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New Upstream Records for Fishes Following Dam Removal in the Cahaba River, Alabama

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Abstract

Population fragmentation by dams of all sizes is a major threat to biodiversity in running waters. Dam removal has become an increasingly popular tool among conservation practitioners because of its potential benefits to aquatic organisms and ecosystems. During fish monitoring following removal of a small run-of-river dam on the Cahaba River, we documented new upstream records between 8 months and 2 years post-removal for five species: Stargazer Shiner, *Notropis uranoscopus*; River Redhorse, *Moxostoma carinatum*; Southern Sand Darter, *Ammocrypta meridiana*; Freckled Darter, *Percina lenticula;* River Darter, *P. shumardi*. These new records suggest that the former dam may have served as a barrier to dispersal of resident species, and that dam removal may have benefited these species by opening additional habitat to colonization.

Keywords

colonization, dispersal, habitat, peripheral populations

Erratum

Upon re-examination of records provided by the Geological Survey of Alabama (GSA), we discovered that a data-reporting error (a shift in rows which caused abundances to align with incorrect species) caused inaccurate species presence for a single site ~1 km (latitude: 33.175, longitude: -87.028) upstream of the Marvel Slab dam in 2004 prior to removal. Because one species in our study was inaccurately reported at this site, we gave a lesser range extension (~ 1 river km) than actually occurred. Prior to dam removal in 2004 the upstream range extent for Skygazer Shiner, *N. uranoscopus*, was downstream of the Marvel Slab near the junction with the Little Cahaba River and our post-removal sampling of the species represents a >22 river km extension. The small range extension for River Redhorse, *Moxostoma carinatum* (~1 km), is correct as originally reported based on GSA sampling records, as this species was collected just above the dam in 2004 prior to removal. The error affected only a single sample at a single site and other GSA data was found to be accurate. By increasing the number of large upstream range extensions (from three to four species), this correction adds support to the idea that the removal of the Marvel Slab opened upstream habitats to a diverse group of fishes.

INTRODUCTION

Population fragmentation due to dams, road crossings, water pollution, and other barriers is a pervasive threat to biodiversity in flowing waters (Dudgeon et al. 2006, Strayer and Dudgeon 2010, Vörösmarty et al. 2010). Removal of such barriers, even large ones, is becoming increasingly popular as a conservation tool to restore connectivity among populations, while also improving recreation and other ecosystem services (Bednarek 2001, Pohl 2002, Doyle et al. 2003). Dam removal can increase dispersal and habitat area for many fishes, even non-migratory resident species (Bednarek 2001, Hart et al. 2002, Bushaw-Newton et al. 2002). The Cahaba River, located in central Alabama, is one of the most biologically diverse rivers for its size in North America, with 128 native fishes, 50 freshwater mussels, 36 gastropods, and 20 crayfishes, including 18 federally protected species (Mayden and Kuhajda 1989, Pierson et al. 1989, Bogan and Pierson 1993, Williams et al. 2008, Smith et al. 2011). Though often referred to as "free-flowing," a small run-of-the-river dam had been present for decades until its removal in 2004. We monitored fish community structure at and upstream of the former dam after its removal and documented new upstream records for several fish species.

METHODS

Study Site

The Cahaba River is located in central Alabama with its headwaters near the city of Birmingham and its outlet into the Alabama River near Selma. Land cover in the watershed is predominantly forest (56%), associated with timber, with urban land use (15% of total area) dominating the headwaters, and pasture land making up 13% of the watershed area (Cawaco Resource Conservation and Development Council 2003). Since the 1960s or 1970s the Cahaba River had a 67 m long, 1.8 m tall, 7.6 m wide run-of-the-river dam, the Marvel Slab (Figure 1), used for transporting coal and timber across the river. Although the structure was technically a vented ford with 40 culverts (0.9 m diameter) allowing water passage, it functioned ecologically as a low-head dam, especially during low water periods when the dam would have prevented upstream movement. In October 2004, the U.S. Army Corps of Engineers, The Nature Conservancy, and other partners removed the Marvel Slab in order to increase connectivity between the river reaches and improve recreational access.

Figure 1. The Cahaba River near Marvel, Alabama, before (left) and after (right) dam removal in 2004. Photos copyright Paul L. Freeman.

Fish Sampling

A total of five riffles on the Cahaba River were sampled for fishes: two "new" riffles – one at the site of the former dam and one ~0.6 km upstream of the dam which had been inundated – and three established ("old") riffles upstream of the "new" riffles (Figure 2). Riffles were sampled with a 4.6 x 1.2 m mesh seine and backpack electrofisher over a two or three day period each spring and summer from summer 2005 to spring 2007, and additionally in fall 2005. Lateral transects were sampled across the downstream, middle and upstream portions of each riffle in order to incorporate the variety of microhabitats in the riffle. Fish were identified and enumerated in the field after sampling of each transect. Fish not easily identified were preserved in 10% formalin and identified in the laboratory.

Historical Records and Analysis

We used Pierson et al. (1989) and records from the University of Alabama Ichthyological Collection (UAIC; through May 2011) and Geological Survey of Alabama (GSA) to determine the upstream extent of species distributions in the Cahaba River prior to the dam removal and compared these to our collections during 2005-2007. We examined 575 UAIC records from the Cahaba River drainage representing 297 localities sampled from 1949-2011 and 160 GSA records representing 48 localities sampled from 1983-2014. There were 40 main channel samples upstream of the Marvel Slab (19 localities) and 170 main channel samples downstream of the dam (74 localities). Because there were few samples prior to dam construction in the 1960s, we could not compare pre- and post- dam construction distributions and focused on pre- and post- dam removal ranges. Range extensions (km) were roughly estimated using the path measure tool in Google Earth (Google, Inc., Mountain View, CA).

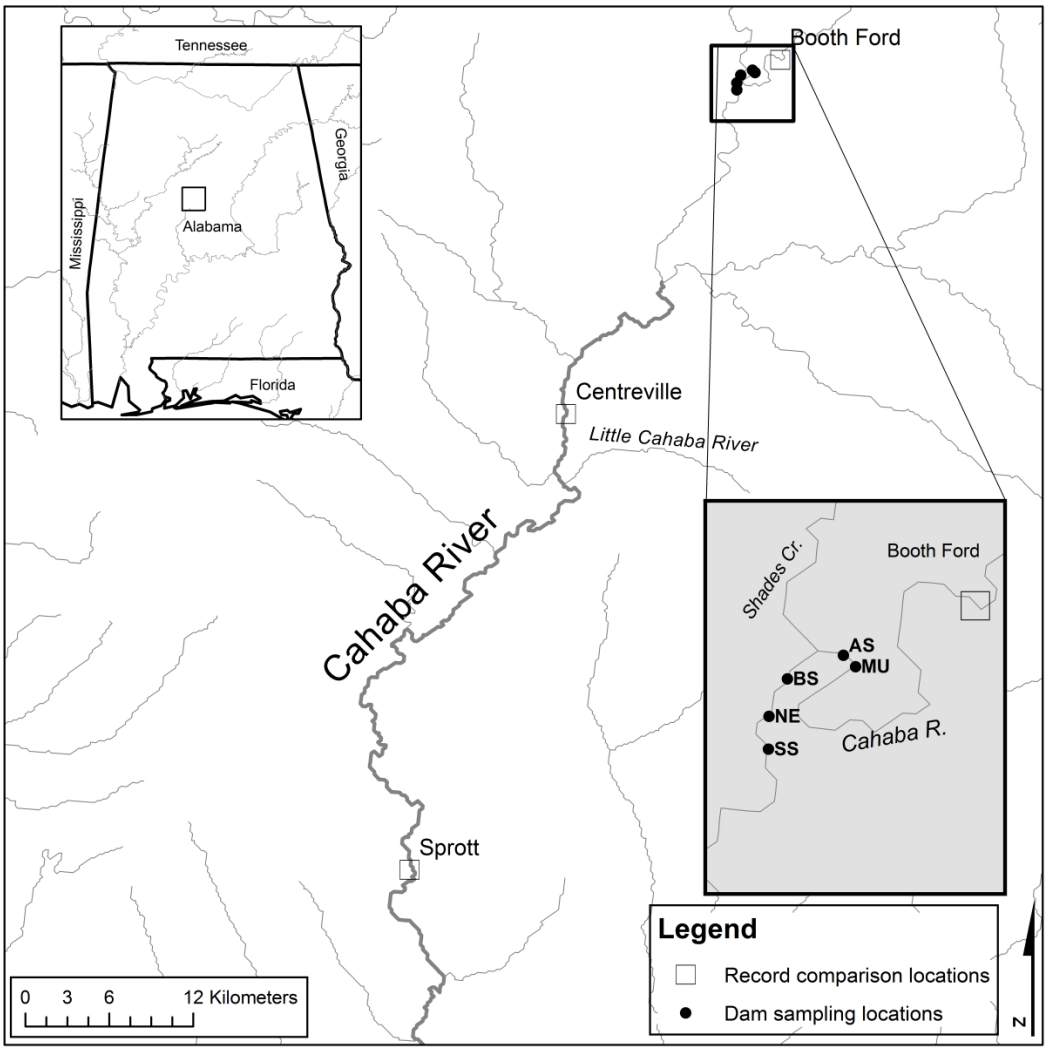

Figure 2. Map of Cahaba River showing sampling sites (SS = former dam site; NE = newly exposed riffle; BS = below Shades Creek; AS = above Shades Creek; MU = most upstream) and sites used to compare historical species records to those collected during this study (see Figure 3).

RESULTS

Five species exhibited range extensions based on comparisons of 2005 – 2007 samples with collections prior to dam removal (Figure 3). These included the Stargazer Shiner, *Notropis uranoscopus*; River Redhorse, *Moxostoma carinatum*; Southern Sand Darter, *Ammocrypta meridiana*; Freckled Darter, *Percina lenticula;* and River Darter, *P. shumardi* (Figure 4). Prior to dam removal, upstream range extents for two species (*P. lenticula, P. shumardi*) were at the junction with the Little Cahaba River based on available records, and one

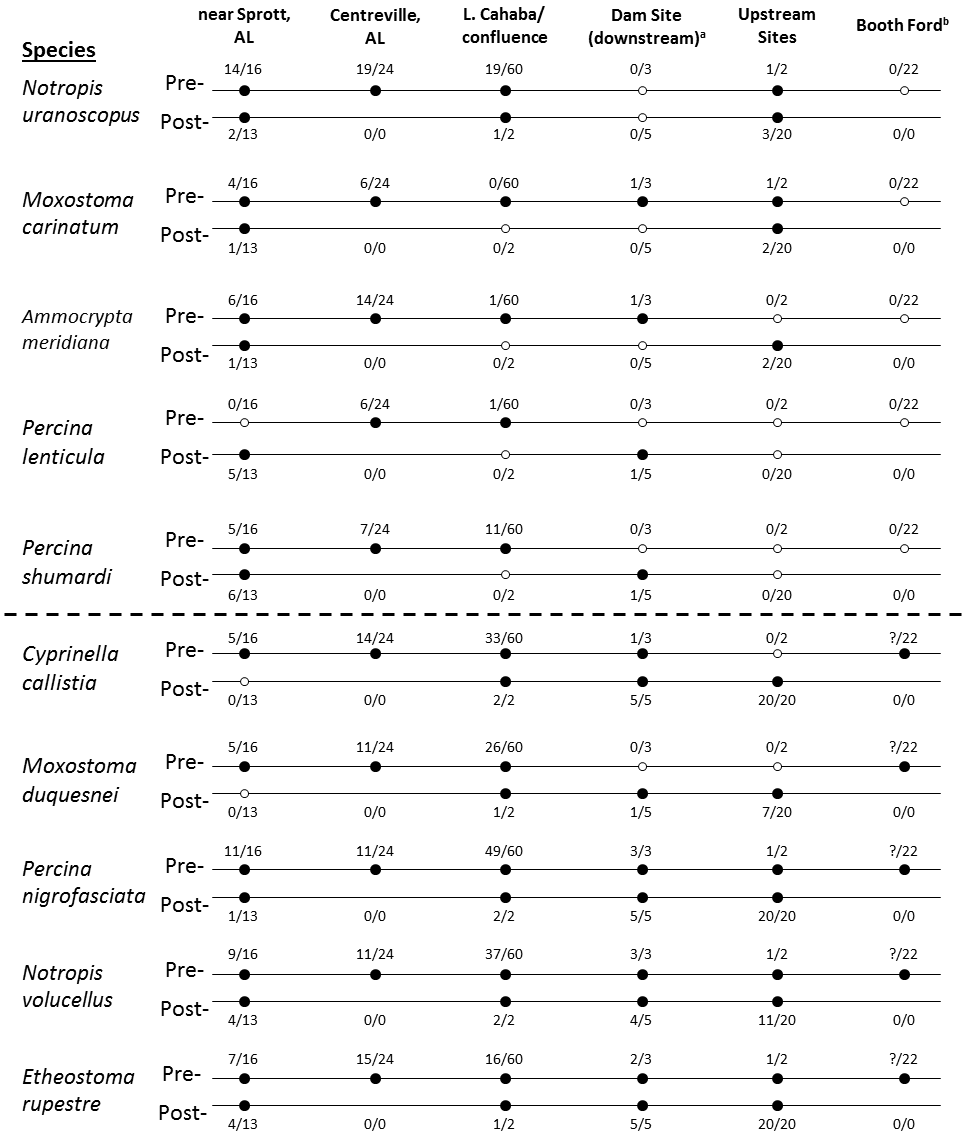

Figure 3. Records for selected fish species before (Pre: pre-2004) and after (Post: post-2004) dam removal on the Cahaba River at selected sites. Numbers above and below circles indicate number of collections in which the species was found out of the total number of collections (filled circles = present; open circles = absent). Dashed line separates new upstream records (above) from species distributed above and below dam throughout pre- and post-removal periods (below). [a] Includes one record that did not specify upstream or downstream; however, this did not affect upstream records. Both *Percina lenticula* and *P. shumardi* were collected at the former dam site in post-removal sampling (2005) but in the upstream transects above the actual location of the dam. [b] Some Booth Ford records were obtained from Pierson et al. (Pierson et al. 1989) and were not separated by date; therefore, question marks indicate that the species was collected at Booth Ford but the number of collections could not be determined (n = at least 2 based on Pierson et al. and GSA records).

species (*A. meridiana*) was found just below the dam in a 2004 sample prior to removal. *Percina lenticula* and *P. shumardi* were collected at the former dam site in the upstream transect above the location of the dam in 2005 (Fig. 2). *Ammocrypta meridiana* was collected at the newly exposed riffle upstream of the dam in 2006 and 2007 (Fig. 2). The new localities sampled post-removal represent range extensions of approximately 2.4 – 22 river km.

Before 2004, range extents for *N. uranoscopus* and *M. carinatum* were also near the Little Cahaba junction (~ 2 river km upstream and ~0.5 river km downstream, respectively). However, in May 2004, prior to dam removal, the GSA captured these two species downstream (*M. carinatum*) and at one of our collecting localities ~1 river km upstream of the dam. Therefore, our observed range extensions for these two species are only ~1 river km.

Although recent (post-2010) data are sparser, there is evidence of continued persistence and dispersal further upstream of our sampling localities for some of these species. For example, *M. carinatum* has been observed spawning in a section of the Cahaba River >90 river km upstream of the slab near Grants Mill in Jefferson County (P. Freeman, pers. obs., 28 April 2013).

DISCUSSION

While it is impossible to determine with certainty whether dam removal allowed range extensions for these species, the coincidence of the range extensions with dam removal for *A. meridiana, P. lenticula,* and *P. shumardi* is suggestive. All the species with documented upstream range extensions are predominantly Coastal Plain species, and upland habitats may be less suitable for all or parts of the life cycles of these species. It is likely that these species were found historically in small numbers above the former dam site before its construction, but gradual downstream drift and lack of riffle colonization by larvae may have caused the species to become extirpated from reaches upstream of the dam. Although larval drift and behavior of the species documented here have not been investigated, other related species of darters (Percidae; Slack et al. 2004, Martin and Paller 2008, Eisenhour et al. 2013), minnows (Cyprinidae; Martin and Paller 2008), and suckers (Catostomidae; D'Amours et al. 2001, Martin and Paller 2008) are well-known to have pelagic or drifting periods in their early life history, and some species like redhorses (*Moxostoma*) make subsequent upstream migrations as small juveniles (Bunt et al. 2013). If this scenario is correct, dam removal likely re-opened access to upstream riffles, and increased access for the two species already found above the dam, and allowed range expansion.

Figure 4. Illustrations of the five species with upstream range extensions. From top to bottom: Stargazer Shiner, *Notropis uranoscopus*; River Redhorse, *Moxostoma carinatum*; Southern Sand Darter, *Ammocrypta meridiana*; Freckled Darter, *Percina lenticula;* and River Darter, *P. shumardi*. Images copyright and used with permission of Joseph R. Tomelleri.

There is additional evidence that the Marvel Slab served as an upstream migration barrier based on a boat electrofishing collection by the GSA prior to dam removal (26 May 2004). In this sample, fish abundance and species richness was much greater below (112 individuals, 20 species) than above (23 individuals, 12 species) the dam. Furthermore, the presence of Bowfin (*Amia calva*), Highfin Carpsucker (*Carpiodes velifer*), Smallmouth Buffalo (*Ictiobus bubalus*), and Freshwater Drum (*Aplodinotus grunniens*) below the dam all represented new upstream records at the time based on Pierson et al. (1989) and Mettee et al. (1996). This further suggests that the Marvel Slab served as a barrier to upstream migration and lends more evidence to the idea that dam removal allowed for range extensions, or re-colonization by several species.

Alternatively, there is the possibility that these main-stem species were present upstream of Marvel Slab but were extirpated when poor wastewater treatment and lack of Best Management Practices during urban and interstate construction were the norm in the 1970s and 1980s in the greater metropolitan Birmingham area. During this same period the Blue Shiner, *Cyprinella caerulea*, and the Southern Studfish, *Fundulus stellifer*, were extirpated from the entire Cahaba River drainage (Boschung and Mayden 2004, Pierson 2004). The Marvel Slab would have been a barrier for upstream movement for these five newly documented species, preventing them from repopulating upstream riffles from source populations on the Coastal Plain once water quality improved in the last 20 years.

A third possibility is that the newly documented species were present but not sampled in upstream reaches prior to dam removal. *Percina lenticula* are notoriously difficult to sample, and large bodied species like *M. carinatum* can be missed in larger rivers with inadequate sampling gear. Given that there were relatively few samples upstream of the dam prior to removal and the fact that many fishes similar to the study species have low detection probabilities, especially with low sample sizes (e.g., *Moxostoma robustum* - Grabowski et al. 2009, *Percina jenkinsi* - Hagler et al. 2011, *Percina aurauntiaca* - Albanese et al. 2011, *Notropis bifrenatus* - Jensen and Vokoun 2013, *Ammocrypta pellucida* - Dextrase et al. 2014), lack of detection is a valid possibility. Although Pierson et al. (1989) did not sample the same riffles from our study, two sites ~6.4 and 7.9 river km above our most upstream site were sampled a combined 23 times from 1978-1984. Pierson et al. (1989) collected a substantial diversity of fishes (42 species) at these two sites, including four large catostomid species and eight small-bodied, cryptobenthic darter species. Therefore it is unlikely that Pierson et al. (1989) failed to collect these five species if they were present, and these

collections were made after the construction of the Marvel Slab, strengthening the argument of upstream range extension due to dam removal.

Peripheral populations, those at the edges of the range of a species, may be of greater conservation value due to differing selective pressures at range edges that promote genetic differentiation and diversity (Luck et al. 2003, Haak et al. 2010). This could be true of populations of predominantly Coastal Plain fishes that exist above the Fall Line in the Cahaba River. Such populations likely face different hydraulic, thermal, and other habitat features as compared to Coastal Plain populations which could promote morphological or life history adaptation at small spatial scales (Machado et al. 2002). The unique adaptations, genetic diversity, or mere locations of peripheral populations of Coastal Plain species above the Fall Line could also be important under future threats such as habitat destruction, episodic pollution, or climate change that may threaten downstream Coastal Plain populations. Based on our findings, small dam removal on the Cahaba River may have contributed to upstream range expansion for several species, opening new habitat area and potentially benefiting these fishes.

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