

Distribution and Status of the Kentucky Arrow Darter *(Etheostoma sagitta spilotum)*



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INTRODUCTION

The Kentucky Arrow Darter (*Etheostoma sagitta spilotum*) was listed as a species of conservation need under the KY Wildlife Action Plan because of its restricted distribution and need for updated information on the status of populations and habitat conditions (Kentucky Department of Fish and Wildlife Resources, 2005). The range of this species falls entirely within the political boundaries of Kentucky, where it is endemic to the upper Kentucky River drainage. It has been reported to be occasional to moderately common in headwater streams (Burr and Warren, 1986), but very few collections have been documented within the last ten years and a comprehensive status survey has not been done. The Cumberland Arrow Darter (*E. s. sagitta*) is endemic to the upper Cumberland River drainage of Kentucky and Tennessee, but has been considered more common and stable than its Kentucky River drainage counterpart, *E. s. spilotum* (Burr and Warren, 1986). A recent status assessment of the Cumberland Arrow Darter has not been done. Although the Kentucky and Cumberland River Arrow Darter populations are currently recognized as a subspecies, these two taxa exist in allopatry and are morphologically distinguishable (Bailey, 1948; Kuehne and Bailey, 1961; pers. observ.); furthermore, intergrades (individuals or populations) have never been identified, bringing into question the validity of subspecific designation, which warrants a more detailed analysis of its taxonomic status. For conservation efforts, these two subspecies are treated as separate management units.

Between April, 2007 and August, 2008, streams were sampled throughout the upper Kentucky River basin to assess the current distribution and status of the Kentucky Arrow Darter, evaluate habitat conditions, and determine potential threats to populations. Information obtained through this work provides the necessary foundation to develop effective conservation actions and long-term monitoring strategies as proposed in the Kentucky Wildlife Action Plan.

METHODS AND MATERIALS

Study Area. -- The largest portion (90%) of the upper Kentucky River basin supporting known populations of Kentucky Arrow Darters drains the Central Appalachian ecoregion. This includes most of the three major forks (North, Middle, and South Fork) and their tributary watersheds (Figure 1). This ecoregion is heavily forested and is characterized by narrow ridges, deep coves, and narrow valleys. Streams draining this region are high gradient and cool, with cobble and boulder substrates and extensive riffles. Surface and underground coal mining, logging, and both gas and oil exploration are common and have degraded many of the streams. A large portion of the South Fork Kentucky River basin, particularly the Red River watershed, lies within the boundaries of the Daniel Boone National Forest (Figure 1). The majority of the remaining watersheds in the Central Appalachian ecoregion supporting Arrow Darters are on private lands (Woods et al. 2002).

The remaining 10% of the streams from which Arrow Darters have been documented lie within the Western Allegheny Plateau ecoregion. These include the Sturgeon Creek and Red River drainages, as well as minor tributaries of the Kentucky River (Silver Creek) and North and South Forks of the Kentucky River (Figure 1). This ecoregion is less rugged and densely forested than the Central Appalachian Ecoregions and is composed of a mosaic of woodlands, pastures, and cropland. Streams in this

region have more moderate gradients than Central Appalachian streams and have mostly sand or boulder substrates. Many of these streams have also been degraded by underground and surface coal mining, logging, agriculture, and oil production (Woods et al. 2002).

Data Acquisition and Field Methods.-- Occurrence records for the Kentucky Arrow Darter from 1890 to 2003 were obtained from the Natural Heritage Program database maintained by the KY State Nature Preserves Commission, with additional records from the Southern Illinois University Ichthyological Research Collection and EDAS database maintained by KY Division of Water, U.S. Forest Service, and Kentucky Department of Fish and Wildlife Resources. A total of 120 occurrence records distributed among 75 streams were reviewed and are summarized according to HUC8 watersheds in Tables 1-4. Within each HUC8, the minor watershed, stream name, number of documented occurrence records, date of last record (observation), and current status (presence/absence) following sampling conducted in 2007 and 2008.

Field sampling began in April 2007, using a backpack electrofisher, dip nets, and a 6 X 10' (1/8" mesh) seine. Because the majority of sites were in headwater streams (<6 mi²) with good water clarity, backpack electrofishing with dip nets proved more effective in capturing Arrow Darters than seining. At each site, all microhabitats within a 200m reach were worked thoroughly to ensure a representative sample. Additional emphasis was placed on pools and areas immediately above and below riffles with bedrock, cobble, and gravel substrates, where Arrow Darters were most likely to occur. Each site was electrofished for 500-2000 seconds, depending on the size of the stream and available habitat. In larger streams, electrofishing was followed by 10-20 seine hauls/sets to effectively work the same area and available habitat. Most fish collected were identified on site, enumerated, and released. A limited number of specimens were retained as vouchers that were fixed in 10% formalin, then transferred to 70% ethanol and archived in the Southern Illinois University Ichthyological Research Collection. Digital photographs were also taken to document breeding color variation in male Arrow Darters, and to document habitat at all sample sites.

RESULTS AND DISCUSSION

Current Distribution.—Within the Kentucky River basin, the Kentucky Arrow Darter occurs in the following five drainages: 1) Sturgeon Creek, 2) Red River, 3) South Fork Kentucky River, 4) Middle Fork Kentucky River, and 5) North Fork Kentucky River (Figure 1). Historic and current distributional records are summarized in Tables 1-4. A synopsis of these records, including observations on habitat conditions within each drainage is given below.

Sturgeon Creek: Number of streams in which Arrow Darters have been documented: pre-2007 = 8; 2007-2008 = 2 (Figure 2). Gilbert (1887) originally described the Kentucky Arrow Darter as *Etheostoma nianguae spilotum* (now *Etheostoma sagitta spilotum*), based on specimens collected from Little Sturgeon Creek near Traveller's Rest, Owsley County. During 2007 and 2008 surveys, Arrow Darters were found in only Wild Dog Creek (n = 1) and Travis Creek (n = 2); both are second order streams in remote, well forested watersheds. Specimens were taken in gently flowing pools (<30

cm deep) around large cobble and boulders. No Arrow Darters were found in lower Cooperas Cave Branch, although habitat conditions appeared to be suitable. No Arrow Darters were found at sites in Little Sturgeon Creek and Duck Fork. Within these watersheds, much of the land had been cleared for agricultural and residential development; active oil wells and logging operations were also observed along Duck Fork. Diminished (or removed) riparian vegetation, siltation, and eutrophication were apparent problems in these streams.

Red River: Number of streams in which Arrow Darters have been documented: pre-2007 = 1; 2007-2008 = 1 (Figure 3). Rockbridge Fork is the only stream in the Red River drainage where the Kentucky Arrow Darter has been reported. Only recently discovered (Greenberg and Steigerwald, 1981), this population is apparently stable. Ten specimens, including at least two age classes, were collected on 14 May 2007. These specimens were taken in pools over silty substrates with patches of detritus and woody debris. Although primarily within the Daniel Boone National Forest, stream bank erosion and siltation are problems in the upper reaches of this watershed.

South Fork Kentucky River: Number of streams in which Arrow Darters have been documented: pre-2007 = 27; 2007-2008 = 12 (Figures 4-8). The best remaining populations of Kentucky Arrow Darter are found in streams within the Daniel Boone National Forest. These include the Buffalo Creek watershed in Owsley County (Figure 4) and small first and second order tributaries of the Red Bird River in Clay and Leslie Counties (Figure 5). These heavily forested streams are within the Central Appalachian ecoregion, characterized by high gradients, cool temperatures, low conductivities (<100 μ S), with cobble and boulder substrates and extensive riffles. Although some oil wells and logging activity was observed within the Red Bird River watershed, impacts appeared to be relatively minor.

In contrast to most streams in the Red Bird River watershed, other portions of the South Fork Kentucky River drainage, such as Goose Creek, Sexton Creek, have had much of the bottomland cleared for agricultural or residential development. Arrow darters have been reported from the Goose Creek (Figure 6) and Sexton Creek (Figure 7) watersheds as recent as 1997, but were absent in 2008. Horse Creek and Laurel Creek (Goose Creek tributaries) and portions of Sexton Creek, all streams with previous records of Arrow Darter presence, were added to the 303d list of waters identified as impaired for one or more pollutants and failed to meet water quality standards (Kentucky Division of Water, 2004). Arrow Darters (n = 3) were collected in Lower Buffalo Creek on 10 May 2007, a tributary of the South Fork Kentucky River in Owsley County (Figure 8), which was also added to the 303d list in 2004. Habitat conditions in this stream were poor, with heavy siltation and eutrophication.

Middle Fork Kentucky River: Number of streams in which Arrow Darters have been documented: pre-2007 = 8; 2007-2008 = 1 (Figure 9). The Middle Fork Kentucky River drainage has far fewer Arrow Darter occurrence records than in the South and North forks. Much of the Middle Fork drainage, including Beech Fork, Greasy Creek and Cutshin Creek has been severely impacted by surface and underground coal mining. Arrow Darters (n = 4) were collected in Hell for Certain Creek on 7 July 2007. Much of this watershed lies within the Daniel Boone National Forest and is mostly forested.

Arrow Darters have not been reported from the Cutshin Creek watershed since 1973 (in Raccoon Creek). Although specimens were reported from Big Laurel Creek (tributary of Greasy Creek) in Harlan County by the Kentucky State Nature Preserves Commission in 1996, subsequent coal mining activity has severely degraded this watershed.

North Fork Kentucky River: Number of streams in which Arrow Darters have been documented: pre-2007 = 34; 2007-2008 = 12 (Figures 10-13). Within the North Fork Kentucky River drainage, the best remaining habitat for the Kentucky Arrow Darter exists in Clemons Fork and Coles Fork (Troublesome Creek watershed) within the boundaries of University of Kentucky's Robinson Forest in Breathitt and Knott counties (Figure 10). These streams are within well forested watersheds and are high gradient with primarily cobble and boulder substrates. In Clemons Fork, Arrow Darters were collected in pools with little or no flow on 21 May 2007 (n = 11) and on 14 August 2008 (n = 2). In Coles Fork, specimens (n = 2) were collected in shallow, isolated pools with no flow on 14 August 2008. No Arrow Darters were encountered at historic localities sampled outside of Robinson Forest in the Troublesome Creek watershed. Many of these streams (e.g., Buckhorn Creek, Balls Fork, Long Fork, and Lost Creek) have been severely impacted by coal mining and poorly regulated logging activities. Lost Creek, Long Fork, and Balls Fork were added to the 303d list of waters identified as impaired for one or more pollutants and failed to meet water quality standards (Kentucky Division of Water, 2004).

Most historic localities sampled in the Quicksand Creek watershed in 2008 failed to produce Arrow Darters (Figure 11). On 11 July 2008, six young-of-year specimens were collected in Laurel Fork Quicksand Creek and five adults and one young-of-year were collected in Middle Fork Quicksand Creek. Both streams were unusually turbid with silty substrates and heavy silt deposition along the exposed banks. An active logging operation was observed in Baker Branch, which confluent Laurel Fork near our sample location. Much of Quicksand Creek and South Fork Quicksand Creek have been added to the 303d list of impaired waters (Kentucky Division of Water, 2004).

Arrow Darters were present at all historic localities in the Frozen Creek watershed, except for Cope Fork (Figure 12). The Frozen Creek watershed is sparsely settled, with small scale agricultural practices (e.g., pasture and row crops). Sampling was conducted on 7 May 2008. Water levels were very low with little or no flow. Upper Frozen Creek, Clear Fork, Negro Branch and Davis Creek had similar habitat characteristics. Arrow Darters (n = 1 to 9) were found primarily in shallow pools (10-30 cm deep) with substrates consisting of bedrock with patches of mixed sand/silt, gravel, cobble and woody debris. Lower Cope Fork has been added to the 303d list due to habitat alterations, total dissolved solids, and siltation. The Kentucky Department of Fish and Wildlife is currently overseeing a stream habitat restoration project on Frozen Creek near the Cope Fork confluence.

Other small tributaries in the lower North Fork Kentucky River basin sampled in 2007 and 2008 for Arrow Darters include Boone Fork (absent), Holly Creek (present, n = 2), Lower Devil Creek and Little Fork (present, n = 1), Walker Creek (present, n = 7), and Hell Creek (present, n = 7) (Figure 13). Silver Creek, a tributary of Kentucky River, produced a single specimen. None of these streams exhibited optimal habitat conditions. They ranged from moderately to severely impacted from erosion and sedimentation. Holly Creek and Hell Creek have been added to the 303d list of impaired streams due to

habitat alterations and total dissolved solids. The Kentucky Department of Fish and Wildlife is currently overseeing a stream habitat restoration project on Holly Creek near the Spring Creek confluence in Wolfe County.

Systematics.—The Arrow Darter, *Etheostoma sagitta*, restricted to upland streams of the Cumberland Plateau, has been recognized as a polytypic species (i.e., has one or more subspecies). *Etheostoma sagitta sagitta* (Cumberland Arrow Darter) is endemic to the upper Cumberland River drainage and *E. s. spilotum* (Kentucky Arrow Darter) to the upper Kentucky River drainage (Kuehne and Bailey, 1961).

Whole specimens and tissue samples acquired from recent surveys were used to determine genetic and morphological variation between and within populations of both taxa (subspecies). The Kentucky Arrow Darter and Cumberland Arrow Darter are separable using a combination of total number of scales in the lateral series, pored lateral scales, and caudal peduncle scales. Specimens of Kentucky Arrow Darter (n = 34) and Cumberland Arrow Darter (n = 35) collected from various streams throughout the Kentucky and Cumberland River basins were examined and distributions of meristic data are given in Tables 5-7. Compared with the Cumberland Arrow Darter, the Kentucky Arrow Darter was found to have lateral scale counts of 62 or fewer in 88% (vs. 63 or more in 94%), pored lateral scale counts of 50 or fewer in 79% (vs. 51 or more in 91%), and caudal peduncle scale counts of 22 or fewer in 72% (vs. 23 or more in 83%) of specimens examined. These meristic differences are consistent with data presented by Kuehne and Bailey (1961) and reflect a trend toward larger scale size and more weakly developed lateral line in the Kentucky Arrow Darter. These two taxa are generally indistinguishable based on general appearance, including pigment pattern and breeding color.

Based on an analysis of mitochondrial DNA (in progress), the two taxa were recovered as divergent, reciprocally monophyletic clades. This preliminary evidence suggests that there has been no recent genetic exchange between populations in the Kentucky and Cumberland River basins, and that they form two evolutionary lineages. This brings into question the validity of prior subspecific designations. Regardless of whether one recognizes these two taxa as species or subspecies, for conservation purposes, Kentucky River and Cumberland River basin populations should be treated as two separate management units (see Recommended Conservation Measures, below).

Habitat and Ecology.—Arrow Darters inhabit small upland streams of the Cumberland Plateau and Cumberland Mountains (Burr and Warren, 1986). Streams found to support Kentucky Arrow Darters during 2007 and 2008 surveys ranged in size from first to third order, with 60% occurring in second order streams (Figure 13). The majority (72%) of these streams were in watersheds draining an area of 20 km² or less (Figure 14). Arrow Darters were typically collected in pools or transitional areas between riffles and pools of moderate to high gradient streams. Individuals were usually associated with bedrock and cobble substrates and occasionally around woody debris. Stream width ranged from 1.5 to 20 m and depth at which individuals were captured ranged from 10 to 45 cm. Seasonal water levels can fluctuate drastically in small headwater streams of the Cumberland Plateau. For example, in Clemons Fork, Lotrich (1973) reported stream widths up to 20 m in riffles that are completely dry later in the summer, when fish are crowded into isolated pools. Arrow Darters and other headwater species are likely more vulnerable during dry periods when they are already near their physical toleration limits.

Several recent studies have shown that specific conductance is the best indicator of disturbance from coal mining; particularly mountain top removal and valley fill operations in the Central Appalachians (Pond et al., 2008). Mattingly et al. (2005) found specific conductance to be a good predictive variable for the presence of Blackside Dace (*Phoxinus cumberlandensis*) in streams of the upper Cumberland River drainage. Specifically, they found Blackside Dace to be absent from stream reaches where conductivity values exceeded 240 μS (low to moderate conductivity) typical of small, undisturbed streams of the Central Appalachians ecoregion. Many of these streams in the upper Cumberland River basin inhabited by Blackside Dace also support Cumberland Arrow Darters. Streams in the upper Kentucky River basin surveyed in 2007 and 2008 had conductivities ranging from 28 to 2,850 μS (Tables 8-9). Most (89%) streams in which Kentucky Arrow Darters were present had conductivity values below 200 μS . Over 50% of streams in which Arrow Darters were present historically, but absent in 2007 and 2008, had conductivities exceeding 250 μS (Figure 15). Other water quality parameters measured include water temperature, dissolved oxygen and pH (Figures 16-18; Tables 8-9). Streams within well forested watersheds having cooler temperatures were found more likely to support Arrow Darters than streams having exposed reaches and warmer temperatures.

Fish Community Composition.—A total of 42 species were collected in the upper Kentucky River basin during the search for Kentucky Arrow Darters (Table 10). Sampling was biased towards smaller-sized (first- to fourth-order) streams; therefore several of the species encountered are representative of headwater communities, whereas others are generally distributed throughout the upper Kentucky River basin. Dominant species (present in all watersheds sampled) were Creek Chub (*Semotilus atromaculatus*), Fantail Darter (*Etheostoma flabellare*) and Johnny Darter (*Etheostoma nigrum*). Headwater species commonly associated with Kentucky Arrow Darters were Creek Chub, Fantail Darter, Rainbow Darter, and Johnny Darter. The Emerald Darter (*Etheostoma baileyi*), listed as a Species of Conservation Need (Kentucky Department of Fish and Wildlife Resources, 2005), was found at 25 of 50 streams sampled; however, this is not indicative of its status since it also occurs in larger streams not sampled during this study. The Emerald Darter and Kentucky Arrow Darter are the only endemic fishes restricted to the upper Cumberland and Kentucky River basins (Kuehne and Barbour, 1983).

Threats and Recommended Conservation Measures.—Arrow Darters, both *Etheostoma s. sagitta* and *E. s. spilotum* exist in one of the most extensively mined areas in North America (Kuehne and Barbour, 1983), with both deep and surface coal mines continuing to operate throughout the region. Siltation from strip mines is the principal cause of aquatic habitat degradation in the upper Kentucky and Cumberland River basins, but extensive logging, oil exploration, road construction, poor agricultural practices, and other forms of development are also contributing factors. Although the Arrow Darter may be moderately tolerant to disturbances such as siltation (Kuehne and Barbour, 1983; Etnier and Starnes, 1993), habitat loss and degradation have also led to extirpation of many populations and reduced abundance levels throughout much of the upper Kentucky River basin.

The following conservation measures are recommended to promote recovery and prevent further loss or decline of Kentucky Arrow Darter populations:

1. Protect and maintain strongest remaining populations and habitat. Examples include the Red Bird River drainage, Rockbridge Fork (Red River drainage), Clemons Fork and Coles Fork (Troublesome Creek drainage).
2. Determine genetic relationships among extant populations within the upper Kentucky River basin and between Kentucky and Cumberland River basins. Preliminary results of research in progress suggest that the Kentucky and Cumberland basin populations represent two evolutionary lineages that through geographic separation have experienced no recent gene flow and should be treated as distinct management units for conservation purposes. In contrast, little genetic structure exists within each basin and haplotypes are often shared across streams, indicating current or recent gene flow throughout the range of each taxon (*Etheostoma sagitta spilotum* and *E. s. sagitta*). Reintroduction efforts should use brood stock taken from within each major basin (Cumberland and Kentucky basins) and as many individuals as possible should be acquired for breeding to perpetuate genetic diversity within each management unit. Any offspring produced should be released in suitable habitat within the historic range but not currently inhabited by Arrow Darters to avoid decreasing the genetically effective population size of existing populations.
3. Determine the feasibility of reestablishing populations into historic habitat and reintroduce where feasible. Identification of appropriate streams with suitable habitat within the known historic range and development of captive propagation protocols are currently underway.
4. Increase stream habitat restoration. Stream restoration activities should focus on areas improving habitat in areas that would promote natural dispersal of existing populations and reestablishment of extirpated populations.
5. Continue periodic monitoring. This includes periodic surveys of existing populations and following any reintroductions or implementation of other restoration activities (e.g., habitat restoration).

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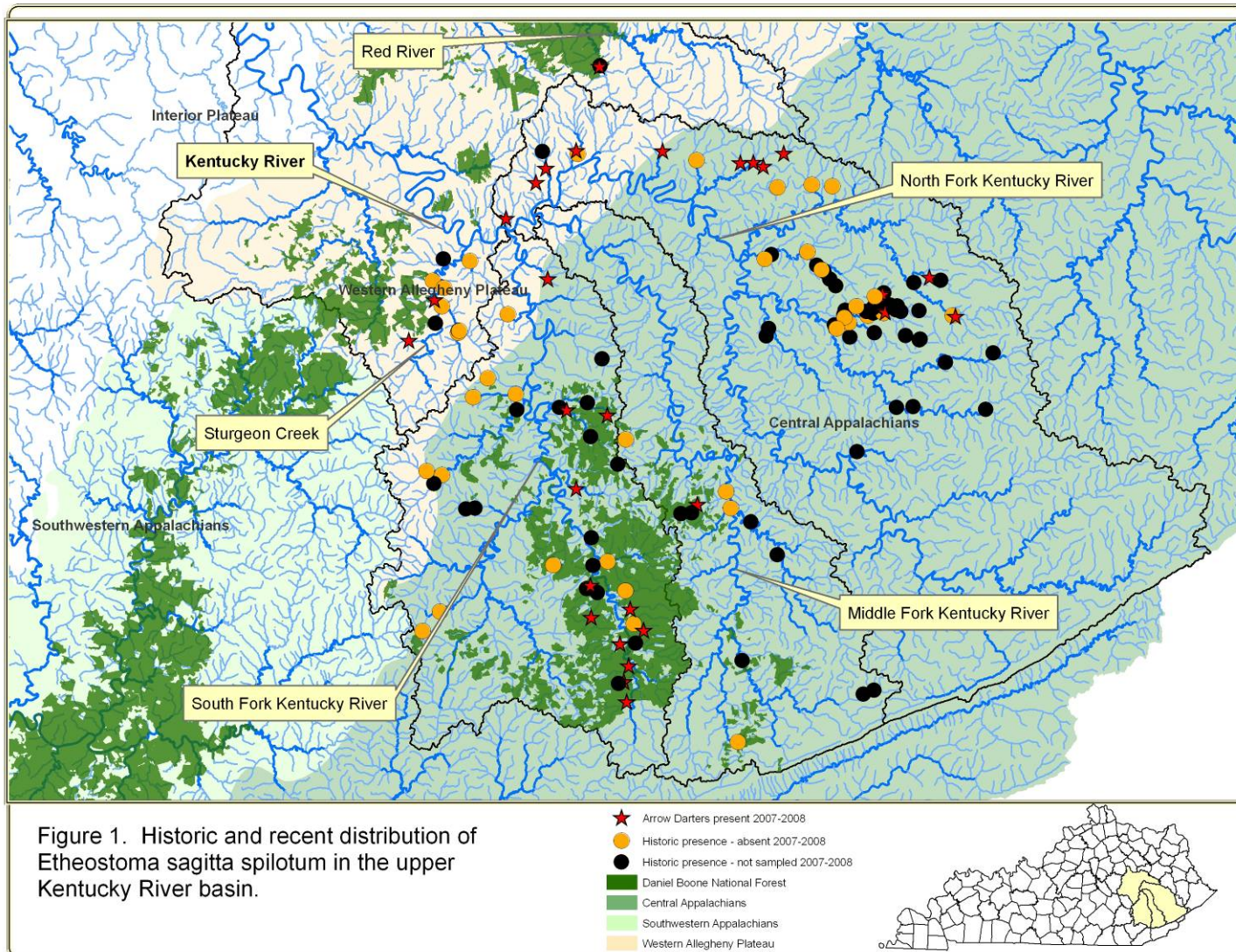
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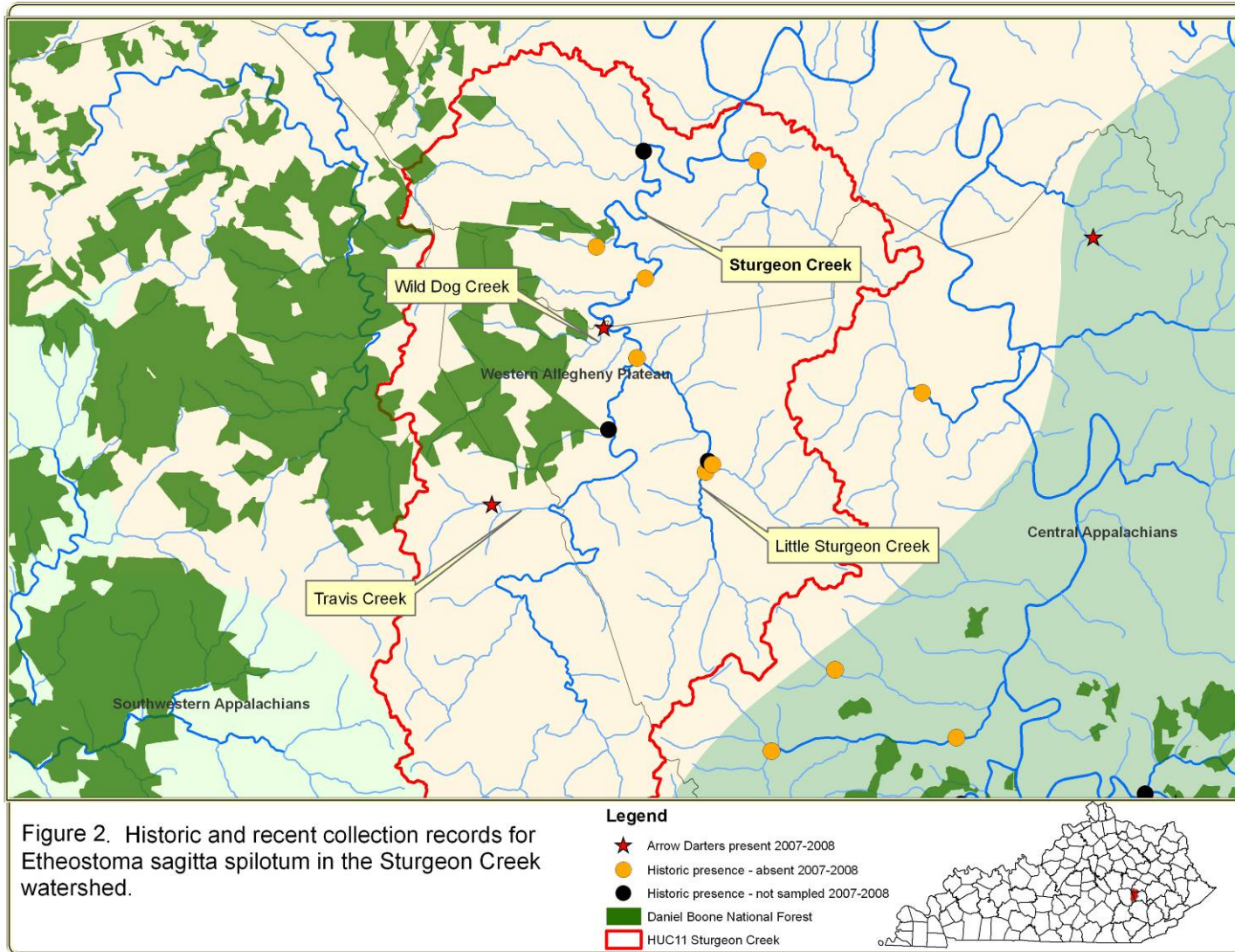
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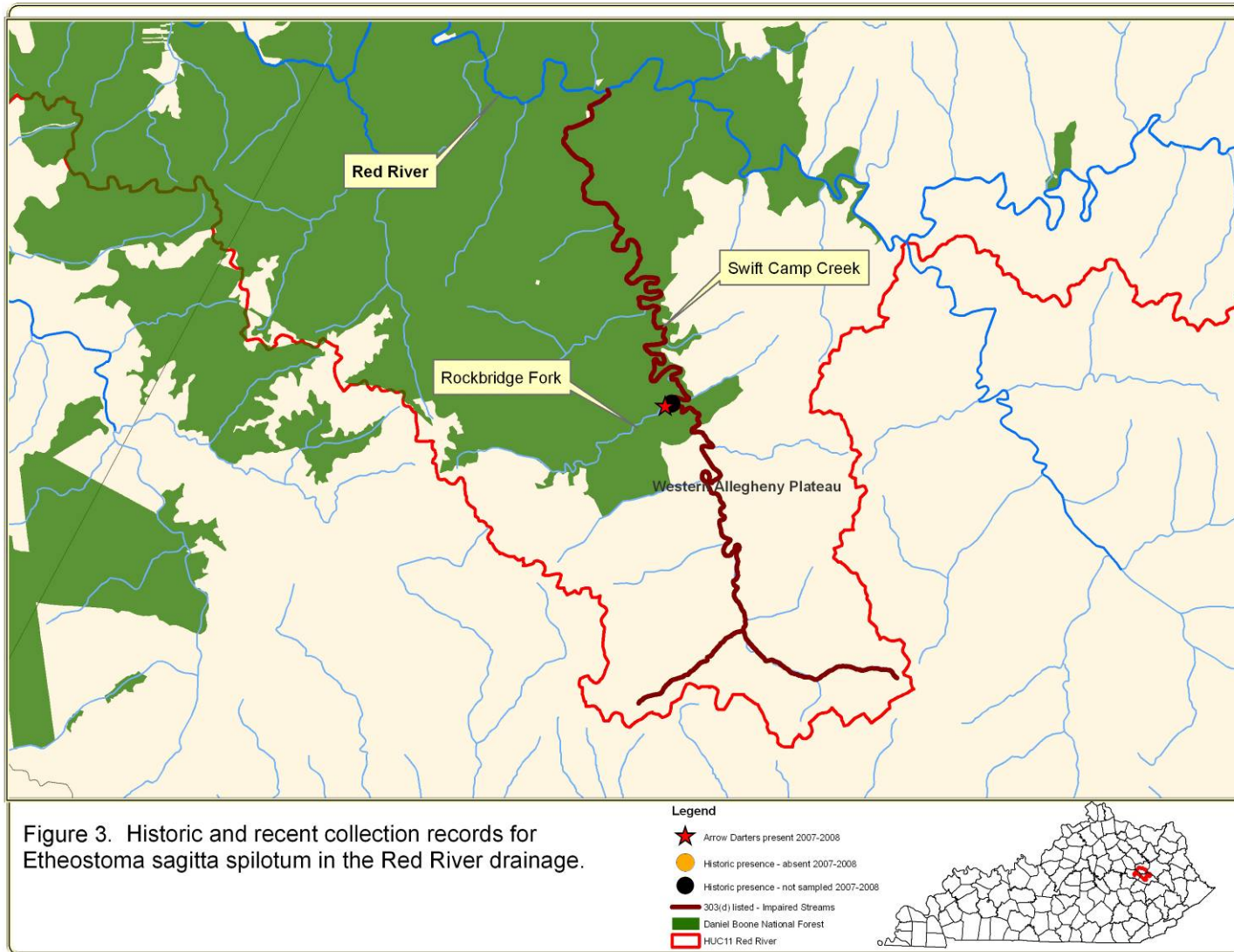
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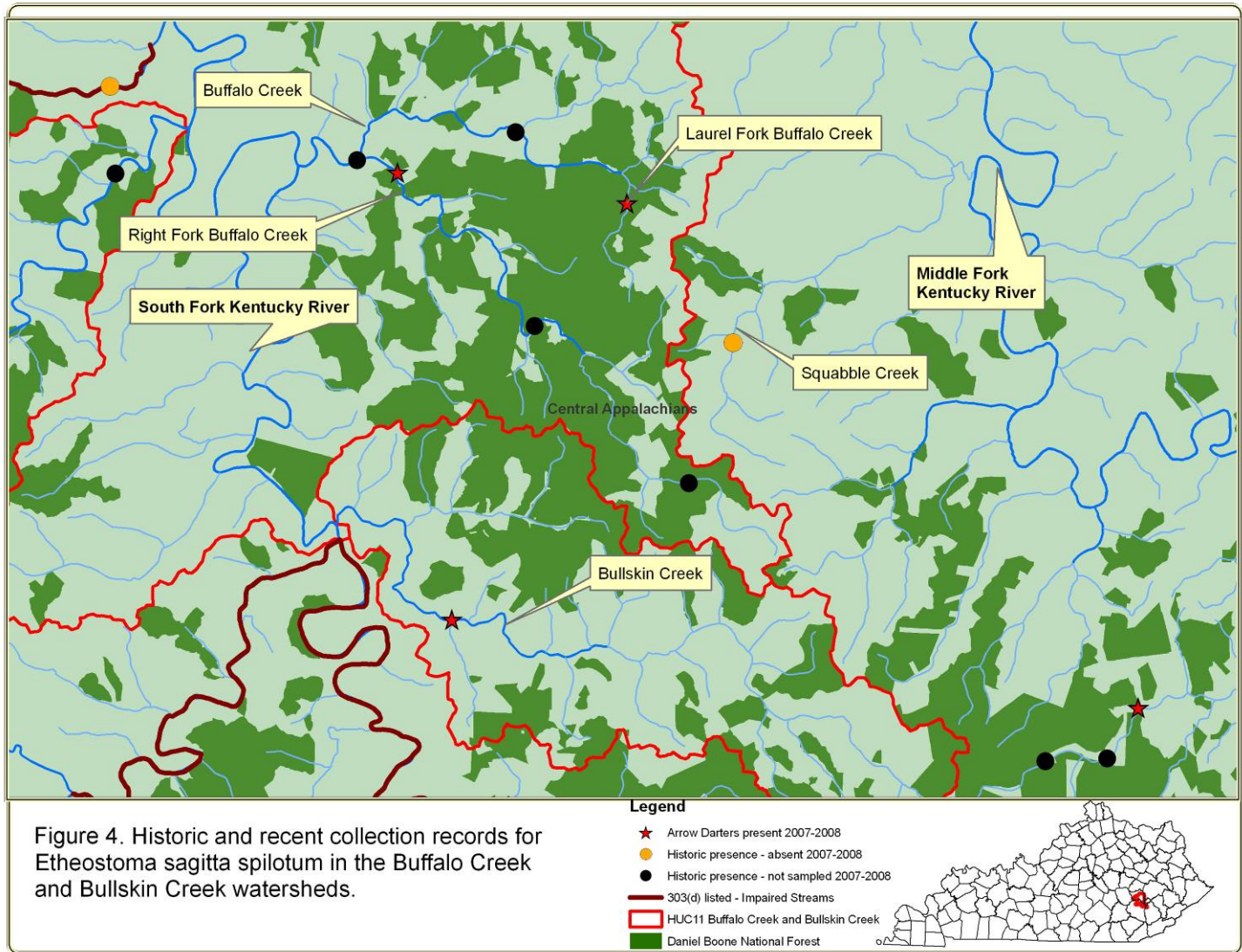
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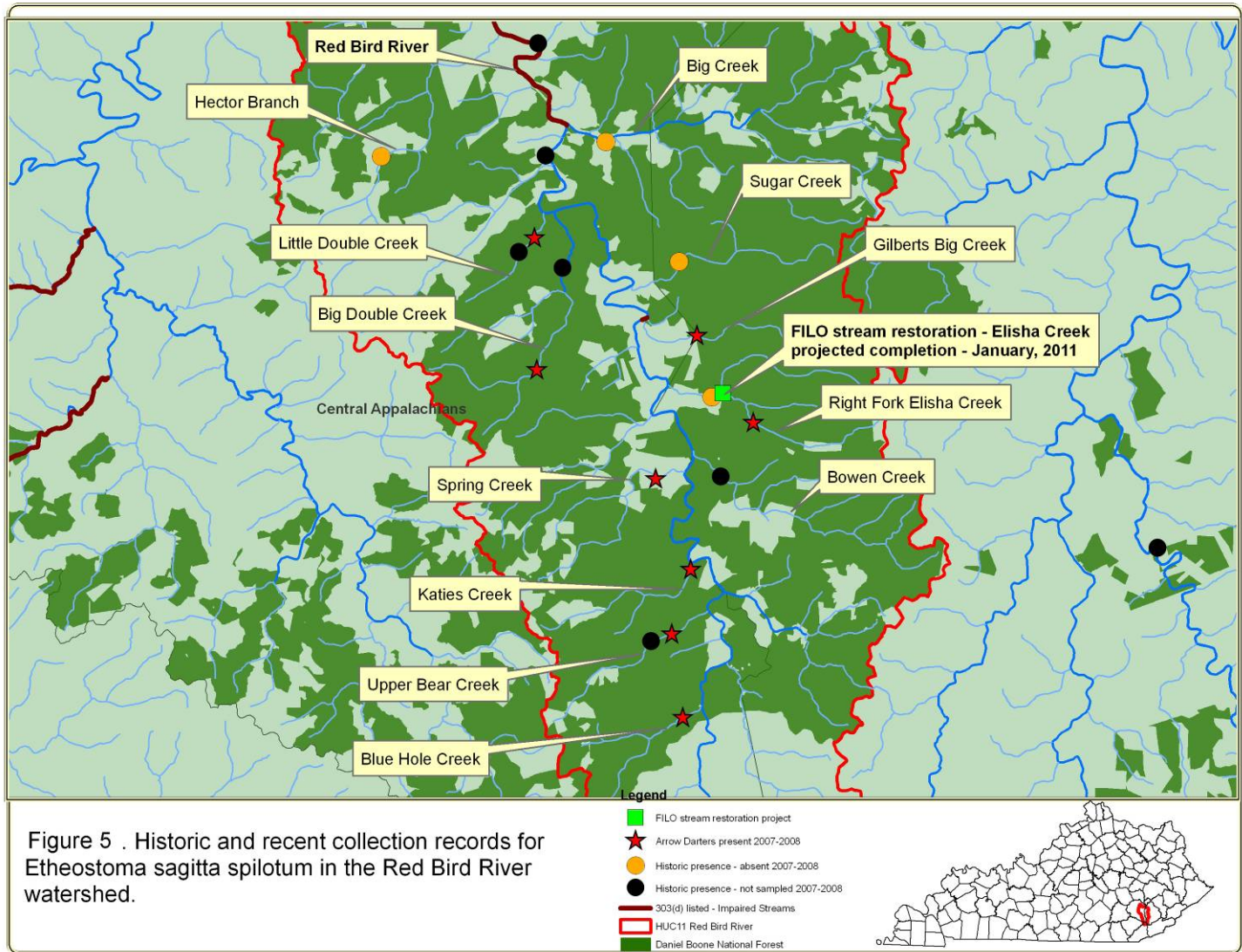
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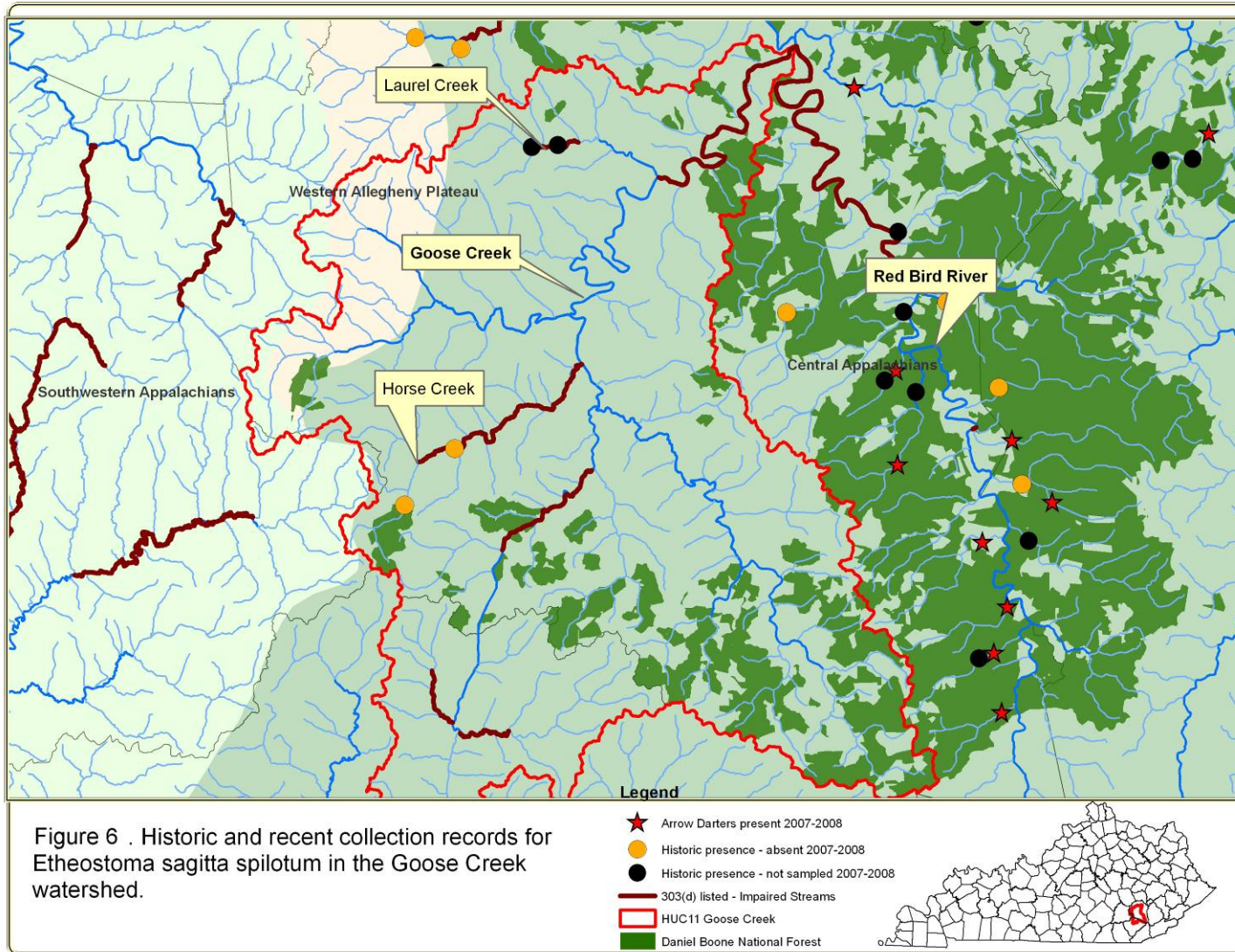


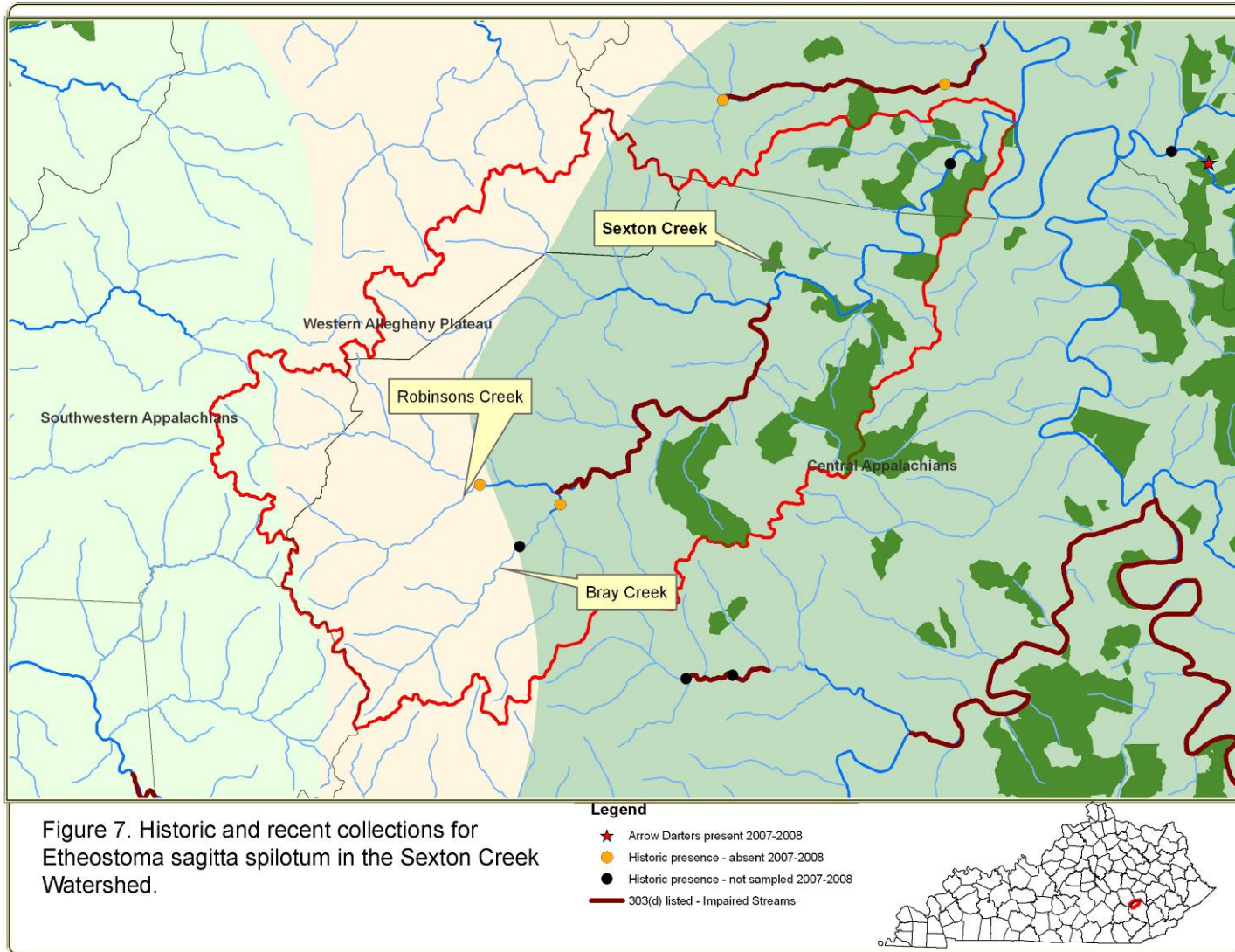


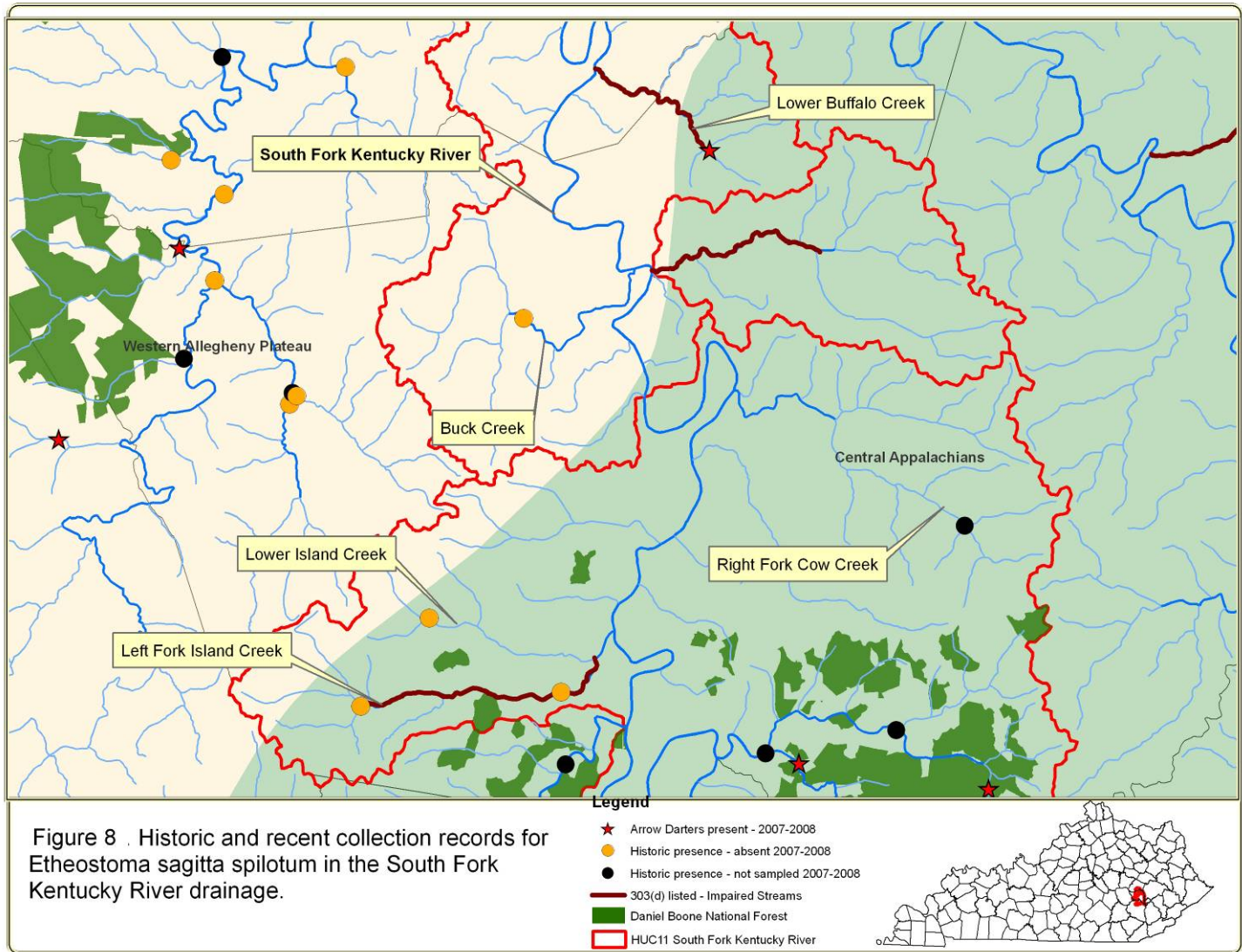


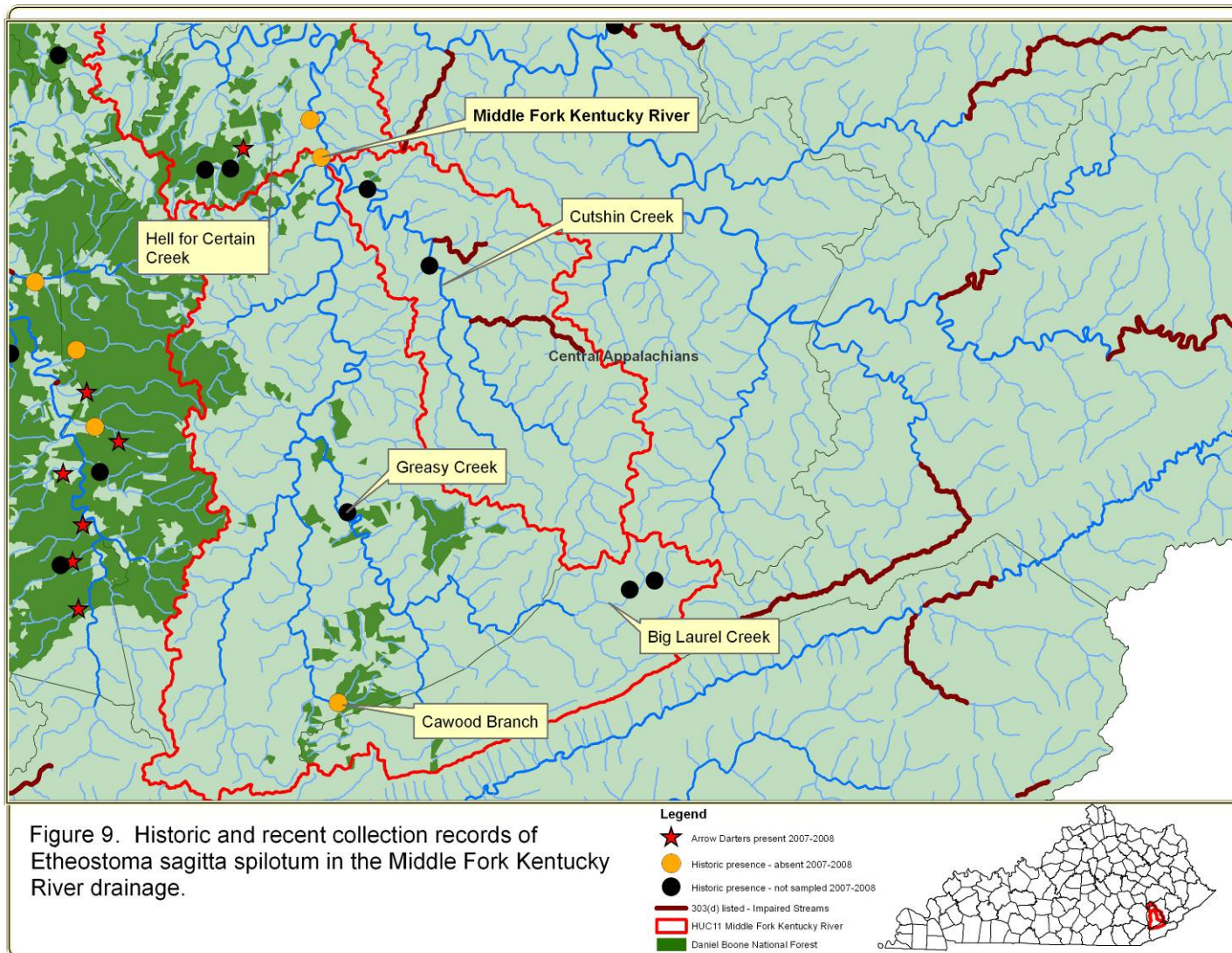


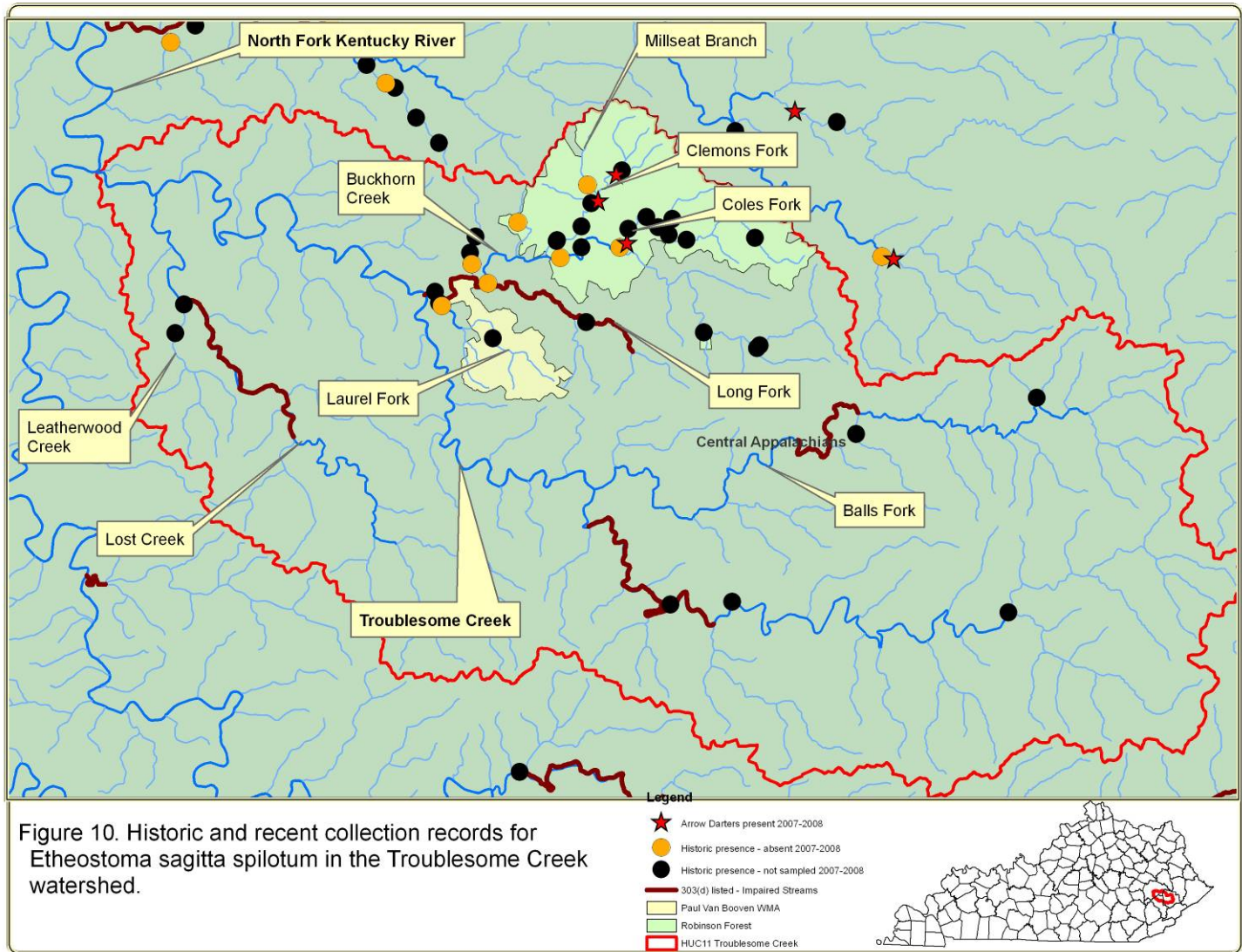


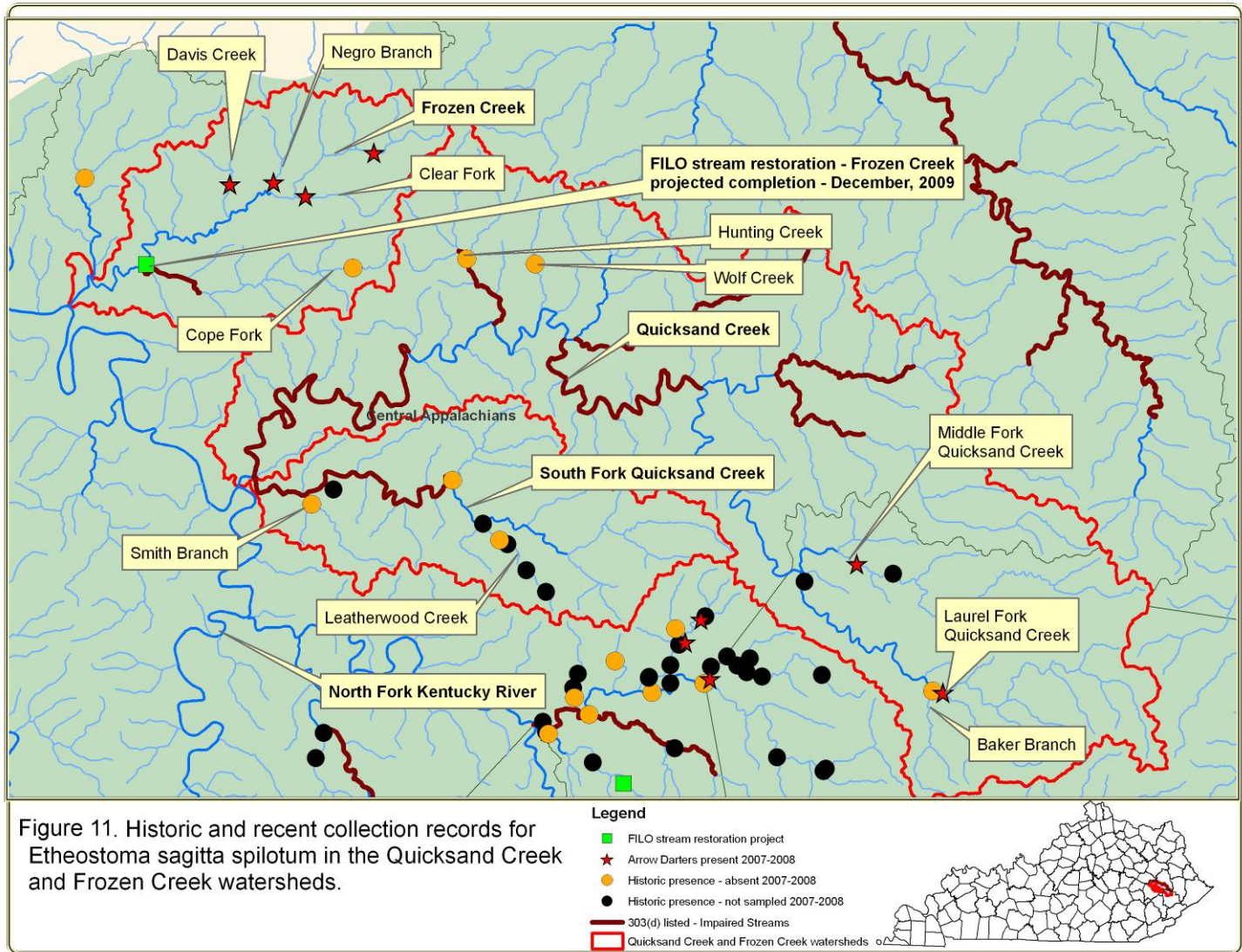


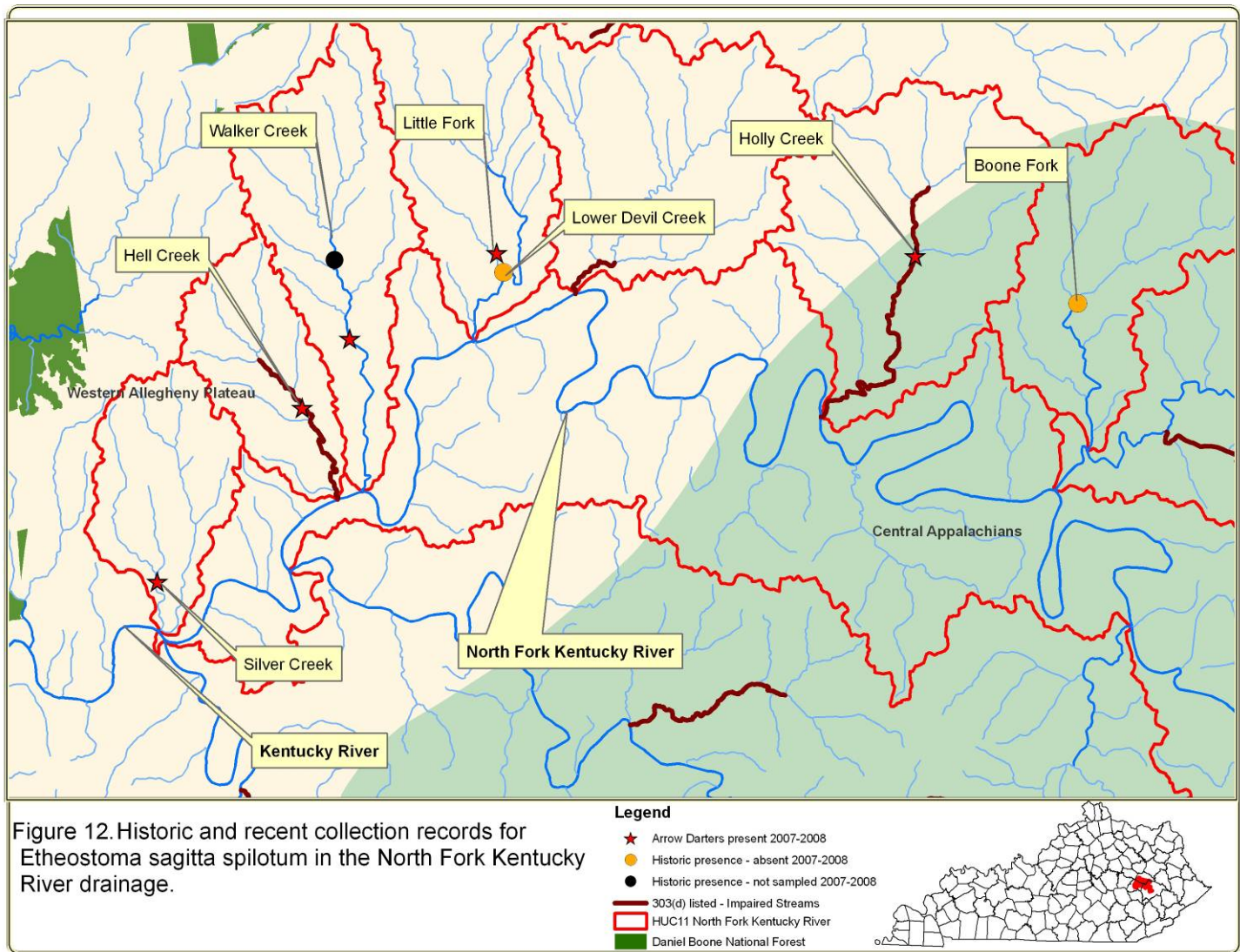












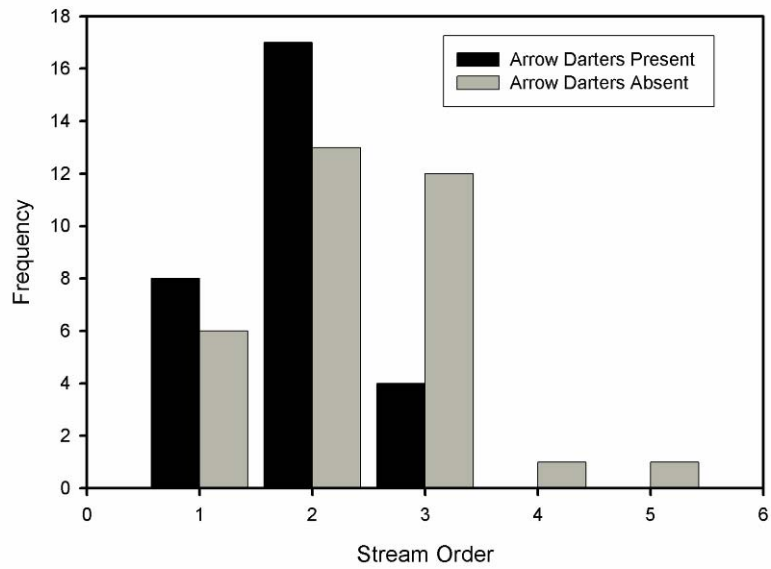


Figure 13. Frequency of Arrow Darter presence or absence relative to stream order during 2007 and 2008 surveys in the upper Kentucky River basin.

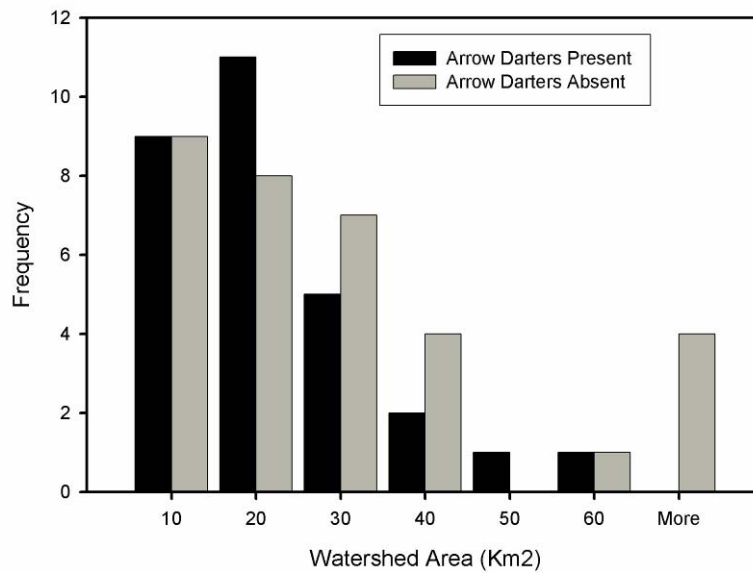


Figure 14. Frequency of Arrow Darter presence or absence relative to watershed area during 2007 and 2008 surveys in the upper Kentucky River basin.

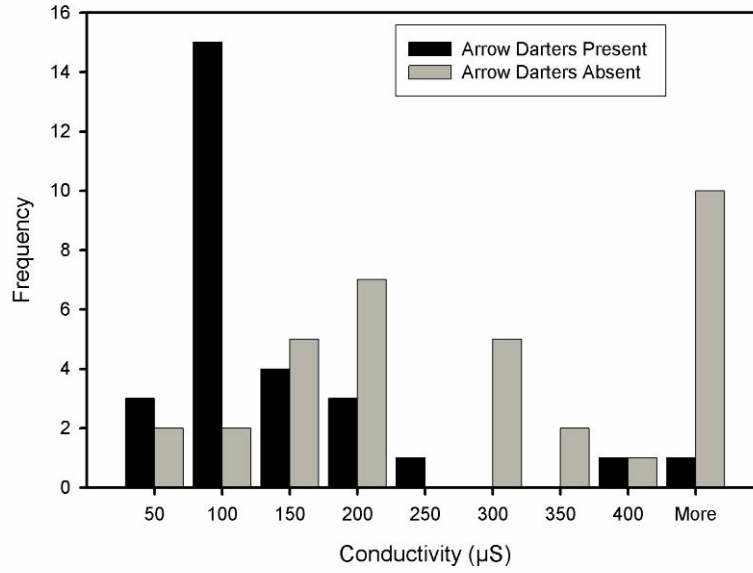


Figure 15. Frequency of Arrow Darter presence or absence relative to conductivity during 2007 and 2008 surveys in the upper Kentucky River basin.

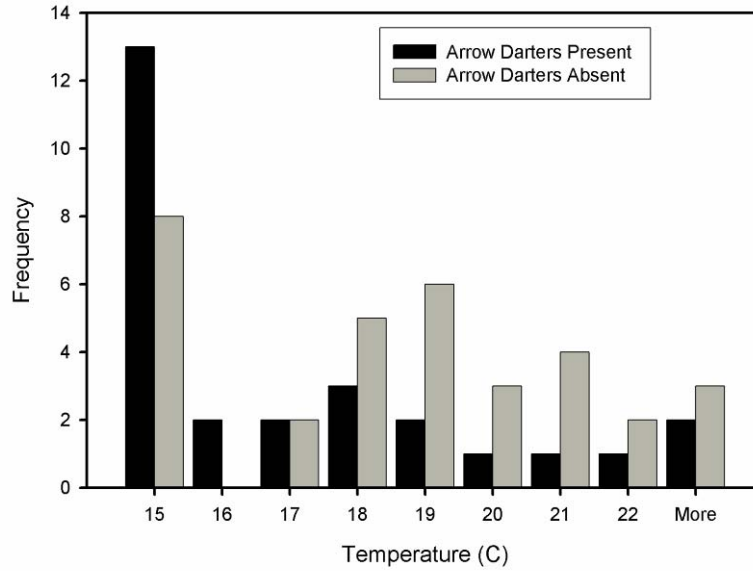


Figure 16. Frequency of Arrow Darter presence or absence relative to water temperature during 2007 and 2008 surveys in the upper Kentucky River basin.

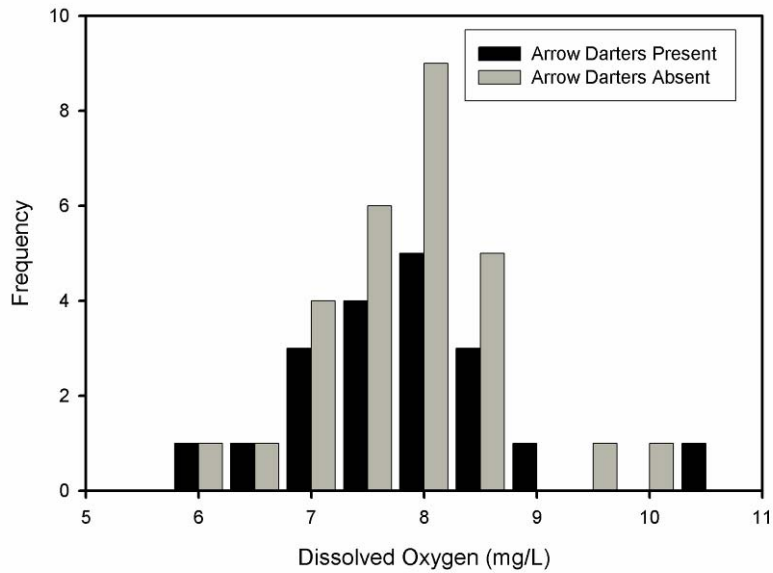


Figure 17. Frequency of Arrow Darter presence or absence relative to dissolved oxygen during 2007 and 2008 surveys in the upper Kentucky River basin.

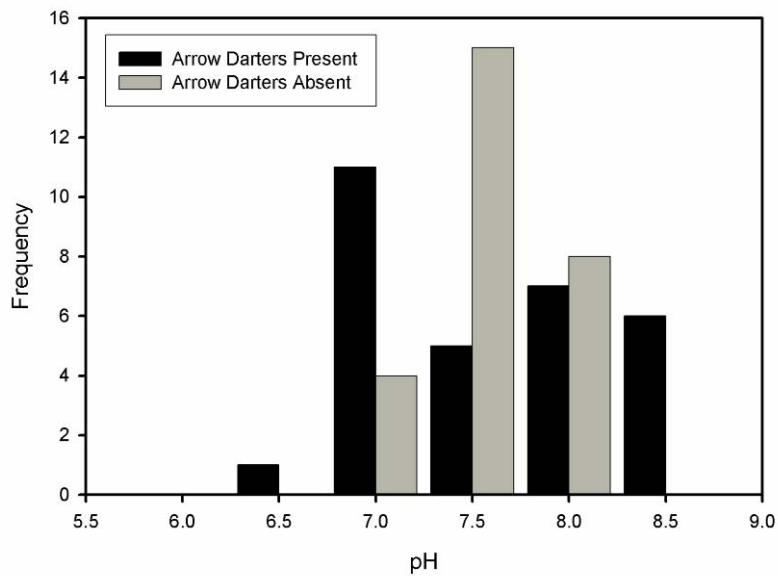


Figure 18. Frequency of Arrow Darter presence or absence relative to pH during 2007 and 2008 surveys in the upper Kentucky River basin.

Table 1. Historic occurrences (Kentucky Nature Preserves Commission database) and results of 2007-2008 status survey of *Etheostoma sagitta spilotum* in the Upper Kentucky River (HUC8) basin.

Watershed	Stream	County	Latitude	Longitude	Previous Records	Last Observed	2007- 2008 Presence
Kentucky River	Silver Creek	Lee	37.5850	-83.7125	1	15-May-96	present
Red River	Rockbridge Fork	Wolfe	37.7689	-83.5631	2	26-Jul-96	present
Sturgeon Creek	Brushy Creek	Owsley	37.4581	-83.8242	1	26-Jul-96	not sampled
Sturgeon Creek	Cooperas Cave Branch	Lee	37.5100	-83.8272	1	16-May-95	absent
Sturgeon Creek	Duck Fork	Lee	37.5334	-83.7693	0	new site	absent
Sturgeon Creek	Little Sturgeon Creek	Owsley	37.4783	-83.8136	2	26-Jul-96	absent
Sturgeon Creek	Rowlette Creek	Owsley	37.4477	-83.7876	0	new site	absent
Sturgeon Creek	Sturgeon Creek	Lee	37.5008	-83.8100	3	14-Oct-98	absent
Sturgeon Creek	Travis Creek	Jackson	37.4378	-83.8660	0	new site	present
Sturgeon Creek	Wild Dog Creek	Owsley	37.4872	-83.8250	2	12-Sep-98	present

Table 2. Historic occurrences (Kentucky Nature Preserves Commission database) and results of 2007-2008 status survey of *Etheostoma sagitta spilotum* in the Middle Fork Kentucky River (HUC8) basin.

Watershed	Stream	County	Latitude	Longitude	Previous Records	Last Observed	2007- 2008 Presence
Beech Fork	Cawood Branch	Leslie	36.9360	-83.3752	0	new site	absent
Cutshin Creek	Cutshin Creek	Leslie	37.2058	-83.3472	1	8-24-1890	not sampled
Cutshin Creek	Raccoon Creek	Leslie	37.1647	-83.3078	1	30-Jun-73	not sampled
Greasy Creek	Big Laurel Creek	Harlan	36.9914	-83.1819	2	9-Jul-96	not sampled
Greasy Creek	Greasy Creek	Leslie	37.0361	-83.3658	1	2-May-70	not sampled
Middle Fork Kentucky River	Hell For Certain Creek	Leslie	37.2294	-83.4286	4	12-Jul-94	present
Middle Fork Kentucky River	Middle Fork Kentucky River	Leslie	37.2231	-83.3772	1	8-28-1890	absent
Middle Fork Kentucky River	Squabble Creek	Perry	37.3103	-83.5358	1	19-Jul-96	absent

Table 3. Historic occurrences (Kentucky Nature Preserves Commission database) and results of 2007-2008 status survey of *Etheostoma sagitta spilotum* in the North Fork Kentucky River (HUC8) basin. Red font = Impaired streams (KY Division of Water 303d list).

Watershed	Stream	County	Latitude	Longitude	Previous Records	Last Observed	2007- 2008 Presence
Frozen Creek	Clear Fork	Breathitt	37.6414	-83.3142	1	10-Aug-95	present
Frozen Creek	Cope Fork	Breathitt	37.6142	-83.2930	1	9-Aug-95	absent
Frozen Creek	Davis Creek	Breathitt	37.6464	-83.3494	1	10-Aug-95	present
Frozen Creek	Frozen Creek	Breathitt	37.6567	-83.2819	1	10-Aug-95	present
Frozen Creek	Negro Branch	Breathitt	37.6467	-83.3289	1	10-Aug-95	present
North Fork Kentucky River	Boone Fork	Breathitt	37.6500	-83.4167	1	4-Aug-98	absent
North Fork Kentucky River	Hell Creek	Lee	37.6283	-83.6650	1	17-Aug-95	present
North Fork Kentucky River	Holly Creek	Wolfe	37.6631	-83.4683	1	5-Aug-98	present
North Fork Kentucky River	Lotts Creek	Perry	37.2886	-83.1814	1	8-26-1890	not sampled
North Fork Kentucky River	Little Fork Lower Devil Creek	Wolfe	37.6664	-83.6018	0	new site	present
North Fork Kentucky River	Lower Devil Creek	Lee	37.6614	-83.5997	1	3-Aug-98	absent
North Fork Kentucky River	Walker Creek	Lee	37.6456	-83.6494	2	2-Jul-96	present
Quicksand Creek	Baker Branch	Breathitt	37.4517	-83.0289	1	29-Sep-94	absent
Quicksand Creek	Bear Branch	Breathitt	37.5325	-83.3047	1	21-Mar-69	not sampled
Quicksand Creek	Hunting Creek	Breathitt	37.6164	-83.2400	1	18-Jul-95	absent
Quicksand Creek	Laurel Fork	Breathitt	37.4511	-83.0242	2	28-Sep-94	present
Quicksand Creek	Leatherwood Creek	Breathitt	37.5121	-83.2280	5	1982	absent
Quicksand Creek	Middle Fork Quicksand Creek	Breathitt	37.4996	-83.0625	1	20-Jul-95	present
Quicksand Creek	Press Howard Fork	Breathitt	37.5347	-83.2493	0	new site	absent
Quicksand Creek	Smith Branch	Breathitt	37.5272	-83.3150	1	8-Aug-95	absent
Quicksand Creek	Wolf Creek	Breathitt	37.6139	-83.2081	1	19-Jul-95	absent
Troublesome Creek	Bear Branch	Breathitt	37.4530	-83.1953	2	7-Nov-70	absent
Troublesome Creek	Boughcamp Branch	Knott	37.4242	-83.0794	1	29-Jun-95	not sampled
Troublesome Creek	Buckhorn Creek	Breathitt	37.4542	-83.1592	7	29-Jun-95	absent
Troublesome Creek	Clemons Fork	Breathitt	37.4808	-83.1356	7	24-May-95	present
Troublesome Creek	Coles Fork	Knott	37.4586	-83.1322	7	19-May-98	present
Troublesome Creek	Laurel Fork (Buckhorn Cr.)	Breathitt	37.4466	-83.1889	2	23-May-95	absent
Troublesome Creek	Laurel Fork (Balls Fk.)	Breathitt	37.3947	-83.0414	1	23-May-95	not sampled
Troublesome Creek	Leatherwood Creek	Breathitt	37.4425	-83.3122	2	1-Oct-69	not sampled
Troublesome Creek	Left Fork Troublesome Creek	Knott	37.3356	-82.9819	1	8-28-1890	not sampled
Troublesome Creek	Lewis Fork	Breathitt	37.4661	-83.1761	1	Jul-59	absent
Troublesome Creek	Long Fork	Breathitt	37.4333	-83.1494	1	Jul-59	absent
Troublesome Creek	Mill Branch	Knott	37.4047	-82.9678	1	22-May-95	not sampled
Troublesome Creek	Millseat Branch	Breathitt	37.4775	-83.1475	1	Jun-76	absent
Troublesome Creek	Snag Ridge Fork	Knott	37.4658	-83.1133	1	Jun-76	not sampled
Troublesome Creek	Troublesome Creek	Perry	37.3417	-83.0936	2	8-28-1890	not sampled

Table 4. Historic occurrences (Kentucky Nature Preserves Commission database) and results of 2007-2008 status survey of *Etheostoma sagitta spilotum* in the South Fork Kentucky River (HUC8) basin. Red font = Impaired streams (KY Division of Water 303d list).

Watershed	Stream	County	Latitude	Longitude	Previous Records	Last Observed	2007- 2008 Presence
Buffalo Creek	Buffalo Creek	Owsley	37.357	-83.5933	2	13-Nov-92	not sampled
Buffalo Creek	Laurel Fork Buffalo Creek	Owsley	37.3411	-83.5636	1	14-Aug-92	present
Buffalo Creek	Right Fork Buffalo Creek	Owsley	37.2803	-83.5486	3	19-Jul-96	present
Bullskin Creek	Bullskin Creek	Clay	37.252	-83.6136	1	6-Aug-98	present
Goose Creek	Horse Creek	Clay	37.0811	-83.8536	2	26-Jun-97	absent
Goose Creek	Laurel Creek	Clay	37.2306	-83.7694	2	14-Aug-70	not sampled
Red Bird River	Big Creek	Clay	37.1611	-83.5678	1	8-8-1890	absent
Red Bird River	Big Double Creek	Clay	37.0939	-83.5956	2	10-Jul-97	present
Red Bird River	Blue Hole Creek	Clay	36.9892	-83.5442	1	16-Jul-97	present
Red Bird River	Bowen Creek	Leslie	37.0606	-83.5278	1	17-Jul-96	not sampled
Red Bird River	Elisha Creek	Leslie	37.0842	-83.5306	1	13-Jul-98	absent
Red Bird River	Gilberts Big Creek	Clay	37.103	-83.5355	1	16-Jul-97	present
Red Bird River	Hector Branch	Clay	37.1583	-83.6517	1	1890	absent
Red Bird River	Katies Creek	Clay	37.0333	-83.54	1	10-Jul-97	present
Red Bird River	Little Double Creek	Clay	37.1333	-83.5953	2	10-Jul-97	present
Red Bird River	Red Bird River	Clay	37.1911	-83.5922	2	6-Jun-70	not sampled
Red Bird River	Left Fork Elisha Creek	Leslie	37.09225	-83.52559	1	9-Aug-03	not sampled
Red Bird River	Right Fork Elisha Creek	Leslie	37.0767	-83.5153	1	15-Jul-92	present
Red Bird River	Spring Creek	Clay	37.0606	-83.5522	1	10-Jul-97	present
Red Bird River	Sugar Creek	Leslie	37.12492	-83.54157	0	new site	absent
Red Bird River	Upper Bear Creek	Clay	37.0142	-83.5475	2	21-Mar-90	present
Sexton Creek	Bray Creek	Clay	37.2717	-83.8192	2	15-Jul-97	absent
Sexton Creek	Robinsons Creek	Clay	37.2767	-83.8428	1	15-Jul-97	absent
Sexton Creek	Sexton Creek	Clay	37.35	-83.7019	1	22-Mar-78	not sampled
South Fork Kentucky River	Buck Creek	Owsley	37.4667	-83.7125	1	19-Oct-78	absent
South Fork Kentucky River	Lower Buffalo Creek	Owsley	37.36884	-83.70297	1	10-Aug-98	present
South Fork Kentucky River	Left Fork Island Creek	Owsley	37.5097	-83.6503	0	new site	absent
South Fork Kentucky River	Lower Island Creek	Owsley	37.3889	-83.7456	1	23-Jul-97	absent
South Fork Kentucky River	Right Fork Cow Creek	Owsley	37.41	-83.5694	1	24-Jul-97	not sampled

Table 5. Frequency distribution of total lateral scales in *Etheostoma sagitta spilotum* and *E. s. sagitta* (sexes combined).

Taxon	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	n
<i>Etheostoma s. spilotum</i>	2		4	2	6	9	3	3	2	1				1		1				34
Red River																				
Western Allegheny Plateau			1	1	4	1		1												8
North Fork Kentucky River																				
Western Allegheny Plateau	1		1		1	4	1													8
Central Appalachians						1		2		1										4
Middle Fork Kentucky River (Hell for Certain Creek)																				
Central Appalachians							1		1					1		1				4
South Fork Kentucky River																				
Western Allegheny Plateau									1											1
Central Appalachians			2	1	1	2														6
Sturgeon Creek																				
Western Allegheny Plateau	1					1	1													3
<i>Etheostoma s. sagitta</i>						1	1			4	6	5	4	7	2	3	1		1	35
Upper Cumberland (above Falls)																				
Southwestern Appalachians										1	1	1		1	1	1			1	7
Central Appalachians										1		1			1					3
Upper Cumberland (below Falls)																				
Southwestern Appalachians							1			1	2		1	3		1				9
Poor Fork																				
Central Appalachians						1					3	3	3	3			1			14
Martins Fork																				
Central Appalachians										1						1				2

Table 6. Frequency distribution of pored lateral scales in *Etheostoma sagitta spilotum* and *E. s. sagitta* (sexes combined).

Taxon	34-36	37-39	40-42	43-45	46-48	49-51	52-54	55-57	58-60	61-63	64-66	n
<i>Etheostoma s. spilotum</i>	2	2	3	11	6	8		2				34
Red River												
Western Allegheny Plateau		2	1	3	2							8
North Fork Kentucky River												
Western Allegheny Plateau				4	1	3						8
Central Appalachians			1	2	1							4
Middle Fork Kentucky River (Hell for Certain Creek)												
Central Appalachians						2		2				4
South Fork Kentucky River												
Western Allegheny Plateau			1									1
Central Appalachians	1			2	2	1						6
Sturgeon Creek												
Western Allegheny Plateau	1					2						3
<i>Etheostoma s. sagitta</i>					3	1	9	5	5	10	2	35
Upper Cumberland (above Falls)												
Southwestern Appalachians					1		1			1		3
Central Appalachians						1	2		1	2	1	7
Upper Cumberland (below Falls)												
Southwestern Appalachians					1		2	2	1	3		9
Poor Fork												
Central Appalachians					1		4	3	3	2	1	14
Martins Fork												
Central Appalachians										2		2

Table 7. Frequency distribution of caudal peduncle scales in *Etheostoma sagitta spilotum* and *E. s. sagitta* (sexes combined).

Taxon	19	20	21	22	23	24	25	26	27	n
Drainage Ecoregion										
<i>Etheostoma s. spilotum</i>	1	3	13	7	7	3				34
Red River										
Western Allegheny Plateau			4	3	1					8
North Fork Kentucky River										
Western Allegheny Plateau			4		3	1				8
Central Appalachians			1	1	2					4
Middle Fork Kentucky River (Hell for Certain Creek)										
Central Appalachians			1		1	2				4
South Fork Kentucky River										
Western Allegheny Plateau				1						1
Central Appalachians	1	1	3	1						6
Sturgeon Creek										
Western Allegheny Plateau		2		1						3
<i>Etheostoma s. sagitta</i>				6	10	10	7	1	1	35
Upper Cumberland (above Falls)										
Southwestern Appalachians					2	1				3
Central Appalachians					1	2	3	1		7
Upper Cumberland (below Falls)										
Southwestern Appalachians				2	2	4	1			9
Poor Fork										
Central Appalachians				3	4	3	3		1	14
Martins Fork										
Central Appalachians				1	1					2

Table 8. Physical and chemical characteristics of streams in which Kentucky Arrow Darters were present during 2007 and 2008 surveys.

N = numbers of specimens collected.

Watershed	Stream	N	Watershed Area (km ²)	Stream Order	Conductivity (µS)	temp C	DO (mg/L)	pH
Buffalo Creek	Laurel Fork Buffalo Creek	3	15.40	1	91	16.26	7.25	7.26
Buffalo Creek	Right Fork Buffalo Creek	1	42.70	3	70	15.01	7.63	7.01
Bullskin Creek	Bullskin Creek	2	56.10	3	750	12.70	8.29	7.10
Frozen Creek	Clear Fork	1	7.80	1	95	18.38	5.20	7.40
Frozen Creek	Davis Creek	2	7.80	2	86	16.68	4.72	7.48
Frozen Creek	Frozen Creek	9	19.20	2	92	18.42	4.50	7.63
Frozen Creek	Negro Branch	1	11.10	2	97	21.33	4.62	7.91
Kentucky River	Silver Creek	1	8.30	2	87	10.32	10.12	7.15
Middle Fork Kentucky River	Hell For Certain Creek	4	16.75	2				
North Fork Kentucky River	Hell Creek	7	20.10	2	188	11.95	7.00	7.86
North Fork Kentucky River	Holly Creek	2	25.40	2	116	13.05	6.20	7.12
North Fork Kentucky River	Little Fork Lower Devil Creek	1	7.30	1				
North Fork Kentucky River	Walker Creek	7	35.80	3	400			
Quicksand Creek	Laurel Fork	6	17.70	3	193	19.10	8.00	7.43
Quicksand Creek	Middle Fork Quicksand Creek	6	38.50	2	102	22.52	7.00	7.64
Red Bird River	Big Double Creek	5	22.10	2	60	12.11	8.29	6.84
Red Bird River	Blue Hole Creek	1	10.00	2	54	9.89		6.79
Red Bird River	Gilberts Big Creek	1	15.10	1	42	11.05	3.04	6.78
Red Bird River	Katies Creek	1	9.60	2	57	13.49	7.91	6.96
Red Bird River	Little Double Creek	3	5.70	1	49	12.01		7.13
Red Bird River	Right Fork Elisha Creek	1	11.80	1	246	22.22	2.10	7.24
Red Bird River	Spring Creek	1	14.90	2	85	12.46	8.13	7.14
Red Bird River	Upper Bear Creek	6	11.30	1	50	14.91	7.75	7.22
Red River	Rockbridge Fork	10	7.60	1	88	11.83	7.36	7.10
South Fork Kentucky River	Lower Buffalo Creek	3	22.10	2	142	20.80	7.14	7.94
Sturgeon Creek	Travis Creek	2	8.70	2	160	15.46	8.69	7.35
Sturgeon Creek	Wild Dog Creek	1	22.90	2	87	17.72	7.18	7.40
Troublesome Creek	Clemons Fork	11	15.60	2	82	12.58	7.60	7.92
Troublesome Creek	Coles Fork	2	17.10	2	60	17.71	3.46	7.55
	Mean	3.5	18.08	2	134.4	15.38	6.63	7.32
	Minimum	1.0	5.70	1	42	9.89	2.10	6.78
	Maximum	11	56.10	3	750	22.52	10.12	7.94

Table 9. Physical and chemical characteristics of streams in which Kentucky Arrow Darters were absent during 2007 and 2008 surveys.

Watershed	Stream	Watershed Area (km ²)	Stream Order	Conductivity (µS)	temp C	DO (mg/L)	pH
Middle Fork Kentucky River	Cawood Branch	5.50	2	43	19.13	7.80	6.80
Frozen Creek	Cope Fork	35.60	1	621	21.88	6.80	7.95
Goose Creek	Horse Creek	23.70	3	118	13.39	7.80	6.49
Middle Fork Kentucky River	Middle Fork Kentucky River	867.30	5				
Middle Fork Kentucky River	Squabble Creek	28.90	2	90	20.20	7.02	6.54
North Fork Kentucky River	Boone Fork	27.60	3	255	20.40	7.22	7.73
North Fork Kentucky River	Lower Devil Creek	37.40	3	195	14.40	7.81	7.29
Quicksand Creek	Baker Branch	8.20	2	2850	17.37	8.30	7.53
Quicksand Creek	Hunting Creek	22.80	3	170	23.42	7.25	8.08
Quicksand Creek	Leatherwood Creek	14.90	1	1008	18.95	8.17	8.25
Quicksand Creek	Press Howard Fork	14.90	2	498	18.96	7.73	7.81
Quicksand Creek	Smith Branch	8.40	2	253	20.88	7.72	7.81
Quicksand Creek	Wolf Creek	8.90	1	343	26.19	7.23	8.23
Red Bird River	Big Creek	66.00	3	156	10.68		6.95
Red Bird River	Elisha Creek	21.20	2			7.55	6.84
Red Bird River	Hector Branch	19.20	2	258	16.02	8.10	8.48
Red Bird River	Sugar Creek	15.10	2	28	10.06		6.75
Sexton Creek	Bray Creek	15.70	2	150	18.00	8.01	6.91
Sexton Creek	Robinsons Creek	14.00	2	155	20.64	6.89	6.69
South Fork Kentucky River	Buck Creek	32.20	3	358	13.29	9.11	7.32
South Fork Kentucky River	Left Fork Island Creek	26.50	3	325	18.10	8.45	6.84
South Fork Kentucky River	Lower Island Creek	17.50	2	118	17.30	7.53	6.64
Sturgeon Creek	Cooperas Cave Branch	6.20	2	135	11.54	9.81	7.27
Sturgeon Creek	Duck Fork	34.00	3	258	13.78	7.85	7.92
Sturgeon Creek	Little Sturgeon Creek	59.80	3	163	19.43	6.77	7.38
Sturgeon Creek	Rowlette Creek	15.10	2				
Sturgeon Creek	Sturgeon Creek	287.20	4	174	22.00		
Troublesome Creek	Bear Branch	5.80	1	845			
Troublesome Creek	Buckhorn Creek	72.80	3	2450	19.18	7.55	8.13
Troublesome Creek	Laurel Fork (Buckhorn Cr.)	9.70	3	2700	24.00		
Troublesome Creek	Lewis Fork	4.00	1	592	17.50		
Troublesome Creek	Long Fork	21.10	3	2615	19.00		
Troublesome Creek	Millseat Branch	4.10	1	152	17.30	4.21	7.73
	Mean	56.10	2	603	18.03	7.61	7.40
	Minimum	4.00	1	28	10.06	4.21	6.49
	Maximum	867.30	5	2850	26.19	9.81	8.48

Table 10. Fishes collected from the upper Kentucky River basin during *Etheostoma sagitta spilotum* status survey in 2007 and 2008. 1 = Buffalo Creek. 2 = Bullskin Creek. 3 = Frozen Creek. 4 = Goose Creek. 5 = Silver Creek. 6 = Middle Fork Kentucky River. 7 = Lower North Fork Kentucky River. 8 = Quicksand Creek. 9 = Red Bird River. 10 = Red River. 11 = Sexton Creek. 12 = South Fork Kentucky River. 13 = Sturgeon Creek. 14 = Troublesome Creek. Species of Greatest Conservation Need are in bold.

Family	Scientific name	Watershed													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cyprinidae															
	<i>Campostoma anomalum</i>	X	X	X	X	X	X	X	X	X		X	X	X	X
	<i>Cyprinella spilotera</i>	X	X				X	X		X					
	<i>Cyprinella whipplei</i>						X			X					
	<i>Luxilus chrysocephalus</i>	X	X	X	X		X	X	X	X		X	X	X	X
	<i>Lythrurus fasciolaris</i>	X	X	X	X		X	X	X	X				X	X
	<i>Nocomis micropogon</i>	X	X					X						X	X
	<i>Notropis buccatus</i>	X	X	X	X		X	X	X			X	X	X	X
	<i>Notropis photogenis</i>						X	X							
	<i>Notropis rubellus</i>	X					X	X	X						X
	<i>Notropis stramineus</i>						X	X							
	<i>Notropis volucellus</i>						X								
	<i>Phoxinus erythrogaster</i>			X	X	X	X	X	X		X	X	X		
	<i>Pimephales notatus</i>	X	X	X	X		X	X	X	X	X	X	X		
	<i>Pimephales promelas</i>											X			
	<i>Rhinichthys obtusus</i>					X	X	X	X	X					X
	<i>Semotilus atromaculatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Catostomidae															
	<i>Catostomus commersonii</i>	X		X	X		X	X	X	X	X		X	X	X
	<i>Hypentelium nigricans</i>	X	X	X			X	X	X	X		X	X	X	X
	<i>Moxostoma duquesnei</i>		X	X					X	X					
	<i>Moxostoma erythrurum</i>		X		X		X	X				X	X		
Ictaluridae															
	<i>Noturus flavus</i>	X	X					X	X				X	X	
Salmonidae															
	<i>Oncorhynchus mykiss</i>	X								X					
Cottidae															
	<i>Cottus bairdii</i>					X		X							
Centrarchidae															
	<i>Ambloplites rupestris</i>	X	X	X			X	X	X	X			X	X	X
	<i>Lepomis cyanellus</i>	X						X	X			X	X	X	
	<i>Lepomis macrochirus</i>			X	X		X	X	X					X	X
	<i>Lepomis megalotis</i>		X	X			X	X	X	X		X	X	X	X
	<i>Micropterus dolomieu</i>	X	X				X	X	X	X			X	X	X
	<i>Micropterus punctulatus</i>						X	X						X	
Percidae															
	<i>Etheostoma baileyi</i>	X	X	X			X	X	X	X		X	X	X	X
	<i>Etheostoma blennioides</i>	X	X	X			X	X	X	X		X	X	X	X
	<i>Etheostoma caeruleum</i>	X	X	X	X	X	X	X	X	X		X	X	X	X
	<i>Etheostoma flabellare</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<i>Etheostoma nigrum</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<i>Etheostoma s. spilotum</i>	X	X	X		X	X	X	X	X	X		X	X	X
	<i>Etheostoma variatum</i>	X	X					X	X	X				X	X
	<i>Etheostoma zonale</i>						X						X	X	X
	<i>Percina caprodes</i>						X	X					X	X	
	<i>Percina copelandi</i>						X								
	<i>Percina maculata</i>	X		X				X	X	X		X	X		X
	<i>Percina sciera</i>						X								
	<i>Percina stictogaster</i>	X	X		X					X			X	X	