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Movement of Translocated Adult Sicklefin Redhorse (*Moxostoma* sp.) in the Oconaluftee River, North Carolina: Implications for Species Restoration

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Movement of Translocated Adult Sicklefin Redhorse (*Moxostoma* sp.) in the Oconaluftee River, North Carolina: Implications for Species Restoration

Abstract

The Sicklefin Redhorse is a rare, undescribed species of *Moxostoma*, endemic to the Hiwassee and Little Tennessee River basins of western North Carolina and northern Georgia, where it has been eliminated from much of its native range. It is listed as endangered in Georgia and threatened in North Carolina. Although it has not been granted federal protected status, this species is the subject of a Candidate Conservation Agreement between federal, state, tribal, and private stakeholders, of which one objective calls for the re-establishment of Sicklefin Redhorse populations throughout its historical range. The objective of our study was to evaluate suitability of North Carolina's upper Oconaluftee River for reintroduction of Sicklefin Redhorse, by tracking movement patterns of translocated individuals. Ten native Sicklefin Redhorse were collected from the Tuckasegee River in Swain County, NC, implanted with radio transmitters and translocated into the Oconaluftee River upstream from Ela Dam. Fish were tracked individually using radio telemetry for six months. Movement patterns for newly translocated fish, as well as seasonal patterns for females, were comparable to those shown in previous studies within the current range of Sicklefin Redhorse. Although some fish moved extensively, the sedentary patterns observed in females suggests that the upper Oconaluftee River may provide suitable overwinter habitat for the Sicklefin Redhorse. However, additional data are needed concerning spawning suitability and rates of downstream migration past Ela Dam before reintroducing Sicklefin Redhorse back to this portion of its native range.

Keywords

Sicklefin Redhorse, Moxostoma, Restoration, Impoundment, Habitat Fragmentation

Cover Page Footnote

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INTRODUCTION

Moxostoma is the most diverse genus within the family Catostomidae, comprising 17 species in the southeastern United States (Cooke et al. 2005). First recognized as a distinct species in 1992, the Sicklefin Redhorse (*Moxostoma* sp.) is endemic to the Hiwassee and Little Tennessee River basins of western North Carolina and northern Georgia (Jenkins 1999). This medium-sized potamodromous catostomid is relatively long-lived, with males persisting up to 20 years, and females 22 years (Favrot 2009, Stowe 2012). Its olive-colored body is elongated and somewhat compressed, similar in shape and color to other redhorse species; however, it is identifiable by a sickle-shaped olive- to red-colored dorsal fin. Pectoral, pelvic, and anal fins are primarily dusky to dark, tinted pale orange or yellow along the edge, while caudal fins are mostly red. Like other *Moxostoma* it is a benthic omnivore, feeding on macroinvertebrates, small bivalves, and gastropods (Jenkins 1999). Sicklefin Redhorse was traditionally an important food source for the Cherokee people throughout the species' historic distribution, with harvest taking place during annual spring spawning migrations (Davis 2016).

Currently, the Sicklefin Redhorse is state-listed as endangered in Georgia (GADNR 2015), and as threatened in North Carolina (NCWRC 2015). Although it has not been granted federal protection under the Endangered Species Act, it is the subject of a Candidate Conservation Agreement (CCA) between federal, state, tribal, and private stakeholders aimed at curbing reductions in population, as the species has been eliminated from 50% of its historical range (USFWS 2015). Factors hindering conservation efforts for many catostomids include a lack of basic natural and ecological life history information, and a misconception that suckers are tolerant fish with little social or ecological value (Cooke et al. 2005). Protection and recovery of the Sicklefin Redhorse has been especially challenging due to the lack of information on movement patterns, habitat use, and overall life history attributes (Favrot and Kwak 2018).

Fragmentation due to stream impoundment, habitat loss, and the restriction of natural range size are thought to be the main factors affecting Sicklefin Redhorse populations (Jenkins 1999, Favrot 2009, Stowe 2012, Coughlan et al. 2007). In particular, dams and their resulting reservoirs have greatly altered the Sicklefin's distribution (Jenkins 1999). Movement patterns of other *Moxostoma* vary seasonally, with upstream movements commonly occurring during pre-spawning periods (Grabowski and Isely 2006, Grabowski and Jennings 2009). Redhorse species richness has been positively related to unimpounded stream fragment length (Reid et al. 2008, McManamay et al. 2015). Shorter fragment lengths may not be sufficient to support yearly spawning migrations (Cooke et al. 2005). In the

Hiwassee River, Favrot and Kwak (2018) documented pre-spawn migrations of Sicklefin Redhorse into upstream tributaries in response to increasing discharge in March and April.

The Sicklefin Redhorse CCA lists re-establishment of populations throughout the species' historical range as a conservation goal. In North Carolina's Oconaluftee River, Sicklefin Redhorse historically occupied sections upstream from the Ela Dam (Figure 1). The Ela dam currently impedes upstream movement from the Tuckasegee River and lower reaches of the Oconaluftee River, where spawning has been documented, into the upper Oconaluftee (Figure 1). The objective of this study was to investigate fall and winter movement patterns of translocated adult Sicklefin Redhorse using radio telemetry to help determine the suitability of the Oconaluftee River upstream of Ela Dam as a future reintroduction site.

METHODS

Study Sites

The Oconaluftee River is a major tributary of the Tuckasegee River, forming at the confluence of Kephart Prong, Kanati Fork, and Smith Branch in the Great Smoky Mountains National Park (Figure 1). This moderately steep, rain-fed mountain stream has coarse substrate and shallow depths, as well as large boulders and bedrock that create deep pools. It is approximately 30 km long, with a maximum headwater elevation of 1,611 m, and drainage area of 477 km^2. The Ela Dam, a 10.6 m hydroelectric dam, creates a small reservoir before the Oconaluftee River confluences with the Tuckasegee River. Approximately 13 km downstream of the confluence, the river enters Fontana Lake, a 410 km^2 lake impounded by Fontana Dam, a 150 m multi-purpose dam completed in the early 1940's.

Study sections were divided into riffles, runs, and pools. Riffles were defined as stream sections where water breaks over substrate, or where the water surface is visibly broken, creating whitewater. Runs were sections of river downstream from riffles, occurring where water flows rapidly without breaking the surface. Pools were defined as sections of the river with a slow current and greater depth than riffles and runs.

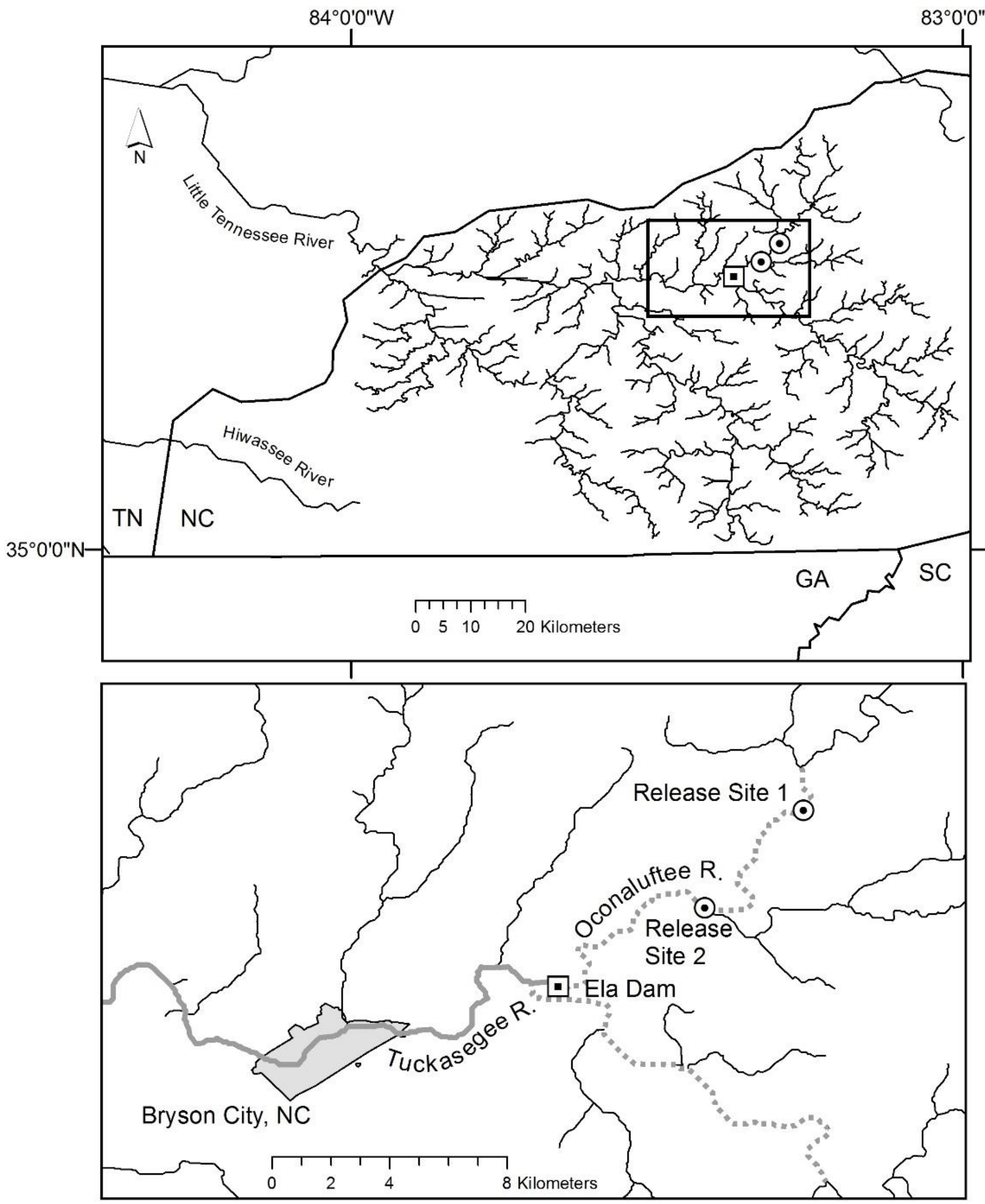

Figure 1. Study area on the Oconaluftee River in western North Carolina, showing release sites for translocated Sicklefin Redhorse (*Moxostoma* sp.). In bottom panel, solid gray line denotes current range, and dotted gray line denotes currently unoccupied portions of historical range targeted for population restoration.

Translocation

On 26 August 2014, personnel of the US Fish and Wildlife Service (USFWS) and the Eastern Band of Cherokee Indians (EBCI) used boat electrofishing to capture ten adult Sicklefin Redhorse from the Tuckasegee River below the confluence of the Oconaluftee River. Sex was determined for all but one of the captured fish (tag #15), and total length (mm), fork length (mm), and weight (kg) were recorded for all individuals. Benzocaine concentrations of 35–40 mg/L were used to anesthetize fish until they experienced a loss of equilibrium and reduced opercular rate.

US Fish and Wildlife Service personnel inserted individual pulse-coded radio transmitter tags (Lotek Nanotag, NTC-6-2, Lotek, Inc., Newmarket, ON, Canada) into the peritoneal cavity of each individual via an incision made in the abdomen, with the trailing antenna protruding through a posterior incision made using a gauged needle. Transmitters had a frequency of 149.320 MHz, a 10 second burst rate, and a 678 day battery life. Fish were allowed to recover in in-stream holding cages before translocation. Two release sites were chosen on the upper Oconaluftee River within the species' historic range, five fish were released at each site in pools where the species was known to previously occur (Figure 1).

Tracking Procedure

Individuals were located using a Lotek SRX-400A telemetry receiver (Lotek, Inc., Newmarket, ON, Canada). Locations were determined using the highest pulse value obtained from the stream bank for a duration of 3 pulse cycles, with visual verification conducted when possible. Tracking surveys were conducted weekly for four weeks after translocation, then every 2-3 weeks thereafter. Global Positioning Systems (GPS) coordinates were recorded for fish locations. Kayaks were used on two occasions to float the river and reservoir created by the Ela dam to search locations not easily accessible by road.

Data Analysis

Data analysis was limited to five individuals that were located throughout the study. The distance an individual moved between tracking surveys was calculated using Google Earth software (www.google.com/earth). If visual verification of an individual's location was not possible, the distance an individual moved was calculated from the center of the river parallel to the strongest pulse signal location from the stream bank. Margin of error for GPS locations was approximately 5 m, therefore an individual was considered stationary if it was found within 5 m of the previously known location. Original release sites were used as 0 m starting points for each fish. Absolute distance moved and total displacement were calculated from an individual's release site. Absolute distance moved was the total sum of distance moved between each location. Displacement was measured as the net distance moved from each release site. Movement patterns for each fish were categorized as either occurring within the same pool and its associated run, upstream across a riffle, or downstream across a riffle. To relate river temperature and discharge to movement patterns, data were obtained from United States Geological Survey gaging station #03512000 on the Oconaluftee River at Birdtown, NC, approximately 3 km downriver from release site #2. Because fish behavior can be altered due to a recovery period after tag implantation, we treated location data obtained for the first 30 days after translocation separately from the rest of the study period (*sensu* Gilroy et al. 2010). This also provided fish an exploratory phase to find suitable habitat (Grabowski and Jennings 2009).

RESULTS

Ten translocated Sicklefin Redhorse were located 79 times between 29 August 2014 and 10 February 2015. Individual fish were located between 2 and 17 times, with a mean of 9.8 locations per individual. Five fish experienced tag failure or met other unknown fates between 7 and 28 September and were excluded from further analyses. Of the remaining fish, four were female, and one was of unknown sex (Table 1). The majority of locations occurred in the same pool/run sequence that the fish had occupied during the previous sampling period.

Individual variation in movement was high, with the total distance an individual moved ranging from 2.0 to 12.8 river kilometers (rkm), and displacement from the release site ranging from 1.4 to 11.8 rkm (Table 1). The largest displacement was seen in fish #14, whereas all other fish remained within 2.3 rkm of their release site (Figure 2). Fish #14 also was the only fish that passed over Ela Dam, while all other fish remained well upstream. Individuals were generally sedentary during winter, with no movements occurring for four of the five individuals (Table 1). Fish #14, however, moved 5.9 km downstream during the winter.

Despite the high level of individual variation, some consistent movement patterns emerged (Figure 2). Movement was much more common during the 30-day readjustment period than afterwards; 7 of 15 detected movements occurred during this time, even though sampling effort was more concentrated (10 of 15 relocation attempts) afterwards. Indeed, two fish remained completely stationary after initial movements during the readjustment period.

Table 1. Physical data and movement patterns for Sicklefin Redhorse (*Moxostoma* sp.) tagged on August 26th, 2014 in the Oconaluftee River, NC. Length refers to total fish length in mm, Relocations are the total number of times an individual was found, Same Relocation is the number of times an individual was found within the same pool or run area, Downstream Displacement is the total displacement an individual traveled from the original release site (km), Total Distance is the total distance an individual moved throughout the survey after the initial adjustment period (km), Fall Range is the linear distance (m) an individual moved within the fall months, Winter Range is the linear distance an individual moved within the winter months. Note: Fish relocated within 5m of the previous position were considered to have remained stationary to account for GPS error.

Fish	Length	Weight	Sex	Release Site	Relocations	Same Relocation	Downstream Displacement	Total Distance	Fall Range	Winter Range
14	591	1.60	Female	2	12	9	11.8	12.8	>5664	unknown
15	538	1.30	Unknown	1	17	13	2.3	3.3	384	0
18	600	1.65	Female	2	15	10	1.4	2.0	310	0
19	510	1.25	Female	1	17	14	1.4	2.1	105	0
20	605	2.00	Female	2	17	14	2.1	2.1	0	0

Downstream movements were much more common than upstream movements, with only 2 of 8 post-readjustment movements occurring in the upstream direction; during the readjustment period, fish only moved downstream. Similarly, long distance movements were infrequent, with only 2 of 8 post-readjustment movements, (3 of 7 during readjustment) covering more than 1 rkm. However, 4 out of 5 fish exhibited overall downstream displacement of more than 1 rkm during the 30-day readjustment phase.

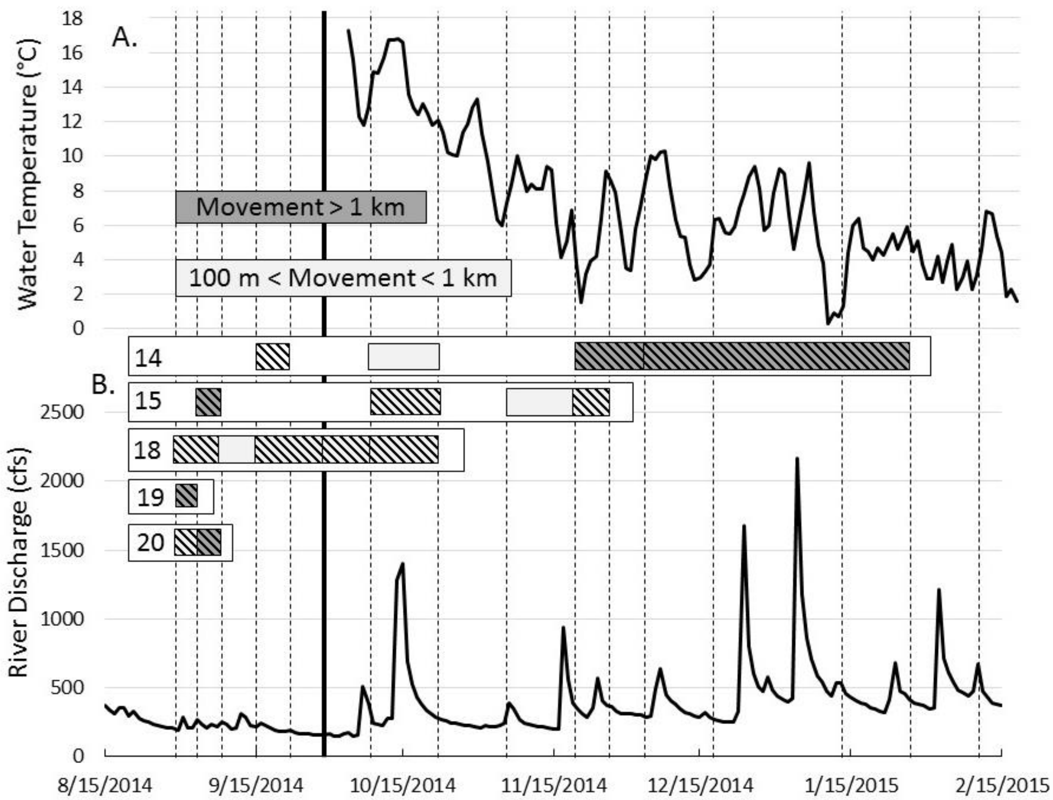

Figure 2. Sicklefin Redhorse (*Moxostoma* sp.) movements relative to water temperature (A) and river discharge (B) on the Oconaluftee River from 29 August 2014 to 10 February 2015. River temperature and discharge measured at United States Geological Survey Gaging Station 03512000 at Birdtown, NC (Note: Water temperature values were missing prior to 3 October 2014). Dashed vertical lines indicate dates that fish were located. Movements of numbered Sicklefin Redhorse individuals denoted by polygons on panel B; light polygons represent movements between 100 m and 1 km in length, and dark polygons represent movements greater than 1 km; hatched polygons indicate downstream movements, and open polygons upstream movements. Placement of polygons indicates date of last confirmed fish location before (left edge of polygon) and first location after (right edge of polygon) movement. See Table 1 for physical data on numbered Sicklefin Redhorse individuals. Dark vertical line indicates end of the 30-day readjustment period.

Due to our small sample size, it is difficult to draw inferences about effects of river discharge and water temperature on movement, but a few observations stood out (Figure 2). As mentioned above, movement rates were lower in winter; fishes #18, #19 and #20 did not move at all after water temperatures dropped below 10° C. However, fishes #14 and #15 both moved at the end of November, when temperatures dropped below 2° C. Temperature fluctuated greatly between relocation efforts. There were four high-flow events above 1,000 cfs (Figure 2). Three of five fish moved in mid-October, the same period as the first high-flow event. Subsequent high-discharge events occurred when water temperatures were low; all fish remained stationary during these periods except fish #14, which was making its long-distance movement downstream.

DISCUSSION

Radio-tagged Sicklefin Redhorse movement patterns were similar to those reported for other *Moxostoma* species following translocation (Favrot 2009, Stowe 2012, Grabowski and Jennings 2009). Most movements occurred in the first month, or readjustment period, when fishes were moving downstream. Such initial patterns of habitat exploration have been observed across many translocated species (Grabowski and Isely 2006, Gilroy et al. 2010). Once this readjustment period ended, with the exception of fish #14, individuals displayed high site fidelity, with very few movements made outside fall and wintering sites. Fish remained stationary over this period even during high flow events, indicating that movements were intentional and not based upon flow variations.

Our results support conclusions of previous studies (Grabowski and Isely 2006, Grabowski and Jennings 2009, Favrot and Kwak 2018), that most *Moxostoma* movements occur during the spawning season, with fewer movements occurring during fall and winter periods. The importance of “imprinting” of spawning sites for catostomids as a reproductive strategy is not well understood (George et al. 2009). Other redhorse species have shown high site fidelity and specificity to both spawning sites and home ranges (Grabowski and Isely 2006). While Robust Redhorse (*Moxostoma robustum*) establish a much larger home range of 16 – 17 km for fall, winter, and spring (Grabowski and Jennings 2009), Sicklefin Redhorse generally have a smaller fall and wintering home range of 0.009 – 10.92 km (Favrot 2009, Favrot and Kwak 2018, Stowe 2012). Four out of five individuals tracked during our study were within the Sicklefin Redhorse fall and winter home range size as reported above. Fish #14 was the only individual to move beyond the previously reported fall and winter range sizes, moving a total of 11.8 km downstream from its release site. Differences in range size between Sicklefin and Robust Redhorse may be due to differences in the lotic systems where they occur.

Although dams are present in both areas, the streams which the Sicklefin Redhorse occupy are small, steep mountain streams whereas the Savannah River, where the Robust Redhorse was studied, is much larger, with smaller drops in elevation. Consequently, range of the Sicklefin Redhorse may be naturally limited compared to that of the Robust Redhorse.

Although limited by the small number of individuals relocated, our results also support conclusions regarding sexual dimorphism in Sicklefin Redhorse movement. Following release, females have been observed in the Tuckasegee to remain stationary after post-spawning in autumn and winter, and only begin to move again in spring (Stowe 2012). Males typically have a smaller home range during fall and winter, but do not always remain stationary throughout the season (Favrot 2009, Stowe 2012). This pattern of females having high fidelity to a single site was generally consistent with our findings. Sex of fish #15 was unknown, but due to the similar patterns displayed by Sicklefin Redhorse females in our study, we suspect the fish #15 was also female.

The exception to female sedentary site fidelity was fish #14, which initially remained in a large pool (216 m length) with an extensive run. This pool was within 200 m of its initial translocation site, and fish #14 remained there at least until November 4, when it began a downstream migration. It is unknown when specific movements occurred; however, this was the only fish to pass over Ela Dam and return to the site where it was initially captured from the Tuckasegee River prior to tag implantation. While it did show initial site fidelity at its release site, it migrated downstream to what was likely its natural over-wintering site.

The Ela Dam and other dams on the Tuckasegee River and its tributaries inhibit the Sicklefin Redhorse's upstream movement throughout its native range. Currently, there is not enough evidence to support or refute whether a population can remain viable upstream of the Ela Dam without removal, although suitable spawning habitat is present. Lack of recruitment from stocking efforts over 10 years combined with documented juvenile Sicklefin Redhorse migrating downstream over Ela Dam (Stowe 2012) may indicate that many of these fish are either not surviving or moving below Ela Dam. Long term monitoring of fish translocations includes consideration of detection probability (George et al. 2009). Very low mark-recapture rates with viable populations of golden and back redhorse species in the Oconaluftee suggest it would be difficult to detect a small population of previously stocked age-0 Sicklefin Redhorse. Since one of our fish did move downstream of Ela Dam, it will be unable to return to its translocation site, or to move back upstream to spawn. The presence of the dam did not appear to affect the movement patterns of any of the remaining fish in the study. Future stocking of a variety of age classes and adult translocation in larger numbers are being considered by the USFWS and the EBCI.

To fully understand whether the Oconaluftee above Ela Dam is suitable for Sickefin Redhorse reintroduction, additional data are needed on both male and female annual movement patterns to determine the full effects that Ela dam may pose to this imperiled species. The fact that most females moved little once the exploratory phase ended suggests that the Oconaluftee still provides suitable overwinter habitat for the Sicklefin Redhorse. However, while appropriate wintering sites are essential, successful spawning in upstream tributaries also needs to be documented, and the rates at which adults, particularly males, are lost due to migration over Ela Dam must be further quantified before moving forward with translocations.

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