Proceedings of The National Conference
On Undergraduate Research (NCUR) 2015
Eastern Washington University, Cheney WA
April 16-18, 2015

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

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Abstract

The southeastern United States contains the most diverse freshwater fauna in North America, yet many of these species are imperiled. The Sicklefin Redhorse is currently an undescribed species of the genus *Moxostoma*, endemic to the Hiawassee and Little Tennessee river basins of western North Carolina and northern Georgia. They are listed as a priority wildlife species of North Carolina with a state status of "significantly rare", and are expected to gain federal protection under the Endangered Species Act within the next year. Like many potamodromous fishes, the Sicklefin Redhorse population is at risk of fragmentation due to stream impediments, habitat degradation, and restriction of its natural home range. The objective of this study was to determine the suitability of the Oconaluftee River, which is historically within Sicklefin Redhorse's home range, for future reintroductions by tracking movement patterns of translocated individuals. Ten native Sicklefin Redhorse were collected from the Tuckasegee River in Swain County, NC, surgically implanted with radio transmitters, and translocated into the Oconaluftee River. Fish were tracked individually using radio telemetry for six months. Movement patterns for newly translocated fish, as well as seasonal patterns for female Sicklefin Redhorse, were comparable to those found within their current range. Although some fish moved extensively, the sedentary patterns observed in females is indicative that the habitat provided in the Oconaluftee River may be suitable for the Sicklefin Redhorse. Continued observation throughout the spawning season will help in fully determining suitability of the Oconaluftee river for future management and restoration of this imperiled species to its native home range.

Keywords: Translocated, Adult Sicklefin, Oconaluftee River, NC

1. Introduction

The southeastern United States has one of the most diverse freshwater fish faunas in North America[1, 2, 3]. The American Fisheries Society lists approximately 662 native freshwater fishes from drainages spanning the southern U.S., from Virginia to southeastern Kansas to Texas, with approximately 28% deemed in need of conservation [2]. Non-game fishes historically have lacked comprehensive management strategies, with many species becoming imperiled before conservation efforts focus on them[3]. The genus *Moxostoma* displays the most diversity of the sucker family Catostomidae, comprising 17 species in the southeast[3, 4]. First recognized as a distinct species in 1992, the Sicklefin Redhorse is currently an undescribed species of *Moxostoma*, endemic to the Hiawassee and Little Tennessee River basins of western North Carolina and northern Georgia[5].

Sicklefin Redhorse are medium-sized potamodromous fish that are relatively long-lived, with males persisting up to 20 years, and females 22 years[7, 8]. Potamodromous fish are born in upstream freshwater habitats, make downstream migrations as juveniles, and migrate upstream to spawn as adults. They have an elongated and somewhat compressed olive-colored body that is similar in shape and color to other redhorse species, but 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 the caudal fins are mostly red. All *Moxostoma* are benthic omnivores that feed on macroinvertebrates, small bivalves, and gastropods [5]. Currently there are three genetically distinct populations of Sicklefin Redhorse, each relating to the three distinct river drainages, the Hiwassee, the Tuckasegee, and the Little Tennessee, with evidence of straying between the Tuckasegee and Little Tennessee populations[9].

Sicklefin Redhorse is listed as a priority wildlife species in North Carolina, with a state status of "significantly rare", and is expected to gain federal protection under the Endangered Species Act within the next year (Mark Cantrell, USFWS, *pers. com*.). When federal protection is gained, it will be one of only three federally listed endangered freshwater fish species endemic to North Carolina[6]. Factors that have slowed conservation efforts for all 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[3]. Conservation efforts for the protection and recovery of this species have been hindered by the limited amount of knowledge concerning movement patterns, habitat use, and overall life history[7].

There is a critical need to identify Sicklefin Redhorse home range and habitat preferences if reintroduction programs are to be successful. Fragmentation due to stream impoundments, habitat loss, and the restriction of natural home range are hypothesized to be the main factors influencing reduced populations of the Sicklefin Redhorse[5, 7, 8, 10]. Stream impoundments not only present physical barriers to natural migratory patterns, but are also responsible for changes in flow regime, temperature, sedimentation levels, riparian vegetation, and stream contours[10, 11]. Each of these changes is known to adversely affect many fishes by increasing habitat loss[11]. Fragmentation and isolation may also limit recolonization by fishes, and prevent full recovery of the community[12, 13]. Habitat loss and fragmentation have resulted in historic home range reductions for many imperiled fishes[5, 14, 15]. Dams and their resulting reservoirs have greatly altered the native home range and habitat of the Sicklefin Redhorse[5]; the Ela Dam impedes their potential upstream movement from the Tuckasegee River into the Oconaluftee River but does not impede any downstream movement. The main objective of this study was to determine the suitability of the Oconaluftee, a river that is historically within Sicklefin Redhorse's home range, for future reintroductions. To determine suitability we looked at individual variation of distances moved during the fall and winter of translocated adult Sicklefin Redhorse.

2. Methodology

2.1 Study Sites

The Oconaluftee River is a tributary of the Tuckasegee River, forming at the confluence of Kephart Prong, Kanati Fork, and Smith Branch in the Great Smoky Mountain National Park. This moderately steep rain-fed mountain stream has low levels of sedimentation, coarse substrate, 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 hydroelectric dam, creates a reservoir before the Oconaluftee River confluences with the Tuckasegee River. Approximately 13 km downstream of the confluence, the river enters Fontana Lake, a 27 km lake impounded by Fontana Dam, the tallest dam in the Eastern United States[8].

2.2. Translocation

Translocation is defined as the movement of wild-caught fishes from one place to another within their known range[18]. On August 26th, 2014, personnel of the US Fish and Wildlife Service (USFWS) and the Eastern Band of Cherokee Indians used standard boat electrofishing to capture ten adult Sicklefin Redhorse from the Tuckasegee River. The sex of each was determined in all but one fish (tag #15). Total length (mm), fork length (mm) and weight (kg) were also measured. Fish were anesthetized and passive integrative transponder tags were inserted into the musculature near the dorsal fin.

Experienced USFWS personnel then inserted individual pulse-coded radio transmitter tags (LOTEK Nanotag, NTC-6-2) into the peritoneal cavity of all captured fish via an incision made in the abdomen. The trailing antenna was allowed to protrude through a posterior incision made using a gauged needle. Transmitters had a frequency of 149.320mHz, a 10 second burst rate, and a guaranteed 678 day battery life. The trailing-wire antennae exited the body through a separate incision created by a surgical needle posterior to the incision made for the transmitter. Fish were then held and allowed to recover before translocation. Each fish had their health assessed and recorded before release. Two release sites were chosen on the Oconaluftee River that were deemed to have suitable habitat.

2.3. Tracking Procedure

Locations were established by myself and volunteers through use of a Lotek SRX-400A telemetry receiver. Tracking and location with antenna was initially accomplished by vehicle, using roadways parallel to the Oconaluftee River. After the general location was established for a specific fish, the exact position was found on foot using the highest pulse value obtained from the river bank for the duration of 3 pulse cycles, with visual verification as often as feasible. Fish were located weekly for the first month, then every 2-3 weeks thereafter. Global Positioning Systems (GPS) coordinates were recorded each time a fish was successfully located. A margin of error for GPS locations was approximately 5m, therefore we considered a fish stationary if it was found within 5m of the previous location. On two occasions kayaks were used to float the river and reservoir created by the Ela dam, in order to determine locations not accessible by roads.

2.4. Data Analysis

Google Earth was used to map movements and calculate distances moved for individual fish. When visual verification for exact location within the stream was not feasible, measurements were calculated from the center of the river based on strongest pulse signal location. Due to a loss of 5 of the fish, only data for the 5 fish that remained throughout the study were analyzed. The release sites were considered a 0m starting point for each fish. The absolute distance moved and total displacement was calculated from each release site. Absolute distance moved is the total sum of distance moved between each relocation. Displacement was calculated as the net distance moved from the release site. Hydrograph data were obtained from the USGS 03512000 gage on the Oconaluftee River at Birdtown, NC.

The term home range is used to describe the entire area in which an individual fish traveled through and used for daily activities during the study. To allow for a recovery period from being caught and implanted with a transmitter, as well as to limit bias related to release location, following a previous telemetry study, location data obtained for home range for the first 30 days was not included in analysis[19]. This also gave a period of time for an exploratory phase, consistent with other studies of translocated fish, to ensure that fish were not found at random spots during movements, but were actively choosing to stay within a given range.

To further understand the significance of each associated movement, all riffles, runs, and pools were identified along the study sites. A riffle is the area of the stream where water breaks over substrate or the water surface is visibly broken creating whitewater. Runs are generally located downstream from a riffle where the water is flowing rapidly until it slows into a pool. A pool is an area of the stream that has slower currents and greater depths than riffles and runs. After each location was mapped, movement patterns were quantified for each fish when it remained within the same pool and its associated run, when it moved to a pool or run upstream through a riffle, and when it moved downstream through a riffle.

3. Results

Radio-tagged Sicklefin Redhorse were relocated 79 times between August 29th, 2014, and February 10th, 2015. Individuals were relocated between 2 and 17 times, averaging 9.8 $\pm$ 6.5 (Mean $\pm$ Standard Deviation) observations per individual. Five of the 10 individuals were presumed to have tag failure or to have met unknown fates between September 7th and September 28th. These individuals were removed from further analysis. Of the remaining five fish, four were female, and one was of unknown sex (Table 1).

Absolute distance moved ranged from 1,958 to 12,755 river meters. Displacement ranged from 1,414 to 11,753 river meters (Figures 1 and 2). The largest displacement and range was seen in fish #14, whereas all other fish remained within 2,300 meters of each release site. Fish #14 was also the only fish that passed over Ela Dam, while all other fish remained well upstream of the Ela reservoir (Figure 2). Downstream movements were not affected by high flow events, as there were no movements made during these events (Figure 5).

Fall home range was calculated following the 30-day recovery period, beginning on September 28th and ending on the first day of winter, December 21st, 2014. Fish #14 was not located from December 2nd until January 27th, therefore determining a definite home range during the study was not feasible. After the 30 days discounted during the recovery period, fall home range for the remaining 4 fish varied from 0 to 384 meters (Table 1), and winter home range was 0 meters, with all fish remaining sedentary.

Fish made a limited amount of movements upstream (Figure 3). Only 3 out of 14 upstream movements went over riffles or runs. Once in a location, fish tended to stay within the same pool with its associated run (Figure 4). All of the movements upstream for fish #14 were within the same pool. Fish #18 and #20 made only one movement upstream through a riffle, but then returned to their wintering home site (Figure 2). Fish #15 and #19 made two movements each upstream through the riffle above its associated wintering site, also to return to their wintering home site (Figure 1).

3.1 Tables and Figures

Table 1. Physical data and home range size for Sicklefin Redhorse tagged on August 26th, 2014 in the Oconaluftee River, NC

Fish #	Total Length (mm)	Weight (kg)	Sex	Fall Range (m)	Winter Range (m)
14	591	1.60	Female	≥5664	unknown
15	538	1.30	Unknown	384	0
18	600	1.65	Female	310	0
19	510	1.25	Female	105	0
20	605	2.00	Female	0	0

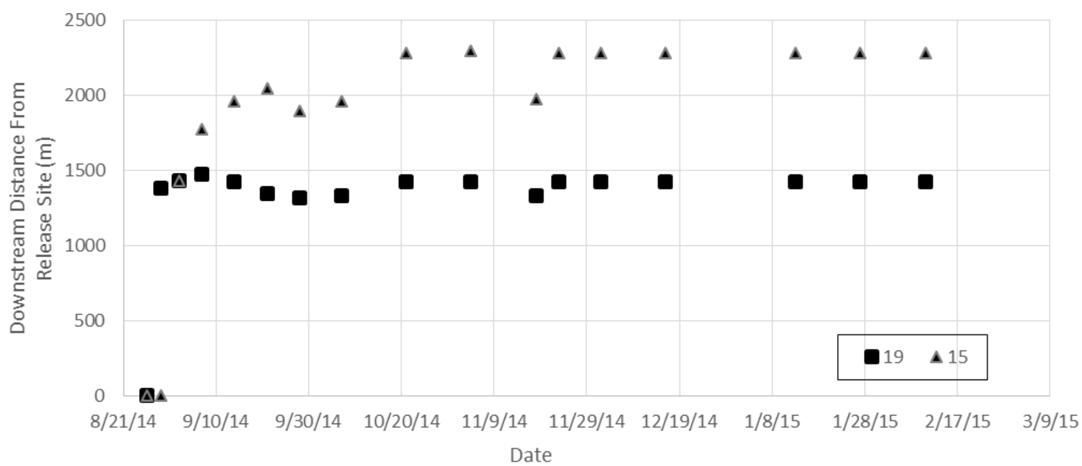

Figure 1. Movement patterns for tagged fish #19 and #15 from release site #1. River meters were calculated with the release site as 0.

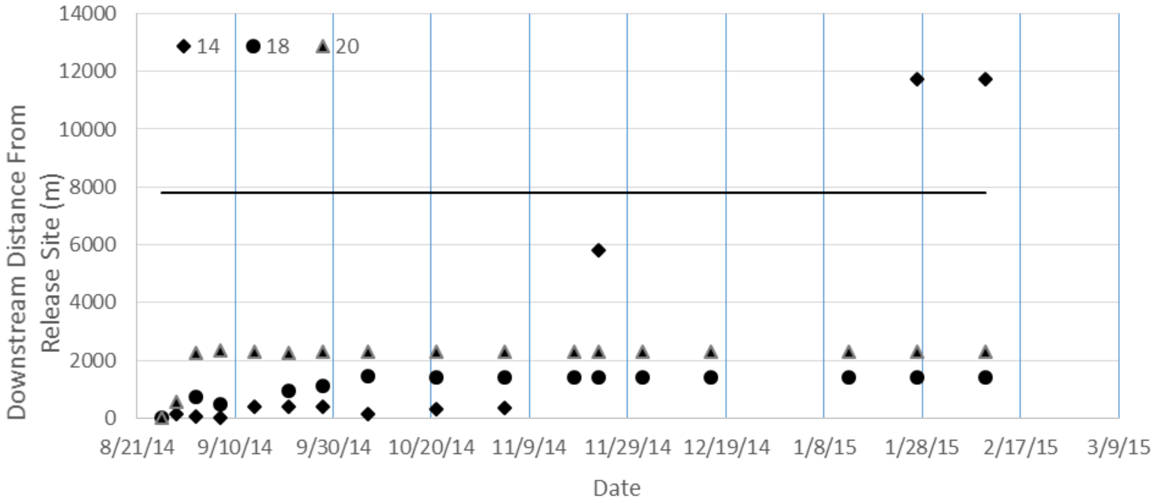

Figure 2. Movement patterns for tagged fish #14, #18, and #20 from release site #2. River meters were calculated with the release site as 0. Line at river meter 7790 marks the location of the Ela Dam.

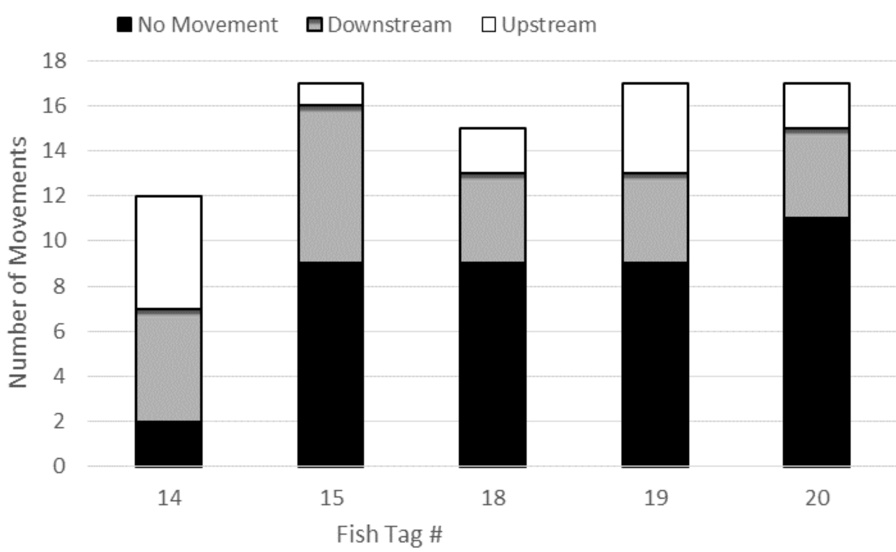

Figure 3. Sicklefin Redhorse movement patterns for each observed relocation

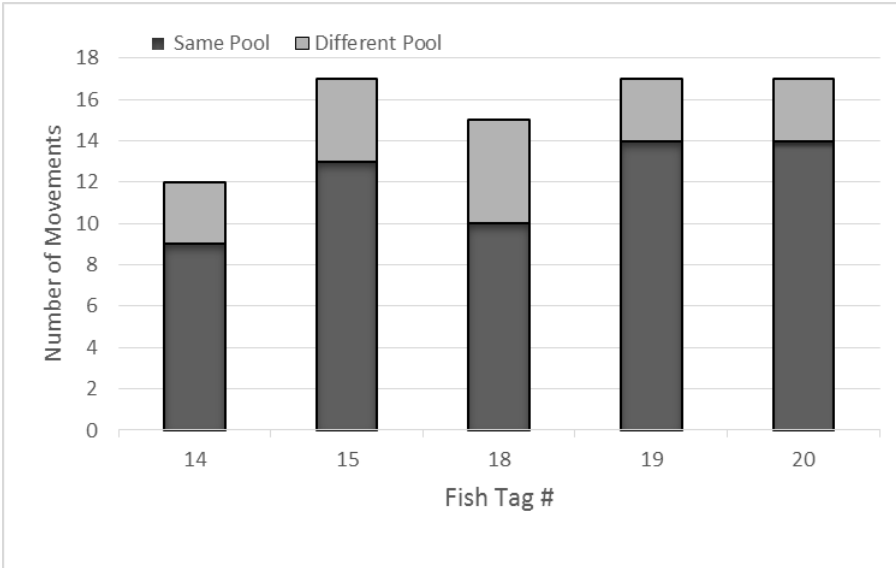

Figure 4. Sicklefin Redhorse movements observed within the same pool or to a different pool.

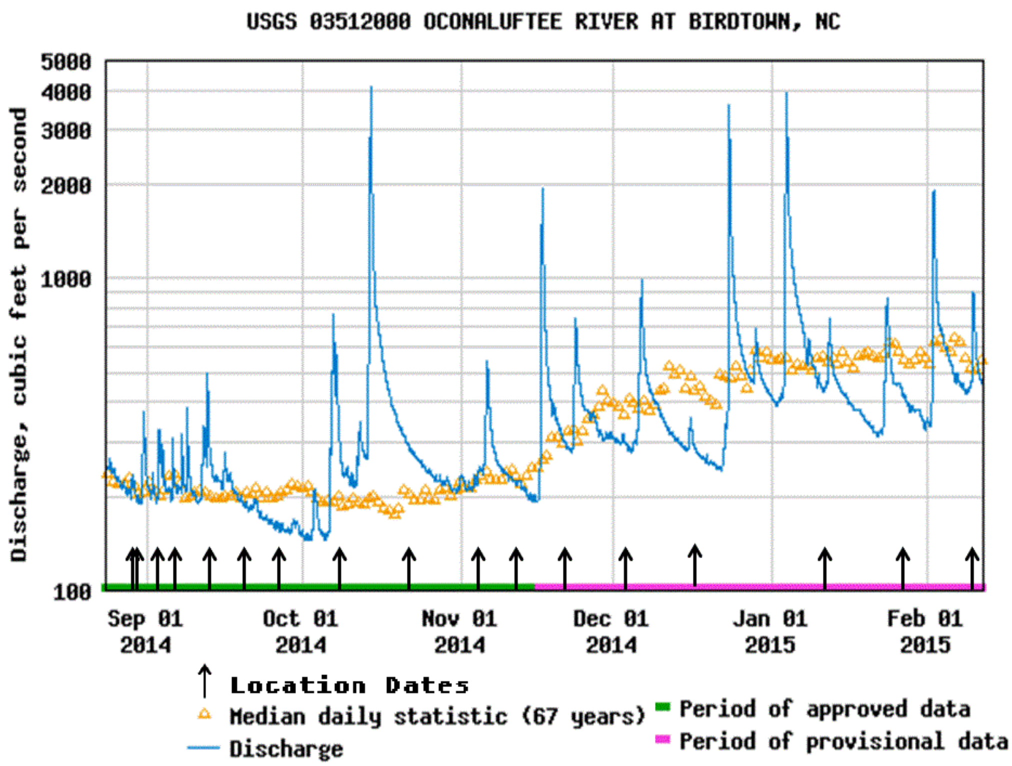

Figure 5. Hydrograph obtained from NC.water.usgs.gov for the USGS 03512000 gage on the Oconaluftee River at Birdtown, NC.

4. Discussion

Knowledge of movement and dispersal is crucial to understanding population dynamics[20]. In the present study, radio-tagged Sicklefin Redhorse showed similar seasonal movement patterns as other *Moxostoma* species following translocation. An initial exploratory phase during the recovery period (Figure 1 and 2) was observed and is consistent with other Robust Redhorse and Sicklefin Redhorse studies[7, 8, 21]. All of the fish seemed to go through this exploratory period that lasted for the allotted 30 days of recovery post release. Most of the movements within the first month were in the downstream direction. Similar patterns of exploration have been observed across many translocated species[17, 19]. Once the exploratory period ended, with the exception of Fish#14, they were found to have 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 made were intentional and not based upon flow variations.

Moxostoma species have been found to exhibit similar movement patterns, with larger movements made during spawning seasons, and fewer movements during post spawning seasons. In a similar study on Robust Redhorse (*Moxostoma robustum*), radio telemetry was essential in assessing the effectiveness of the stocking program, and whether individuals integrated into the resident population[16, 17]. Other redhorse species have shown a high site fidelity and specificity to both spawning sites and home ranges[17]. While Robust Redhorse establish a much larger home range of 16-17km for fall, winter, and spring [16], Sicklefin Redhorse have been seen to have a much smaller fall and wintering home range, 0.009 – 10.92km[7, 8]. All five fish in this study fall within the fall and winter home range previously found for Sicklefin Redhorse (Table 1, Figure 2). These findings may be consistent when considering the available habitat these two species occupy. While the movement of both of these imperiled species are limited from fragmentation created by dams impeding upstream movement, their native home ranges are quite different. The streams which the Sicklefin Redhorse occupy are smaller, steeper mountain streams in northern Georgia and western North Carolina, whereas the Savannah River, where the Robust Redhorse was studied, is 505 km in length, with much smaller drops in elevation. Consequently, home range of the Sicklefin Redhorse may be both naturally and unnaturally limited compared to that of the Robust Redhorse.

While seasonal patterns of movement have been observed between different *Moxostoma* species, there are also clear differences in the pattern of movement found between the sexes for Sicklefin Redhorse. Following release, females have been observed in the Tuckasegee to remain stationary following post spawning in autumn and winter, and only begin to move again in spring[8]. This pattern of females having high fidelity to a single site is consistent with this study's observations, with few exceptions. Males typically have a smaller home range during the fall and winter, but do not always remain stationary throughout the season[7, 8]. Sex of fish #15 is unknown, but due to the same observable patterns seen throughout other Sicklefin Redhorse females, it may also be a female. Due to the loss of the 3 tagged males, a comparison between the sexes was not achievable. Since the fate of these fish is truly unknown, they may have made long migrations of over 13 km into Lake Fontana where water depths are too deep for fish location. If relocation was not feasible due to water depth in Lake Fontana, then movements made by these fish would be faster than what has previously been observed, with one fish moving at least 7km in one week. Long post spawning migrations would not be unusual compared to some of the movements of males in Favrot (2009) and Stowe (2014), but it cannot be fully determined unless these fish are located again this spring.

The exception to female sedentary site fidelity was fish #14, which initially remained loyal to a relatively large pool (216 m) with an extensive run. This pool was within 200m of its initial translocation, and remained there at least until November 4th, when it then began a downstream migration. With access to the entirety of the reservoir restricted, it is unknown when specific movements occurred. However, this was the only fish observed successfully passing Ela Dam and returning to the site where it was initially electrofished from on the Tuckasegee. While it did show high fidelity initially to its release site, it then migrated downstream to its natural over-wintering site.

The Ela Dam and other dams on the Tuckasegee River and its tributaries inhibit the Sicklefin Redhorse's movement upstream. While one of our fish did move downstream of Ela Dam, it will not be able to naturally move upstream to return to its preferred translocation site, nor would any other of our females that had found suitable wintering sites. This supports previous findings of dams frequently being implicated as causes of population decline and extirpation of freshwater fishes[22, 23]. The presence of the dam did not affect the movement patterns of any of the remaining fish in the study. While this study has only observed the fall and winter movement patterns, the upper Oconaluftee River does provide coarse substrate, shallow depths, less sedimentaion, and fewer high flow events compared to the the Tuckasegee River, so it may be suitable for spawning[8]. To fully understand whether the Oconaluftee is suitable for Sickefin Redhorse populations, the ability for them to reproduce within this reach is paramount. If our males did survive and travel downstream of Ela Dam, they would be prevented from reaching the remaining females due to the dam. This creates a huge barrrier preventing future matings and the re-establishment of the population.

Continued observations of the remaining fish will proceed through the spawning season and the duration of the radiotags. While the sample size is too small for any significant statistical analysis, continued observation of these fish throughout the spawning season will be important in understanding this potamodromous fish’s lifecycle patterns. Because the females moved so little once the exploratory phase ended, it can be suggested that, to some degree, the Oconaluftee is suitable for the establisment of the Sicklefin Redhorse. We do not believe that the sedentary patterns were due su While wintering sites are essential, continued observations are also necessary to fully understand the life history of this rare fish.

5. Acknowledgements

I would like to express my deepest appreciation to my advisor, Dr. David Gillette, for always being there to answer my questions no matter how big or small. Thank you to Vanessa Hunter, my partner in crime throughout the project, Mike LaVoie, Mark Cantrell, C. Reed Rossell, Dallas Bradley, Jesse Blanton, all of the collaborators at The Eastern Band of Cherokee Indians and the USFWS, and all the Environmental Studies students, who helped with collecting data. To d.w. giddens, I thank for your time in the field, editing my drafts, fully expressing your opinions, being there when I unexpectedly lost my data, and, most importantly, for all the times in-between.

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