

Kentucky Arrow Darter
(Etheostoma spilotum)

Status Review:
Summary and Evaluation



*Photo courtesy of Dr. Matthew Thomas,
Kentucky Department of Fish and Wildlife Resources*

U.S. Fish and Wildlife Service
Southeast Region
Kentucky Ecological Services Field Office
Frankfort, Kentucky

September 2022

STATUS REVIEW
Kentucky Arrow Darter (*Etheostoma spilotum*)

GENERAL INFORMATION

Current Classification: Threatened

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Reviewers:

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Date of original listing/4(d) rule: October 5, 2016 (81 FR 68963)

Critical habitat final rule: October 5, 2016 (81 FR 69312)

Methodology used to complete the review: In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of a status review is to assess each threatened species or endangered species to determine whether its status has changed and if it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants ([50 CFR 424.11](#)). In conducting this 5-year review, the U.S. Fish and Wildlife Service (Service) relied on the best available information pertaining to historical and current distributions, life history, ecology, and habitat of this species. We announced initiation of this review in the Federal Register on June 23, 2021 (86 FR 37178) with a 60-day comment period and received one public comment. The National Council for Air and Stream Improvement (NCASI) provided information regarding the use and effectiveness of forestry best management practices and their importance in protecting aquatic species and stream habitats in the United States. We have noted best management practices in the review. The primary sources of information used in this analysis were the 2016 final listing rule (81 FR 68963), the 2017 recovery outline, peer-reviewed reports, agency reports, unpublished survey data and reports, and personal communications with recognized experts. This review was completed by the U.S. Fish and Wildlife Service, Kentucky Ecological Services Field Office (KFO), Frankfort, Kentucky. All literature and documents used for this review are on file at the KFO. All recommendations resulting from this review are the result of thoroughly reviewing the best available information on the Kentucky arrow darter.

FR Notice citation announcing the species is under active review: June 23, 2021 (86 FR 37178)

Species' Recovery Priority Number at start of 5-year review ([48 FR 43098](#)): 11. The Kentucky arrow darter is a species with a moderate degree of threat and a low recovery potential.

Review History:

This is the first 5-year status review for this species.

REVIEW ANALYSIS**Listed Entity****Taxonomy and nomenclature**

The taxon is still considered a valid entity by the Service. The revised and currently accepted classification for the Kentucky arrow darter is *Etheostoma sagitta spilotum* (Page *et al.* 2013). This change in taxonomy from the currently listed entity, *E. spilotum* (50 CFR 17.11), is a more accurate reflection of the published literature, but it does not impact the taxon's status or interpretation of its threats. Species-level recognition of the Kentucky Arrow Darter (as *E. spilotum*) is supported in a forthcoming publication based on morphological data combined with updated genetic analyses, including a species delimitation analysis using multi-locus DNA sequence data (Thomas 2022, pers. comm.).

Distinct Population Segment (DPS) ([61 FR 4722](#))

The Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This species was not listed as a DPS, and we have no new information that would indicate the species should be listed as a DPS under the Service's 1996 DPS Policy.

Recovery Criteria**Recovery Plan or Outline**

At the time of this review, recovery criteria for this species have not been finalized. A recovery outline has been completed (Recovery outline for Kentucky arrow darter (*Etheostoma spilotum*), February 15, 2017).

Biology and Habitat Summary**Habitat**

Kentucky arrow darters typically inhabit pools or transitional areas between riffles and pools (glides and runs) in moderate- to high-gradient, first- to third-order streams with rocky substrates (Thomas 2008). The species is most often observed near some type of cover (*e.g.*, boulders, bedrock ledges, large cobble, or woody debris) in depths ranging from 10 to 45 centimeters (cm) (4 to 18 inches (in)) and in streams ranging from 1.5 to 20 meters (m) (4.9 to 65.6 feet (ft)) wide. Kentucky arrow darters typically occupy streams with watersheds of 25.9 square kilometers (km²) (10 square miles (mi²)) or less, and many of these habitats, especially in first-order reaches, can be intermittent in nature (Thomas 2008). During the driest periods, the species appears to survive by retreating into shaded, isolated pools or by dispersing into larger tributaries (Lotrich 1973, Lowe 1979, Etnier and Starnes 1993, Appalachian Technical Services 2011, Service unpublished data).

Diet

Kentucky arrow darters feed primarily on mayflies (Order Ephemeroptera), specifically the families Heptageniidae (genus *Stenonema*) and Baetidae (Lotrich 1973). Mayflies comprised 77

percent of identifiable food items (420 of 542 items) in 57 Kentucky arrow darter stomachs from Clemons Fork, Breathitt County (Lotrich 1973). Large Kentucky arrow darters (individuals over 70 mm (2.8 in) total length) often feed on small crayfishes (Lotrich 1973), but other food items include larval blackflies, midges, caddisfly larvae, stonefly nymphs, beetle larvae, microcrustaceans, and dipteran larvae (Lotrich 1973, Etnier and Starnes 1993). In July 2021, we examined gut contents of one individual collected from Frozen Creek, Breathitt County, and three individuals collected from Clemons Fork, Breathitt County (Service unpublished data). These specimens were provided as part of an ongoing population genetics study by Austin Peay State University (APSU 2020). The gut of the Frozen Creek specimen was dominated by midges (Genus *Ablabesmyia*), along with a few mayflies (Families Baetidae and Caenidae). Each of the Clemons Fork specimens contained two or three, relatively large, burrowing mayfly larvae (Family Ephemeridae, Genus *Ephemer*), suggesting that the Kentucky Arrow Darter has the ability to extract these mayflies from their burrows.

Reproduction and Life History

Male Kentucky arrow darters establish territories over riffles from March to May, where they are quite conspicuous in water 5 to 15 cm (2 to 6 in) deep (Kuehne and Barbour 1983). Males fan out a depression in the substrate and defend these sites vigorously. Initial courtship behavior involves rapid dashes, fin-flaring, nudging, and quivering motions by the male followed by similar quivering responses of the female, who then precedes the male to the nest. The female partially buries herself in the substrate, is mounted by the male, and spawning occurs (Etnier and Starnes 1993). It is assumed that the male continues to defend the nest until the eggs have hatched. The spawning period extends from April to June, but peak activity occurs when water temperatures reach 13°C (55°F), typically in mid-April (Bailey 1948, Kuehne and Barbour 1983).

Young Kentucky arrow darters can reach 50 mm (2 in) in length by the end of the first year (Lotrich 1973, Kuehne and Barbour 1983), when these individuals are generally sexually mature and participate in spawning with older age classes (Etnier and Starnes 1993). Juvenile Kentucky arrow darters can be found throughout the channel but are often observed in shallow water along stream margins near root mats, rock ledges, or some other cover. The species' maximum length is 120 mm (4.7 in), and its lifespan can extend for up to 5 years (Lotrich 1973, Lowe 1979, Kuehne and Barbour 1983, Thomas and Brandt 2020).

Baxter (2015) used PIT-tags (electronic tags placed under the skin) and placed antenna systems to study intra- and inter-tributary movements of the Kentucky arrow darter in Elisha Creek and Gilberts Big Creek in Clay and Leslie counties. PIT-tags were placed in a total of 126 individuals, and movements were tracked from May 2013 to May 2014. Recorded movements ranged from 134 m (439 ft) (upstream movement) to 4,078 m (13,379 ft or 2.5 mi) (downstream movement by a female in Elisha Creek). Intermediate recorded movements included 328 m (1,076 ft) (downstream), 351 m (1,151 ft) (upstream), 900 m (2,952 ft) (upstream/downstream), 950 m (3,116 ft) (downstream), 1,282 m (4,028 ft) (downstream), and 1,708 m (5,603 ft) (downstream). Thomas and Brandt (2020, 2022) observed intertributary movements of up to 1 km (0.4 mi) in the Hector Creek system, Clay County.

Genetics

Blanton *et al.* (2019) provided the first study of the species' population genetics. They studied contemporary and historical patterns of genetic diversity and structure through analyses of tissue samples (fin clips) collected from 14 localities across the species' range. Contemporary genetic patterns were evaluated using microsatellite data (a short segment of DNA that is repeated multiple times, occurs throughout the genome, and varies from one individual to another), while historical patterns of diversity and gene flow were studied using mitochondrial DNA (DNA located in the cell's mitochondria). Microsatellite data for 10 populations (12 localities) revealed low genetic diversity within and a high degree of contemporary isolation and genetic structure among Kentucky arrow darter populations. Populations of the species appeared to be more genetically isolated than even those of other imperiled fishes, such as the blue-masked darter, *Etheostoma akatulo*, another range-limited species (Fluker *et al.* 2010, Austin *et al.* 2011, Robinson *et al.* 2013). These results were in sharp contrast to mitochondrial DNA analyses, which showed widespread historical gene flow across the Kentucky arrow darter's range. Blanton *et al.* (2019) concluded that the contemporary isolation, lack of gene flow, and low genetic diversity were a direct result of recent anthropogenic stressors that decreased habitat quality and population connectivity, ultimately leading to range-wide population isolation and loss. A second range-wide genetics study (APSU 2019) is underway and will provide new estimates of genetic diversity and effective population size across the species' range. The new study will compare current levels of genetic diversity with results reported by Blanton *et al.* (2019).

Distribution

The Kentucky arrow darter occurred historically in at least 74 streams in the upper Kentucky River drainage of eastern Kentucky (Gilbert 1887, Woolman 1892, Kuehne and Bailey 1961, Kuehne 1962, Branson and Batch 1972, Lotrich 1973, Branson and Batch 1974, Harker *et al.* 1979, Greenberg and Steigerwald 1981, Branson and Batch 1983, Branson and Batch 1984, Kornman 1985, Burr and Warren 1986, Measel 1997, Kornman 1999, Stephens 1999, Ray and Ceas 2003, Thomas 2008, Service 2012, Service 2014, and Service 2017). The species' distribution spanned portions of four 8-digit hydrologic unit code (HUC) watersheds (Upper Kentucky, South Fork Kentucky, Middle Fork Kentucky River, and North Fork Kentucky) in 10 Kentucky counties (Breathitt, Clay, Harlan, Jackson, Knott, Lee, Leslie, Owsley, Perry, and Wolfe) (Thomas 2008, Service 2017) (Figure 1).

Based on historical records and survey data collected across the species' historical range since 2000, the Kentucky arrow darter has declined significantly range-wide and has been eliminated from large portions of its former range, including 35 of 74 historical streams (72 HUC14 watersheds) and large portions of the drainage that would have been occupied historically by the species (Figure 1; Appendix A). Forty-four percent of the species' extirpations (16 streams) have occurred since the mid-1990s, and the species has disappeared completely from several watersheds (*e.g.*, Lott Creek, Sexton Creek, South Fork Quicksand Creek, Troublesome Creek headwaters).

Extant populations of the Kentucky arrow darter currently occupy 52 small stream systems (88 HUC14 watersheds) (Figure 1; Appendix A). Populations in ten of these streams have been discovered since 2000, and one additional population (Long Fork, Clay County) was established through a reintroduction project led by KDFWR and Conservation Fisheries, Inc. (Thomas and

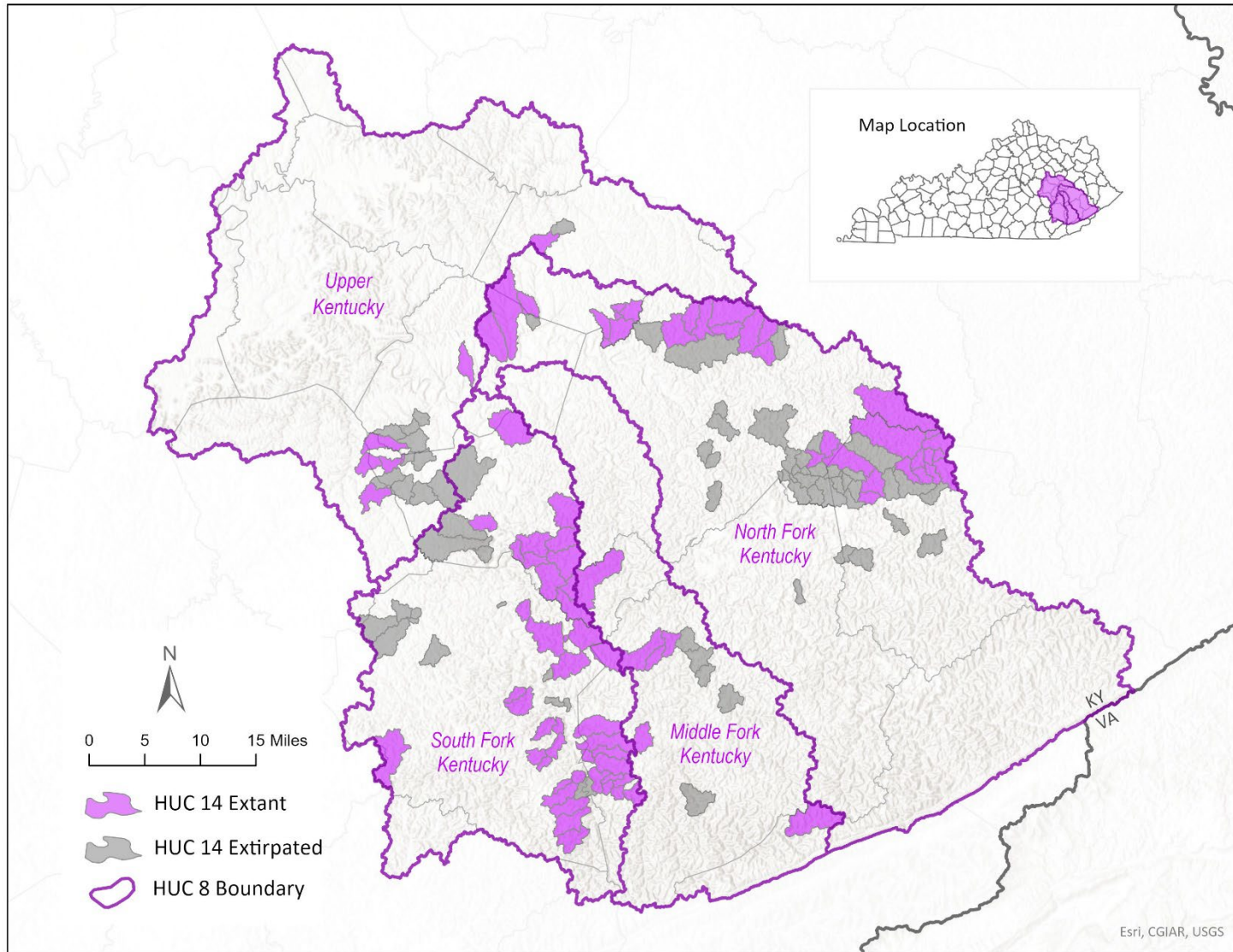


Figure 1. Current distribution of the Kentucky arrow darter based on positive HUC14 occurrence records (2000-present) in the upper Kentucky River drainage.

Brandt 2020). Of the species' 52 extant streams, we consider over half of these populations (27) to be "vulnerable", and most remaining populations are isolated and restricted to short stream reaches (Appendix A). No extirpations have been documented since the species was listed in 2016.

Threats (Five-Factor Analysis) Summary

As specified in section 4 (a)(1) of the Act, a species' status must be determined through consideration of the following five factors:

- A. present or threatened destruction, modification, or curtailment of its habitat or range;
- B. over-utilization of the species for commercial, recreational, scientific, or educational purposes;
- C. disease or predation;
- D. inadequacy of existing regulatory mechanisms; and
- E. other natural or manmade factors affecting its continued existence.

Factor A continues to be the primary threat for the Kentucky arrow darter. The primary stressors associated with this factor are water quality degradation (pollution), siltation (excess sediments suspended or deposited in a stream), and channel disturbance associated with surface coal mining, logging, agriculture, road construction and maintenance, and other human development activities in the upper Kentucky River drainage (Branson and Batch 1972, 1974; Pond 2004; Mattingly *et al.* 2005; Johnson *et al.* 2010; Palmer *et al.* 2010; Pond 2010; USEPA 2011; Hitt and Chambers 2014; Pond 2014, 2015; Kentucky Department of Water [KDOW] 2018a, 2018b). Ongoing and proposed surface coal mining activities represent a high magnitude and imminent threat to the species' recovery. These activities have the potential to introduce high concentrations of dissolved metals and other substances that can increase stream conductivity and alter stream water quality. Hitt *et al.* (2016) provided new information on the species' sensitivity to elevated conductivity by modeling occurrence and abundance data at 208 historical sites in the upper Kentucky River drainage. Their results indicated a sharp decrease in Kentucky arrow darter abundance when conductivity levels exceeded 261 $\mu\text{S}/\text{cm}$ (95% confidence interval of 151-370). Similar responses to elevated conductivity have been reported for the blackside dace (*Chrosomus cumberlandensis*), another imperiled headwater fish in the coalfields region (Hitt *et al.* 2016, Black *et al.* 2013) of Kentucky. Although coal production has been declining since 2000, there is still a significant amount of mining activity and coal production across the species' range, including a total of 97 active surface mine permits (Barbour 2022, pers. comm.; Commonwealth of Kentucky 2021). Habitats across the species' historical range also continue to be degraded by legacy effects associated with mining (*e.g.*, elevated conductivity, stream loss, increased sediment).

Siltation continues to be a major stressor of aquatic systems in the upper Kentucky River drainage (KDOW 2018a, 2018b). Excessive stream siltation is typically caused by soil erosion and stormwater runoff associated with upland land use activities (*e.g.*, agriculture, forestry, mining, road or pipeline construction, and general urbanization), but it can also be caused by activities that directly destabilize stream channels and remove riparian vegetation (*e.g.*, dredging or channelization, construction projects, land development). Siltation can affect fishes through abrasion of gill tissues, suffocation of eggs or larvae, reductions in disease tolerance, degradation of spawning habitats, modification of migration patterns, and reductions in food availability

(Berkman and Rabeni 1987, Waters 1995, Wood and Armitage 1997, Meyer and Sutherland 2005). Appropriate best management practices that are properly implemented can be effective in protecting water quality and instream habitats, which can moderate this threat in many instances.

Unintentional collection by anglers (for use as bait) may occur in some portions of the species' range; however, overutilization of the species for commercial, recreational, scientific, or educational purposes (Factor B) is not considered to be a significant threat. The species is undoubtedly consumed by predators (*e.g.*, herons, sunfishes), but we consider this to be a normal aspect of the species' population dynamics. Disease or predation (Factor C) is not considered to be a threat to the species.

Existing regulatory mechanisms (Factor D) have provided for some improvements in water quality and habitat conditions in the upper Kentucky River drainage, but existing regulatory mechanisms have been inadequate in fully protecting streams inhabited by the species. Sedimentation and non-point source pollutants continue to represent an imminent threat of low to moderate magnitude across the species' range. Further, the information available to us at this time does not indicate that the magnitude or imminence of this threat is likely to be appreciably reduced in the foreseeable future.

The species' fragmented distribution and the disjunct nature of many of its populations (Factor E) has reduced its contemporary gene flow (Blanton and Cashner 2016, Blanton *et al.* 2019). This restricts the natural interchange of genetic material between populations and makes natural repopulation following localized extirpations virtually impossible without human intervention. The small size and low genetic diversity of many Kentucky arrow darter populations also makes them vulnerable to extirpation from toxic chemical spills, habitat modification, progressive degradation from runoff (non-point source pollutants), natural catastrophic changes to their habitat (*e.g.*, flood scour, drought), and other stochastic disturbances.

Between July 25 and July 30, 2022, several thunderstorm complexes developed across eastern Kentucky and brought heavy rain, deadly flash flooding, and devastating river flooding to the upper Kentucky River drainage and other parts of central Appalachia (National Weather Service 2022). These thunderstorms caused periodic rainfall rates in excess of 4 inches (in) per hour across complex terrain that led to widespread, catastrophic impacts to the region. Radar-based rainfall estimates suggest that up to 14 to 16 in of rain fell during this 5-day period in a narrow swath, with many more locations receiving 6 to 10 in of rain. These rainfall values occurring in such a short period of time are incredibly rare: there is less than a 1 in 1000 chance for this much rainfall over five days in a given year. Based on our review of news and weather reports from across the region, we suspect that many Kentucky arrow darter streams in Breathitt, Clay, Knott, Leslie, Owsley, and Perry counties were damaged severely by this event, but we currently have no information about the magnitude or scope of these effects. Over the next year, the Service will work with its federal and state partners to determine how this event may have affected the species and its habitats.

Synthesis

The Kentucky arrow darter is a small benthic fish that typically occupies rocky pools in headwater streams of the upper Kentucky River drainage in eastern Kentucky. The species once occurred in small streams throughout the drainage, but it has now been eliminated from large

portions of its historical range, including 35 of 74 historical streams (72 HUC14 watersheds). The Kentucky arrow darter currently occupies 52 small stream systems (88 HUC14 watersheds) across 10 Kentucky counties, but most remaining populations are isolated and restricted to short stream reaches. Of the species' 52 extant streams, we consider 27 of these populations to be "vulnerable" to extirpation. The species' continues to be impacted by poor water quality, habitat that is altered chemically and physically by anthropogenic activities such as surface coal mining, oil and gas exploration, logging, agriculture, poor land use practices, and development. Current regulatory mechanisms, such as the Federal Clean Water Act, have contributed to some improvements in water quality and habitat conditions, especially on public lands; however, these mechanisms have been inadequate in fully protecting the Kentucky arrow darter and its habitats. The species' fragmented distribution, lack of gene flow, and low genetic diversity increases its vulnerability to extirpation from chemical spills, habitat disturbance, catastrophic weather events (drought, floods), and a variety of other stochastic disturbances. Recent catastrophic flooding across the upper Kentucky River drainage (July 25-29, 2022) has undoubtedly affected many Kentucky arrow streams, but the magnitude and scope of these effects are unknown at this time. Because of its restricted distribution and continued vulnerability to these threats, and our uncertainty with regard to the viability of individual populations across the range, we believe that the species continues to meet the definition of a threatened species.

RECOMMENDED FUTURE ACTIVITIES

This species does not have a final recovery plan. While completing this status review, we have identified the following potential recovery activities which are included below.

Recovery Activities

- Continue to utilize existing legislation and regulations to protect the species and its habitats (*e.g.*, Act, federal and state surface mining laws, Clean Water Act, state water quality regulations).
- Continue to protect, restore, and enhance habitat quality across the species' range. Federal, state, and private parties should continue to work cooperatively (through Farm Bill programs, Partners for Fish and Wildlife projects, Kentucky Wild Rivers Program, etc.) to restore and protect habitats for the species.

Monitoring and Research Activities

- Conduct periodic monitoring (five-year intervals) of extant populations and search for new populations in least-disturbed watersheds.
- Consult with agency partners and species experts to determine which biological or ecological studies are needed to better understand the species' life history and sensitivity to threats (*e.g.*, elevated conductivity). Using this information, determine what management strategies are needed to improve the species' status across its range.
- Continue research on population genetics; evaluate gene flow and genetic diversity across the species' range.

- Investigate the effects of catastrophic July 2022 flooding on the Kentucky arrow darter and its habitats in Breathitt, Clay, Knott, Leslie, Owsley, and Perry counties.

RESULTS / SIGNATURES

U.S. Fish and Wildlife Service Status Review of Kentucky arrow darter

Status Recommendation:

On the basis of this review, we recommend the following status for this species. A 5-year review presents a recommendation of the species status. Any change to the status requires a separate rulemaking process that includes public review and comment, as defined in the Act.

Uplist to Endangered

Delist:

The species is extinct

The species does not meet the definition of an endangered or threatened species

The listed entity does not meet the statutory definition of a species

No change needed

FIELD OFFICE APPROVAL:

Field Supervisor, Kentucky Ecological Services Field Office, Fish and Wildlife Service

Approve _____

REGIONAL OFFICE APPROVAL:

Acting for:

Assistant Regional Director – Ecological Services, Fish and Wildlife Service

Approve _____

REFERENCES

- Appalachian Technical Services. 2011. Upper Buckhorn Creek arrow darter survey. Technical Report. 17 pp.
- Austin, J.D., H.L. Jelks, B. Tate, A.R. Johnson, and F. Jordan. 2011. Population genetic structure and conservation genetics of threatened Okaloosa darters (*Etheostoma okaloosae*). *Conservation Genetics* 12:981-989.
- Austin Peay State University (APSU). 2019. Scope of Work - 2019 Austin Peay State University Kentucky Arrow Darter Genetics Project (Grant #F20AC00226). Biology Department, Austin Peay State University, Clarksville, Tennessee.
- Barbour, T. 2022. Personal communication (email correspondence) regarding active mining permits in the upper Kentucky River drainage. Environmental Scientist Consultant, Division of Mine Permits, Kentucky Department of Natural Resources, Frankfort, Kentucky.
- Baxter, J.B. 2015. Distribution, movement, and ecology of *Etheostoma spilotum* (Gilbert), the Kentucky arrow darter, in Gilberts Big Creek and Elisha Creek, Red Bird River basin, Clay and Leslie counties, Kentucky. M.S. Thesis, Eastern Kentucky University, Richmond, Kentucky. 62 pp.
- Bailey, R.M. 1948. Status, relationships, and characters of the percid fish, *Poeciliichthys sagitta* Jordan and Swain. *Copeia* 1948:77-85.
- Berkman, H.E. and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. *Environmental Biology of Fishes* 18:285-294.
- Black, T.R., B.K. Jones, and H.T. Mattingly. 2013. Development and validation of habitat models for the threatened blackside dace, *Chrosomus cumberlandensis*, at two spatial scales. *Southeastern Naturalist* 12:27-48.
- Blanton, R.E. and M.F. Cashner. 2016. Patterns of genetic variation and gene flow in the federally threatened Kentucky arrow darter, *Etheostoma spilotum* (Percidae). Unpublished final project report prepared for the Kentucky Department of Fish and Wildlife Resources and U.S. Fish and Wildlife Service, Kentucky Field Office. 37 pp.
- Blanton, R.E., M.F. Cashner, M.R. Thomas, S.L. Brandt, and M.A. Floyd. 2019. Increased habitat fragmentation leads to isolation among and low genetic diversity within populations of the imperiled Kentucky arrow darter (*Etheostoma sagitta spilotum*). *Conservation Genetics*, <https://doi.org/10.1007/s10592-019-01188-y>.
- Branson, B.A. and D.L. Batch. 1972. Effects of strip mining on small stream fishes in east-central Kentucky. *Proceedings of the Biological Society of Washington*. 84:507-518.
- Branson, B.A. and D.L. Batch. 1974. Additional observations on the effects of strip mining on small-stream fishes in east-central Kentucky. *Transactions of the Kentucky Academy of Science* 35:81-83.
- Branson, B.A. and D.L. Batch. 1983. Fishes of the South Fork of the Kentucky River, with notes and records from other parts of the drainage. *Southeastern Fishes Council Proceedings* 4:1-15.

- Branson, B.A. and D.L. Batch. 1984. Fishes of the Middle Fork of the Kentucky River, Kentucky. Southeastern Fishes Council Proceedings 1:4–13.
- Burr, B.M. and M.L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Kentucky State Nature Preserves Commission Scientific and Technical Series Vol. 4.
- Commonwealth of Kentucky. 2021. Kentucky Quarterly Coal Report (2021-Q4). Retrieved from <https://eec.ky.gov/Energy/News-Publications/Quarterly%20Coal%20Reports/2021-Q4.pdf>.
- Etnier, D.A. and W.C. Starnes. 1993. The Fishes of Tennessee. The University of Tennessee Press, Knoxville, Tennessee. 681 pp.
- Fluker, B.L., B.R. Kuhajda, N.J. Lang, and P.M. Harris. 2010. Low genetic diversity and small long-term population sizes in the spring endemic watercress darter, *Etheostoma nuchale*. Conservation Genetics 11:2267-2279.
- Gilbert, C.H. 1887. Descriptions of new and little known etheostomoids. Proceedings of the United States National Museum 10:47–64.
- Greenberg, L.A. and S. Steigerwald. 1981. New distributional record for *Etheostoma sagitta* in Kentucky. Transactions of the Kentucky Academy of Science 42:37.
- Harker, D.F., S.M. Call, M.L. Warren, K.E. Camburn, and P. Wigley. 1979. Aquatic biota and water quality survey of the Appalachian Province, eastern Kentucky. Kentucky State Nature Preserves Commission, Frankfort, Kentucky. Technical Report. 1,152 pp.
- Hitt, N.P. and D.B. Chambers. 2014. Temporal changes in taxonomic and functional diversity of fish assemblages downstream from mountaintop mining. Freshwater Science 33:915–926.
- Hitt, N.P., M. Floyd, M. Compton, and K. McDonald. 2016. Threshold Responses of Blackside Dace (*Chrosomus cumberlandensis*) and Kentucky Arrow Darter (*Etheostoma spilotum*) to Stream Conductivity. Southeastern Naturalist 15: 41-60.
- Johnson, B.R., A. Haas, and K.M. Fritz. 2010. Use of spatially explicit physicochemical data to measure downstream impacts of headwater stream disturbance. Water Resources Research 46:1-15.
- Jordan, D.S. and J. Swain. 1883. List of fishes collected in the Clear Fork of the Cumberland, Whitley County, Kentucky, with descriptions of three new species. Proceedings of the United States National Museum 6:248-251.
- Kentucky Division of Water (KDOW). 2018a. Integrated report to Congress on the condition of water resources in Kentucky, 2016. Assessment results with emphasis on the Big Sandy, Little Sandy, Tygarts River, and Kentucky River basin management units and a statewide update. Kentucky Energy and Environment Cabinet. Frankfort, Kentucky. 156 pp.
- Kentucky Division of Water (KDOW). 2018b. List of Kentucky 303(d) streams, 2016 Integrated Report. Kentucky Energy and Environment Cabinet. Frankfort, Kentucky. 156 pp.
- Kornman, L. 1985. Muskellunge streams investigation in Red River, Station Camp Creek, and Sturgeon Creek. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky. Fisheries Bulletin 77. 65 pp.

- Kornman, L. 1999. Warmwater stream fishery surveys, Northeastern Fishery District (Project 2). Pages 118–133 *In* Annual Performance Report, Part II, Projects 2-8 (Sport Fish Restoration Grant F-50, Segment 21). Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.
- Kuehne, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. *Ecological Society of America* 43:608–614.
- Kuehne, R.A. and R.M. Bailey. 1961. Stream capture and the distribution of the percid fish *Etheostoma sagitta*, with geologic and taxonomic considerations. *Copeia* 1961:1–8.
- Kuehne, R.A. and R.W. Barbour. 1983. *The American darters*. The University of Kentucky Press, Lexington, Kentucky. 177 pp.
- Lotrich, V.A. 1973. Growth, production, and community composition of fishes inhabiting a first-, second-, and third-order stream of eastern Kentucky. *Ecological Monographs* 43:377–397.
- Lowe, J.E. 1979. The life history, behavior, and ecology of *Etheostoma sagitta* (Jordan and Swain). Unpublished M.S. thesis, University of Tennessee. 73 pp.
- Mattingly, H.T., J. E. Detar, B. K. Jones, and C. F. Walton. 2005. Factors affecting the distribution and recovery of the threatened blackside dace in Kentucky and Tennessee. Unpublished final project report prepared for the U.S. Fish and Wildlife Service, Tennessee Ecological Services Field Office. Cookeville, Tennessee. 126 pp.
- Measel, P. 1997. Terrestrial and aquatic baseline report for the reconstruction of KY 15 from KY 28 in Perry County to Haddix in Breathitt County, Kentucky Transportation Cabinet Item Numbers 10-285.00 and 10-286.00. T.H.E. Engineers, Inc., Lexington, Kentucky. 105 pp.
- Meyer, J.L. and A.B. Sutherland. 2005. Effects of excessive sediment on stress, growth, and reproduction of two southern Appalachian minnows, *Erimonax monachus* and *Cyprinella galactura*. Unpublished final project report for grant #1434-HQ-97-RU-01551, Department of Interior. University of Georgia, Institute of Ecology. Athens, Georgia.
- National Weather Service. 2022. Historic July 26th-July 30th, 2022 Eastern Kentucky Flooding. Retrieved from <https://www.weather.gov/jkl/July2022Flooding>, August 3, 2022.
- Near, T.J., C.M. Bossu, G.S. Bradburd, R.L. Carlson, R.C. Harrington, P.R. Hollingsworth, Jr., B.P. Keck, and D.A. Etnier. 2011. Phylogeny and temporal diversification of darters (Percidae: Etheostomatinae). *Systematic Biology* 60:565-595.
- Page, L.M., H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea, N.E. Mandrak, R.L. Mayden, and J.S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico (7th edition). American Fisheries Society, Special Publication 34.
- Palmer, M.A., E S. Bernhardt, W.H. Schlesinger, K.N. Eshleman, E. Foufoula-Georgiou, M.S. Hendryx, A.D. Lemly, G.E. Likens, O.L. Loucks, M.E. Power, P.S. White, and P.R. Wilcock. 2010. Mountaintop mining consequences. *Science* 327:148–149
- Pond, G.J. 2004. Effects of surface mining and residential land use on headwater stream biotic integrity in the eastern Kentucky coalfield region. Kentucky Department for Environmental Protection, Division of Water, Frankfort, Kentucky. 48 pp.

- Pond, G.J. 2010. Patterns of Ephemeroptera taxa loss in Appalachian headwater streams (Kentucky, USA). *Hydrobiologia* 641:185–201.
- Pond, G.J. 2012. Biodiversity loss in Appalachian headwater streams (Kentucky, USA): Plecoptera and Trichoptera communities. *Hydrobiologia* 679:97-117.
- Pond, G.J. 2015. Personal communication regarding conductivity thresholds for aquatic organisms and potential threats to the Kentucky arrow darter posed by sewage bacteria and parasites (email correspondence). U.S. Environmental Protection Agency, Wheeling, West Virginia.
- Ray, J.M. and P.A. Ceas. 2003. Fish survey and bioassessment of Station Camp Creek and Sturgeon Creek in the upper Kentucky River drainage. *Southeastern Fishes Council Proceedings* 46: 1–15.
- Robinson, J.D., J.W. Simmons, A.S. Williams, and G.R. Moyer. 2013. Population structure and genetic diversity in the endangered bluemask darter (*Etheostoma akatulo*). *Conservation Genetics* 14:79-92.
- Stephens, D. 1999. Warmwater stream fishery surveys, Southeastern Fishery District (Project 2). Pages 159–174 *In* Annual Performance Report, Part II, Projects 2–8 (Sport Fish Restoration Grant F-50, Segment 21). Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.
- Thomas, M.R. 2008. Distribution and status of the Kentucky arrow darter (*Etheostoma sagitta spilotum*). Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky. State and Tribal Wildlife Grant T-9-RSI-1. 9 pp. + figures.
- Thomas, M.R. 2022. Personal communication regarding the taxonomic status of the Kentucky arrow darter (email correspondence). Ichthyologist, Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.
- Thomas, M.R. and S. Brandt. 2020. Kentucky arrow darter (*Etheostoma spilotum*) reintroduction monitoring in Long Fork, Red Bird River drainage, Kentucky. Final report for State Wildlife Grant project T-64. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.
- Thomas, M.R. and S. Brandt. 2022. Targeted sampling for federally listed fish species in Kentucky: 2021 interim State Wildlife Grant report (Section II). Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.
- Thomas, M.R. and R.E. Blanton. 2008. Systematics and conservation status of the arrow darter, *Etheostoma sagitta* (Percidae: *Litocara*). Page 46 *In* Southeastern Fishes Council Annual Meeting Abstracts (Contributed Oral Presentation), Chattanooga, Tennessee. 70 pp.
- U.S. Environmental Protection Agency (USEPA). 2011. The Effects of mountaintop mines and valley fills on aquatic ecosystems of the Central Appalachian Coalfields. Office of Research and Development, National Center for Environmental Assessment, Washington, DC. EPA/600/R-09/138F, 2011.
- U.S. Fish and Wildlife Service (Service). 2012. Project report: surveys for the Kentucky arrow darter, *Etheostoma spilotum* Gilbert, in the upper Kentucky River drainage, 2007–2012. Kentucky Ecological Services Field Office. Frankfort, Kentucky. 4 pp.

- U.S. Fish and Wildlife Service (Service). 2014. Range-wide conservation strategy for the Kentucky arrow darter (*Etheostoma spilotum* Gilbert). Kentucky Ecological Services Field Office, Frankfort, Kentucky. 40 pp.
- U.S. Fish and Wildlife Service (Service). 2017. Recovery outline for the Kentucky arrow darter (*Etheostoma spilotum* Gilbert). Kentucky Ecological Services Field Office, Frankfort, Kentucky. 26 pp.
- U.S. Fish and Wildlife Service (Service) unpublished data. Field observations and survey data collected 2009–2022 by the Kentucky Ecological Services Field Office, Frankfort, Kentucky.
- Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7, Bethesda, Maryland. 251 pp.
- Wood, P.J and P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. *Environmental Management* 21:203-217.
- Woolman, A.J. 1892. Report of an examination of the rivers of Kentucky, with lists of the fishes obtained. *Bulletin of the U. S. Fish Commission*. 10:249–288.

APPENDIX A. SUPPORTING DOCUMENTATION

Table A-1. Summary and status of Kentucky Arrow Darter streams (historical and currently occupied) in the Upper Kentucky River Drainage. Streams in bold font indicate populations discovered since 2000.

HUC 8 Watershed	Sub-Drainage Tributaries	Stream	County	Current Status ¹	Date of Last Observation
North Fork Kentucky	Lotts Creek	Lotts Creek	Perry	Extirpated	1890
North Fork Kentucky	Troublesome Creek	Left Fork Troublesome Creek	Knott	Extirpated	1890
North Fork Kentucky	Troublesome Creek	Troublesome Creek	Perry	Extirpated	1960
North Fork Kentucky	Troublesome Creek	Mill Branch	Knott	Extirpated	1995
North Fork Kentucky	Troublesome Creek	Laurel Fork (of Balls Fork)	Knott	Extirpated	1995
North Fork Kentucky	Troublesome Creek	Buckhorn Creek (headwaters)	Knott	Vulnerable	2013
North Fork Kentucky	Troublesome Creek	Eli Fork	Knott	Vulnerable	2013
North Fork Kentucky	Troublesome Creek	Boughcamp Branch (headwaters)	Knott	Vulnerable	2013
North Fork Kentucky	Troublesome Creek	Buckhorn Creek (mainstem)	Breathitt, Knott	Extirpated	2013
North Fork Kentucky	Troublesome Creek	Coles Fork	Breathitt, Knott	Stable	2013
North Fork Kentucky	Troublesome Creek	Snag Ridge Fork	Knott	Stable	2013
North Fork Kentucky	Troublesome Creek	Clemons Fork	Breathitt	Stable	2021
North Fork Kentucky	Troublesome Creek	Millseat Branch	Breathitt	Extirpated	1976
North Fork Kentucky	Troublesome Creek	Lewis Fork	Breathitt	Extirpated	1959
North Fork Kentucky	Troublesome Creek	Long Fork	Breathitt	Extirpated	1959
North Fork Kentucky	Troublesome Creek	Bear Branch	Breathitt	Extirpated	2015
North Fork Kentucky	Troublesome Creek	Laurel Fork (of Buckhorn)	Breathitt	Extirpated	1976
North Fork Kentucky	Troublesome Creek	Lost Creek	Breathitt	Extirpated	1997
North Fork Kentucky	Quicksand Creek	Laurel Fork	Knott	Stable	2011
North Fork Kentucky	Quicksand Creek	Baker Branch	Knott	Extirpated	1994
North Fork Kentucky	Quicksand Creek	Middle Fork	Knott	Stable	2015
North Fork Kentucky	Quicksand Creek	Spring Fork	Breathitt	Vulnerable	2013
North Fork Kentucky	Quicksand Creek	Wolf Creek	Breathitt	Extirpated	1995
North Fork Kentucky	Quicksand Creek	Hunting Creek	Breathitt	Vulnerable	2013
North Fork Kentucky	Quicksand Creek	Leatherwood Creek	Breathitt	Extirpated	1982
North Fork Kentucky	Quicksand Creek	Bear Creek	Breathitt	Extirpated	1969
North Fork Kentucky	Quicksand Creek	Smith Branch	Breathitt	Extirpated	1995
North Fork Kentucky	Frozen Creek	Frozen Creek	Breathitt	Stable	2021

HUC 8 Watershed	Sub-Drainage Tributaries	Stream	County	Current Status ¹	Date of Last Observation
North Fork Kentucky	Frozen Creek	Clear Fork	Breathitt	Vulnerable	2008
North Fork Kentucky	Frozen Creek	Negro Branch	Breathitt	Vulnerable	2008
North Fork Kentucky	Frozen Creek	Davis Creek	Breathitt	Vulnerable	2008
North Fork Kentucky	Frozen Creek	Graham Branch	Breathitt	Vulnerable	2020
North Fork Kentucky	Frozen Creek	Cope Fork	Breathitt	Extirpated	1995
North Fork Kentucky	Frozen Creek	Boone Fork	Breathitt	Extirpated	1998
North Fork Kentucky	Holly Creek	Holly Creek	Wolfe	Vulnerable	2007
North Fork Kentucky	Lower Devil Creek	Lower Devil Creek	Lee, Wolfe	Extirpated	1998
North Fork Kentucky	Lower Devil Creek	Little Fork	Lee, Wolfe	Vulnerable	2011
North Fork Kentucky	Walker Creek	Walker Creek	Lee, Wolfe	Stable	2013
North Fork Kentucky	Hell Creek	Hell Creek	Lee	Vulnerable	2021
Middle Fork Kentucky	Greasy Creek	Big Laurel Creek	Harlan	Vulnerable	2009
Middle Fork Kentucky	Greasy Creek	Greasy Creek	Leslie	Extirpated	1970
Middle Fork Kentucky	Cutshin Creek	Cutshin Creek	Leslie	Extirpated	1890
Middle Fork Kentucky	Middle Fork	Middle Fork	Leslie	Extirpated	1890
Middle Fork Kentucky	Rockhouse Creek	Laurel Creek	Leslie	Vulnerable	2022
Middle Fork Kentucky	Hell For Certain Creek	Hell For Certain Creek	Leslie	Stable	2021
Middle Fork Kentucky	Squabble Creek	Squabble Creek	Perry	Vulnerable	2015
South Fork Kentucky	Red Bird River	Blue Hole Creek	Clay	Stable	2008
South Fork Kentucky	Red Bird River	Upper Bear Creek	Clay	Stable	2021
South Fork Kentucky	Red Bird River	Katies Creek	Clay	Stable	2007
South Fork Kentucky	Red Bird River	Spring Creek	Clay	Stable	2021
South Fork Kentucky	Red Bird River	Bowen Creek	Leslie	Stable	2021
South Fork Kentucky	Red Bird River	Elisha Creek	Leslie	Stable	2014
South Fork Kentucky	Red Bird River	Gilberts Big Creek	Clay, Leslie	Stable	2021
South Fork Kentucky	Red Bird River	Sugar Creek	Clay, Leslie	Stable	2008
South Fork Kentucky	Red Bird River	Big Double Creek	Clay	Stable	2021
South Fork Kentucky	Red Bird River	Little Double Creek	Clay	Stable	2021
South Fork Kentucky	Red Bird River	Ulysses Creek	Clay	Vulnerable	2012
South Fork Kentucky	Red Bird River	Big Creek	Clay	Extirpated	1890
South Fork Kentucky	Red Bird River	Jacks Creek	Clay	Vulnerable	2009
South Fork Kentucky	Red Bird River	Hector Branch	Clay	Vulnerable	2015
South Fork Kentucky	Red Bird River	Long Fork (of Hector Branch)	Clay	Stable	2021
South Fork Kentucky	Goose Creek	Horse Creek	Clay	Vulnerable	2022

HUC 8 Watershed	Sub-Drainage Tributaries	Stream	County	Current Status ¹	Date of Last Observation
South Fork Kentucky	Goose Creek	Laurel Creek	Clay	Extirpated	1970
South Fork Kentucky	Bullskin Creek	Bullskin Creek	Clay, Leslie	Stable	2021
South Fork Kentucky	Buffalo Creek	Laurel Fork	Owsley	Stable	2021
South Fork Kentucky	Buffalo Creek	Cortland Fork	Owsley	Vulnerable	2014
South Fork Kentucky	Buffalo Creek	Lucky Fork	Owsley	Stable	2014
South Fork Kentucky	Buffalo Creek	Left Fork	Owsley	Stable	2014
South Fork Kentucky	Buffalo Creek	Right Fork	Owsley	Vulnerable	2009
South Fork Kentucky	Buffalo Creek	Buffalo Creek	Owsley	Vulnerable	2021
South Fork Kentucky	Sexton Creek	Bray Creek	Clay	Extirpated	1997
South Fork Kentucky	Sexton Creek	Robinsons Creek	Clay	Extirpated	1997
South Fork Kentucky	Sexton Creek	Sexton Creek	Owsley	Extirpated	1978
South Fork Kentucky	Lower Island Creek	Lower Island Creek	Owsley	Extirpated	1997
South Fork Kentucky	Doe Creek	Doe Creek	Owsley	Vulnerable	2019
South Fork Kentucky	Cow Creek	Right Fork Cow Creek	Owsley	Stable	2022
South Fork Kentucky	Buck Creek	Buck Creek	Owsley	Extirpated	1978
South Fork Kentucky	Lower Buffalo Creek	Lower Buffalo Creek	Lee, Owsley	Vulnerable	2022
Upper Kentucky	Silver Creek	Silver Creek	Lee	Vulnerable	2008
Upper Kentucky	Sturgeon Creek	Travis Creek	Jackson	Vulnerable	2008
Upper Kentucky	Sturgeon Creek	Brushy Creek	Jackson, Owsley	Extirpated	1996
Upper Kentucky	Sturgeon Creek	Little Sturgeon Creek	Owsley	Extirpated	1996
Upper Kentucky	Sturgeon Creek	Wild Dog Creek	Jackson, Owsley	Stable	2021
Upper Kentucky	Sturgeon Creek	Granny Dismal Creek	Lee, Owsley	Vulnerable	2013
Upper Kentucky	Sturgeon Creek	Cooperas Cave Branch	Lee	Extirpated	1996
Upper Kentucky	Sturgeon Creek	Sturgeon Creek	Lee	Extirpated	1998
Upper Kentucky	Swift Camp Creek	Rockbridge Fork	Wolfe	Vulnerable	2021

¹Current Status: Stable = (1) there is little evidence of significant habitat loss or degradation, (2) darter abundance has remained relatively constant or increased during recent surveys, and/or (3) evidence of relatively recent recruitment has been documented since 2000; Vulnerable = (1) there is ample evidence of significant habitat loss or degradation since the species' original capture, (2) there is an obvious decreasing trend in abundance since the historical collection, and/or (3) no evidence of relatively recent recruitment has been documented (since 2000); and Extirpated = (1) all known suitable habitat has been destroyed or severely degraded, (2) no live individuals have been observed since 2000, and/or (3) live individuals have been observed since 2000, but habitat conditions do not appear to be suitable for reproduction to occur (e.g., elevated conductivity, siltation) and there is supporting evidence that the observed individuals are transients (fishes originating from another stream that occupy a particular habitat for only a short time).