershed, we assume there has been some reduction in the longhead darter's range, particularly within stream habitat now inundated by Barren River Lake. Prior to the impoundment of the Barren River, surveys revealed that the longhead darter was widely distributed and relatively abundant in the future reservoir area (Cicerello 2003, p. 11). The Barren River Lake Dam stands 44.5 m (146 ft) high and was completed in 1964. Most records were collected between 1959 and 1963 (KDFWR 2018, unpublished data); however, longhead darter has been documented as recently as 1996 above the Barren River Lake Dam. We assume there is no connectivity between longhead darters above and below the dam.

Because recent occurrence data are sparse in some areas and at least two large dams have resulted in a reduction in the species' historical range, we ranked occurrence extent as moderate. Water quality is ranked as high. Overall, we conclude that the Green River population currently has moderate to high resiliency.

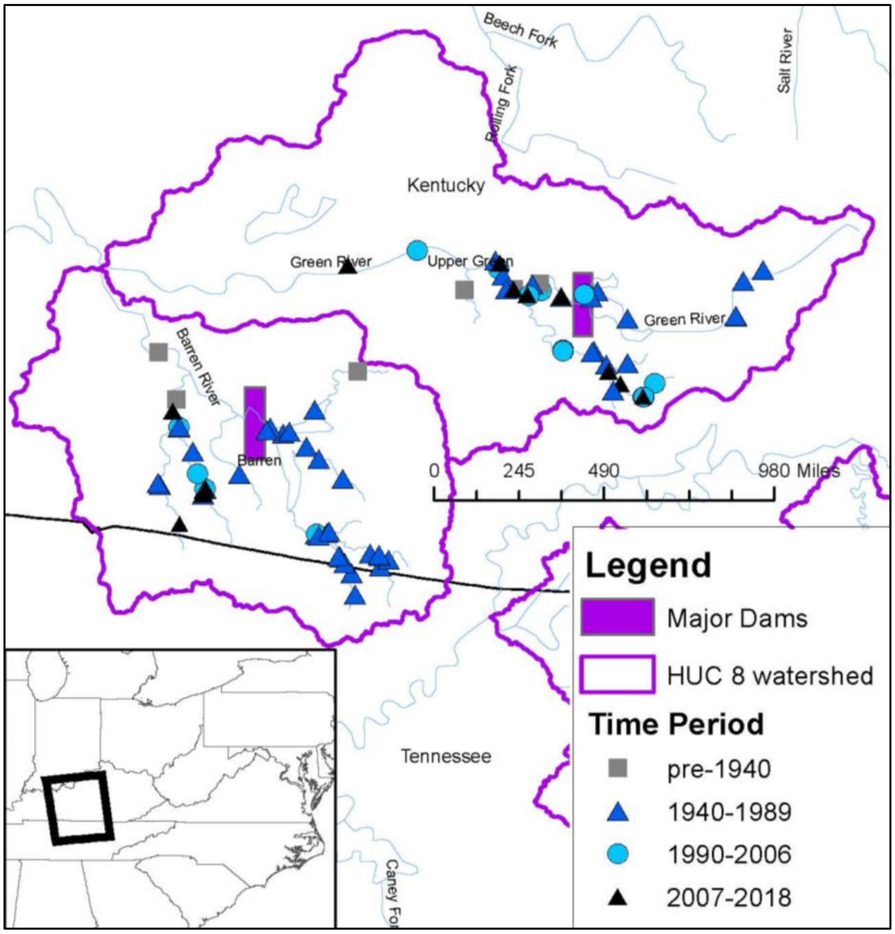

Figure 14. Distribution of the longhead darter in the #8 Green River population, Kentucky/Tennessee, based on positive occurrence records (1890 – present).

<u>#9 Cumberland River, Kentucky/Tennessee</u>

Longhead darter was last observed in 1891 within two subwatersheds of the Cumberland River drainage (*i.e.*, South Fork Cumberland River and Obey River watersheds; figure 15). Within the South Fork Cumberland River watershed, the longhead darter was documented in the Little South Fork, Wayne County, Kentucky (Kirsch 1893, p. 268). Within the Obey River watershed, Kirsch 1893 (pp. 263–264) collected the longhead darter from the Obey River, Pickett County, Tennessee, and Eagle Creek, Overton and Pickett Counties, Tennessee. Note, the locations of Kirsch's collections in the Obey River watershed were approximate, and both referenced the town of Olympus; consequently, only one point is approximated in figure 15 based on unpublished data received from the Tennessee Department of Environment and Conservation (TDEC 2018). Longhead darter is considered extirpated from the Cumberland River drainage (Burr and Warren 1986, p. 336).

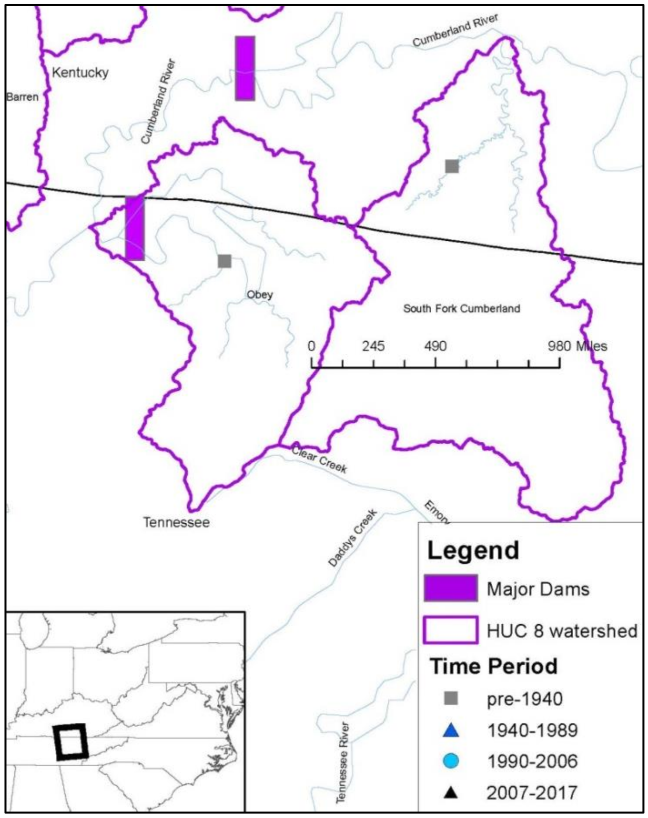

Figure 15. Distribution of the longhead darter in the #9 Cumberland River population, Kentucky/Tennessee, based on positive occurrence records (1891 – present).

#10 Duck River, Tennessee

The Duck River watershed is one of the most biologically diverse river systems in the nation (Tennessee Valley Authority 2018). The longhead darter in the Duck River population is represented by a few reported observations between 1971 and 1978 (TDEC 2018, unpublished data). Current population status is considered unknown. The Duck River population includes the Duck and Buffalo rivers, Tennessee (figure 16). The Buffalo watershed is approximately 70 percent forest, 19 percent agriculture, and 4 percent development. The Upper Duck watershed is approximately 46 percent agriculture, 41 percent forest, and 9 percent development. Connectivity within the population is likely influenced by the presence of the Normandy Dam (figure 16). The Normandy Dam is a 34 m (110 ft) high dam that forms a 27 km (17 mile) long reservoir in the Duck River. There is likely little interaction between longhead darters located upstream and downstream of the Normandy Dam. Because the current population status is unknown, longhead darter surveys were conducted in 2018 by the Tennessee Aquarium Conservation Institute (Raines and Kuhajda 2017, entire). Two locations with historical records in the Duck River were surveyed in 2018; however, no longhead darters were observed but additional surveys are planned (Neely 2018).

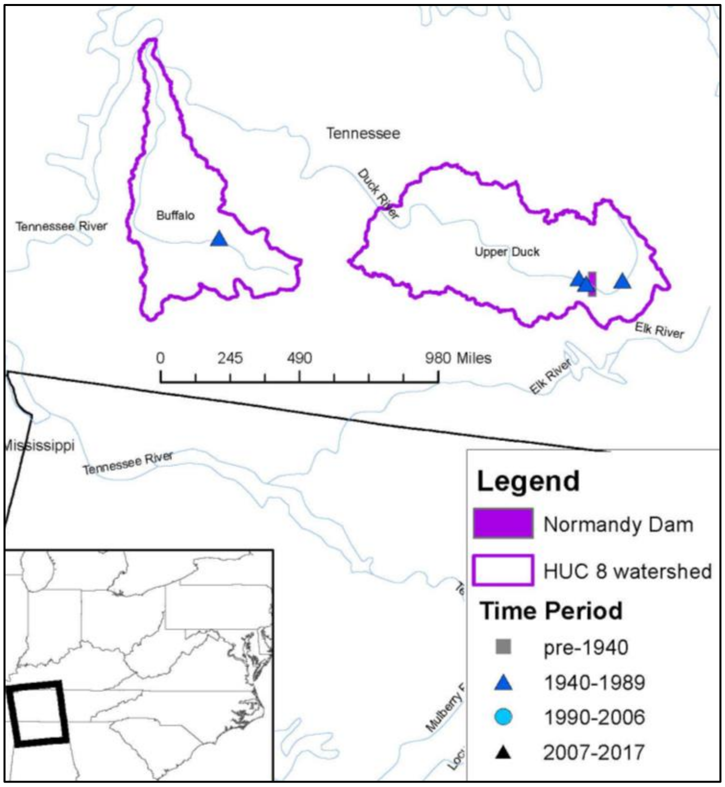

Figure 16. Distribution of the longhead darter in the #10 Duck River population, Tennessee, based on positive occurrence records (1971 – present).

Summary of resiliency—The longhead darter is persisting (*e.g.*, Kinniconick Creek and Green River) and in some cases expanding[5] (*e.g.*, Upper Allegheny, Allegheny River, and Elk River) in 50 percent of its historical range (5 of 10 populations). We are aware of three extirpations representing a complete loss of resiliency in those populations. The resiliency of two populations is unknown. Of the 5 known extant populations, we consider 3 (60 percent) to have high resiliency and 2 (40 percent) to have moderate to high resiliency. Consequently, extant populations range between moderate to high and high resiliency.

<u>Redundancy</u>—Redundancy describes the ability of a species to withstand catastrophic events by maintaining multiple, resilient populations distributed within the species' ecological settings and across the species' range.

The longhead darter currently occurs in approximately 50 percent of its historical range (5 of 10 known populations). Therefore, redundancy has declined since its historical state. However, redundancy for the longhead darter is currently evidenced by multiple extant populations distributed across two physiographic provinces (*i.e.*, four populations in the Appalachian Plateaus and one population in the Interior Low Plateaus). The longhead darter is represented by three populations with high resiliency and two populations with moderate to high resiliency.

[5] As a result of increased abundance or improved survey techniques.

Three longhead darter populations have been extirpated, and the resiliency of two populations is unknown. Connectivity between extant populations has been reduced because of geographic isolation between watersheds, or eliminated by the construction of dams. The species' redundancy and representation has been strengthened by its expanding range (as a result of increased abundance or improved survey techniques) and high resiliency within the Upper Allegheny, Allegheny River, and Elk River populations and persistence in the Kinniconick Creek and Green 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 Kinniconick Creek because the species' distribution within that watershed is limited to a single stream. The likelihood of extirpation is much lower in the Upper Allegheny, Allegheny River, Elk River, and Green River populations due to the species' widespread occurrence, which includes both the mainstem and multiple tributaries. Given these factors, we conclude the longhead darter currently has moderate redundancy.

Representation—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.

As discussed in Chapter 2, we are aware of a single longhead darter genetic study (Page and Near 2007, entire). Although we are aware of some morphological variations between populations (Page 1978, p. 658–659), we are not aware of any behavioral differences with which to characterize the longhead darter's representation range-wide; therefore, we rely on environmental diversity of longhead darter habitats to characterize its current representation.

As discussed in Chapter 2, longhead darters are known from a variety of different environmental settings in two distinct physiographic provinces: Appalachian Plateaus and Interior Low Plateaus. Populations have been documented in rivers with varying physical and chemical characteristics (*e.g*., gradient, substrate, flow, and alkalinity). The longhead darter is widely distributed and currently maintains representation in four populations in the Appalachian Plateaus and one population in the Interior Low Plateaus. In the Appalachian Plateaus province, the longhead darter is represented by four populations with moderate to high (n=1) and high (n=3) resiliency. In the Interior Low Plateaus, the species is represented by one population with moderate to high resiliency. The species no longer occupies all of its historical tributary systems, so there has potentially been a reduction in the species' genetic and environmental diversity (representation) over time. Given the longhead darter retains representation in two physiographic provinces and is persisting and/or expanding in at least 50 percent of its historical range, we conclude that the species' representation is moderate.

Summary of Current Condition

Five of 10 historical populations for the longhead darter are considered to be extant. Of the remaining five historical populations, three are considered to be extirpated and the statuses of two are unknown. The extant populations range between moderate to high and high resiliency. The longhead darter has moderate redundancy. The darter is present within two physiographic provinces from which it is historically known, and surveys have documented an expansion in range within some populations. This leads us to conclude that the longhead darter's representation is also moderate.

CHAPTER 5—SPECIES' FUTURE VIABILITY

Methodology

Using the same methodology and criteria described above for assessing current condition, we modeled three scenarios to assess the potential viability of the longhead darter at 10, 25, and 50 years in the future. We assume these timeframes are reasonable because we have data to reasonably predict changes in land cover (*e.g.*, conversion of forest to urban development) and concomitant (naturally accompanying) changes in water quality within this timeframe. Here we describe three plausible future scenarios and whether there will be a change from current conditions to any of the 3Rs under each scenario. Our future scenarios differ by considering variations that are predicted in land cover, water quality, and occupancy. These three scenarios capture the range of likely viability outcomes that the longhead darter could exhibit within 50 years. Tables and figures summarizing the future conditions under each scenario at 10, 25, and 50 years are provided below. Tables summarizing individual components used to characterize future conditions are detailed in appendix A.

To assess changes in land cover, we determined the rate of land cover change between 2001 and 2011 using National Land Cover Database (NLCD) data (Homer *et al*. 2015, entire). We determined the rate of forest cover change for each HUC 8 watershed encompassing longhead darter populations except for the Kinniconick Creek population, whereby we relied on the smaller HUC 10 watershed for our analysis because it encompasses the entire population and is therefore considered most representative. Total amount of forest included NLCD Land Cover Classifications deciduous forest, evergreen forest, mixed forest and shrub/scrub. Tables summarizing our forest cover analysis are detailed in appendix B. Lastly, we assumed the rate of development would influence water quality and vary within each of our three scenarios. Total amount of development included NLCD Land Cover Classifications open space, low intensity, medium intensity, and high intensity development.

Scenario 1: Continuation of Current Trend

Current trends suggest that longhead darters are stable or expanding (as a result of increased abundance or improved survey techniques) within extant populations. Between 2001 and 2011, forest cover decreased between 0.004 percent and 2.1 percent (average equals 0.64 percent decrease) within current or historical watersheds encompassing longhead darter populations. Development increased approximately 1.7 percent, 0.6 percent, and 0.5 percent within the Lower Allegheny (#2 Allegheny River population), Upper Duck (#10 Duck River population), and Barren (#8 Green River population) watersheds, respectively. Changes in the amount of development were less evident (*i.e.*, 0.2 percent or less) in the remaining watersheds. The amount of agriculture remained relatively stable or slightly decreased across all watersheds. Under Scenario 1, we predict the following:

- Same rate of forest loss as the rate observed between 2001 and 2011.
- Same rate of urban development as the rate observed between 2001 and 2011.
- No changes to water quality impairments (*i.e.*, 303(d) streams).

- Same rate of improvement of waste water discharge controls.
- Same rate of combined sewer overflow separation (*i.e*., 30 percent or more).
- Little change in water volume within developing watersheds from water withdrawals.
- Maintenance of existing riparian forested buffers.

Tables summarizing individual components used to characterize future conditions at 10, 25, and 50 years are detailed in appendix A. Tables summarizing our forest cover analysis are detailed in appendix B.

Results - Scenario 1 (Continuation of Current Trend): Based on assumptions for continuing trends, the conditions of 10 longhead darter populations are predicted to remain relatively unchanged from the current condition within 50 years (table 4, figure 17). Under Scenario 1, the species' resiliency, redundancy and representation remained unchanged (*e.g*., all current populations remained extant).

Table 4. Scenario 1 summary: Longhead darter population conditions at 10, 25, and 50 years. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Current Population Condition Score		Scenario 1: Cont. of Current Trend		
				10 Years	25 Years	50 Years
1	Upper Allegheny, NY/PA	H		H	H	H
2	Allegheny River, NY/PA	H		H	H	H
3	Elk River, WV	H		H	H	H
4	Walhonding River, OH	0		0	0	0
5	Kinniconick Creek, KY	M H		M H	M H	M H
6	Johns Creek, KY	UKN		UKN	UKN	UKN
7	Redbird Creek, KY	0		0	0	0
8	Green River, KY/TN	M H		M H	M H	M H
9	Cumberland River, KY/TN	0		0	0	0
10	Duck River, TN	UKN		UKN	UKN	UKN

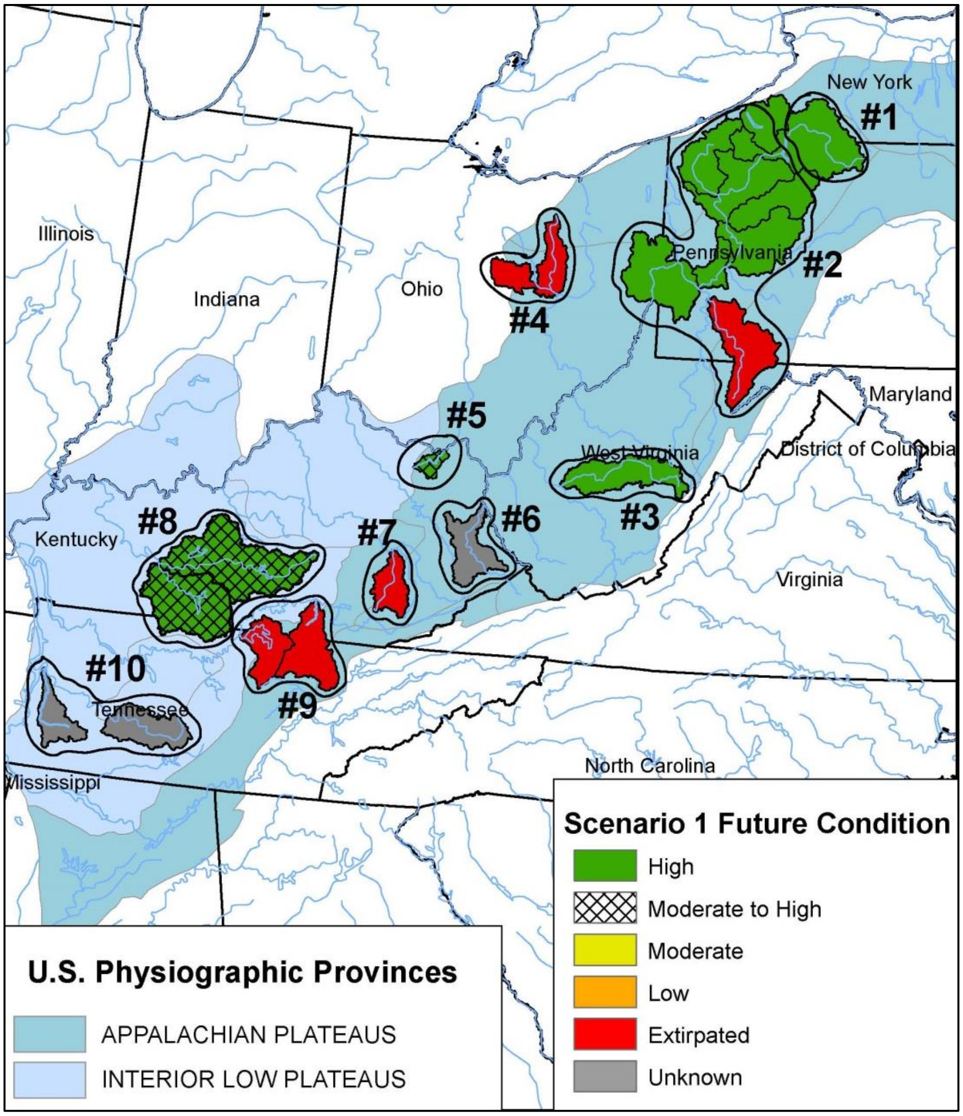

Figure 17. Summary of predicted condition of longhead darter populations under Scenario 1 within 50 years of continuation of current trend (illustrated by HUC 8 watersheds[6]).

[6] #5 Kinniconick Creek population illustrated by HUC 10 watershed.

Scenario 2: Optimistic Scenario

Similar to Scenario 1, Scenario 2 assumes longhead darters are stable or expanding (as a result of increased abundance or improved survey techniques) within extant populations. Between 2001 and 2011, the amount of forest cover decreased on average 0.64 percent (range = 0.004 percent to 2.1 percent) within current or historical watersheds encompassing longhead darter populations, primarily due to increased urbanization. For the optimistic scenario, we predict a 0.5 percent reduction in the rate of forest loss across all watersheds, a value we assume is within the range of plausible future scenarios. We assume a reduced rate of forest loss equates to a reduced rate of urban development. In addition, under Scenario 2 we anticipate that longhead darters will be reintroduced into the Upper Muskingum basin (*e.g.*, Walhonding River, Ohio) where they are currently absent but known to have occurred previously. Other darters have naturally repopulated the Muskingum basin and current reintroduction efforts include the Tippecanoe darter (Zimmerman 2018b) because the habitat is suitable and historical stressors have been reduced. Ohio State University is currently collaborating with the Ohio Division of Wildlife and Pennsylvania Fish and Boat Commission on plans for reintroducing longhead darters into 4 streams within the Upper Muskingum basin (Zimmerman 2018a; Zimmerman 2018b; Zimmerman 2018c). Successful reintroduction would result in an increase in occupancy, occurrence extent, and occurrence complexity within the Walhonding River population. In addition to the reintroduction, under Scenario 2, we assume the following:

- Reduced rate of forest loss (0.5 percent less) from the rate observed between 2001 and 2011.
- Reduced rate of urban development from the rate observed between 2001 and 2011.
- Reduced water quality impairments (*i.e.*, 303(d) streams) except for Johns Creek population where there was a 0.85 percent increase in barren land between 2001 and 2011, largely from mining activities.
- Increased rate of improvement of waste water discharge controls, including adoption of EPA's 2013 ammonia criteria (EPA 2013b, entire; *i.e.*, assumes all States within the range of longhead darter will adopt within 10 to 25 years).
- Increased rate of combined sewer overflow separation (*i.e.*, 60 percent or more).
- Little change in water volume within developing watersheds from water withdrawals.
- Maintenance or some increase in riparian forested buffers (*e.g.*, Natural Resources Conservation Service private landowner agreements).

Tables summarizing individual components used to characterize future conditions at 10, 25, and 50 years are detailed in appendix A. Tables summarizing our forest cover analysis are detailed in appendix B.

Results - Scenario 2 (Optimistic Scenario): Based on assumptions for the optimistic scenario, the conditions of 9 longhead darter populations are predicted to remain relatively unchanged from their current conditions, and the condition of 1 population is predicted to have improved within 50 years (table 5, figure 18). Under Scenario 2, the species' redundancy would improve (the addition of a single population), representation would remain unchanged, and the resiliency of the 1 improved population is predicted to increase.

Table 5. Scenario 2 summary: Longhead darter population conditions at 10, 25, and 50 years. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as “high” condition (H), “moderate” condition (M), “low” condition (L), “unknown” condition (UKN), or “presumed extirpated” (0).

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Population</th><th rowspan="2" colspan="2">Current Population Condition Score</th><th colspan="6">Scenario 2: Optimistic</th></tr>
<tr><th colspan="2">10 Years</th><th colspan="2">25 Years</th><th colspan="2">50 Years</th></tr>
<tr><td>1</td><td>Upper Allegheny, NY/PA</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td></tr>
<tr><td>2</td><td>Allegheny River, NY/PA</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td></tr>
<tr><td>3</td><td>Elk River, WV</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td><td colspan="2">H</td></tr>
<tr><td>4</td><td>Walhonding River, OH</td><td colspan="2">0</td><td colspan="2">M</td><td colspan="2">M</td><td colspan="2">M</td></tr>
<tr><td>5</td><td>Kinniconick Creek, KY</td><td>M</td><td>H</td><td>M</td><td>H</td><td>M</td><td>H</td><td>M</td><td>H</td></tr>
<tr><td>6</td><td>Johns Creek, KY</td><td colspan="2">UKN</td><td colspan="2">UKN</td><td colspan="2">UKN</td><td colspan="2">UKN</td></tr>
<tr><td>7</td><td>Redbird Creek, KY</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>8</td><td>Green River, KY/TN</td><td>M</td><td>H</td><td>M</td><td>H</td><td>M</td><td>H</td><td>M</td><td>H</td></tr>
<tr><td>9</td><td>Cumberland River, KY/TN</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>10</td><td>Duck River, TN</td><td colspan="2">UKN</td><td colspan="2">UKN</td><td colspan="2">UKN</td><td colspan="2">UKN</td></tr>
</table>

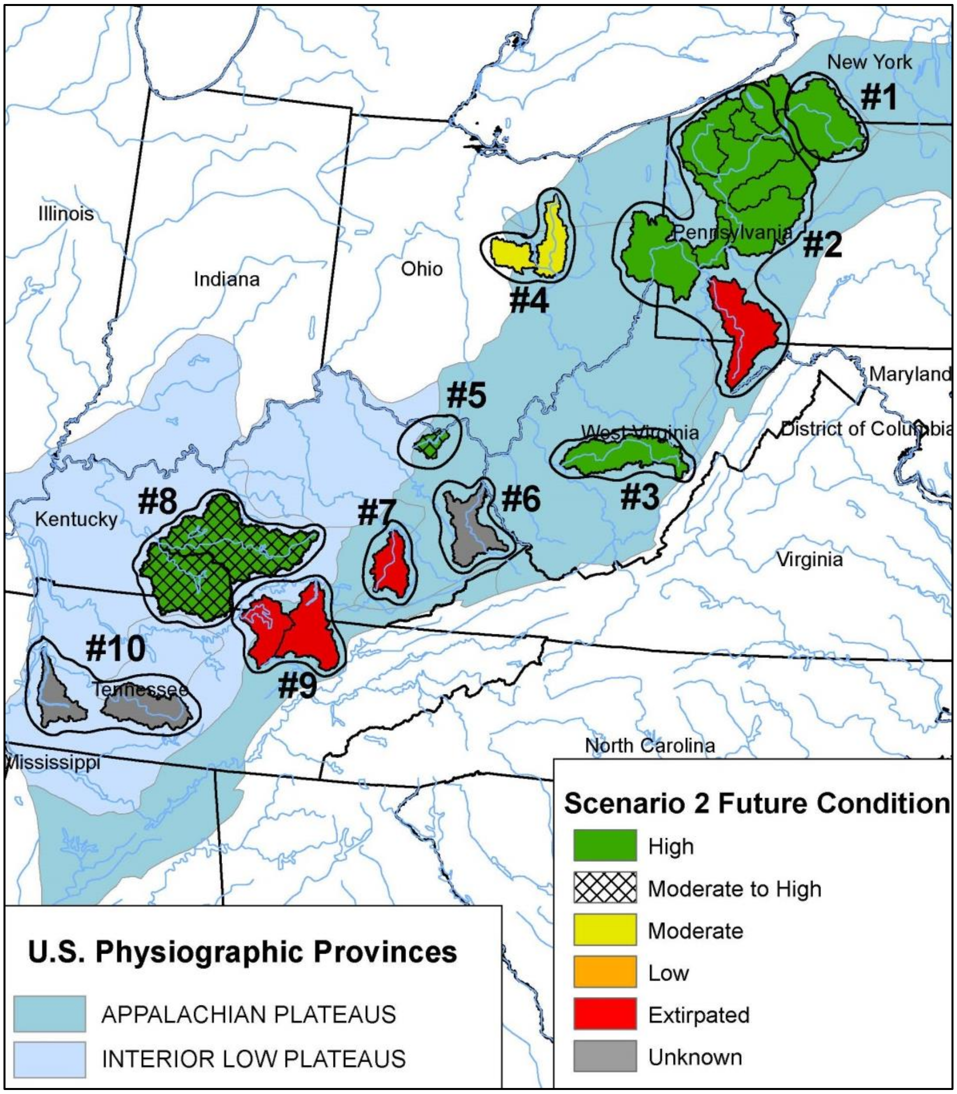

Figure 18: Summary of predicted condition of longhead darter populations under Scenario 2 within 50 years of optimistic scenario (illustrated by HUC 8 watersheds[7]).

[7] #5 Kinniconick Creek population illustrated by HUC 10 watershed.

Scenario 3: Pessimistic Scenario

Under Scenario 3, longhead darters will decrease in occurrence extent (assume this equates to decreased abundance) if/when water quality component reaches "low" category (*i.e*., extensive water quality impairments known to impact populations). Although occurrence extent may be reduced within populations, we expect impacts to be localized and not lead to a complete loss of occupancy (*i.e*., no extirpations are anticipated under this scenario within the next 50 years). Between 2001 and 2011, the amount of forest cover decreased on average 0.64 percent (range = 0.004 percent to 2.1 percent) within current or historical watersheds encompassing longhead darter populations, primarily due to increased urbanization. For the pessimistic scenario, we predict a 0.5 percent increased rate of forest loss across all watersheds, a value we assume is within the range of plausible future scenarios. We assume an increased rate of forest loss equates to an increased rate of urban development, specifically within watersheds with 0.5 percent or greater rate of urban development observed between 2001 and 2011 (*i.e*., #2 Allegheny River, #8 Green River, and #10 Duck River populations). Under Scenario 3, we assume the following:

- Increased rate of forest loss (0.5 percent greater) from the rate observed between 2001 and 2011.
- Increased rate of urban development as the rate observed between 2001 and 2011.
- Increased number of water quality impairments (*i.e*., 303(d) streams) within watersheds with equal to or greater 0.5 percent rate of development observed between 2001 and 2011.
- Assume same rate of improvement of waste water discharge controls; however, increase in the number of sewage treatment plants; therefore, increased ammonia.
- Assumes reduced rate of combined sewer overflow separation (*i.e*., 30 percent or less).
- Assumes lower water volume within developing watersheds due to increased water withdrawals.
- Assumes decrease in forested riparian buffers.

Tables summarizing individual components used to characterize future conditions at 10, 25, and 50 years are detailed in appendix A. Tables summarizing our forest cover analysis are detailed in appendix B.

Results - Scenario 3 (Pessimistic Scenario): Based on assumptions for the pessimistic scenario, the conditions of 8 longhead darter populations are predicted to remain relatively unchanged from their current condition, and the conditions of 2 populations are predicted to decrease within 50 years (table 6, figure 19). Under Scenario 3, the species' redundancy and representation remained unchanged (*e.g*., all current populations remained extant), although the resiliencies of 2 populations are predicted to decrease.

Table 6. Scenario 3 summary: Longhead darter population conditions at 10, 25, and 50 years. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as “high” condition (H), “moderate” condition (M), “low” condition (L), “unknown” condition (UKN), or “presumed extirpated” (0).

No.	Population	Current Population Condition Score	Scenario 3: Pessimistic		
			10 Years	25 Years	50 Years
1	Upper Allegheny, NY/PA	H	H	H	H
2	Allegheny River, NY/PA	H	H	M	M
3	Elk River, WV	H	H	H	H
4	Walhonding River, OH	0	0	0	0
5	Kinniconick Creek, KY	M / H	M / H	M / H	M / H
6	Johns Creek, KY	UKN	UKN	UKN	UKN
7	Redbird Creek, KY	0	0	0	0
8	Green River, KY/TN	M / H	M / H	M	M
9	Cumberland River, KY/TN	0	0	0	0
10	Duck River, TN	UKN	UKN	UKN	UKN

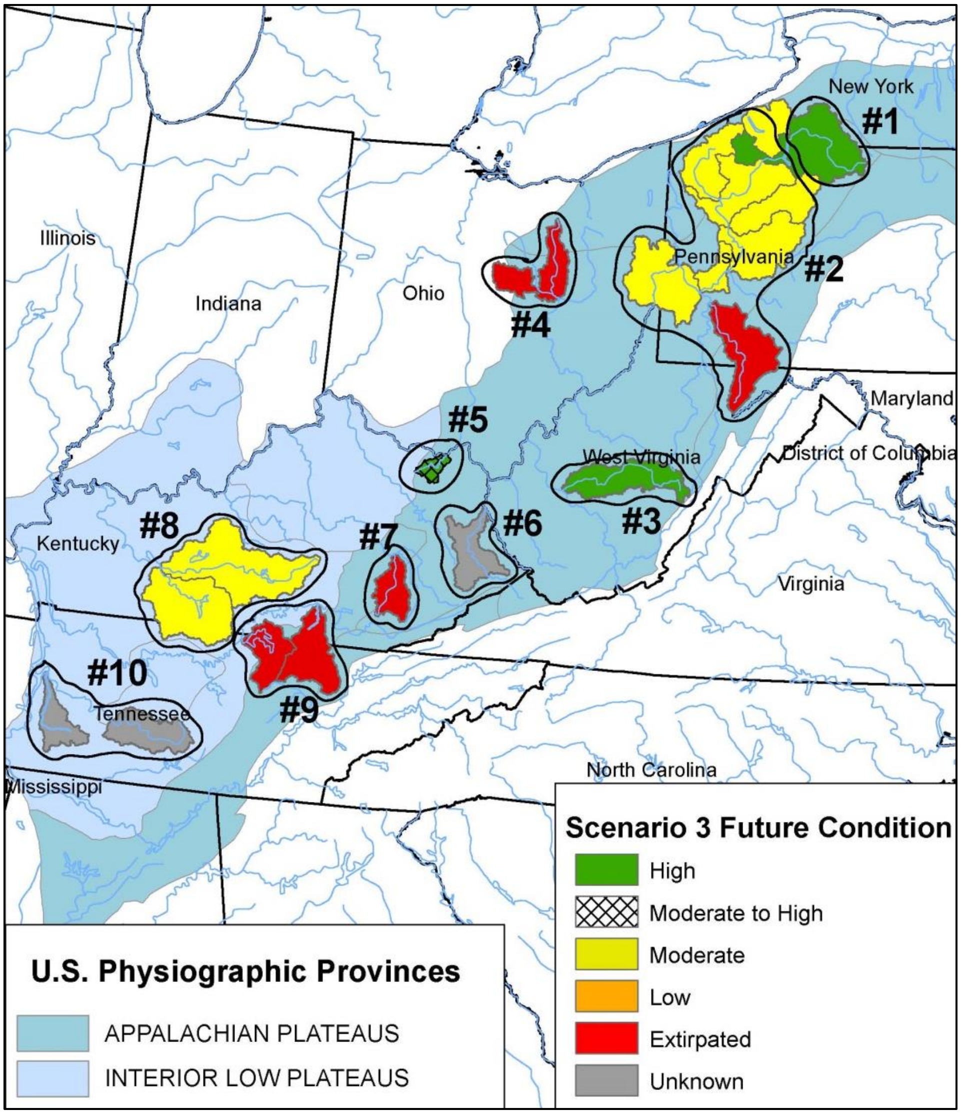

Figure 19. Summary of predicted condition of longhead darter populations under Scenario 3 within 50 years of pessimistic scenario (illustrated by HUC 8 watersheds[8]).

[8] #5 Kinniconick Creek population illustrated by HUC 10 watershed.

Summary of Species' Future Viability

The best available data indicate that, of the 10 known longhead darter populations, 5 are extant, 2 are unknown, and 3 are extirpated. Longhead darter occurrence data suggest the species is persisting and in some cases expanding in 50 percent (5 of 10) of extant populations. We assume the observed longhead darter expansion is the result of either increased abundance and/or improved survey techniques.

We considered what the longhead darter needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation. For the purpose of this assessment, we generally define viability as the ability of the longhead darter to sustain populations in natural river ecosystems over time.

Based on the longhead darter's life history and habitat needs, we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' current condition and viability. We evaluated how these stressors may be currently affecting the species and whether, and to what extent, they would affect the species in the future. While impairments to water quality (*e.g.*, sedimentation, agricultural and urban runoff) and dams have likely influenced the species' current condition, longhead darters are predicted to persist within all currently extant populations in the future under each of the future scenarios assessed.

Under the three plausible scenarios, the longhead darter will be represented by a minimum of five populations while maintaining moderate to high resiliency and moderate redundancy and representation.

CHAPTER 6 – UNCERTAINTY

Predicting the future condition requires us to make plausible assumptions. Our analyses are predicated on multiple assumptions, which could lead to over- and underestimates of viability. In table 7, we identify the key sources of uncertainty and indicate the likely effect of our assumptions on the viability assessment.

Table 7. Assumptions made in the analysis and the impact on our viability assessment if such assumptions are incorrect. "Overestimates" means the viability of the species is optimistic. "Underestimates" means the viability of the species is pessimistic. "Either" means the impact could lead to over- or underestimates if our assumption is incorrect.

Assumption	**Impact on Viability Assessment**
Each component used to assess population condition is weighted equally.	Either
Two populations lacking recent surveys are considered unknown status (*i.e.*, not extant).	Either
The current known range accurately represents the number of stream miles occupied by longhead darter.	Underestimates
The extent and magnitude of future influences are accurately predicted.	Either
Occupancy is an adequate surrogate for assessing abundance and growth rate.	Overestimates
Water quality subcomponents (*i.e.*, 303(d) impairments and land cover) are correlated with longhead darter occupancy and/or occurrence extent.	Either

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APPENDIX A

SCENARIO 1. Continuation of Current Trend.

Scenario 1 (10-years). Longhead darter population conditions at 10 years under the continuation of current trend scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as “high” condition (H), “moderate” condition (M), “low” condition (L), “unknown” condition (UKN), or “presumed extirpated” (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	H	H
2	Allegheny River, NY/PA	H	H	H	M	M	H
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	0	0	0	H	L	0
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	H	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	M	UKN

Scenario 1 (25-years). Longhead darter population conditions at 25 years under the continuation of current trend scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	H	H
2	Allegheny River, NY/PA	H	H	H	M	M	H
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	0	0	0	H	L	0
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	M	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	L	UKN

Scenario 1 (50-years). Longhead darter population conditions at 50 years under the continuation of current trend scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Population</th><th rowspan="2">Occupancy</th><th rowspan="2">Occurrence Extent</th><th rowspan="2">Occurrence Complexity</th><th colspan="2">Water Quality</th><th rowspan="2"></th><th rowspan="2" colspan="2">Population Condition Score</th></tr>
<tr><th>303(d) Streams</th><th>Land Cover</th></tr>
<tr><td>1</td><td>Upper Allegheny, NY/PA</td><td>H</td><td>H</td><td>H</td><td>M</td><td>H</td><td></td><td colspan="2">H</td></tr>
<tr><td>2</td><td>Allegheny River, NY/PA</td><td>H</td><td>H</td><td>H</td><td>M</td><td>M</td><td></td><td colspan="2">H</td></tr>
<tr><td>3</td><td>Elk River, WV</td><td>H</td><td>H</td><td>H</td><td>M</td><td>H</td><td></td><td colspan="2">H</td></tr>
<tr><td>4</td><td>Walhonding River, OH</td><td>0</td><td>0</td><td>0</td><td>H</td><td>L</td><td></td><td colspan="2">0</td></tr>
<tr><td>5</td><td>Kinniconick Creek, KY</td><td>H</td><td>H</td><td>L</td><td>H</td><td>H</td><td></td><td>M</td><td>H</td></tr>
<tr><td>6</td><td>Johns Creek, KY</td><td>UKN</td><td>UKN</td><td>UKN</td><td>L</td><td>M</td><td></td><td colspan="2">UKN</td></tr>
<tr><td>7</td><td>Redbird Creek, KY</td><td>0</td><td>0</td><td>0</td><td>H</td><td>M</td><td></td><td colspan="2">0</td></tr>
<tr><td>8</td><td>Green River, KY/TN</td><td>H</td><td>M</td><td>H</td><td>H</td><td>L</td><td></td><td>M</td><td>H</td></tr>
<tr><td>9</td><td>Cumberland River, KY/TN</td><td>0</td><td>0</td><td>0</td><td>H</td><td>M</td><td></td><td colspan="2">0</td></tr>
<tr><td>10</td><td>Duck River, TN</td><td>UKN</td><td>UKN</td><td>UKN</td><td>H</td><td>L</td><td></td><td colspan="2">UKN</td></tr>
</table>

SCENARIO 2. Optimistic Scenario.

Scenario 2 (10-years). Longhead darter population conditions at 10 years under the optimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as “high” condition (H), “moderate” condition (M), “low” condition (L), “unknown” condition (UKN), or “presumed extirpated” (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	H	H
2	Allegheny River, NY/PA	H	H	H	M	M	H
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	H	H	M	H	L	M
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	H	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	M	UKN

Scenario 2 (25-years). Longhead darter population conditions at 25 years under the optimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as “high” condition (H), “moderate” condition (M), “low” condition (L), “unknown” condition (UKN), or “presumed extirpated” (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	H	H	H
2	Allegheny River, NY/PA	H	H	H	H	M	H
3	Elk River, WV	H	H	H	H	H	H
4	Walhonding River, OH	H	H	M	H	L	M
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	H	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	M	UKN

Scenario 2 (50-years). Longhead darter population conditions at 50 years under the optimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Population</th><th rowspan="2">Occupancy</th><th rowspan="2">Occurrence Extent</th><th rowspan="2">Occurrence Complexity</th><th colspan="2">Water Quality</th><th rowspan="2"></th><th rowspan="2" colspan="2">Population Condition Score</th></tr>
<tr><th>303(d) Streams</th><th>Land Cover</th></tr>
<tr><td>1</td><td>Upper Allegheny, NY/PA</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td></td><td colspan="2">H</td></tr>
<tr><td>2</td><td>Allegheny River, NY/PA</td><td>H</td><td>H</td><td>H</td><td>H</td><td>M</td><td></td><td colspan="2">H</td></tr>
<tr><td>3</td><td>Elk River, WV</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td></td><td colspan="2">H</td></tr>
<tr><td>4</td><td>Walhonding River, OH</td><td>H</td><td>H</td><td>M</td><td>H</td><td>L</td><td></td><td colspan="2">M</td></tr>
<tr><td>5</td><td>Kinniconick Creek, KY</td><td>H</td><td>H</td><td>L</td><td>H</td><td>H</td><td></td><td>M</td><td>H</td></tr>
<tr><td>6</td><td>Johns Creek, KY</td><td>UKN</td><td>UKN</td><td>UKN</td><td>L</td><td>M</td><td></td><td colspan="2">UKN</td></tr>
<tr><td>7</td><td>Redbird Creek, KY</td><td>0</td><td>0</td><td>0</td><td>H</td><td>M</td><td></td><td colspan="2">0</td></tr>
<tr><td>8</td><td>Green River, KY/TN</td><td>H</td><td>M</td><td>H</td><td>H</td><td>L</td><td></td><td>M</td><td>H</td></tr>
<tr><td>9</td><td>Cumberland River, KY/TN</td><td>0</td><td>0</td><td>0</td><td>H</td><td>M</td><td></td><td colspan="2">0</td></tr>
<tr><td>10</td><td>Duck River, TN</td><td>UKN</td><td>UKN</td><td>UKN</td><td>H</td><td>L</td><td></td><td colspan="2">UKN</td></tr>
</table>

SCENARIO 3. Pessimistic Scenario.

Scenario 3 (10-year). Longhead darter population conditions at 10 years under the pessimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	M	H
2	Allegheny River, NY/PA	H	H	H	M	M	H
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	0	0	0	H	L	0
5	Kinniconick Creek, KY	H	H	L	H	H	M H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	H	0
8	Green River, KY/TN	H	M	H	H	L	M H
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	H	M	UKN

Scenario 3 (25-year). Longhead darter population conditions at 25 years under the pessimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality		Population Condition Score
					303(d) Streams	Land Cover	
1	Upper Allegheny, NY/PA	H	H	H	M	M	H
2	Allegheny River, NY/PA	H	M	H	L	M	M
3	Elk River, WV	H	H	H	M	H	H
4	Walhonding River, OH	0	0	0	H	L	0
5	Kinniconick Creek, KY	H	H	L	H	H	M / H
6	Johns Creek, KY	UKN	UKN	UKN	L	M	UKN
7	Redbird Creek, KY	0	0	0	H	M	0
8	Green River, KY/TN	H	M	H	M	L	M
9	Cumberland River, KY/TN	0	0	0	H	M	0
10	Duck River, TN	UKN	UKN	UKN	M	L	UKN

Scenario 3 (50-year). Longhead darter population conditions at 50 years under the pessimistic scenario. Horizontal hatching indicates a change from the current condition. Population condition scores are categorized as "high" condition (H), "moderate" condition (M), "low" condition (L), "unknown" condition (UKN), or "presumed extirpated" (0).

No.	Population	Occupancy	Occurrence Extent	Occurrence Complexity	Water Quality			Population Condition Score
					303(d) Streams	Land Cover		
1	Upper Allegheny, NY/PA	H	H	H	M	M		H
2	Allegheny River, NY/PA	H	M	H	L	M		M
3	Elk River, WV	H	H	H	M	H		H
4	Walhonding River, OH	0	0	0	H	L		0
5	Kinniconick Creek, KY	H	H	L	H	H		M / H
6	Johns Creek, KY	UKN	UKN	UKN	L	M		UKN
7	Redbird Creek, KY	0	0	0	H	M		0
8	Green River, KY/TN	H	M	H	M	L		M
9	Cumberland River, KY/TN	0	0	0	H	M		0
10	Duck River, TN	UKN	UKN	UKN	M	L		UKN

APPENDIX B

Scenario 1. Under the continuation of current trend scenario, we predict the same rate of forest loss as the rate observed between 2001 and 2011.

No.	Population	2001 Forest Cover (%)	2011 Forest Cover (%)	Rate of forest loss between 2001 and 2011	Scenario 1: Continuation of Current Trend			
					Predicted rate of forest loss	Forest Cover in 10 years (%)	Forest Cover in 25 years (%)	Forest Cover in 50 years (%)
1	Upper Allegheny, NY/PA	80.196	80.192	-0.004	-0.004	80.188	80.182	80.172
2	Allegheny River[9], NY/PA	64.247	63.806	-0.441	-0.441	63.365	62.703	61.601
3	Elk River, WV	90.975	90.588	-0.387	-0.387	90.201	89.620	88.651
4	Walhonding River, OH	37.711	37.535	-0.177	-0.177	37.358	37.093	36.652
5	Kinniconick Creek, KY	85.495	85.260	-0.235	-0.235	85.025	84.673	84.087
6	Johns Creek, KY	79.385	78.089	-1.296	-1.296	76.793	74.850	71.610
7	Redbird Creek, KY	83.783	82.416	-1.367	-1.367	81.049	78.999	75.583
8	Green River, KY/TN	45.305	45.050	-0.256	-0.256	44.794	44.411	43.772
9	Cumberland River, KY/TN	75.392	74.813	-0.579	-0.579	74.233	73.364	71.916
10	Duck River, TN	53.754	52.393	-1.361	-1.361	51.032	48.991	45.588

[9] Conewango, French, Lower Allegheny, Middle Allegheny-Redbank, and Middle Allegheny-Tionesta watersheds were used in our analysis because they encompass most of the longhead darter records and therefore, are considered most representative of the population. We did not include Clarion, Upper Ohio, or Youghiogheny watersheds because they encompass very few longhead darter occurrence records (n=4), all of which occur at the extreme edges of the watersheds. We also did not include the Upper Allegheny watershed because only a small portion of the watershed (below Kinzua dam) is within the #2 Allegheny River population.

Scenario 2. Under the optimistic scenario, we predict a reduced rate of forest loss (0.5 percent less) from the rate observed between 2001 and 2011.

No.	Population	2001 Forest Cover (%)	2011 Forest Cover (%)	Rate of forest loss between 2001 and 2011	Scenario 2: Optimistic			
					Predicted rate of forest loss	Forest Cover in 10 years (%)	Forest Cover in 25 years (%)	Forest Cover in 50 years (%)
1	Upper Allegheny, NY/PA	80.196	80.192	-0.004	0.496	80.688	81.432	82.672
2	Allegheny River[10], NY/PA	64.247	63.806	-0.441	0.059	63.865	63.953	64.101
3	Elk River, WV	90.975	90.588	-0.387	0.113	90.701	90.870	91.153
4	Walhonding River, OH	37.711	37.535	-0.177	0.323	37.858	38.343	39.152
5	Kinniconick Creek, KY	85.495	85.260	-0.235	0.265	85.525	85.923	86.587
6	Johns Creek, KY	79.385	78.089	-1.296	-0.796	77.293	76.100	74.110
7	Redbird Creek, KY	83.783	82.416	-1.367	-0.867	81.549	80.249	78.083
8	Green River, KY/TN	45.305	45.050	-0.256	0.244	45.294	45.661	46.272
9	Cumberland River, KY/TN	75.392	74.813	-0.579	-0.079	74.733	74.614	74.416
10	Duck River, TN	53.754	52.393	-1.361	-0.861	51.532	50.241	48.088

[10] Conewango, French, Lower Allegheny, Middle Allegheny-Redbank, and Middle Allegheny-Tionesta watersheds were used in our analysis because they encompass most of the longhead darter records and therefore, are considered most representative of the population. We did not include Clarion, Upper Ohio, or Youghiogheny watersheds because they encompass very few longhead darter occurrence records (n=4), all of which occur at the extreme edges of the watersheds. We also did not include the Upper Allegheny watershed because only a small portion of the watershed (below Kinzua dam) is within the #2 Allegheny River population.

Scenario 3. Under the pessimistic scenario, we predict an increased rate of forest loss (0.5 percent greater) from the rate observed between 2001 and 2011.

No.	Population	2001 Forest Cover (%)	2011 Forest Cover (%)	Rate of forest loss between 2001 and 2011	Scenario 3: Pessimistic			
					Predicted rate of forest loss	Forest Cover in 10 years (%)	Forest Cover in 25 years (%)	Forest Cover in 50 years (%)
1	Upper Allegheny, NY/PA	80.196	80.192	-0.004	-0.504	79.688	78.932	77.672
2	Allegheny River[11], NY/PA	64.247	63.806	-0.441	-0.941	62.865	61.453	59.101
3	Elk River, WV	90.975	90.588	-0.387	-0.887	89.701	88.370	86.153
4	Walhonding River, OH	37.711	37.535	-0.177	-0.677	36.858	35.843	34.152
5	Kinniconick Creek, KY	85.495	85.260	-0.235	-0.735	84.525	83.423	81.587
6	Johns Creek, KY	79.385	78.089	-1.296	-1.796	76.293	73.600	69.110
7	Redbird Creek, KY	83.783	82.416	-1.367	-1.867	80.549	77.749	73.083
8	Green River, KY/TN	45.305	45.050	-0.256	-0.756	44.294	43.161	41.272
9	Cumberland River, KY/TN	75.392	74.813	-0.579	-1.079	73.733	72.114	69.416
10	Duck River, TN	53.754	52.393	-1.361	-1.861	50.532	47.741	43.088

[11] Conewango, French, Lower Allegheny, Middle Allegheny-Redbank, and Middle Allegheny-Tionesta watersheds were used in our analysis because they encompass most of the longhead darter records and therefore, are considered most representative of the population. We did not include Clarion, Upper Ohio, or Youghiogheny watersheds because they encompass very few longhead darter occurrence records (n=4), all of which occur at the extreme edges of the watersheds. We also did not include the Upper Allegheny watershed because only a small portion of the watershed (below Kinzua dam) is within the #2 Allegheny River population.