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Surveys for the Diamond Darter (*Crystallaria cincotta*), an Endangered Species Known Historically from the Green River in Kentucky

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Abstract

The Diamond Darter formerly occurred in the Ohio River basin in Kentucky, Tennessee, Ohio, and West Virginia; however, it is now extant only within a 22-mile section of the Elk River in west-central West Virginia. Due to its decline and currently restricted range, the Diamond Darter was federally listed as endangered in 2013. In Kentucky, the species is known only from six pre-1930 records: lower Cumberland River (1 record), upper Green River (3 records), and Ohio River (2 records). It was last collected in the Green River near Cave Island, Edmonson County, in 1929. Extensive sampling for fish in the middle and upper Green River during the past 30 years using seines and electrofishing (backpack and boat units) has failed to detect the species. The Diamond Darter is difficult to collect using standard sampling methodologies because it is nocturnally active and can occur in depths and current velocities not easily worked with a seine or electrofisher. Because the upper Green River contains habitat similar to that occupied by the species the Elk River, a 95-mile section from Cave Island (Mammoth Cave National Park) to upstream of Greensburg has been designated a critical habitat unit (unoccupied). During 2012-2015, we completed sampling within the critical habitat unit using a benthic trawl at 38 sites and nocturnal sampling with seines and spotlights at six sites. Our objective was to determine if the species still persists in the Green River and document fish community composition, habitat, and water quality variables. We documented a total of 55 species of fish, but the Diamond Darter was not encountered. Updated distributional data were obtained for six state-listed species of conservation concern, as well as a general inventory of the fish fauna and habitat conditions. This information is intended to help guide future Diamond Darter recovery actions (e.g., reintroduction).

Introduction

The Diamond Darter is the second and most recently described member of the genus *Crystallaria* (Welsh and Wood 2008). It is a small, slender perch (maximum size 3 inches [77 mm]) having a somewhat translucent yellow-tan body marked with four wide brown dorsal saddles and 12-14 mid-lateral blotches. The species once had a widespread but spotty distribution the Ohio River basin (Etnier and Starnes 1993), but is now restricted to the lower 37 km (22 mi) of the Elk River, Kanawha County, West Virginia (Welsh et al. 2013, Ruble et al. 2014).

In the Elk River, no Diamond Darter population estimates are available and despite concerted sampling efforts, less than 50 individuals have been collected since it was first discovered there in 1980 (Cincotta and Hoeft 1987, Welsh et al. 2009, Ruble et al. 2014). The species was federally listed as endangered due to its decline and continued threats to its existence (USFWS 2013).

Because of its rarity, little is known about the life history and ecology of the Diamond Darter.

In Kentucky, the Diamond Darter is known only from six historic records, three of

which are in the Green River (Table 1). It was last collected in the Green River near Cave Island (now within Mammoth Cave National Park), Edmonson County, in 1929 (Burr and Warren, 1986). Despite extensive sampling for fishes in the middle and upper Green River during the past 30 years, the Diamond Darter has not been reported. However, conventional sampling gears such as seines and electrofishers have not been consistently effective at detecting this species. Furthermore, fish sampling is typically conducted during daytime hours. In the Elk River, sampling at night has proven more effective in capturing the species because of its apparently increased crepuscular and nocturnal activity (Welsh and Wood, 2008; Welsh et al. 2013).

The upper Green River contains patches of habitat similar to that occupied by the Diamond Darter in the Elk River; these include deep riffles, runs, and flowing pools over sand and gravel. A 152.1 km (94.5 mi) section of the Green River from Roachville Ford (River Mile 294.8) to the downstream end of Cave Island (River Mile 200.3) has been designated as a critical habitat unit (CHU) for the Diamond Darter (USFWS 2013). The Green River CHU is being treated as unoccupied, pending a systematic

survey using gear appropriate for capturing the species. This paper summarizes results of an intensive survey (2012-2015) for the Diamond Darter within the Green River CHU.

Methods

The study area includes the section of the mainstem Green River designated as critical habitat for the Diamond Darter (Figure 1). A total of 41 fish sampling sites were selected arbitrarily throughout the CHU based on accessibility, depth, flow, and presence of sand and small gravel substrates. Special emphasis was placed on areas having extensive flowing pools, runs, and deep riffles. These included locations where Shoal Chub (*Macrhybopsis hyostoma*), Streamline Chub (*Erimystax dissimilis*), and Stargazing Minnow (*Phenacobius uranops*) have been collected; species that have habitat preferences similar to those described for the Diamond Darter (Osier 2005, Welsh et al. 2013).

Between 19 September 2012 and 22 September 2015, boat-assisted trawling using an 8' modified trawl (i.e., Mini-Missouri Trawl [Herzog et al. 2005]) was conducted during daylight hours at 38 sites. The trawl

Table 1: Historic collection records for Diamond Darter in Kentucky. UMMZ = University of Michigan Museum of Zoology. USNM = U.S. National Museum of Natural History (Smithsonian Institution). FMNH = Field Museum of Natural History. OSUM = Ohio State University Museum of Zoology.

Locality	Date	Source
Green River, 5 mi SW of Greensburg, Green Co.	7 August 1890	Woolman (1892), UMMZ 197713 (1)
Green River, 0.5 mi E of Greensburg, Green Co.	8 August 1890	Woolman (1892), USNM 63786 (1)
Green River, near Cave Island, Edmonson Co.	31 August 1929	Giovannoli, L., USNM 89467 (2)
Cumberland River, at Kuttawa, Lyon Co.	unknown	FMNH 6825 (1)
Ohio River, near Rising Sun, IN, Boone Co.	1887	Jordan (1899), USNM 39619 (1)
Ohio River, at Russell, Greenup Co.	31 May 1899	OSUM 9688 (1)

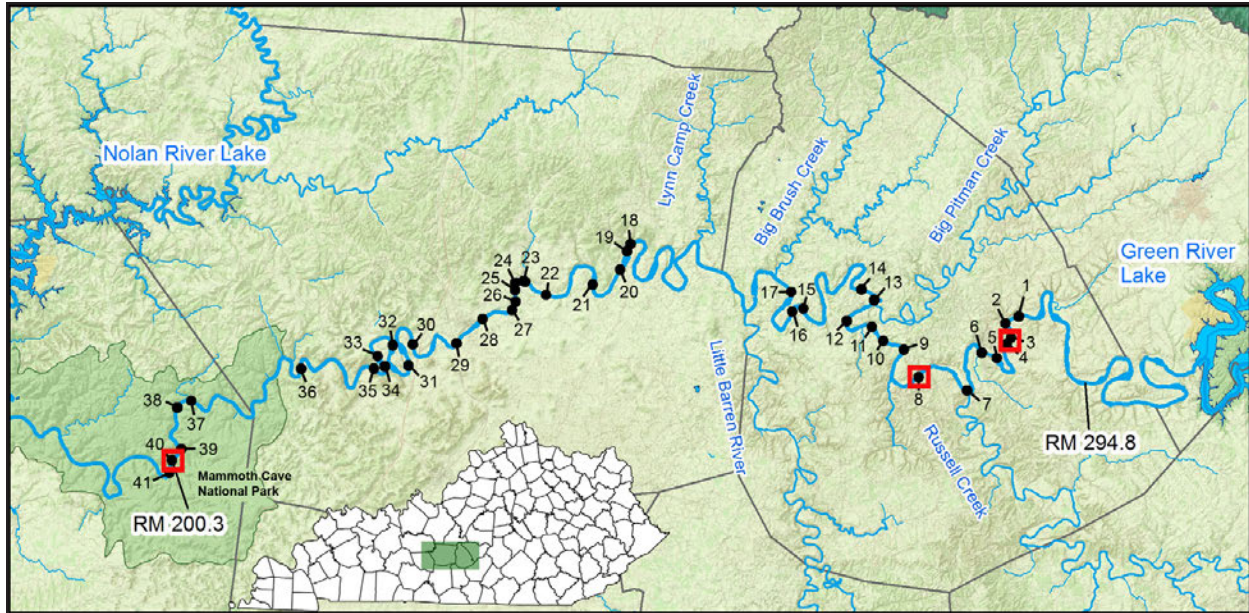


Figure 1: Fish sampling sites in the Green River within the Diamond Darter CHU. Squares = historic localities for Diamond Darter. RM = river mile.

was pulled through pool and riffle/pool transition areas at depths ranging 0.2-2.0 m and current velocities ranging 0.03-1.8 m·s⁻¹. Multiple hauls were performed at each site; the number of hauls per site varied (1-5) depending on the amount of habitat present, stream width and depth, and presence of obstructions (e.g., snags). In addition to trawling, we used a 15' X 6' (1/8" mesh) seine at six sites (1, 6, 7, 20, 36, and 40 [Figure 1]) after dusk (8:30-12:30 p.m.) aided by headlamps and hand-held spotlights. Seining and spotlight searches generally followed methods used in the Elk River by Osier (2005) and Welsh et al. (2013).

Most fish collected were identified on site, enumerated, photo-documented, and released. A limited number of voucher specimens were retained and archived at Kentucky Department of Fish and Wildlife Resources (KDFWR), Frankfort, and the biological collection maintained by Mammoth Cave National Park (MCNP). At each site, stream width, average depth,

current velocity, water temperature, pH, and conductivity were recorded. Substrate composition, riparian zone, and canopy coverage were estimated qualitatively.

Results and Discussion

A total of 106 species of fish have been reported from the mainstem Green River within the Diamond Darter CHU (Table 2). This list is based mostly on vouchered collection records reviewed and compiled by Burr and Warren (1986). We also reviewed and included records from a large volume of post-1986 fish collection data from state and federal agencies, academic institutions and private consultants.

Our sampling effort at 41 sites in the mainstem Green River within the CHU produced 55 fish species representing 12 families (Table 2). Approximately 60% of the species captured were darters (family Percidae, 18 species) and minnows (family Cyprinidae, 15 species). These results demonstrate the effectiveness of the

Missouri trawl in capturing small-bodied, benthic fishes in deeper riverine habitats, as described by Herzog et al. (2005). It did not effectively capture larger species and active swimmers (e.g., pelagic species). Despite our effort to resample historic localities and additional sites with appropriate habitat using specialized gear during day and night, the Diamond Darter was not detected in the CHU.

Most (89%) of the species we captured during our survey are considered occasional to generally distributed and often abundant in suitable habitat. A large portion (43%) of the 106 species known from the CHU are sporadic, several of which are rare and based on fewer than five occurrences. We captured 4 of 11 species within the CHU that have a state conservation status (KSNPC 2012, KDFWR 2013) and 3 of 5 species considered “at-risk” (i.e., have been petitioned for federal listing, USFWS 2012). Occurrence of these species within the CHU is summarized in Table 3.

Conclusions and Recommendations

The Diamond Darter is one of 13 species that may be extirpated from the Green River within the CHU (Table 2). These species have not been collected in the CHU in over 50 years and are known from fewer than five occurrence records. This suggests that they may have been uncommon in the upper Green River historically. Regarding the Diamond Darter in the Green River, Woolman (1892) noted that it was “[n]ot widely distributed, nor common anywhere.” The ability to ascribe Diamond Darter extirpation to potential threats is hampered by insufficient quantification of populations (Grandmaison et al. 2003). Habitat degradation from impoundment, excessive siltation, and stream flow modification are main factors believed to be responsible for the widespread extirpation of Diamond Darter populations and are the main threat to its continued persistence (Welsh et al. 2009). How the large reservoir and series of locks and dams on the Green River have impacted the Diamond Darter is uncertain; however,

Table 3: Occurrences of state-listed and at-risk fish species during 2012-2015 survey within the Green River CHU. Site numbers correspond to map in Figure 1.

Scientific Name	Common Name	Site (number of individuals)
<i>Notropis ariommus</i>	Popeye Shiner	40(6)
<i>Phenacobius uranops</i>	Stargazing Minnow	6(6), 7(6), 19(1), 23(2), 38(2)
<i>Ammocrypta clara</i>	Western Sand Darter	23(12), 27(1), 32(6), 33(1), 35(2), 37(12), 39(11), 40(9), 41(2)
<i>Etheostoma maculatum</i>	Spotted Darter	1(3), 2(1), 3(4), 4(2), 5(1), 7(4), 8(4), 11(7), 12(8), 13(4), 18(5), 21(2), 22(2), 23(117), 25(5), 27(3), 29(6), 30(3), 33(1), 36(1), 38(65), 41(1)
<i>Etheostoma tippecanoe</i>	Tippecanoe Darter	1(4), 3(1), 7(1), 16(2), 17(7), 18(6), 19(10), 21(11), 22(1), 23(22), 25(7), 27(4), 28(11), 30(3), 34(2), 37(2), 38(15), 41(1)
<i>Percina macrocephala</i>	Longhead Darter	7(1), 8(7)

one of the reasons the species may have been able to persist in the Elk River is because it remains largely unimpounded except for a single dam approximately 100 miles upstream of its confluence (Strager 2008).

Sites that appeared most promising for rediscovering the Diamond Darter were near Greensburg (site 6), mouth of Russell Creek (site 7), Sims Bend northeast of Munfordville (site 23), and in MCNP (sites 37-41). These sites offered the best potential in terms of high species richness and habitat diversity, including large expanses of clean sand and gravel. Sites near Greensburg and in MCNP were locations where the species had been collected historically (Table 1). Species with habitat requirements similar to the Diamond Darter such as Streamline Chub and Stargazing Minnow were present in all four areas. The substrate becomes noticeably more sandy from the vicinity of Munfordville downstream, which coincides with the presence of Western Sand Darter.

Protection of existing free-flowing riffle-pool-run habitat in the Green River is highly important to maintain the diverse array of fishes and other aquatic organisms that occur there. This could only serve to benefit the Diamond Darter, if it still exists, and would be necessary for any attempt to re-establish the species in the Green River through captive propagation and reintroduction. The proposed removal of Lock and Dam No. 6 at the western edge of MCNP, if implemented, would restore the natural flow regime to an estimated six miles of the Green River (Stantec Consulting Services, Inc. 2015). Ongoing efforts to restore natural flow and temperature regimes through reoperation of Green River Dam (i.e., Sustainable Rivers Project, Konrad 2010) should be continued in conjunction with long-term biological monitoring.

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Table 2: Fishes recorded from the mainstem Green River within the Diamond Darter CHU during 1890-2015. Species collected in 2012-2015 and number of sites present are indicated. Distribution: G = generally distributed, O = occasional, S = sporadic (from Smith 1965). Kentucky State Nature Preserves Commission (KSNPC) and U.S. Fish and Wildlife Service (USFWS) conservation status: E = endangered, T = threatened, S = special concern, Ex = presumed extirpated, P = petitioned species. * unsubstantiated; needs verification. ** likely extirpated from the CHU.

Scientific Name	Common Name	Distribution in CHU	No. of sites: 2012-2015	Status	
				KSNPC	USFWS
<i>Ichthyomyzon bdellium</i>	Ohio Lamprey	S	2		
<i>Ichthyomyzon greeleyi</i>	Mountain Brook Lamprey	S		T	
<i>Lampetra aepyptera</i>	Least Brook Lamprey	S			
<i>Lampetra appendix</i>	American Brook Lamprey	S		T	
<i>Lepisosteus oculatus</i> *	Spotted Gar *	S			
<i>Lepisosteus osseus</i>	Longnose Gar	O	3		
<i>Amia calva</i> *	Bowfin *	S			
<i>Hiodon tergisus</i>	Mooneye	O			
<i>Anguilla rostrata</i>	American Eel	S			P
<i>Dorosoma cepedianum</i>	Gizzard Shad	G			
<i>Campostoma oligolepis</i>	Largescale Stoneroller	G	15		
<i>Carassius auratus</i> *	Goldfish *	S			
<i>Cyprinella spiloptera</i>	Spotfin Shiner	G	10		
<i>Cyprinella whipplei</i>	Steelcolor Shiner	S			
<i>Cyprinus carpio</i>	Common Carp	O			
<i>Erimystax dissimilis</i>	Streamline Chub	G	20		
<i>Erimystax x- punctatus</i> **	Gravel Chub **	S		Ex	
<i>Hybognathus nuchalis</i> **	Mississippi Silvery Minnow **	S			
<i>Hybopsis amblops</i>	Bigeye Chub	G	15		
<i>Hybopsis amnis</i> **	Pallid Shiner **	S		E	
<i>Hypophthalmichthys molitrix</i>	Silver Carp	S			
<i>Luxilus chrysocephalus</i>	Striped Shiner	G	5		
<i>Lythrurus fasciolaris</i>	Scarlet Shiner	G	1		
<i>Macrhybopsis hyostoma</i>	Shoal Chub	S			
<i>Macrhybopsis storeriana</i> **	Silver Chub **	S			
<i>Nocomis effusus</i>	Redtail Chub	S			
<i>Notemigonus crysoleucas</i>	Golden Shiner	S			
<i>Notropis ariommus</i>	Popeye Shiner	S	1		P
<i>Notropis atherinoides</i>	Emerald Shiner	O	1		
<i>Notropis boops</i> **	Bigeye Shiner **	S			
<i>Notropis buchanani</i>	Ghost Shiner	S			
<i>Notropis micropteryx</i>	Highland Shiner	G	22		

Table 2: Continued

Scientific Name	Common Name	Distribution in CHU	No. of sites: 2012-2015	Status	
				KSNPC	USFWS
<i>Notropis photogenis</i>	Silver Shiner	G	11		
<i>Notropis volucellus</i>	Mimic Shiner	G	22		
<i>Opsopoeodus emiliae</i> **	Pugnose Minnow **	S			
<i>Phenacobius uranops</i>	Stargazing Minnow	O	5	S	
<i>Pimephales notatus</i>	Bluntnose Minnow	G	14		
<i>Pimephales promelas</i> *	Fathead Minnow *	S			
<i>Pimephales vigilax</i>	Bullhead Minnow	O	1		
<i>Semotilus atromaculatus</i>	Creek Chub	S	2		
<i>Carpionodes carpio</i> *	River Carpsucker *	S			
<i>Carpionodes cyprinus</i> *	Quillback *	S			
<i>Carpionodes velifer</i> *	Highfin Carpsucker *	S			
<i>Hypentelium nigricans</i>	Northern Hog Sucker	G	30		
<i>Ictiobus bubalus</i>	Smallmouth Buffalo	O			
<i>Minytrema melanops</i>	Spotted Sucker	O			
<i>Moxostoma anisurum</i>	Silver Redhorse	S			
<i>Moxostoma breviceps</i>	Smallmouth Redhorse	O	2		
<i>Moxostoma carinatum</i>	River Redhorse	O	1		
<i>Moxostoma duquesnei</i>	Black Redhorse	O	4		
<i>Moxostoma erythrurum</i>	Golden Redhorse	G	7		
<i>Ameiurus melas</i>	Black Bullhead	S			
<i>Ameiurus natalis</i>	Yellow Bullhead	S			
<i>Ictalurus punctatus</i>	Channel Catfish	G	12		
<i>Noturus elegans</i>	Elegant Madtom	O	3		
<i>Noturus eleutherus</i>	Mountain Madtom	G	9		
<i>Noturus exilis</i> **	Slender Madtom **	S		E	
<i>Noturus flavus</i> **	Stonecat **	S			
<i>Noturus miurus</i>	Brindled Madtom	G	17		
<i>Noturus nocturnus</i>	Freckled Madtom	S			
<i>Noturus stigmosus</i> **	Northern Madtom **	S		S	
<i>Pylodictis olivaris</i>	Flathead Catfish	O	1		
<i>Esox masquinongy</i>	Muskellunge	S			
<i>Labidesthes sicculus</i>	Brook Silverside	G	3		
<i>Fundulus catenatus</i>	Northern Studfish	G	5		
<i>Fundulus notatus</i>	Blackstripe Topminnow	S			
<i>Gambusia affinis</i>	Western Mosquitofish	G	2		
<i>Cottus carolinae</i>	Banded Sculpin	G	26		
<i>Morone chrysops</i>	White Bass	O			
<i>Ambloplites rupestris</i>	Rock Bass	G	8		
<i>Lepomis cyanellus</i>	Green Sunfish	S			

Table 2: Continued

Scientific Name	Common Name	Distribution in CHU	No. of sites: 2012-2015	Status	
				KSNPC	USFWS
<i>Lepomis gulosus</i>	Warmouth	S			
<i>Lepomis macrochirus</i>	Bluegill	G	1		
<i>Lepomis megalotis</i>	Longear Sunfish	G	11		
<i>Micropterus dolomieu</i>	Smallmouth Bass	G	17		
<i>Micropterus punctulatus</i>	Spotted Bass	G	6		
<i>Micropterus salmoides</i>	Largemouth Bass	G			
<i>Pomoxis annularis</i>	White Crappie	O			
<i>Pomoxis nigromaculatus</i>	Black Crappie	S			
<i>Ammocrypta clara</i>	Western Sand Darter	O	9	E	
<i>Ammocrypta pellucida</i> **	Eastern Sand Darter **	S			
<i>Crystallaria cincotta</i> **	Diamond Darter **	S		Ex	E
<i>Etheostoma bellum</i>	Orangefin Darter	G	28		
<i>Etheostoma blennioides</i>	Greenside Darter	G	25		
<i>Etheostoma caeruleum</i>	Rainbow Darter	G	14		
<i>Etheostoma flabellare</i>	Fantail Darter	O	6		
<i>Etheostoma jimmycarter</i>	Bluegrass Darter	G	29		
<i>Etheostoma kennicotti</i>	Stripetail Darter	O	6		
<i>Etheostoma lawrencei</i>	Headwater Darter	S			
<i>Etheostoma maculatum</i>	Spotted Darter	G	22	T	
<i>Etheostoma nigrum</i>	Johnny Darter	S	1		
<i>Etheostoma rafinesquei</i>	Kentucky Darter	O	1		
<i>Etheostoma tippecanoe</i>	Tippecanoe Darter	G	18		P
<i>Etheostoma zonale</i>	Banded Darter	G	36		
<i>Percina caprodes</i>	Logperch	G	8		
<i>Percina copelandi</i>	Channel Darter	G	17		
<i>Percina evides</i>	Gilt Darter	G	25		
<i>Percina macrocephala</i>	Longhead Darter	S	2	E	P
<i>Percina maculata</i>	Blackside Darter	S	1		
<i>Percina phoxocephala</i>	Slenderhead Darter	O	1		
<i>Percina sciera</i>	Dusky Darter	O			
<i>Percina shumardi</i> **	River Darter **	S			
<i>Percina stictogaster</i> **	Frecklebelly Darter **	S			
<i>Sander canadensis</i>	Sauger	G			
<i>Sander vitreus</i>	Walleye	G			
<i>Aplodinotus grunniens</i>	Freshwater Drum	G	1		
Total species		106	55	11	5