Conservation and Restoration of the Robust Redhorse *Moxostoma robustum* in the Oconee River, Georgia

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1. Introduction

This report is the sixth report in a series of bi-annual reports required by the Federal Energy Regulatory Commission (FERC) license for Georgia Power Company's (GPC) Sinclair Hydroelectric Project (FERC No. 1951). Article 404 of the Sinclair Project license, issued by the FERC on 19 March 1996 (effective date 1 May 1996), requires the submission of a progress report every two years to the FERC, "*which summarizes the status of the robust redhorse and makes a determination on the adequacy of flow releases in meeting the needs of this species*."

The original report, titled *Conservation and Restoration of the Robust Redhorse, Volume 1*, was submitted to the FERC in June 1998. Because conservation activities had begun prior to the issuance of the Sinclair license, *Volume 1,* presented detailed information about the rediscovery of the robust redhorse in 1991, the formation of the Robust Redhorse Conservation Committee (RRCC) in 1995, and other significant activities that occurred through April 1998. The second bi-annual report, titled *Conservation and Restoration of the Robust Redhorse, Volume 2,* was submitted to the FERC in April 2000 and was limited to conservation activities that occurred from June 1998 through April 2000. *Conservation and Restoration of the Robust Redhorse, Volume 3,* was submitted to the FERC in May 2002 and was limited primarily to activities that occurred between June 2000 and April 2002. *Conservation and Restoration of the Robust Redhorse, Volume 4,* was limited to activities that occurred between April 2002 and May 2004, and *Conservation and Restoration of the Robust Redhorse, Volume 5*, was limited to activities between May 2004 and May 2006.

This report begins with March 2007 activity results and continues through December 2008. The format of this report has been modified from that of the previous 5 volumes such that greater emphasis is placed on recent activities than on previously documented and reported work. More thorough discussions of activities prior to 2007 can be found in Volume 5 and in information maintained at the RRCC website, www.robustredhorse.com.

The material for this report was gathered from many sources, including complete and incomplete project reports, RRCC updates, letters, personal communications, and oral presentations (Appendix A).

1.1 Sinclair Hydroelectric Project

Sinclair Dam, a 45 megawatt hydroelectric project owned and operated by GPC, was completed in 1952 on the Oconee River near Milledgeville, GA. The dam forms the 15,330 acre Lake Sinclair, a popular fishing and recreation destination in central Georgia (Figure 1). The Sinclair Project is primarily used to provide generation capacity during peak demand periods, and it serves as the lower reservoir for Georgia Power's Wallace Dam pumped storage project.

During the early stages of FERC relicensing in 1991, a rare fish was “rediscovered” in the Oconee River downstream of the Sinclair Project. The fish was eventually identified as the robust redhorse (*Moxostoma robustum*) by several ichthyologists.

Figure 1. State of Georgia showing the location of GPC’s Sinclair Hydroelectric Project and major rivers within the Georgia portion of the historic range for the robust redhorse.

1.2 Robust Redhorse (*Moxostoma robustum*)

The robust redhorse was originally described in 1870 by Edward Cope from specimens collected in the Yadkin River, NC. Unfortunately, Cope’s original specimens were lost, and labels from those specimens were mistakenly applied to another species. Over the next 100 years, the robust redhorse was known by only two specimens, collected from the Savannah River, Georgia/South Carolina in 1980 and from the Pee Dee River, North Carolina in 1985. Those two specimens were believed to belong to an undescribed species of redhorse. The discovery of the Oconee River population of robust redhorse helped to clarify the description of this species.

In August 1991, biologists from the Georgia Department of Natural Resources (GA-DNR) collected five large suckers from the Oconee River downstream of Sinclair Dam.

Several well-known ichthyologists including Dr. Henry Bart (then curator of the Auburn University fish collection), Dr. Byron Freeman, curator of the University of Georgia (UGA) fish collection, and Dr. Robert Jenkins of Roanoke College, Virginia, worked to identify the specimens. They concluded the five specimens from the Oconee River were the same species as the two existing specimens collected in 1980 and 1985, and all these specimens belonged to the species originally described by Cope in 1870. The currently accepted historic range consists of southeastern Atlantic slope rivers, extending from the Altamaha River system in Georgia to the Pee Dee River system in North and South Carolina.

Subsequent reviews of available information by many agencies and individuals suggested that conservation and restoration actions should begin immediately for this species. Part of the concern centered on the lack of other records for the species, which potentially indicated that a sole remnant population had been rediscovered in the Oconee River. Another concern was that fish collections from the Oconee River showed a population comprised primarily of larger individuals (all greater than 400 mm TL), prompting concerns about a senescing population or some other problems that might be affecting recruitment of robust redhorse. The concerns included artificial flows from power generation, erosion and siltation, and introduced predatory species such as flathead catfish.

1.3 Robust Redhorse Conservation Committee

The RRCC was formed by the signing of a Memorandum of Understanding (MOU) in 1995. The RRCC was designed as a stakeholder partnership to restore the robust redhorse throughout its currently accepted former range. The primary goals of the RRCC are to implement research and conservation measures, enhance recruitment in existing populations, and re-establish robust redhorse populations in appropriate river systems within the species' former range.

The RRCC directs recovery efforts for the robust redhorse and sets priorities for necessary research and action building on previous results. Through collaborative information and resource sharing among members and other interested parties, the RRCC has identified potential threats to the species, conducted research related to those threats, and formulated solutions and implemented conservation actions. The RRCC has also been very effective in publicizing the recovery effort. As originally intended, the RRCC has been the driving force behind the conservation and restoration of the robust redhorse.

Mr. David Coughlan of Duke Energy served as the 6th Chair of the RRCC from October 2006 through October 2008. Mr. Forrest Sessions of South Carolina DNR is the current Chair and will serve in that capacity through 2010. While some individual representatives have changed, member organizations comprising the Executive Committee (Excom) have remained the same since 2005. Those members include the Georgia Department of Natural Resources (GA DNR), South Carolina Department of Natural Resources (SC DNR), North Carolina Wildlife Resources Commission (NC WRC), US Fish and Wildlife Service (USFWS), United States Geological Survey

(USGS), Georgia Power Company (GPC), Progress Energy and a representative from Academia.

Memorandum of Understanding

The MOU's purpose is to establish and describe the RRCC. The first MOU was approved in 1995 and expired December 31, 2004. The MOU was revised, became effective Jan 1, 2005, and expires December 31, 2009. No changes to the MOU have been made since the 2005 revision.

Robust Redhorse Conservation Strategy

The Robust Redhorse Conservation Strategy (Strategy) describes the extent of knowledge of robust redhorse and its distribution, discusses problems facing the species, and lists specific goals and objectives for robust redhorse conservation throughout its historic range. The Strategy also outlines procedures and actions believed necessary to reach those conservation goals and objectives. The Strategy is intended to be a flexible document and the RRCC may revise the Strategy as new information becomes available. No changes to the Conservation Strategy have been made since its approval in 2003.

Robust Redhorse Conservation Committee: Policies

The RRCC has developed a policy document, adopted October 18, 2002, which unifies practices and activities of member organizations needed to implement the long- and short-term goals established in the Strategy. These policies also provide a framework for the development of individual management plans for specific robust redhorse populations. In general, the policies are organized such that consistency among goals, conservation activities, and administration of the RRCC are maintained at all levels.

1.4 Candidate Conservation Agreement with Assurances for the Robust Redhorse: Ocmulgee River, Georgia

One of the primary stated goals for the RRCC is to create additional populations of robust redhorse by introducing the species to rivers within its historic range. In many cases, reintroduction can be successfully accomplished without incident. However, the RRCC recognized that reintroducing a rare species with potential to require future listing under the Endangered Species Act (ESA) could be problematic. In this case, the RRCC needed a sound approach for effectively handling one of the most critical components of the conservation effort.

One approach, published by the USFWS in 1999 (64 Federal Register 32726-32736 and 50 C.F.R. §§ 13 and 17), was the use of Candidate Conservation Agreements with Assurances (CCAA). CCAAs promote conservation actions by encouraging partnerships between private entities and state and federal natural resources agencies to protest rare species with the goal of addressing potential threats to their survival. Voluntary participants in such agreements may receive assurances from the USFWS that limit risk, should the target species of that agreement become listed under the ESA.

The Ocmulgee River, a candidate site for reintroduction, provided an opportunity for applying the CCAA policy. The upper reaches of the Ocmulgee River are influenced by generation from GPC's Lloyd Shoals Hydroelectric facility, which has a 30-year FERC license expiring January 1, 2024. During relicensing, minimum flow was increased to enhance aquatic habitat, and a labyrinth weir was constructed to improve dissolved oxygen concentrations in the river. GA DNR, USFWS, and the RRCC determined that the 18 mile reach downstream of Lloyd Shoals Dam was suitable habitat for a proposed reintroduction.

GPC has invested considerable time and dollars on environmental enhancements to the upper Ocmulgee River and believed these enhancements would also benefit any potential robust redhorse population. However, GPC also believed that a reintroduction of robust redhorse potentially represented an undefined risk to the Lloyd Shoals facility, if the species was federally listed under the ESA. GPC expressed these concerns to GA DNR and the USFWS, and those disccusions ultimately led to a CCAA for the robust redhorse (Candidate Conservation Agreement with Assurances for the Robust Redhorse (*Moxostoma robustum*), Ocmulgee River, Georgia, 2001).

Under the CCAA, GPC agreed to support specific conservation actions following introduction by the Georgia DNR, including funding for telemetry studies on the reintroduced fish, surveys, and population estimates. In return, GPC received assurances that if the robust redhorse is listed under the ESA, and the CCAA has been implemented in good faith by GPC, the USFWS will not require additional land, water, or resource restrictions beyond those that GPC voluntarily committed to under the terms of the original agreement. These assurances include the preservation of the flow regime described in the current FERC license for the Lloyd Shoals Project. The assurances are provided through an Enhancement of Survival Permit which will take effect if and when the robust redhorse is federally listed under the ESA.

This CCAA is important because it provides additional conservation actions for the robust redhorse while providing some regulatory certainty and operational flexibility to GPC. However, the CCAA might be more important to the overall conservation effort because it provides a working example of how potential reintroductions can be structured as a cooperative effort to benefit the species. It is believed that this CCAA for the robust redhorse was the second CCAA implemented in the United States. It was also the first CCAA to involve an aquatic species and a private company.

1.5 Flow Advisory Team for the Oconee River

The Flow Advisory Team for the Oconee River (Advisory Team) is implemented under Article 404 of the Sinclair license. The current members of the Advisory Team are the GA-DNR, GPC, Georgia Wildlife Federation (GWF), USFWS, and USGS. The primary responsibilities of the Advisory Team are to monitor the effectiveness of the negotiated flows for the Sinclair Project for the robust redhorse in the Oconee River. The agreement provides that the Advisory Team reviews flow data from the Oconee River, studies developed by the RRCC, and other pertinent information related to the robust redhorse to help determine if any changes to the negotiated flow agreement are necessary. If studies suggest that flow changes are needed for the Oconee River to improve habitat for the robust redhorse, the Advisory Team may petition the FERC, under consensus of members, with its recommendations. These recommendations would then be subject to appropriate FERC evaluation and approval.

Negotiated Flow Agreement

A negotiated flow agreement was finalized in 1995 (implemented June 1996) prior to the submittal of the license application for the Sinclair Project. The negotiated flow agreement, outlined in Table 1 below, was designed primarily to enhance reproductive success of the robust redhorse. Specifically, the flow agreement provides: 1) significant increases in minimum flows throughout the year, 2) a significant increase in flow stability throughout the year, and 3) run-of-river flows during spawning and early rearing periods for robust redhorse. Although primarily directed at robust redhorse, anadromous species were also considered during the formation of the flow agreement. The effects of this flow regime are discussed further below.

Table 1 Negotiated flow agreement for the Sinclair Hydroelectric Project.

MONTH	FLOW	OPERATION
Dec - Feb	500 cfs minimum	normal peaking
Mar - Apr	1500 cfs minimum	modified peaking[a]
May	run-of-river	
Jun[b] - Nov	700 cfs minimum	normal peaking

[a] modified peaking refers to the number of units (1 or 2) utilized, depending on inflow into the reservoir
[b] from June 1-10, units are operated run-of-river unless electric system demands necessitate normal peaking operation. The agreement also provides for an increase in generation (from 5 to 7 days per week) to reduce extended low-flow periods that previously resulted from little weekend generation.

2. Current Rangewide Species Status

Currently, robust redhorse populations exist in the Oconee, Ocmulgee, Ogeechee, and Broad Rivers, Georgia; in the Savannah River, Georgia and South Carolina; in the Broad and Wateree Rivers, South Carolina; and in the Pee Dee River drainage, North and South Carolina (Figure 2). The Oconee, Savannah, and Pee Dee populations are native, while the remaining five are introduced.

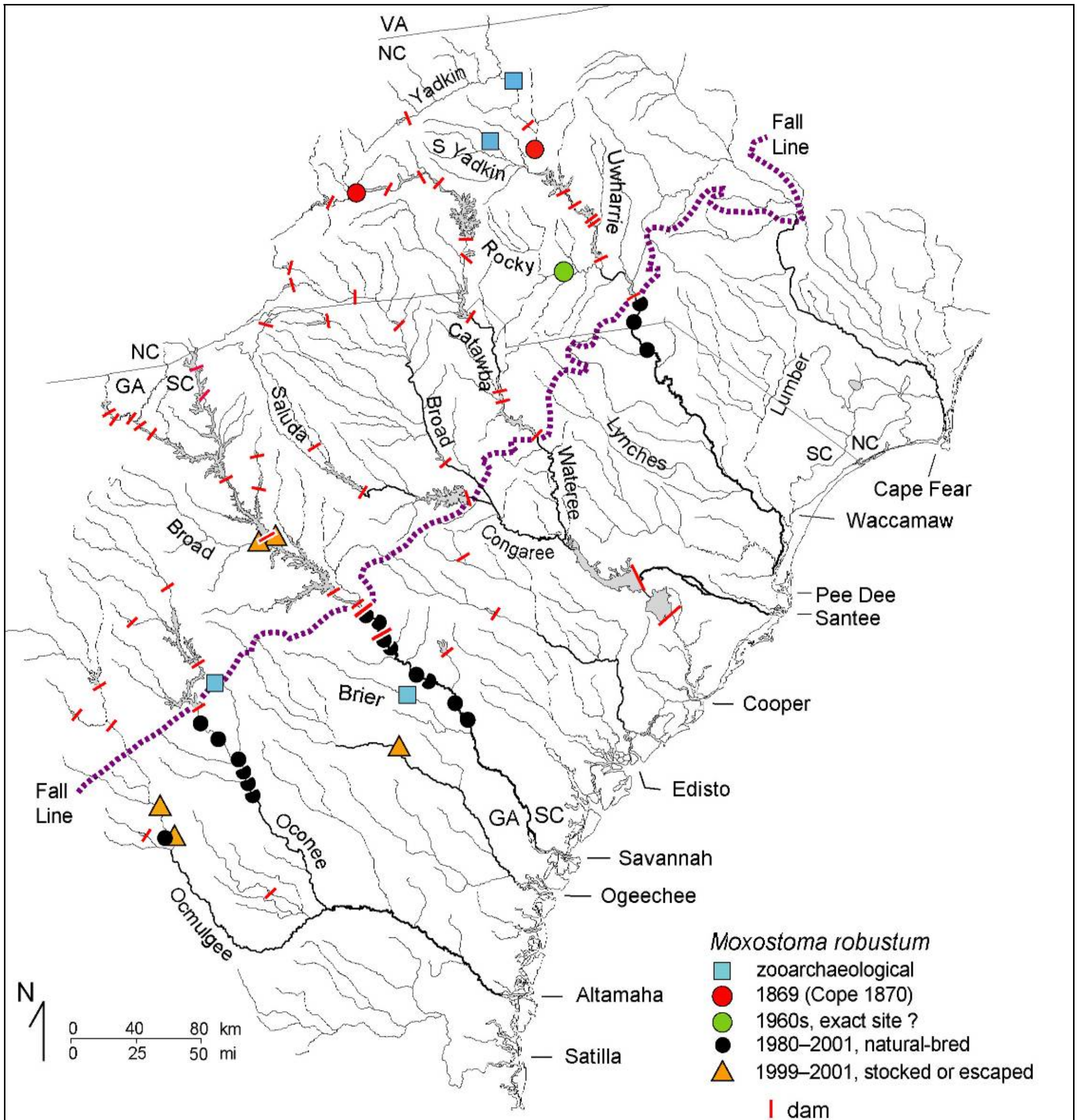

Fig. 00. Robust redhorse records of natural-bred fish (squares and circles); and of artifically-bred fish (triangles) captured after stocking or escape from rearing ponds. Dams shown mainly for larger streams (south of Cape Fear drainage). Savannah R. sites of the 4 record symbols crossed by dam symbols are below respective dams. Fall Line drawn from Anonymous (1963a–c) and Harris and Zullo (1991). Oconee R. detail in Fig. 00; hypothetical total range in Fig. 00.

Map by R. E. Jenkins, B. J. Freeman, and J. W. Evans (Dec 2001)

Figure 2. Map of the current range of robust redhorse in Georgia, South Carolina, an North Carolina.

2.1 Oconee River Population (GA)

Most information on the status of the Oconee River population is based on selective electro-fishing along a 30 river mile section during spring broodfish collection from 1994 to 2008. During broodfish collection and other studies on the Oconee River between 2002 and 2008, catch rates of adult fish decreased from previous years, and no juveniles or young-of-year were collected. Adult population estimates have also declined over this time period. A more in depth discussion of the Oconee River population status is included below in Section 3.

2.2 Ocmulgee River Population (GA)

Activities associated with robust redhorse conservation in the Ocmulgee River are described in an update to FWS in Appendix B. To date, 13,734 robust redhorse representing 10 year classes have been stocked into the Ocmulgee River below Lloyd Shoals Dam. Electrofishing surveys conducted in 2008 yielded 13 individuals from four year classes ranging in size from 300 to 600 mm TL (total length), and catch rates in Ocmulgee averaged 1.3 fish/hour.

In summary, stocking efforts in the Ocmulgee River appear to have been successful, although continued monitoring is necessary to fully document this success. Robust redhorse from various size classes have been collected in monitoring efforts to date, and two untagged juvenile specimens collected in 2008 indicate some level of natural reproduction and recruitment in the river. Stocking has been suspended in the Ocmulgee due to these findings and in conjunction with the observation of spawning activity, higher than suspected survival of stocked fish, and the need to redirect limited resources towards more intensive monitoring of the population. While the Ocmulgee population was originally intended as a refugial or reintroduced population, recent studies have suggested that native robust redhorse might have been present within the system at the time of initial stocking. Telemetry studies have also demonstrated that specimens may move great distances within the Altamaha Basin, and individuals comprising Oconee and Ocmulgee populations may coexist in lower reaches of each river and within the Altamaha below their confluence.

GPC has also studied the effectiveness of the labyrinth weir below Lloyd Shoals Dam, designed to improve tailrace water quality, since 1991. Results of those studies showed that weir improvements on instream water quality were highly variable, so GPC designed and installed passive draft tube aeration systems on three of six turbines in hopes of achieving more consistently improved water quality in the tailrace. The implementation of this aeration system has resulted in an overall increase and stabilization of tailrace dissolved oxygen concentrations and a 75% decrease in downstream manganese levels. After careful review of tailrace water quality conditions prior to weir construction, with the weir in place, and after installation of passive draft tube aeration, GPC consulted with GA DNR to assess the need for maintaining the weir structure. GA DNR concurred with the GPC finding that the passive aeration system improved water quality far above those conditions produced by the weir, and in December 2007, they approved a GPC proposal to remove the weir structure. Work is currently underway to remove the weir structure and improve aquatic habitat at its former location. Full documentation of weir removal planning activities is available in the FERC eLibrary under filing numbers 20080715-0093 and 20080917-0177.

2.3 Broad, Wateree, and Savannah River Populations (SC)

South Carolina's efforts have involved stocking fingerlings from Savannah River-strain broodstock. South Carolina has stocked the Broad River, SC every year since 2004 and the Wateree River every year since 2005. All fish were either tagged with coded-wire tags or P.I.T. tags, and mature fish of hatchery origin have been collected in both rivers. The stated goal for these stockings was to introduce progeny from 100 reproducing pairs. That goal should be met after next year's stocking (2009). At that point, activities will shift to an "evaluation" period and future stocking will be either postponed or terminated. At this time, the size of the Savannah River population is unknown (Forrest Sessions, SC DNR, personal communication).

2.4 Broad River Population (GA)

Four year classes (n = 32,189) were stocked in the Broad River, GA, between 1995 and 1998 from the Oconee River stock. Although populations are not expected to mix due to Clark Hill Reservoir, stocking halted after the incidental collection of a single robust redhorse from the native Savannah River population in October 1998. At present, the population in the Broad River (GA) is stable. A telemetry study is currently being conducted in the Broad by Dr. Bud Freeman at the University of Georgia.

2.5 Ogeechee River Population (GA)

A total of 43,048 robust redhorse from 7 year classes have been stocked into the Ogeechee River to date. 2008 electrofishing surveys yielded 34 individuals representing five year classes and a catch rate of 5.0 fish/hour. Of those robust redhorse stocked in the Ogeechee, 75 were relocated into the Oconee in 2007 and 2008 to supplement the Oconee population and for use in an ongoing telemetry study. The Ogeechee population continues to be an excellent refugial population and source of fish for stocking, research, and propagation efforts (Jimmy Evans GA DNR, personal communication).

In 2009, GA DNR will create gravel spawning bars in the Ogeechee. The project is designed to test the effectiveness of gravel bar augmentation or restoration in promoting natural instream spawning of robust redhorse. A monitoring program is in place to document changes in the Ogeechee population over time, with the ultimate management goal for the Ogeechee as a self-sustaining population.

3. Status of the Oconee River Population through 2008

The Oconee River robust redhorse population has been sampled extensively since 1991. In general, sampling strategies have been diverse in nature and technique, and have targeted various life stages and numerous habitat types within the system. Some of the most rigorous sampling efforts have targeted adult robust redhorse during their spawning aggregation and subsequent migrations to known spawning areas within the river. Other sampling surveys have been conducted in proposed spawning locations (i.e. in locations where suitable gravel substrate and flow velocities exist for spawning activity), in meander/bend sections of river where studies have suggested that robust redhorse preferred habitats exist (i.e., outside bends and pools associated with moderate flows and woody debris), and in various other habitats where surrogate species studies and laboratory experimentation has suggested that the species might reside. With these studies, numerous datasets have been developed, and results from those data have been highly variable.

The two most consistent long-term datasets for analysis of adult population status have resulted from broodfish collection for propagation activities and exploratory monitoring surveys designed to identify additional spawning aggregates or spawning locations. While targeted collections at known spawning sites were highly productive at the onset of species monitoring, collections of adult robust redhorse at those sites has steadily declined over time. Causes of this decline are unclear, but several hypotheses seem to fit. The first hypothesis is that the adult robust redhorse population originally sampled in abundance in the early 1990's was senescing, and recruitment of juveniles was slow or nonexistent. Another potential cause of the decline is a shift in spawning location driven by either repeated sampling/handling at known sites, change of the known sites to a point where they no longer supported large-scale spawning activities, or shifts in preferred locations due to changes in flow (including changes in flow regime related to drought). Instream flow conditions in the Oconee River might also have led to the apparent decline in spawning aggregate abundance at known sites, since the population was relatively stable prior to the flow change and has clearly declined since the implementation of the current flow regime in 1995 (Figures 3 and 4 below). Flathead catfish abundances within the Altamaha Basin have also steadily increased since their discovery in the system in 1970's, and with their increase comes increased predation potential above and beyond that of the existing predator community. Any or all of these factors, coupled with numerous years of excessive drought, may have ultimately led to the continued decline in adult robust redhorse collections at known spawning sites.

For long-term monitoring purposes, targeted broodfish/spawning adult collections and the resulting data may be somewhat biased in that only those fish actively spawning or moving onto the spawning bar are collected and included. Those targeted collections might also be misleading if flows change resulting in missed spawning cues or if the condition of the known spawning sites becomes degraded over time. Spawning site collections also may not incorporate suitable effort, gears, or location for collecting non-spawning or lesser dominant individuals. To best understand the status of the population in its entirety, the right combination of gear type(s), sampling location(s), and seasonality must be achieved. To that end, we have analyzed data from the Oconee River collected during monitoring and exploratory surveys, generally using consistent methods (i.e. electrofishing gears and techniques), and collected during Spring of each year to address the current status of the population, provide context for future management, provide insight on enhancing the monitoring program, and set up a long-term database from which causation of the population's apparent decline can be addressed.

Current Status

The most recent population estimate calculated using mark-recapture techniques is for 2005. Since 2005, high variability in catch rates and low sample sizes have not lent themselves to these population estimation methods. The 2005 population estimate for the Oconee River is 113 adult robust redhorse with a standard error of 160, representing a 75% decrease in adult population size since the 1998 estimate. While a declining trend is apparent in annual population estimates, those same estimates seem to more precisely follow a pattern of stability, then catastrophic event, followed by stability, then catastrophic event, etc. There are no significant differences in population estimates from 1995 through 1998. The 1999 and 2000 population estimates are significantly lower than those estimates from 1995, 1997 and 1998, and are approaching significant difference from 1996. Since 2001, the population estimate has been relatively stable annually at a statistically lower level than 1999-2000 (Figure 3).

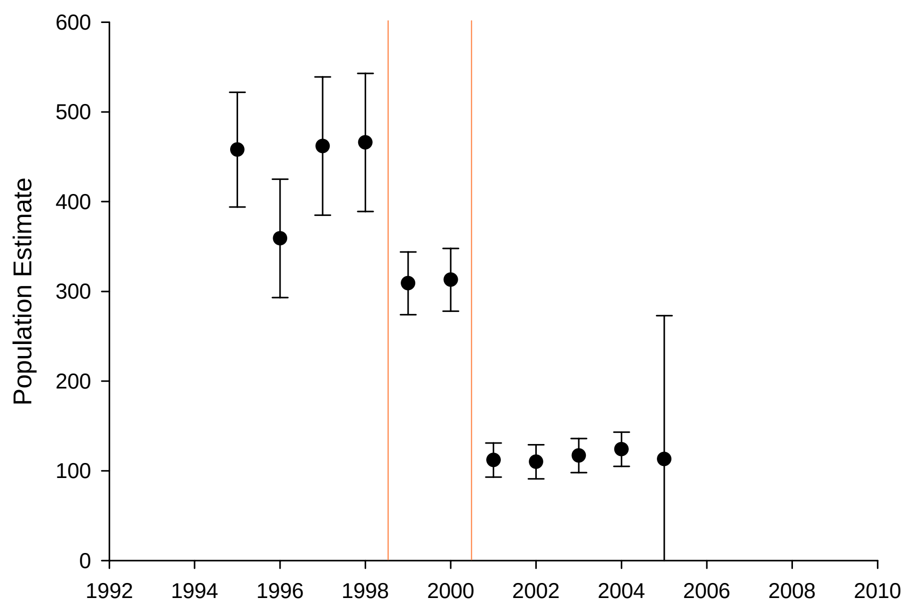

Figure 3. Mark-recapture population estimates of adult robust redhorse in the Oconee River, GA from 1995-2005. Error bars around estimates depict standard error of the calculated estimate. The vertical bars indicate statistically significant incremental changes in population size between statistically similar segments.

Given an overall decrease in population estimates since 1995, one would expect catch rates to follow a similar trend. Unfortunately, the declining trend in catch rates adheres more to a true declining trend than to a stepwise, incremental decrease. There are, however, two significant events in catch rate trends. The first is a significant decrease in catch rates between 1995 and 1996, the first full year after adoption of the current flow regime. The second, a statistically significant decrease in catch rates between 2000 and 2001. Since 2001, the catch rate of adult robust redhorse has been relatively stable (although still declining gradually) in the Oconee at a level less than 10% of catch rates observed in 1994 (Figure 4).

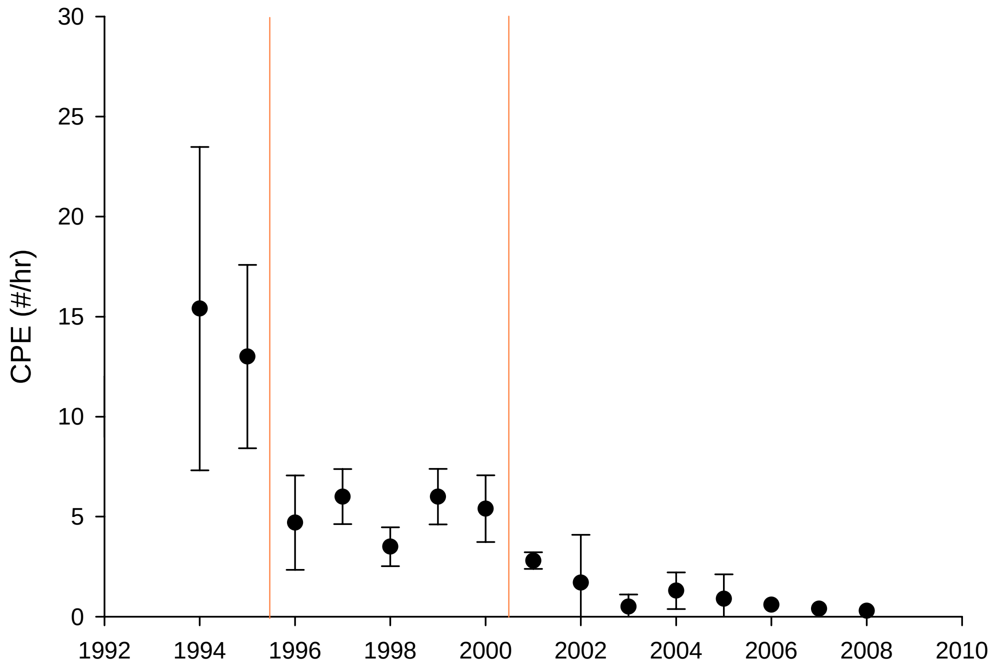

Figure 4. Mean annual electrofishing catch rates of adult robust redhorse in the Oconee River, GA from 1994-2008 Error bars around means depict 95% confidence intervals. The vertical bars indicated statistically significant, catastrophic changes in catch rates between years.

There is some level of agreement between metrics, although not all years are similar between metrics. The lower catch rate in 1996 corresponds to the lower population estimate from the same year, and both metrics indicate a significant decrease in the population between 2000 and 2001. Since 2001 however, catch rates have continued to decline annually, while population estimates have remained low and unchanged over the same time period. This discrepancy between population estimates and catch rates may indicate a relatively stable but small population whose population size is significantly low as to make sampling more difficult and increase variability among sites and/or years. This speculation may also be supported by the differences in magnitude of metric changes from early to later years; 75% decline in population estimate compared to greater than 90% decline in catch rates.

Cause(s) of the apparent decline in the Oconee robust redhorse population remain unknown, but analysis of long-term datasets provides a context for closer examination of likely factors. With at least 3 catastrophic events affecting the population estimate and/or catch rate since 1994, comparisons can be made between and among years to look for these causes. Changes in instream flow, either through drought or regulation, changes in predator abundance, loss or displacement of gravel substrate, increases in sedimentation, and numerous other factors remain the likely causes, and addressing those incrementally over short time frames should ultimately further our knowledge of why the population may have declined.

4. Additional Related Activities

4.1 Oconee River Gravel Survey

Gravel mapping surveys were conducted intermittently in 2005 and 2006 by Georgia Power Company during various robust redhorse population surveys in the Oconee River, GA from Sinclair Dam to Highway 80 (RM 143 to 75). An additional survey dedicated to mapping gravel deposits was conducted throughout the reach in March-April 2007. Gravel deposits (gravel bars or beds) in the Oconee River represent potential robust redhorse spawning habitat. Visual or remote detection of previously undocumented gravel deposits may directly provide a method to locate potential robust redhorse spawning sites in addition to the gravel bar (and annual spawning activity) documented at Avant Mine.

The river between Sinclair Dam and Highway 22 (RM 140.6) in Milledgeville was traversed on foot and visually surveyed during low flow conditions (<650 cfs). Shallow depths and rocky shoals in this reach of the river prohibited effective use of a motor boat during the survey period. The river downstream of Highway 22 was surveyed by boat during low flow conditions (<l000 cfs). Visual observations and hydroacoustic measurements were recorded in the search for indicators of submerged gravel deposits (gravel in river banks) and gravel armored point bars. Locations of substantial gravel deposits were confirmed using a 10-foot long hand-held, metal probe/rod. GPS coordinates were recorded at each confirmed gravel location.

The Plate Index serves as a study area map with the numbered plates showing gravel deposits in more detailed stretches of the Oconee River and is included in Appendix C. Gravel deposits occur regularly upstream of Highway 22 (Plates 1 and 2). Additionally, a large side-channel gravel bar, similar in size and consistency to the Avant Mine gravel bar, exists in the same area (Plate 1).

As in 1994 (EA report), gravel point bars occur fairly regularly in the meandering sections of the river (between RM 119 and RM 100.5) and are similar in consistency (Plates 9-13). Current swept, clean gravel extended into the river channel transitioning to coarse sand and eventually finer particles with distance downstream and increasing bar elevation.

Mid-channel gravel was re-confirmed at three locations including 1) Avant Mine spawning site (Plate 8), 2) just downstream of Avant Mine (Plate 9), and 3) immediately below the Oconee railroad trestle (Plate 13).

Although monitored during the 2007 spawning season, no robust redhorse were observed at the side-channel gravel bar upstream of Highway 22. Due to drought conditions in the months prior to and during the 2007 spawning season (March and April), many areas of the river were de-watered (and probably impassable) including shoals downstream at Highway 22.

Based on findings from the recent gravel surveys and consideration of the initial gravel mapping survey conducted in 1994, we summarize the following points:

1) at least one major gravel bar previously located downstream of the Avant Mine and documented with robust redhorse spawning activity is no longer present;
2) the gravel bar located just downstream of the Oconee, GA railroad trestle has degraded somewhat resulting in a higher percentage of fine grained particles;
3) one minor, side-channel gravel bar is no longer present (located between Avant Mine and the Oconee railroad trestle;
4) a side-channel gravel deposit has been documented downstream of Highway 22 bridge;
5) little is known about the occurrence of thalweg gravel deposits throughout the study area owing to difficulties in probing at greater depth complicated by water currents;
6) there is little or no need to re-survey between the Hardwick boat ramp to a point near the Baldwin-Wilkinson County line or much of the reach downstream of Highway 57 owing to the predominant alluvial, sandy substrate;
7) the river downstream of Highway 22 has been thoroughly surveyed visually and with manual probing, thus future effort towards the discovery of additional gravel deposits and potential robust redhorse spawning sites should focus between Sinclair Dam and Highway 22.

4.2 Gravel Augmentation and Spawning Bar Creation

Habitat augmentation has begun within the Oconee River, primarily aimed at refurbishing existing gravel spawning areas and creating additional gravel bars. In 2008, GA DNR deposited a pile of gravel, similar in size and type to that in the river, just upstream of the Avant Mine spawning bar site. The gravel was piled on the shoreline at the low water mark, with the hope that it would be distributed downstream to collection areas during high flow event. While the project seems promising, very few high flow events have been possible since installation of the deposit due to the ongoing drought. In spite of relatively low flows, the gravel pile has begun to be redeposited downstream as expected.

A grant has been obtained by GA DNR for 2009 to add additional gravel substrate to other portions of the river where gravel bars have become degraded or may not have previously existed. If a lack of suitable spawning substrate is a cause of robust redhorse population decline in the Oconee River, these actions should help to contribute to the conservation effort. In any event, the augmentation will likely result in increased sampling within the river and may serve to concentrate adult aggregates at the newly created gravel bars during spawning season.

4.3 Genetic Identification of Sucker Larvae (Nairn 2006)

In 2004, over 2,100 larval sucker specimens were collected in the Oconee River and were sent to UGA for genetics testing. The objective of this study was simple, using genetic markers, determine species from the sample. Of the 2,136 larval suckers tested using genetic markers developed by Wirgin et al. (2004), 1,950 were successfully identified and four were robust redhorse (0.2%). Attempts were made to isolate DNA from those samples using standard methods as well, and success of those methods was very low. This study provides additional information for robust redhorse conservation by substantiating the Wirgin et al. study, and eliminating the standard methods for DNA isolation from future consideration for larval fish identification.

4.4 Abundance and Distribution of Larval and Juvenile Robust Redhorse in the Oconee River (Peterson et al. 2008)

From 1995 through 2006, UGA and USGS studied the reproductive success of robust redhorse in a reach of the lower Oconee River. While successful reproduction and production of larvae was documented throughout that 12-year period, the results were highly variable. This variability is believed to be caused in part by climatic conditions resulting in flood and drought years. Through comparison of hydrologic conditions to annual reproductive output, the study concluded that age-0 redhorses in general produced stronger year classes when May-June maximum mean flows were low, seven to 14 day periods of flows below the 25^{th} percentile were common in April through June, and June flows in excess of the 75^{th} percentile were infrequent.

During this same study period, there were no collections of age-1+ juvenile robust redhorse, despite numerous annual attempts. While survival of juveniles to adulthood is evident over the period as shown in adult collections, habitat use and survival rates of juveniles are still unknown. It is speculated that the inability to collect juveniles in the Oconee River could result from poor recruitment, sampling ineffectiveness, low detection rates by standardized gears, changes in adult spawning location, and/or an overall decline in the population.

4.5 Effects of River Discharge on Juvenile Carpsuckers in the Oconee River (Peterson and Jennings 2007)

From 1994 through 2001, UGA conducted seine surveys in the Oconee River in search of robust redhorse juveniles and other sucker species. During that time, no robust redhorse juveniles were collected, but important information relate to flow effects on suckers in general was gained. Carpsuckers (*Carpoides* spp.) were common among juvenile sucker species collected, and growth and abundance of that species were compared to river discharge in hopes of identifying causes of variability. Results of that study indicate that 1) moderate flows during spawning and rearing seasons are integral to producing large year classes; and 2) river discharge is highly variable, but conditions exist to produce strong carpsucker year classes every few years. The conclusion of this study was that river flows should be managed as to simulate historic flows typical of the region, and achieving these flow targets is most achievable by considering regional climatic conditions.

5. Flow Suitability for Oconee River Robust Redhorse

Members of the Flow Advisory Team have been actively involved in the creation of an Oconee River Management Plan (ORMP) and have directed much of their time and effort towards that task. The ORMP addresses all facets of robust redhorse conservation within the Oconee and identifies gaps in research, directs future research and management activities, and is designed to be adaptive in its consideration of flow effects. Upon completion of the ORMP, the Flow Advisory Team will reconvene to determine suitability of the current flow regime and to explore alternate flow scenarios incorporating recent research findings following the guidelines of the ORMP.

At present, it appears that conservation activities in the Oconee River have not enhanced or stabilized the declining Oconee robust redhorse population. Population estimates and catch rates continue to decline, in spite of stocking and modified flows. While the current flow regime from Sinclair Dam was designed to benefit various life stages of the species, it is more through the robust redhorse's continued decline that flow and habitat availability may not have been the leading causes.

In the Ocmulgee River, robust redhorse appear to be doing well. GPC's Lloyd Shoals Dam is operated in a manner similar to the previous flow regime at Sinclair prior to 1996 (i.e. continuous 400 cfs minimum flow or inflow at Lloyd Shoals). Given the apparent success of conservation efforts in the Ocmulgee under a less restrictive flow regime, perhaps greater attention should be directed at other possible sources of robust redhorse decline, and required flows from Sinclair Dam should be modified back to a lower minimum flow level with fewer seasonal restrictions. A modification of this type would also fit the adaptive management framework of the ORMP, such that a change in flow regime similar to that of Lloyd Shoals could be monitored closely over a three to five year period of time and response of the Oconee robust redhorse population to that flow regime change could be adequately documented. This type of real-world experimentation would lead to better knowledge of the population's response to flow changes than any habitat suitability model or any flow strategy designed from incomplete data representing only a single life stage with little or no ability to account for temporal variability over longer time steps.

6. Future Directions for Oconee River Robust Redhorse Conservation

Understanding the causes of the decline in the Oconee River robust redhorse numbers represents the most important future direction for the species' recovery. While restoration effort in most of the native range have been highly successful in spite of full understanding of causation, the Oconee River has not responded as well to those same techniques. Drawing parallels and analyzing difference between the Oconee and other populations is important, but equally important is active experimentation into specific causes in the decline in the Oconee. Adaptive conservation strategies with real-world experimentation provide an opportunity for direct measures of success and virtually instantaneous changes to the strategy in the event of failure or setbacks. With the successful advancement of hatchery propagation techniques, coupled with the successful establishment of refugial populations with good genetic diversity, risks associated with adaptive management are minimized.

Attention for future efforts within the Oconee River will also likely include the exploration of habitats above GPC's Wallace Dam in the upper Piedmont Ecoregion portion of the basin. Success in North Carolina of reintroduction efforts coupled with Cope's original description of the species' range and preferred habitat, are largely driving that interest. Also, Wallace and Sinclair dams are an obstacle to flathead catfish movements in the basin, and the upper reaches of the Oconee River might contain suitable habitat with lower predation pressure. Prior to any effort to stock robust redhorse in the upper Oconee, complete surveys of both fish fauna and available habitat will need to be conducted. Those studies should also consider fundamental questions like 'why are robust redhorse not already here?' before any attempt is made to recreate or establish a population.

Habitat restoration activities will continue for the foreseeable future, and study of current project success should guide future efforts. Regardless whether habitat is limiting for robust redhorse, rapid human population expansion, increased development, and increased demands for water in the region have necessitated improvement and protection of aquatic habitats. Also, with the institution of the National Fish Habitat Initiative and resulting partnerships, like the Southeastern Aquatic Resource Partnership (SARP), new funding has become available to enhance and protect degraded habitats within highly developed watershed.

Finally, the partnership among members of the Robust Redhorse Conservation Committee will continue to guide robust redhorse conservation efforts throughout its range. Each year, the committee recaps lessons learned through management and research, and refocuses on steps for the following year or years. The Oconee River robust redhorse population is of the highest priority with the Committee, and restoring the population of robust redhorse within the river is among its highest goals.

APPENDIX A

Robust redhorse literature of interest (Partial Listing)

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APPENDIX B

GPC letter to the US Fish and Wildlife Service describing activities in 2007 and 2008 associated with the Ocmulgee River Candidate Conservation Agreement with Assurance for robust redhorse.

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5131 Maner Road
Smyrna, Georgia 30080

Tel 404.799.2100
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GEORGIA POWER
A SOUTHERN COMPANY

December 10, 2008

Ms. Sandy Tucker
U. S. Fish and Wildlife Service
Westpark Center, Suite D
105 Westpark Drive
Athens, Georgia 30606

Dear Ms. Tucker:

The enclosed is a summary of the conservation actions conducted during 2007 and 2008 for the Candidate Conservation Agreement with Assurances for the Robust Redhorse, *Moxostoma robustum*, Ocmulgee River, Georgia, (CCAA) as described in Agreement Number 1448-40181-01-K-005. This report summarizes activities conducted during 2007 and 2008 towards fulfillment of phases 1 and 2 of the CCAA. Specific activities addressed include stocking the project site (Conservation Action 1), studying the movement of introduced juvenile robust redhorse (Conservation Action 2), and monitoring the abundance and distribution of introduced robust redhorse (Conservation Action 3). We have also begun planning and coordination for activities associated with Conservation Action 4 (monitoring the adult population in the Ocmulgee River and estimating population size), as a result of our January 2008 modification to the CCAA.

In addition to specific activities related to the CCAA, Georgia Power has experienced some internal organizational changes resulting in new personnel assigned to robust redhorse issues. As a result of those changes, I will serve as the Company's contact for general robust redhorse activities, GPC's representative on the RRCC Excom, and Oconee and Ocmulgee TWG representative. Tony Dodd of GPC will be our representative on the Oconee River Flow Advisory Team and will also be actively involved in the RRCC and various CCAA activities. Tony and I are both grateful to your office, especially Alice Lawrence, and Jimmy Evans of Georgia DNR for assisting us with our transition, and we look forward to working with you on robust redhorse conservation issues in the future.

Please contact me at 404-799-2159 if you have further questions regarding this report.

Sincerely,

Joe E. Slaughter, IV
Fisheries Biologist
Georgia Power Company

December 10, 2008
CCAA 2007 Progress Report
1448-40181-01-K-005

XC:
With attachments.

Jimmy Evans, Georgia Department of Natural Resources
Forrest Sessions, Chairman Robust Redhorse Conservation Committee
David Moore, Troutman Sanders
John Biagi, Georgia Department of Natural Resources
Mike Harris, Georgia Department of Natural Resources
Chuck Huling, Georgia Power
Doug Jones, Georgia Power
Jimmy Helms, Georgia Power
Cheryl Wheeler, Georgia Power
Mike Phillips, Georgia Power

2007-08 Progress Report: Candidate Conservation Agreement with Assurances for the Robust Redhorse, *Moxostoma robustum*, Ocmulgee River, Georgia

Agreement Number 1448-40181-01-K-005

Conservation Action 1. *Georgia DNR will stock the Project Site with approximately 4,000 hatchery-reared robust redhorse fingerlings each year for five years.*

From November 2007 through March 2008, a total of 550 hatchery reared robust redhorse representing four year classes were stocked into the Ocmulgee River; 542 stocked at the Lloyd Shoals ramp, and 8 stocked at the Highway 83 ramp. An additional 24 robust redhorse were retained in tanks at Warm Springs Hatchery for further methodological studies. Hatchery survival prior to these stocking events was highly variable and generally low (25% overall survival), largely driven by the poor survival of robust redhorse in pond culture settings (4.5%). Tank culture at Warm Springs yielded a survival rate of 51%, and robust redhorse stocked from that facility represented the greatest portion of fish stocked (500 of 550) during the time period. To date a total of 13,734 robust redhorse, representing 10 year classes have been stocked into the Ocmulgee River in the reach between Lloyd Shoals and Juliette dams.

In October 2007, the Robust Redhorse Conservation Committee (RRCC) agreed to suspend hatchery production of robust redhorse indefinitely, resulting in the suspension of further stockings of the Ocmulgee project site as outlined in Conservation Action 1. Hatchery production was suspended primarily because monitoring suggested that survival rates appeared sufficient to establish a viable robust redhorse population, assuming sufficient reproduction and recruitment (Jimmy Evans GA-DNR personal communication). The discovery of a spawning aggregation and suspected wild-spawned juveniles further suggested that stocking efforts might no longer be necessary. Increasing difficulty in capturing broodstock from the Oconee River and poor survival of fish in the overall hatchery production system also contributed to the suspension of hatchery production.

On January 3, 2008, the FWS issued a modification to the CCAA, which allows GPC to move forward with Conservation Actions 3 and 4 under the Adaptive Management provision without reaching the original stocking target of 20,000 fingerlings.

Conservation Action 2. *Georgia Power will fund two surveys, one in year 1 (2002) and one in year 3 (2004) on the movement of introduced juvenile robust redhorse.*

A third movement survey was completed in 2008 by UGA, and the final report from that study is included in Appendix A. This study follows telemetry studies conducted by Bud Freeman (UGA) and Cecil Jennings (UGA Coop Unit/USGS). Given the completion of the two prescribed studies and the additional 2008 study, we believe there are no further requirements related to this Conservation Action.

Conservation Action 3. *Georgia Power will conduct or fund six surveys in order to monitor abundance and distribution of juvenile and adult robust redhorse within Project Site.*

The third of five status surveys, performed in alternating years, under Conservation Action 3 was conducted in 2007 and 2008. That survey is described below.

A follow-up tracking survey from Conservation Action 2 conducted in early May 2007 resulted in the documentation of a spawning aggregate of apparently reproductive robust redhorse in the Ocmulgee River, downstream of Juliette Dam. The spawning aggregate was documented at between 1 and 1.5 m depth with flows generally less than 1 m/s. One radio tagged individual was also documented with this spawning aggregate. GA-DNR sampled that section of river during April 2008.

The third status survey was conducted in Fall 2007 with assistance from GA-DNR and FWS. That survey combined electrofishing and experimental hoop netting methods within the Lloyd Shoals Dam to Highway 16 reach in an effort to not only monitor survival of stocked fish, but also to test alternate collection methods which we hoped might improve catch rates. Results of that survey and experiment were presented at the 2008 Robust Redhorse Conservation Committee Annual Meeting in Boomer, NC, and that presentation is included in Appendix B. In summary, four robust redhorse individuals were collected during two electrofishing passes within the reach (two individuals per pass), all of which were previously stocked and/or tagged individuals representing three year classes. No robust redhorse or other species of catostomid were collected in experimental hoop nets, and baiting hoop nets or pools within the reach did not affect catch rates. In general, this survey shows that stocked robust redhorse are persisting within the Ocmulgee, however, samples sizes are too low to estimate survival or success of stocking efforts.

The fourth monitoring survey under Conservation Action 3 is scheduled for Fall 2009 and may be conducted in conjunction with adult population surveys outlined in Conservation Action 4.

Conservation Action 4. *Following the establishment of an adult refugial population in the Project Site, Georgia Power will fund three surveys to measure population size utilizing the mark-recapture methods used to estimate the population size of the Oconee River robust redhorse population.*

The first survey under Conservation Action 4 was conducted in March and April 2008 as a collaborative effort with GA-DNR. GPC and GA-DNR sampled various sections of the Ocmulgee River using standardized electrofishing techniques. A total 13 robust redhorse were collected, believed to represent 4 year classes. Two of the individuals collected were untagged/unmarked juveniles smaller in length than stocked sizes, which indicate some level of successful reproduction and recruitment within the system.

GPC and USGS have begun designing two-year studies for monitoring the Ocmulgee population and estimating population size using mark-recapture and other available techniques. These studies, tentatively slated to begin in Fall 2009, are intended to document the status of the existing Ocmulgee River adult population and estimate the number of adult robust redhorse within the river as stocked fish grow and recruit to the population.

Joe E. Slaughter, IV
Fisheries Biologist/Senior Environmental Analyst
Georgia Power Company

Appendix A

Post-release movements and habitat use of stocked robust redhorse *Moxostoma robustum* in the Ocmulgee River, Georgia

By

T. B. Grabowski and C. A. Jennings
Georgia Cooperative Fish and Wildlife Research Unit
Athens, Georgia

Submitted to Georgia Power Company

March 2008

Post-release movements and habitat use of stocked robust redhorse *Moxostoma robustum* in the Ocmulgee River, Georgia

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EXECUTIVE SUMMARY

Robust redhorse *Moxostoma robustum* is a large riverine catostomid once abundant in medium- to large rivers along the Atlantic slope in the southeastern U.S. Currently, only three extant native populations are known and conservation and recovery efforts include the establishment of refugial populations. A Candidate Conservation Agreement with Assurances (CCAA) was developed for robust redhorse as a collaborative effort between Georgia Power, the Georgia Department of Natural Resources, and the U.S. Fish and Wildlife Service to expedite the reintroduction of the species into the Ocmulgee River, Georgia. This report documents the movement patterns and habitat use of 30 hatchery-reared adult and subadult robust redhorse transported from refugial populations established in the Broad River, Georgia and Ocmulgee River, Georgia. The objectives of this study were to assess the habitat use patterns of these stocked individuals, estimate the proportion of individuals that would remain within the study reach between Lloyd Shoals Dam and Juliette Dam, determine how far these individuals would move from their release point, and evaluate whether the stocked fish were able to integrate into the existing population of robust redhorse in the Ocmulgee River. From April 2006 through May 2007, a programmable scanning radio receiver was used to track the stocked fish , which exhibited an exploratory phase for the first three months before adopting behavior patterns, including spawning migrations that were comparable to wild fish. Approximately half of the stocked fish remained within the original study area between Lloyd Shoals Dam and Juliette Dam, while the remaining fish were distributed as far downstream as river kilometer 167.95 (near Abbeville,

Georgia). The fish remaining within in the study reach were found primarily in association with rocks and sandy substrate while those that had moved below Juliette Dam were found primarily in association with large woody debris without any apparent substrate preference. At least some stocked robust redhorse seemed fully integrated into the resident population as evidenced by their presence in spawning aggregations with resident individuals, which suggests the stocking program in the Ocmulgee River has the potential to augment the wild population with individuals that will replicate the behavior and functionality of a resident, wild individuals.

In the process of completing the original objectives of this study, we were able to conduct two concurrent, smaller-scale studies. We present data further illustrating the effectiveness of using radio-tagged, hatchery-reared individuals as “guide fish” to direct sampling efforts and locate spawning aggregations of resident fish and were able to evaluate both the capture probability of robust redhorse and their response to a boat-mounted electrofisher. Catch per unit effort of untagged robust redhorse was higher when we focused electrofishing effort on areas occupied by radio-tagged individuals compared to past survey efforts. In May 2007, tracking of two radio-tagged robust redhorse led us to two previously unknown spawning aggregations of resident fishes. The use of radio-tagged “guide fish” should be considered if data on rare or cryptic species are proving difficult to obtain.

An incomplete understanding of the behavioral responses of robust redhorse to sampling methodologies and their susceptibility, or capture probability, to a particular gear type can potentially hinder conservation efforts. We use radio-tagged robust redhorse in the Ocmulgee River, Georgia to assess the immediate and long term response of this species to boat-mounted electrofishing as well as its capture probability. Transects containing 1-8 radio-tagged individuals were sampled, and all stunned catostomids rising to the surface were identified to species, counted, and released. The positions of each radio-tagged robust redhorse were recorded prior to sampling and at 1-hour, 24-hour, and 3-5 day intervals after sampling. Each transect was analogous to a repeated sample and used to estimate mean abundance and capture probability. Only one radio-tagged individual and six untagged individuals were captured after a total of 7.46 hours of effort. Radio-tagged robust redhorse did not seem to exhibit an immediate response to the sampling efforts. Some movement away from their original position was observed in radio-tagged robust redhorse immediately post-sampling (mean ± SE: 0.15 ± 0.05 km; range: 0.0 – 0.80 km), after 24 hours (0.19 ± 0.05 km), and after 3-5 days (0.23 ± 0.14 km) was observed when the tracker relocated fish at the conclusion of sampling activities. However, this movement was not different than that exhibited by fish located at similar intervals without exposure to electrofishing. A mean capture probability of 0.031 with 95% Bayesian credibility intervals of 0.002- 0.111 was estimated from the best approximating model. Boat electrofishing under the conditions we experienced in the Ocmulgee River does not appear to be a particularly effective method to capture this species and may not be a useful method for sampling riverine catostomids or other species whose behavior and habitat selection renders them cryptic. Given the importance of accurate population estimates to conservation efforts, alternative approaches or multiple strategies should be considered when assessing the population status of such species.

ACKNOWLEDGEMENTS

We thank Tyler Ferguson for his assistance for conducting day-to-day data collection operations in the field; Shannon Albeke and Kristin Meehan for their assistance with GIS data analysis; and Michael Abney, Wayne Clark, Rebecca Cull Peterson, Jimmy Evans, Kelly Filer, Russell Parr, Colin Shea, and Krista Woodward for their assistance in the field. Funding for this study was provided by Georgia Power (Project number: 20-21-RR272-077). This manuscript benefited from the comments and suggestions of Michael Abney, Philip Boon, David Higginbotham, Alice Lawrence, Michael Nichols, O. Patrick Olafsson, Rebecca Cull Peterson, Carl R. Ruetz III, Wayne Starnes, and Shawn Young. Cooperating agencies for the Georgia Cooperative Fish and Wildlife Research Unit are the U. S. Geological Survey, the University of Georgia, Georgia Department of Natural Resources, and the Wildlife Management Institute. Reference to trade names does not imply endorsement by the U.S. Government.

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Post-release movements and habitat use of stocked robust redhorse in the Ocmulgee River, Georgia

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Introduction

The use of hatchery-reared fish has become a common and controversial conservation strategy to supplement existing or establish new populations of threatened and endangered species (Levin *et al.*, 2001; Brannon *et al.*, 2004). Numerous studies demonstrate hatchery-reared fish are not necessarily equivalent to their wild counterparts (for review see Munro and Bell, 1997 and Huntingford, 2004). Frequently hatchery-reared fish exhibit higher energy expenditures, higher mortality rates or lower reproductive success compared to wild individuals; this apparent reduced fitness has been attributed to both their naiveté and unfamiliarity with the local environment such as the location of refuge, foraging, and spawning habitats (Cresswell, 1981; Helfrich and Kendall, 1982; McGinnity *et al.*, 2004); the presence of predators or competitors (Olla *et al.*, 1998; Kellison *et al.*, 2000; Bettinger and Bettoli, 2002); and fluctuating or unfamiliar abiotic conditions (Bettinger and Bettoli, 2002; Ward and Hilwig, 2004). The differences in performance and survival between hatchery-reared individuals and their wild counterparts become less pronounced as hatchery-reared fish acclimatize to local conditions (for review see Huntingford, 2004).

Often, the long-term success of a stocking effort can be determined during the acclimatization process as hatchery-reared fish become integrated into the existing population (Huntingford, 2004). For potadromous and diadromous species, integration into an existing population must include learning both the appropriate cues for initiating migratory behavior in a particular system and the locations of suitable spawning habitat used by resident fishes. Attempts to use hatchery-reared individuals as part of a conservation strategy for potadromous or diadromous fishes have yielded mixed results. Despite efforts to imprint individuals to “natal” spawning habitats, hatchery-reared salmonids and sturgeons exhibit a much greater propensity to stray or wander than wild fish (Quinn, 1993; Smith *et al.*, 2002; Jonsson *et al.*, 2003a; 2003b). Hatchery-reared individuals also tend to exhibit much higher activity levels immediately after stocking than at later post-stocking times, often leading to the dispersal of a significant proportion of sexually immature stocked individuals out of the population they were meant to augment (Cresswell, 1981; Mueller *et al.*, 2003).

Robust redhorse is an imperiled catostomid species listed as endangered by the state of Georgia and has a conservation and recovery strategy heavily dependent upon the use of hatchery-reared individuals. Like many catostomid species, there is relatively little information available upon which to base an assessment of the strategy’s success (Cooke *et al.*, 2005). Robust redhorse was originally described in 1870, but was “lost to science” until its “rediscovery” in 1991 (Bryant *et al.* 1996; Ruetz and Jennings, 2000). The species seems to have been extirpated from much of its range, but native populations persist in the piedmont and upper coastal plain regions of three Atlantic Slope rivers (the Altamaha, Savannah, and Pee Dee drainages) in North Carolina, South Carolina, and Georgia (Bryant *et al.*, 1996; Ruetz and Jennings, 2000). Conservation and recovery efforts have identified the goal of locating and/or establishing six self-sustaining populations of robust redhorse as a top priority (Robust Redhorse Conservation Committee, 2002). The captive propagation and release of individuals has been the primary means by which this target is being reached. To this end, robust redhorse have been introduced to the Broad and Ogeechee rivers in Georgia and in the Wateree and Broad rivers in South Carolina and have been stocked into the Ocmulgee River in Georgia to supplement an existing population of unknown size (DeMeo, 2001; R. Self, South Carolina Department of Natural Resources, personal communication). However, there has been little assessment of the post-release dispersal, movements, and habitat use of robust redhorse at this time, and there has not yet been long-term monitoring of these populations. Wild adults are potadromous and make long-distance upstream migrations (>100 km) to spawning habitat in spring (Grabowski and Isely 2006). Adult robust redhorse also demonstrate a high degree of fidelity and specificity to both spawning sites and home ranges (Grabowski and Isely 2006, 2007). Whether hatchery-reared, stocked fish can adopt a similar behavioral pattern without imprinting on local conditions during early life history stages is unclear. This uncertainty also can be associated with the reintroduction and conservation efforts for this species in rivers where hatchery-reared individuals have been used to augment existing populations or establish new ones.

We employed radio telemetry to assess the movement patterns and habitat use of hatchery-reared robust redhorse stocked into the Ocmulgee River. The study fish were comprised of naturalized individuals collected from stocked populations in other river systems that consist of individuals originating from the same evolutionarily significant unit as the reintroduced population in the Ocmulgee River. The use of transplanted naturalized individuals allowed us to evaluate the ability of the stocked fish to acclimate to a new river system and integrate into an existing population without having to account for the effects of hatchery fish adjusting to the natural conditions, such as navigating in flowing water and locating food and shelter.

Methods

Study area

The Ocmulgee River is about 400 km long and drains approximately 9,900 km^2 in the Piedmont and Coastal Plain physiographic provinces of central Georgia. It is one of two major tributaries that merge to form the Altamaha River (Fig. 1). This study focused primarily on a 30-km reach of the Ocmulgee River bounded by Lloyd Shoals Dam near the city of Jackson, Georgia on the upstream end and by Juliette Dam in the town of Juliette, Georgia downstream (Fig. 1). Lloyd Shoals Dam is a main-stem hydroelectric facility and is an impassable barrier to upstream fish migration, whereas Juliette Dam is a low-head dam passable only in the downstream direction. This 30-km reach was selected by the Robust Redhorse Conservation Committee as a suitable location for establishing a refugial population because it contains suitable robust redhorse habitat, including several potential spawning sites, and was thought to be free of introduced predators (DeMeo, 2001). Predation by flathead catfish *Pylodictis olivaris* has been hypothesized to be a contributing factor in the decline of robust redhorse in the Altamaha River system since its introduction in the 1970's (Bart *et al.*, 1994; Cooke *et al.*, 2005). Although the species is prevalent throughout much of the system, Juliette Dam had apparently blocked its

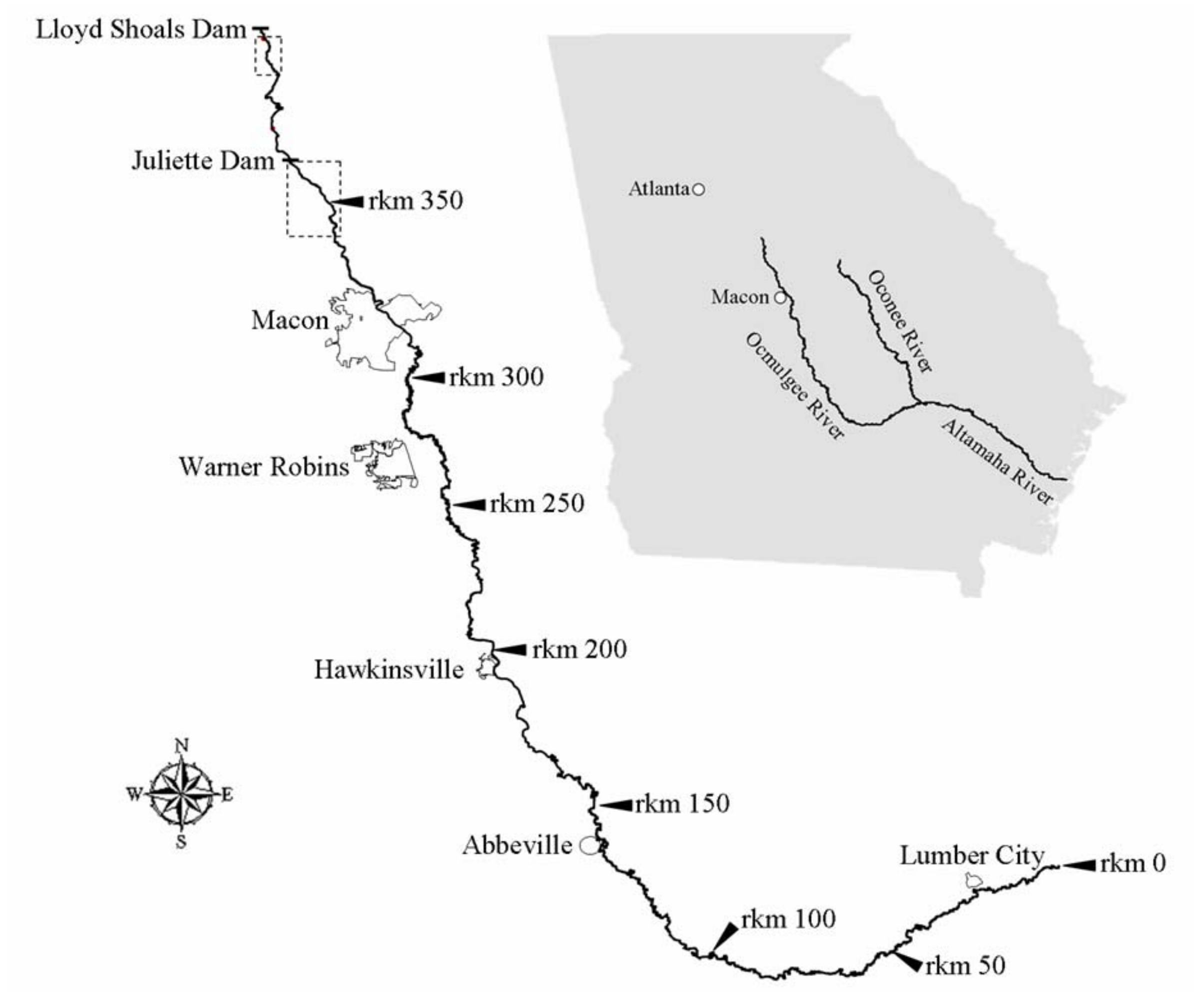

Figure 1. The Ocmulgee River from its confluence with the Oconee River at river kilometer (rkm) 0 to Lloyd Shoals Dam at rkm 394.5. Areas highlighted by dashed lines indicate non-navigable portions of the river. Inset shows the position of the Altamaha River systems in the state of Georgia.

upstream movements (DeMeo, 2001). However, recent reports suggest that the species is present and may be in the process of becoming established in this reach of the Ocmulgee River (J. Evans, Georgia Department of Natural Resources, personal communication). Robust redhorse were first stocked into this reach of the Ocmulgee River in 2002 and 13,095 individuals ranging from fingerlings to young adults (age-5) have been stocked as of 2005 (J. Evans, Georgia Department of Natural Resources, pers. comm.). These fingerlings are the progeny of broodstock captured from the Oconee River, Georgia.

Data collection

Standard boat electrofishing techniques were used to collect adult and subadult robust redhorse from refugial populations established in the Broad River and Ocmulgee River of Georgia during March and early April 2006. Like the Ocmulgee River population, these populations were established with the progeny of broodstock collected from the Oconee River. All fish were transported to outdoor holding facilities at the University of Georgia.

A frequency-coded radio transmitter with trailing wire antenna (Advanced Telemetry Systems, Isanti, Minnesota) was surgically implanted into each fish. Transmitters weighed approximately 26.0 g in air and did not exceed the maximum 2.0% of the body weight of the fish as recommended by Winter (1996). The transmitters had a manufacturer guaranteed battery life of 360 days. Each fish was anesthetized by immersion in a 140 mg/L buffered MS-222 solution. The fish was removed from this solution, placed in a surgical cradle, and kept sedated by pumping a 70 mg/L buffered MS-222 solution over its gills. A radio transmitter was implanted into the peritoneal cavity (Fig. 2), and the whip antennae exited the body via an exit portal created by a lopher surgical needle 3-4 cm posterior to the incision (Ross and Kleiner, 1982). The entire surgery for each individual was completed in 5-7 minutes, and all radio-tagged fish were allowed to recover for eight days prior to release.

Thirty radio-tagged robust redhorse were released into the Ocmulgee River immediately below Lloyd Shoals Dam at river kilometer (rkm) 393.95 on 19 April 2006 and subsequently were relocated weekly by boat or canoe for the duration of the transmitters' battery life. Shoals and other obstructions rendered approximately 10 rkm between Lloyd Shoals Dam and Juliette Dam and 40 rkm between Juliette Dam and Macon, Georgia navigable only by canoe when conditions allowed (Fig. 1). Therefore, radio-tagged robust redhorse occupying these river segments were relocated at a lower frequency relative to their counterparts in the navigable portions of the river. Fish were located using an ATS R2100 programmable scanning radio receiver (Advanced Telemetry Systems, Isanti, Minnesota[1]) with a loop antenna. The precise location of the fish was determined by disconnecting the coaxial cable from the antennae and using it to determine the position of the tagged fish to within one meter. Once the position of the fish had been fixed, latitude and longitude were determined with a hand held GPS receiver and recorded. Later, fish position was converted from latitude and longitude to rkm with ArcGIS 9.2 mapping software (Environmental Systems Research Institute, Redlands, California[1]). Depth, temperature, dissolved oxygen (DO), turbidity, and bottom current velocity also were recorded at each location. Additionally, the substrate

[1] Reference to trade names does not constitute U.S. Government endorsement of commercial products

Figure 2. Photographs taken of the surgical site of one of the study fish immediately after implantation of a radio-transmitter (top) and of the surgical site after approximately one year at liberty after surgery (bottom).

composition (muddy, sandy, or rocky) and dominant available cover (none, woody debris, boulders) with which each fish was associated was assessed qualitatively.

Data analysis

Absolute distance moved, displacement, and estimates of minimum daily movement were calculated for each radio-tagged robust redhorse by season. Absolute distance moved was defined as the absolute value of distance moved between relocations and calculated as $|P_{t+1}-P_t|$, where P_t is an individual's position in rkm at time t and P_{t+1} is that same individual's position at time $t+1$. Displacement was calculated as the net distance moved using $P_{t+1}-P_t$. Upstream movements are indicated by a positive number and downstream movements by a negative one. Seasonal absolute movement and displacement were calculated by summing for each individual over a season. Student's *t*-tests were used to evaluate the null hypotheses that mean seasonal displacement was not different from zero (Zar 1996), suggesting movement was not directional. The hypothesis that these values differed seasonally (fixed effects) was tested with a mixed model analysis of variance (ANOVA) while controlling for individuals and position relative to Juliette Dam (random effects) (Zar 1996). Dunnett's means separation was used to identify differences in treatment means (Zar 1996). ANOVA was used to evaluate seasonal and positional (relative to Juliette Dam) differences in mean depth, temperature, DO, and turbidity. Seasonal and positional differences in substrate and cover were assessed using χ^2 analysis. All means are reported ± 1 SE unless otherwise noted. A significance level of $\alpha = 0.05$ was used for all tests.

Results

We captured a total of 30 adult and subadult robust redhorse from the Broad River (*n*=10; 8 males, 2 females) and the Ogeechee River (*n*=20; 16 males, 4 females). Individuals captured from the Broad River were larger (513-573 mm TL, 1644-2778 g) than those from the Ogeechee River (429-502 mm TL, 1021-1843 g). We relocated the tagged fish a total of 1,041 times between April 2006 and May 2007. Individuals were relocated from four to 83 times, averaging 37.2 ± 4.4 observations per individual. Two of the radio-tagged fish met with unknown fates. These individuals were not relocated during the course of this study and were presumed dead. An additional four fish died or shed their transmitters during this study (one in May 2006; two in August 2006; one in September 2006) and were removed from further analysis. The mortality rate for the radio-tagged robust redhorse stocked into the Ocmulgee River was 20.0%.

General movement patterns

The radio-tagged robust redhorse released into the Ocmulgee River can be roughly separated into two groups: those that remained in the study reach between Lloyd Shoals Dam (hereafter referred to as upstream fish) and Juliette Dam and those that passed Juliette Dam (hereafter referred to as downstream fish). Eighteen of the 28 individuals remained upstream of Juliette dam. These fish seemed to undergo an exploratory period that lasted until mid-June 2006. During this time, these fish made frequent movements between Lloyd Shoals Dam and Juliette Dam (Fig. 3). The majority of upstream fish seemed to establish home ranges near their release point after this initial

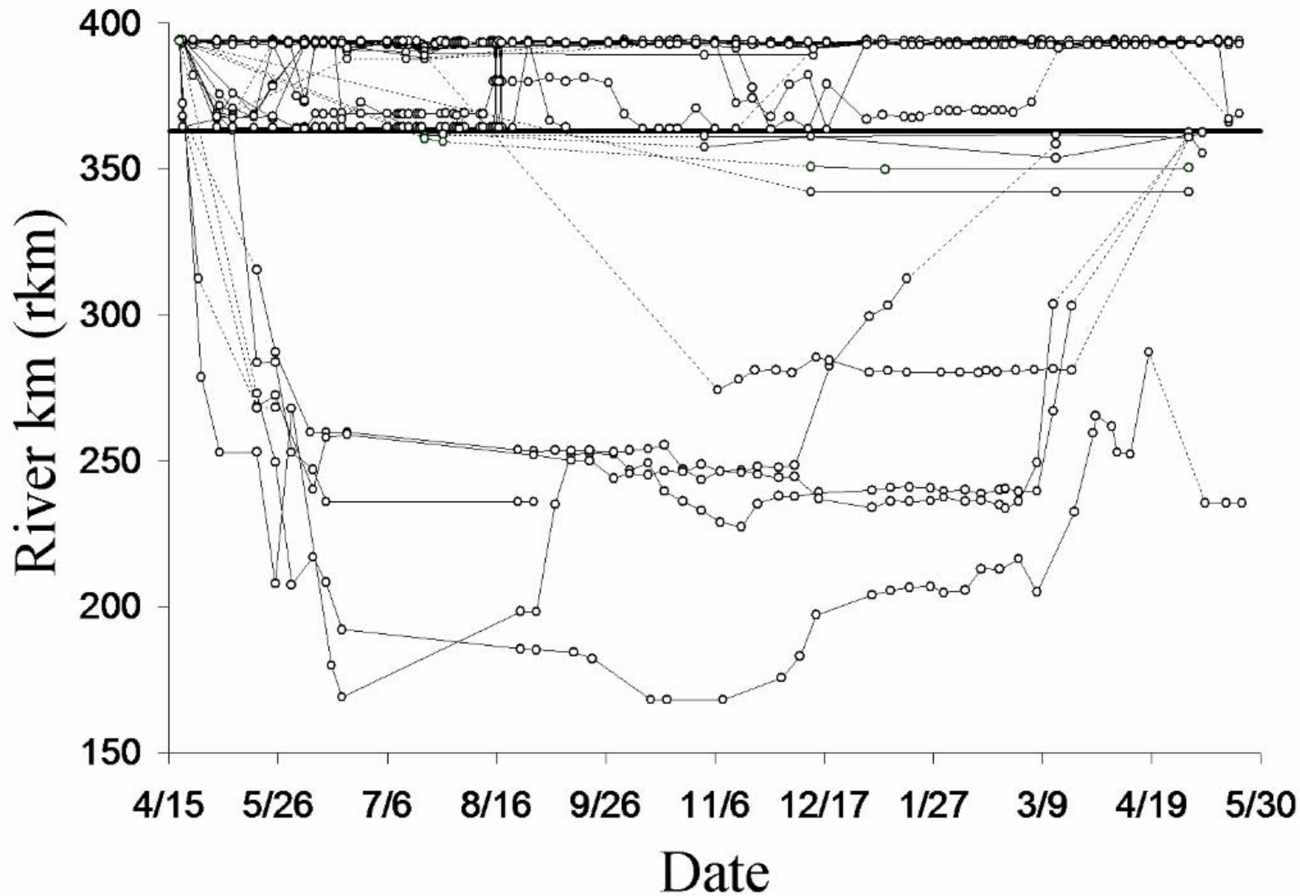

Figure 3. River kilometer (rkm) location of radio-tagged robust redhorse released in the Ocmulgee River, Georgia April 2006 – June 2007. Location of Juliette Dam is represented by the solid horizontal line at rkm 362.5. Dashed lines indicate periods where that individual was not found.

exploratory period. A few individuals made seasonal shifts in home range, spending summer, fall and winter near Juliette Dam and moving up to Lloyd Shoals during spring (Fig. 3). In late July and early August, the oxygenation system at Lloyd Shoals Dam failed, which resulted in hypoxic conditions for several km downstream. During this period, the radio-tagged robust redhorse left this area and resettled in positions either in the non-navigable portion of the river or near Juliette Dam and returned to their previous locations within two weeks after DO levels had returned to normal. The 10 downstream fish exhibited a similar exploratory period of consistent downstream movement interspersed with erratic upstream movements. During this period, individuals below Juliette Dam were located as far downstream as rkm 167.95. Most of the downstream fish seemed to complete their exploratory period by mid-June 2006, but two individuals apparently did not establish long-term home ranges (Fig. 3). All remaining analyses excluded these exploratory periods from consideration.

Habitat use patterns

In general, radio-tagged robust redhorse remained within the confines of the main channel of the Ocmulgee River regardless of their position relative Juliette Dam. However, there were two notable exceptions. On 10 May 2006, a fish was located in the Towaliga River, a small tributary of the Ocmulgee River approximately 5.5 km upstream of Juliette Dam. This individual moved back into the Ocmulgee River sometime before it was relocated again on 24 May 2006. During high water events in mid-January 2007, one downstream fish was found on the floodplain about 50 m from the edge of the main river channel. This fish was not found in association with any smaller streams or tributaries of the Ocmulgee.

The habitat occupied by radio-tagged robust redhorse differed by season and/or their position relative Juliette Dam (Fig. 4). The type of substrate fish were associated with was related to position relative to Juliette Dam ($\chi^2 = 170.7$; d.f. = 2; $P < 0.0001$) but did not differ by season ($\chi^2 \leq 7.5$; d.f. = 6; $P \geq 0.27$). Upstream fish were found primarily in association with sandy substrate (82.0%), whereas relocations of downstream fish were split among mud (20.0%), sand (39.0%), and rocky or gravel (41.0%) substrates (Fig. 5). Likewise, the available cover a radio-tagged fish was likely to associate with was related to position relative Juliette Dam ($\chi^2 = 108.1$; d.f. = 3; $P < 0.0001$). Downstream fish were located primarily in proximity to woody debris (80.0%), but their upstream counterparts were found primarily near rocks (51.9%) and woody debris (39.5%). Regardless of position relative Juliette Dam, radio-tagged robust redhorse demonstrated seasonal shifts in the available cover with which they associated ($\chi^2 = 101.6$; d.f. = 9; $P < 0.0001$). A larger number of individuals were observed in association with rocks during spring (63.0%) than other seasons (28.1-46.7%) (Fig. 6). Downstream fish were consistently found in deeper ($F_{7,856} = 19.33$; $P < 0.0001$) and faster-flowing ($F_{7,507} = 6.68$; $P < 0.0001$) water than their upstream counterparts regardless of season. On average downstream fish were located in water that was 2.53 ± 0.09 m deep and flowing at 0.21 ± 0.02 ms^{-1}, whereas upstream fish were found in 1.82 ± 0.03 m of water with a current velocity of 0.11 ± 0.01 ms^{-1}. Both upstream ($F_{3,693} = 4.25$; $P = 0.006$) and downstream ($F_{3,163} = 8.45$; $P < 0.0001$) fish exhibited seasonal differences in water depth and tended to be located in the deepest water during winter. Current velocity at locations occupied

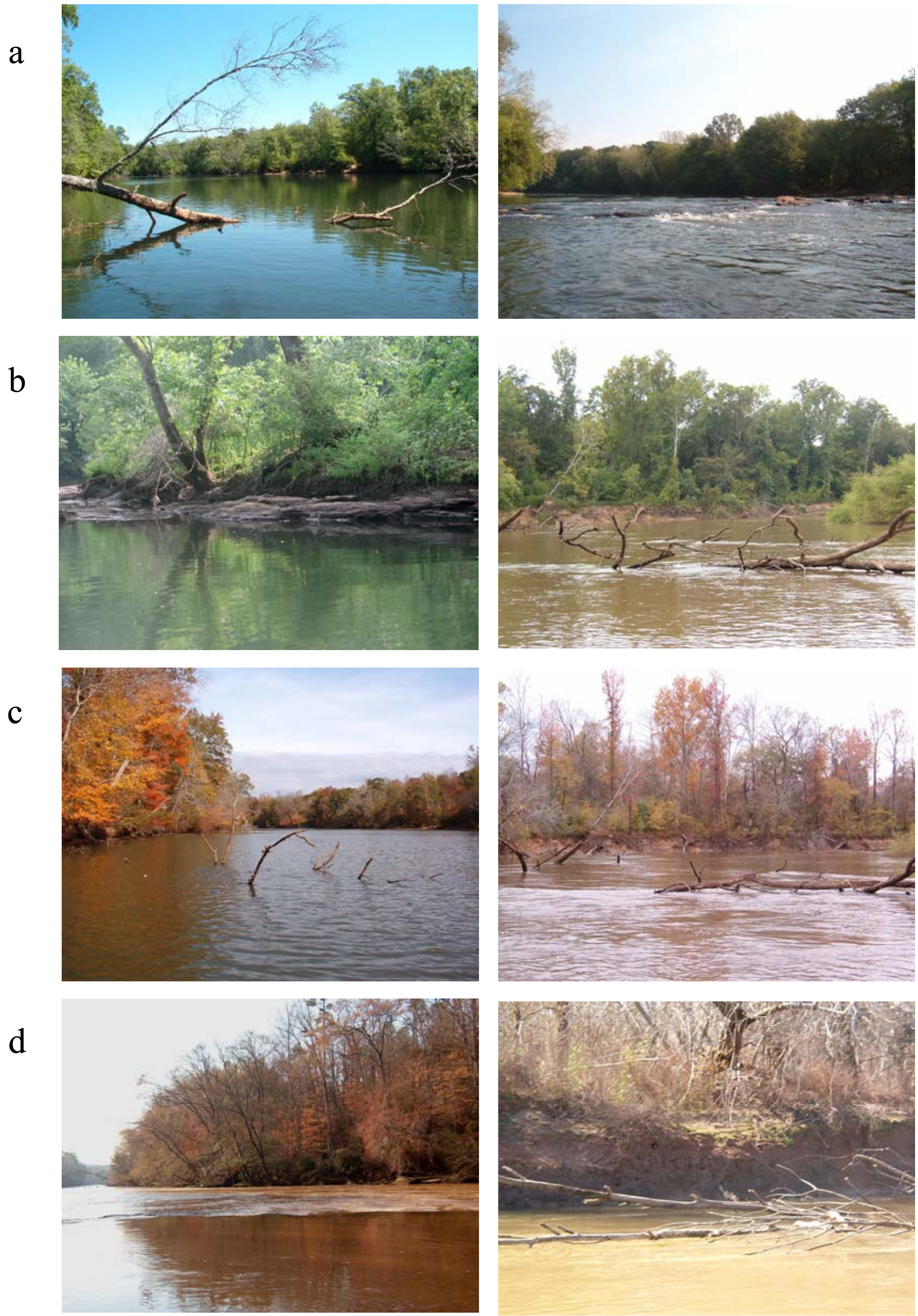

Figure 4. Photographs of robust redhorse habitat above (left column) and below (right column) Juliette Dam in spring (a), summer (b), autumn (c), and winter (d).

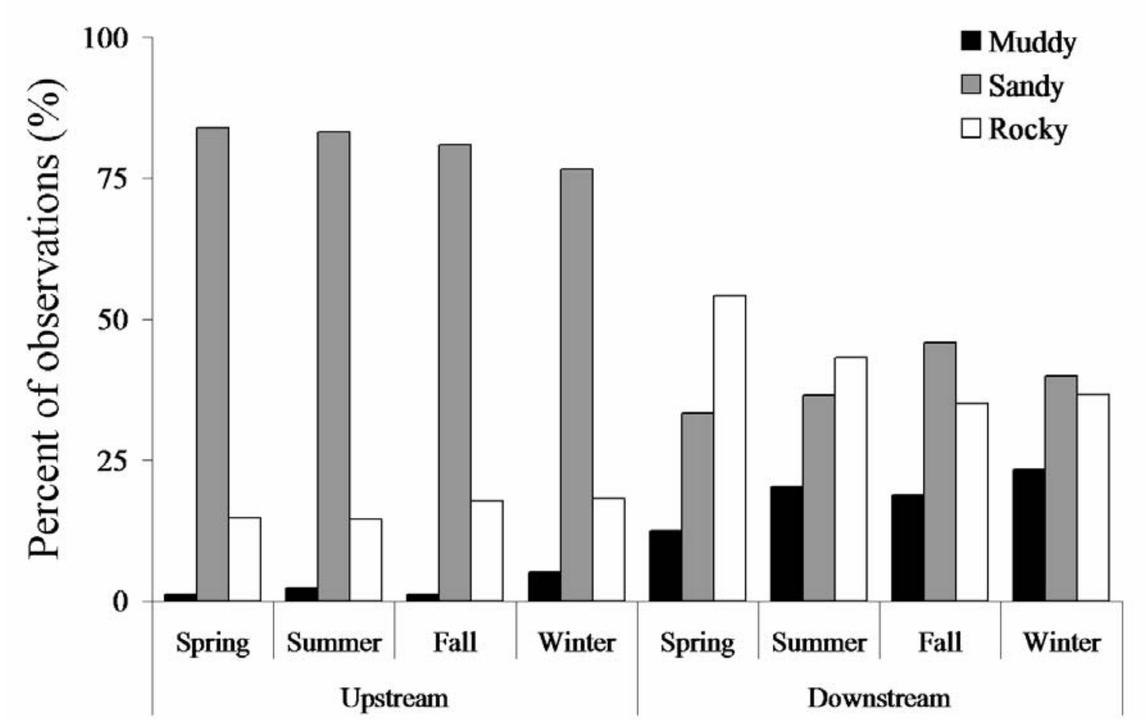

Figure 5. Seasonal frequency of observations over muddy, sandy, and rocky substrates of stocked radio-tagged robust redhorse upstream and downstream of Juliette Dam in the Ocmulgee River, Georgia, April 2006 – June 2007.

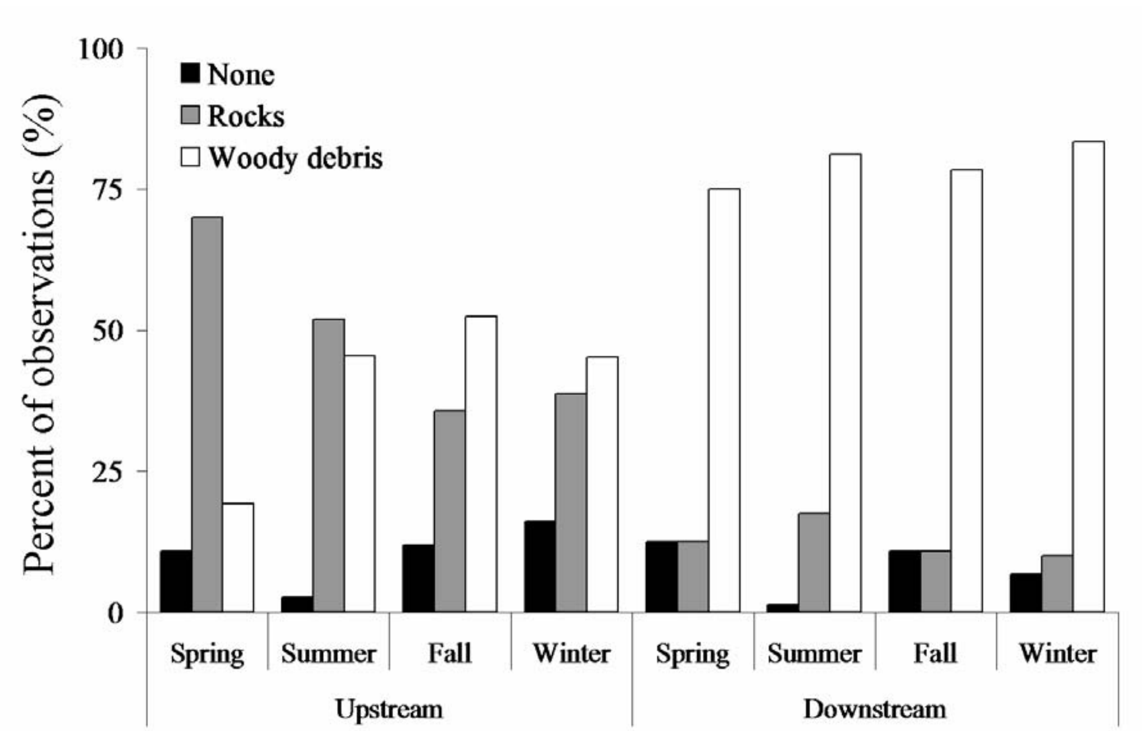

Figure 6. Seasonal frequency of observations of the cover (none, rocks, woody debris) used by stocked radio-tagged robust redhorse upstream and downstream of Juliette Dam in the Ocmulgee River, Georgia, April 2006 – June 2007.

by radio-tagged robust redhorse upstream ($F_{3,89}$ = 0.017; P < 0.41) or downstream ($F_{3,118}$ = 0.004; P = 0.94) of Juliette Dam did not differ seasonally.

Seasonal movement patterns

These seasonal changes in habitat association seem to correspond to seasonal movement patterns of the radio-tagged robust redhorse. Radio-tagged robust redhorse exhibited seasonal differences in absolute movement ($F_{3,90}$ = 5.50; P = 0.002) and were most active in the summer ($t_{90} \leq 3.21$; $P \leq 0.002$) when mean absolute movement was 49.0 ± 9.2 km (Fig. 7). Individuals exhibited about the same level of activity the other three seasons ($t_{90} \leq 0.00$; $P \geq 0.89$), moving approximately 16-17 km per season. However, this movement was not directed upstream or downstream. Displacement also varied seasonally ($F_{3,90}$ = 3.19; P = 0.03) with spring being the only season where net movement was upstream. Displacement for the other three seasons did not differ statistically from zero ($t_{90} \leq 0.90$; $P \geq 0.08$) (Fig. 5).

Discussion

Radio-tagged fish stocked into the Ocmulgee River adopted behavioral patterns that were consistent with those reported for wild fish (Grabowski and Isely, 2006) within 90-120 days of their release. Before they were fully acclimatized to the Ocmulgee River, the radio-tagged fish exhibited an exploratory pattern of movement and behavior, mostly in the downstream direction. A similar pattern was noted in younger, hatchery-reared

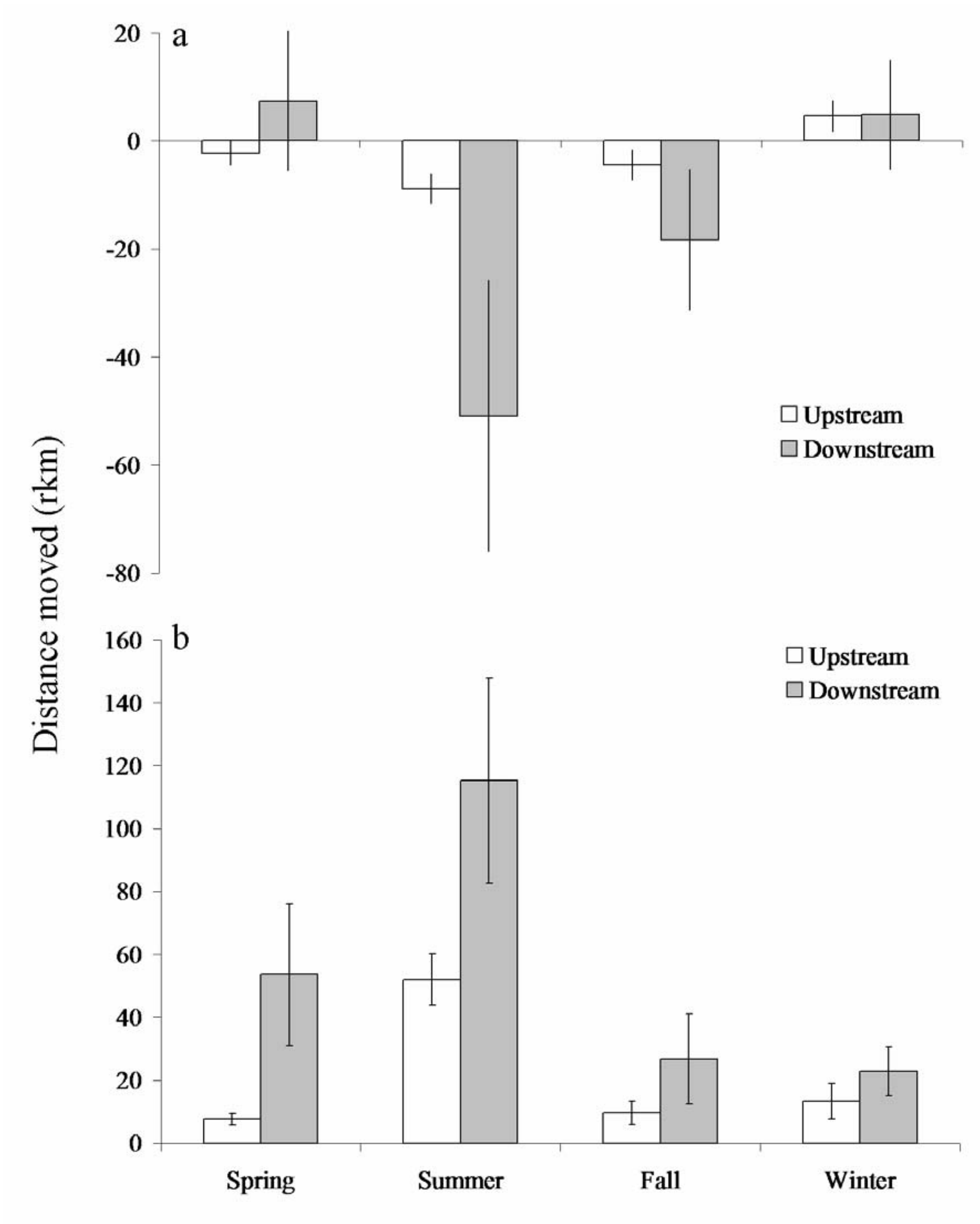

Figure 7. Mean seasonal displacement (a) and absolute movement (b) of stocked radio-tagged robust redhorse upstream and downstream of Juliette Dam in the Ocmulgee River, Georgia, April 2006 – June 2007. Error bars represent standard error.

robust redhorse stocked directly from rearing facilities in 2002 at the same location on the Ocmulgee River (Jennings and Shepard, 2003). These juveniles were still exhibiting consistent downstream movements 80 days after release when the radio-transmitters reached the end of their battery life. Approximately one third of study fish passed Juliette Dam during the course of the 2002 study (Jennings and Shepard, 2003). Examples of similar periods of exploratory behavior in stocked individuals can be found for numerous species including razorback sucker *Xyrauchen texanus* (Mueller *et al.* 2003), brown trout *Salmo trutta* (Aarestrup *et al.* 2005), and paddlefish *Polyodon spathula* (Pitman and Parks 1994). However, the length of the exploratory period observed in the individuals stocked into the Ocmulgee River suggest that many of these studies cited may have been of insufficient duration to determine if the study fish eventually settled into a pattern of behavior typical of a wild fish.

After the radio-tagged robust redhorse completed their exploratory phase, differences in their habitat use patterns seemed to be dependent upon their position relative Juliette Dam. However, hydrologic and geomorphic differences between the two areas are the most probable explanation for the observed differences in habitat use. The Ocmulgee River above Juliette Dam is characteristic of a large piedmont river with high gradient, shallow water, primarily gravel and sand substrate, and frequent shoals. Below Juliette Dam particularly downstream of Macon, Georgia, the Ocmulgee River becomes a coastal plain river and has a relatively lower gradient, a meandering channel, predominately sand and mud substrate, and frequent sand bars and deep pools that are typical of coastal plain rivers. A similar pattern was observed in the Savannah River where fish exhibited different habitat selection depending upon their position relative to a dam that served as a division between the piedmont and coastal plain regions of the river (Grabowski and Isely, 2006). Regardless of their position relative to Juliette Dam, radio-tagged robust redhorse were consistently found in the main channel associated with current, deep water, and physical structure, particularly woody debris. Occasionally, individuals left the main channel during high water events. This movement and habitat use pattern is similar to the habitat preferences previously described for this species (Jennings and Shepard, 2003; Grabowski and Isely 2006; R. Heise, North Carolina Wildlife Resources Commission, personal communication). In the Ocmulgee River, robust redhorse seem to be able to find suitable non-spawning habitat in both piedmont and coastal plain habitats that meet species-specific minimum standards of cover, depth, current velocity, and water quality.

Although the upstream-downstream differences seen in habitat use by radio-tagged robust redhorse probably are an artifact of differences of habitat quality and availability, the observed seasonal differences in movement and habitat use were consistent with that described for wild radio-tagged robust redhorse in other systems (Grabowski and Isely, 2006; R. Heise, North Carolina Wildlife Resources Commission, personal communication). The robust redhorse stocked into the Ocmulgee River eventually adopted behavior patterns in which individuals were mostly sedentary and spent the majority of their time within a relatively small linear home range. This was demonstrated by the low mean seasonal absolute movement and dispersal, and the small seasonal ranges during spring, fall and winter. Late spring and early summer was the only exception to this sedentary lifestyle as fish generally became more active and most individuals initiated upstream migrations presumably for the purpose of locating spawning habitat.

Despite many tagged robust redhorse making upstream movements in the spring, only two were observed as part of an aggregation of spawning resident fish (Grabowski and Jennings, *in review*). These two fish were found in shoal habitat approximately 1.0 rkm downstream of Juliette Dam. We were unable to determine if the other radio-tagged fish below Juliette Dam participated in spawning activities. The radio-tagged robust redhorse above Juliette Dam did move upstream into Lloyd Shoals during spring. However, visual surveys by divers did not find suitable spawning habitat as described by Freeman and Freeman (2001) and Grabowski and Isely (2007) in the areas occupied by these individuals. This habitat in the form of mid-channel gravel bars is present above Juliette Dam; however, this study was conducted during a period of severe drought in central Georgia. Gravel bars that may have served as spawning habitat for robust redhorse were left exposed during spring and early summer. Shoal habitat similar to that used by spawning fish below Juliette Dam (Grabowski and Jennings, *in review*) was readily available to upstream individuals during the course of this study but did not seem to be used. Other hatchery-reared catostomids, such as razorback sucker (Marsh *et al.*, 2005; Modde *et al.*, 2005), have been observed associated with spawning aggregations of wild counterparts. However, the proportion of stocked individuals able to successfully locate and participate in a spawning aggregation was not addressed in these studies.

The radio-tagged robust redhorse stocked into the Ocmulgee River suffered a 20.0% mortality rate. This rate is comparable to mortality rates of wild radio-tagged robust redhorse in the Savannah River (Grabowski and Isely, 2006) and to hatchery-reared pallid sturgeon *Scaphirhynchus albus* (Jordan *et al.*, 2006). Determining whether death was because of complications related to the surgical procedure performed on these individuals, an unfamiliarity with local conditions, or natural causes was impossible. However, the relatively low mortality of stocked fish acclimatized to natural conditions suggest that the majority of mortality experienced by stocked fish may be related to their naiveté about life outside the hatchery environment and not due to their unfamiliarity with local conditions. The radio-tagged individuals stocked into the Ocmulgee River had been living under natural conditions in other river systems for several years prior to being transplanted and thus had been exposed to predators, competitors, fluctuating abiotic conditions, and patchy resources.

The use of hatchery-reared robust redhorse to establish a refugial population in the Ocmulgee River seems to be a viable strategy to aid in the recovery of this species. The stocked individuals did not leave the Ocmulgee River to enter the Altamaha or Oconee rivers, even during their exploratory period. Most of the fish that passed Juliette Dam adopted a behavioral pattern similar to that seen in wild fish (Grabowski and Isely, 2006; R. Heise, North Carolina Wildlife Resources Commission, personal communication) and seemed to integrate into an existing population of robust redhorse, locate suitable spawning habitat, and participate in spawning. The presence of introduced predators, such as flathead catfish, leaves doubt as to how successful these individuals will be in contributing to a self-sustaining population. However, approximately two-thirds of the fish released during this study remained above Juliette Dam where flathead catfish are thought to have not yet become established. Like their downstream counterparts, these upstream individuals behaved comparably to wild fish, but whether individuals upstream of Juliette Dam will be able to form a self-sustaining population remains to be seen. In addition to concerns about the arrival of flathead catfish to this portion of the river, our results suggest this portion of the river may not possess suitable spawning habitat. The radio-tagged robust redhorse above Juliette Dam did initiate upstream spring migrations, presumably in preparation of spawning. However, these migrations did not end at a spawning aggregation as in other systems (Grabowski and Isely, 2006). Whether suitable spawning habitat as described by Freeman and Freeman (2001) and Grabowski and Isely (2007) was available to them is unclear. The results of this study suggest hatchery-reared individuals can be used to establish or augment populations of robust redhorse in the Ocmulgee River and others in the region where this species has been extirpated. Our results also demonstrate the importance of long-term monitoring programs, including behavioral assessments for determining the success of stocking programs for riverine fishes.

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RADIO-TAGGED "GUIDE FISH": A NOVEL APPROACH FOR UNCOVERING INFORMATION ABOUT RARE OR CRYPTIC FISHES

The behavior and habitat selection of many fish species render them cryptic, difficult to observe, capture, or study, and ultimately, poorly known (Bruton 1995). The cryptic nature of such species leads to uncertainty as to the status of local populations or even whether a population is present within a system. This uncertainty imposes difficult challenges on resource management agencies tasked with managing such species in the face of continued anthropogenic alteration and destruction of aquatic habitats (Bruton 1995; McKinney 1999). Oftentimes, data on which to base management or conservation efforts or to determine critical habitat for protection are non-existent, and generating these data can be expensive and time consuming. Occasional serendipitous discoveries can help inform this process, but this approach is unreliable.

Robust redhorse *Moxostoma robustum* (Cope) offers an excellent example of the difficulties uncertainty imposes on conservation of cryptic species. Robust redhorse is a large catostomid native to medium to large rivers along the south Atlantic coast but is currently known from three drainages in North Carolina, South Carolina, and Georgia (Cooke *et al.* 2005). Stocked populations have been established both in additional drainages and in other portions of the Altamaha and Savannah drainages as well as other rivers in Georgia and South Carolina. This species was first described by Cope (1869), but the description and the fish were "lost to science" for 121 years until the fish was "rediscovered" in the Oconee River in central Georgia during 1991 (Ruetz and Jennings

2000; Cooke *et al.* 2005). Robust redhorse probably went unnoticed for such a long time because of a combination of habitat selection (i.e., robust redhorse occupying difficult-to-sample riverine habitats; Grabowski and Isely 2006), restricted range because of dam construction, population decline, and a historic neglect on the part of fisheries agencies towards non-game species such as suckers (Cooke *et al.* 2005). Robust redhorse spend most of their time in deep (>2 m) water in association with large woody debris along the outer edge of riverbends (Grabowski and Isely 2006). This habitat is difficult to sample effectively with standard methods such as electrofishing (Bayley and Austen 2002). As a result, early efforts to determine the status of this species in its historic range were hampered, and new data about the species habitat use and distribution were acquired with the occasional capture of one or two individuals (DeMeo 1997, 1998, 1999, 2000, 2001).

Radio-telemetry of wild individuals has played a major role in assessing the movement patterns and habitat use of known populations of robust redhorse in the Savannah River (Grabowski and Isely 2006) and the Pee Dee River (R.J. Heise pers. comm.). Further, telemetry has been instrumental in locating previously unknown populations by successfully directing sampling efforts to locations occupied by this species and allowing for the identification of spawning aggregations. In this paper, we describe the use of radio-tagged hatchery-reared "guide fish" to direct sampling efforts to successfully capture resident fish and to identify the timing and location of spawning. We were able to evaluate the effectiveness of this technique as part of a larger study examining the movement patterns and habitat use of robust redhorse stocked into the Ocmulgee River, Georgia (Grabowski and Jennings *in press*).

A total of 30 robust redhorse were captured, tagged with radio transmitters, transplanted to the Ocmulgee River, and tracked for 13 months. The study fish were collected from refugial populations established with progeny from Oconee River broodstock. The individuals from these refugial populations were of hatchery origin, but they had been at liberty for at least three years prior to capture. Radio transmitters with a trailing wire antenna were surgically implanted into the abdominal cavity. A lopher needle was used to create a small secondary opening in the body wall and served as a conduit for the trailing whip antennae to exit. These fish were maintained in holding tanks for 10 days after surgery before they were transported to and released in the Ocmulgee River in April 2006. Location of each fish was determined weekly through May 2007 (Grabowski and Jennings *in press*).

Towards the end of the life of the transmitters, the locations of radio-tagged fish were used in conjunction with electrofishing surveys to determine the detection probability of robust redhorse when employing the survey criteria recommended by the Robust Redhorse Conservation Committee (2002). A total of five transects, each ~1.5 rkm long, were sampled via boat-mounted electrofishing on 23 February, 2 March, 8 March, 5 April, and 19 June 2007. One transect was sampled on each date, and each transect had at least two (range = 2-6) radio-tagged hatchery-reared individuals. The electrofishing boat crew was aware that tagged individuals were present in the transect but were unaware of their locations within it (Grabowski *et al. in review*). Untagged, resident robust redhorse were captured while sampling the specific locations (i.e., the same piece of large woody debris) occupied by radio-tagged fish during three of the five sampling events (23 February (n=2), 2 March (n=2), and 19 June (n=2). Untagged robust redhorse were not encountered in areas unoccupied by the radio-tagged fish. Only one of the radio-tagged fish was captured during 7.5 hours of electrofishing effort (Grabowski *et al. in review*). Mean (±SE) catch per unit effort (CPUE) of untagged fish for these five sampling events was 1.32 ± 0.59 fish per hour. In comparison, CPUE of robust redhorse during survey efforts on the Ocmulgee River without the benefit of radio-tagged, hatchery-reared "guide fish" have been very low (0.15 - J.W. Evans pers. comm.; 0.0 - C.A. Jennings unpublished data).

In the current study, sampling in areas occupied by radio-tagged hatchery-reared fish yielded a higher CPUE than when sampling was conducted without such knowledge. The use of radio-tagged wild fish to guide sampling efforts also has proven to be effective in the Savannah River (Grabowski and Isely 2006) and the Pee Dee River (R.J. Heise, pers. comm.). We were unable to find examples in the literature of radio-tagged, hatchery-reared fish employed in the same role. However, a similar approach has been suggested by Baras and Lagardere (1995) and employed by Diggle *et al.* (2004), who used radio-tagged wild common carp *Cyprinus carpio* Linneaus as "Judas fish" to increase the effectiveness of eradication efforts in Tasmania. The use of radio-tagged individuals of wild or hatchery origin may assist researchers who have been unsuccessful or met with only limited success when trying to locate and monitor populations of rare or cryptic fishes.

In addition to helping to find untagged resident fish, radio-tagged, hatchery-reared "guide fish" in this study led us to a previously unknown spawning location. On 8 May and 10 May 2007, two radio-tagged male robust redhorse (453 mm TL, 1276 g; 447 mm TL, 1332 g) relocated at a site in the Ocmulgee River were part of a group of at least 10 individuals spawning in shoals at rkm 362.5 (Fig. 8). Although spawning was suspected in the Ocmulgee River, where the spawning occurred was not known to researchers. Both of these fish were located over substrate composed of loose gravel similar to that reported to be used by robust redhorse for spawning in other rivers (Freeman and Freeman 2001; Grabowski and Isely 2007). However, the water depth of the location where these aggregations formed was deeper reported in other populations (Freeman and Freeman 2001; Grabowski and Isely 2007).

The likelihood of finding this aggregation without a radio-tagged individual acting as a guide would have been virtually zero. Conventional wisdom about where robust redhorse spawn has limited sampling efforts to surveying large, mid-channel gravel bars, similar to known robust redhorse spawning sites in other systems (Freeman and Freeman 2001; Grabowski and Isely 2007). Our surveys for robust redhorse spawning aggregations in the Ocmulgee River followed similar search patterns. Additionally, the portion of the river where the spawning aggregation was found is navigable only by canoe. The only reason we were there was to locate radio-tagged individuals not found during our standard telemetry transects in the readily accessible portions of the river. Finally, the habitat occupied by this spawning aggregation was not conducive to a thorough visual examination because of the speed with which a canoe is carried through it and the occupants of the canoe being intensely focused on avoiding boulders. Our extended presence in this habitat was only because radio-tagged fish were located there; after we stopped to record the tracking data, we then discovered the spawning aggregation. Wild radio-tagged robust redhorse in both the Savannah and Pee Dee rivers have been employed to determine the timing and location of spawning

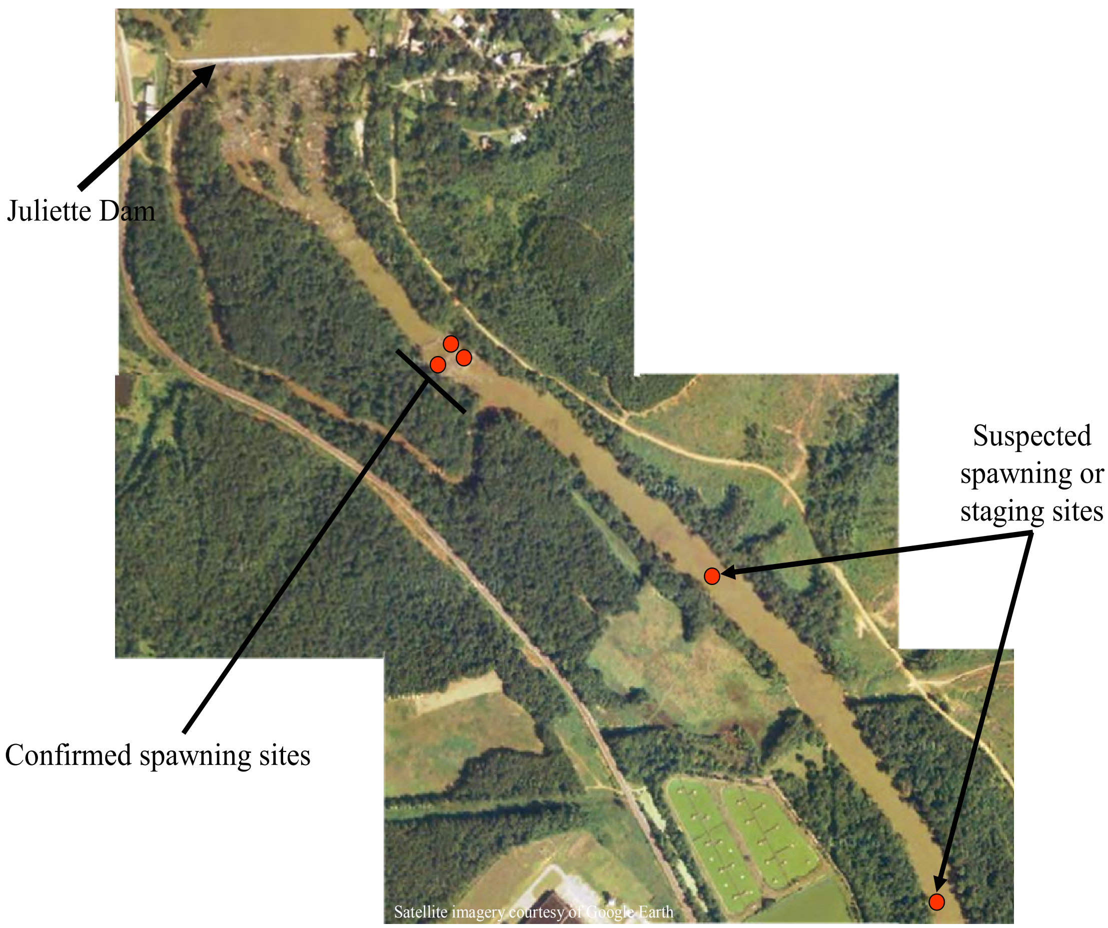

Figure 8. Satellite imagery of the Ocmulgee River, Georgia immediately below Juliette Dam. Locations where spawning, staging, or radio-tagged robust redhorse were observed are marked with red circles.

aggregations (e.g., Grabowski and Isely 2006). The use of wild, radio-tagged "guide fish" to locate spawning habitat also has been successfully applied to both white sturgeon *Acipenser transmontanus* Richardson in the Kootenai River (Paragamian *et al.* 2002) and Gulf sturgeon *Acipenser oxyrinchus desotoi* Vladykov in the Pascagoula River system (Heise, Slack, Ross and Dugo 2004) and to common carp (Diggle *et al.* 2004). Radio-tagged, hatchery-reared razorback sucker *Xyrauchen texanus* (Abbott) released into the Green River, Utah were relocated at a known spawning area with wild fish (Modde *et al.* 2005). However, we are unaware of other examples where radio-tagged hatchery-reared individuals were used for the express purpose of locating previously unknown spawning aggregations of resident fish.

Our results indicate that hatchery-reared individuals can be useful "guide fish" for finding wild individuals in situations where wild individuals are unavailable for use as "guide fish". There are two considerations that should be made prior to employing hatchery-reared individuals as "guide fish." Hatchery-reared individuals frequently demonstrate behaviors that are markedly different from their wild counterparts (Huntingford 2004) and as a result may suffer elevated levels of mortality. These behavioral differences tend to become less pronounced as individuals become naturalized (Huntingford 2004). Researchers attempting to use hatchery-reared "guide fish" that have not acclimatized to life outside of a hatchery should be prepared for possible high levels of mortality and allow time for the newly released fish to adjust. A second consideration is avoiding potential genetic consequences the assimilation of "guide fish" may have upon a target population. In the Ocmulgee River, such concerns were not an issue because the resident robust redhorse population because the transplanted individuals originated from the same evolutionary significant unit as the resident population (Wirgin *et al.* 2001). However, using such genetically similar individuals may not always be possible and evaluating both the methods of surgically sterilizing "guide fish" prior to release and the migratory behavior relative to control fish after release may be necessary (Collins *et al.* 2004).

The implicit assumption of almost all telemetry studies is tagged individuals do not differ in their behavior or habitat selection from untagged fish. Although this assumption may not always hold true, it was not a concern in this study (Grabowski and Jennings, in press). We have found the use of radio-tagged hatchery-reared "guide fish" to potentially offer a powerful tool to enable fishery managers and researchers to direct sampling, survey, and observation efforts to locations and times that offer a high probability of success.

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CAPTURE PROBABILITY AND BEHAVIORAL RESPONSE OF ROBUST REDHORSE, A CRYPTIC RIVERINE FISH, TO ELECTROFISHING*

Introduction

Robust redhorse *Moxostoma robustum* is an imperiled riverine catostomid native to the Piedmont and upper coastal plain reaches of large Atlantic Slope rivers in Georgia and the Carolinas (Cope 1869, Bryant *et al.* 1996). Originally described in 1869, the species was "lost to science" for over a century prior to its "rediscovery" in 1991 (Bryant *et al.* 1996). Despite being formerly abundant (Cope 1869), native populations of robust redhorse currently are known from only the Oconee River in the Altamaha River drainage of central Georgia, the Savannah River along the Georgia – South Carolina border, and the Yadkin-Pee Dee River drainage in North and South Carolina (Bryant *et al.* 1996; DeMeo 2001). Population estimates based on mark-recapture data from the Oconee River (Jennings *et al.* 2000; DeMeo 2001) and the Savannah River (Grabowski and Isely *in press*) suggest only small populations of not more than 500 individuals remain in these rivers.

Robust redhorse may be considered a cryptic species by virtue of its behavior and habitat preferences. Individuals spend the majority of their time in deep, fast-flowing

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water along the outer edge of river bends in association with large woody debris (Jennings *et al.* 1996, Grabowski and Isely 2006, Grabowski and Jennings *in press*). These habitats are difficult to sample effectively with standard techniques such as boat-mounted electrofishers or gillnets (Bayley and Peterson 2001, Bayley and Austen 2002) and may be part of the reason why robust redhorse were "lost to science" (Grabowski and Isely 2006). Current population estimates probably are biased low because of low catchability and violations of population estimator assumptions, such as the influence of temporary emigration on the assumption of a closed population (Kendall 1999, Grabowski and Isely *in press*), and that all individuals have equal probability of capture (Pollock *et al.* 1990). However, important conservation priorities and activities such as population assessments, formulating stocking recommendations, and the evaluation of recovery efforts would benefit from improved estimates of abundance that take into account this imperfect detectability (MacKenzie *et al.* 2005; Martin *et al.* 2007). Additionally, the response of robust redhorse to single or repeated sampling surveys is not known, but could potentially influence capture probabilities.

Our objectives were to: (1) observe the behavioral response of individuals to both single and repeated sampling efforts, and (2) estimate the capture probability of robust redhorse sampled with standard boat-electrofishing techniques proscribed by the Robust Redhorse Conservation Committee (2002). To accomplish this, we used radio-tagged individuals that were part of a recently completed telemetry study in the Ocmulgee River, Georgia.

Methods

Study area.—The Ocmulgee River is approximately 400 km in length and drains about 9,900 km^2 in the Piedmont and upper Coastal Plain physiographic provinces of central Georgia. It and the Oconee River are the two major tributaries that merge to form the Altamaha River. Attempts to collect robust redhorse in the Ocmulgee River and confirm the presence of a resident, native population have been largely unsuccessful (DeMeo 2001). Since 2002, robust redhorse progeny from Oconee River broodstock have been stocked into the Ocmulgee River to establish a self-sustaining population.

Our study focused primarily on a 2-km reach bounded by Lloyd Shoals Dam at river kilometer (rkm) 394.5 near the city of Jackson, Georgia and the impassable shoals immediately downstream of the crossing of Georgia Highway 16 at rkm 392.65 (Figure 9). This section of river contains a variety of habitat types including rocky shoals, deep pools, and bends with large woody debris. Three additional surveys were made further downstream below rkm 241.00. This downstream portion of the river was characteristic of the upper coastal plain and consisted primarily of a series of meanders with sandbars and large woody debris as the primary habitat features.

Data collection. — The fish used in this evaluation were part of a study examining movements and habitat use of robust redhorse stocked into the Ocmulgee River. Study fish (n=30) were surgically implanted with radio-tags and released near Lloyd Shoals Dam at rkm 393.95 on 19 April 2006 (Grabowski and Jennings, *in press*). Our sampling efforts for this study were initiated near the end of the manufacturer’s 1-year guaranteed transmitter battery life to allow fish to acclimatize to the local environment and to minimize interference with the telemetry study.

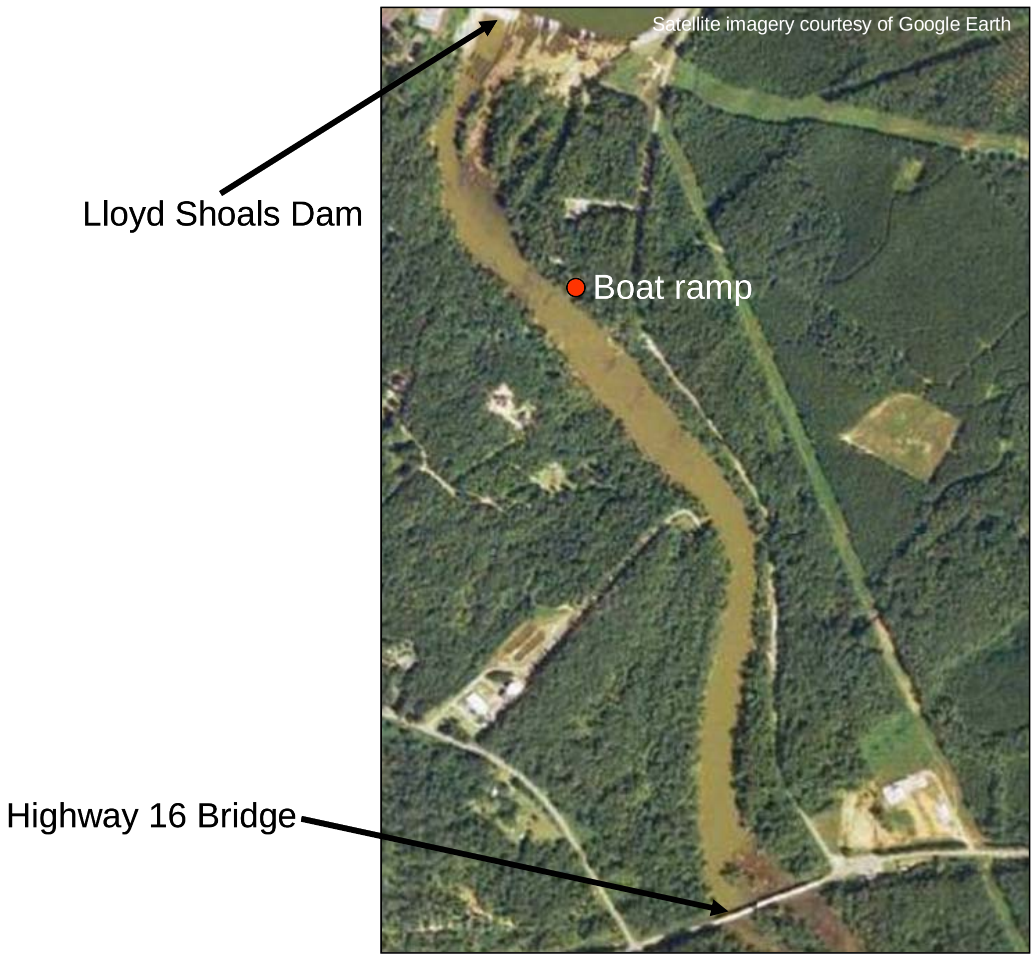

Figure 9. Primary sample area for radio-tagged robust redhorse on the Ocmulgee River, Georgia. Sampling was initiated at the boat ramp and proceeded along the western bank (left) to the Highway 16 bridge, then back upstream along the eastern bank (right) to a point approximately halfway between the boat ramp and the bridge.

Sampling events were conducted on 23 February, 2 March, 8 March, 5 April, and 19 June 2007. Radio-tagged robust redhorse were located prior to sampling by boat using ATS R2100 programmable scanning radio receiver (Advanced Telemetry Systems, Isanti, Minnesota) with a loop antenna. The precise location of the fish was determined by disconnecting the coaxial cable from the antennae and using it to determine the position of the tagged fish to within 1 m as described by Grabowski and Jennings (*in press*). Upon locating a fish, its position was determined and recorded with a 12-channel, WAAS-enabled, hand-held global positioning unit (Garmin International, Inc., Olathe, Kansas). Fish position was converted from latitude and longitude to rkm with ArcGis 9.2 (Environmental Systems Research Institute, Redlands, California). Water temperature (°C), depth (m), current velocity ($m \cdot s^{-1}$), turbidity (NTU), and dissolved oxygen levels (mgL^{-1}) were recorded at each fish location. Additionally, the dominant substrate type (muddy, sandy, rocky) and cover type (none, rocks, woody debris) was noted.

After all radio-tagged robust redhorse within a transect had been located, the tracking boat returned to the ramp and rendezvoused with the electrofishing boat. The electrofishing crew was made aware of the length of the transect and the number of fish present but not told of their positions. The electrofishing crew then sampled the defined area at least 0.19 hours of pedal time per rkm, which is the minimum effort suggested to determine the presence of robust redhorse in an area (Robust Redhorse Conservation Committee 2002). The electrofishing boat was outfitted with a Smith-Root Type VI-A electrofisher (Smith-Root, Inc., Vancouver, Washington) set at 600 V, 60 Hz DC, and 6-7 ms pulse width. The voltage and pulse width settings were altered as necessary to maintain a 4-5 A output. The tracker followed the electrofishing boat at a safe distance and monitored fish response during sampling, noting any movement of radio-tagged fish as the electrofishing boat passed their position. The electrofishing crew collected all catostomids that surfaced around the boat. Each was identified to species and enumerated. The sex of each robust redhorse was determined and each individual was measured (mm TL) and weighed (g). All captured fish were allowed to recover and released alive. After the electrofishing crew completed sampling, the tracker relocated the position of each individual as described above. The tracker also returned to relocate these fish after 24 hours and again 3-5 days later.

Data analysis.—Both absolute movement and displacement of each individual was calculated for 1-2 hours, 24 hours, and 3-5 days post-sampling. Displacement was calculated as the difference between the initial fish position and its position upon relocation. Negative values for displacement indicated downstream movement and upstream movement was represented by positive values. Absolute movement was simply the absolute value of displacement (Grabowski and Isely 2006, Grabowski and Jennings *in press*). We evaluated the directionality of the displacement with Student's t-test to evaluate whether mean displacement differed from zero. A one-way repeated measures analysis of variance (ANOVA) was used to compare the absolute movement and displacement of individuals exposed to one, two, three, and four sampling events. A paired student's t-test was used to compare the movement of individuals in the study to individuals relocated at similar time intervals from the larger telemetry study (Grabowski and Jennings *in press*). A significance level of $\alpha = 0.05$ was used for all of the abovementioned tests.

We wanted to estimate the probability of capturing a robust redhorse with boat electrofishing equipment and the abundance of untagged robust redhorse in the study transects. For radio-tagged robust redhorse, we estimated the capture probability (*p*) for each sampling transect as:

$$\hat{p}_i = \frac{c_i}{N_i}$$

where *N* is the known number of radio-tagged robust redhorse and *c* is the number of radio-tagged fish captured in transect (*i*). One method for estimating the abundance of untagged robust redhorse is to adjust the number of untagged fish catch by the estimated capture probability following Thurow *et al.* (2006). This approach, however, ignores the potentially useful information from the capture histories of the untagged robust redhorse. Fish abundance and capture probability can be estimated from repeat fish collection samples with the technique for estimating abundance from repeated samples described by Royle and Nichols (2003). We treated each transect as analogous to a repeated sample from a sample site and estimated mean abundance (L) and capture probability as:

$$L(w) = \binom{T}{w}\left(1-(1-r_i)^{k_i}\right)^{w}\left((1-r_i)^{k}\right)^{T-w}\frac{e^{-\lambda}\lambda^{k_i}}{k_i!}$$

where *w* is the number of observed detections in *T* total transects, λ is the mean of a Poisson distribution of the assumed robust redhorse abundance, *r* is the capture probability of untagged robust redhorse, and likelihood is evaluated with respect to *k*— the number untagged of robust redhorse in transect *i*.

To accommodate the complex model structure, we used Markov Chain Monte Carlo (MCMC) as implemented in BUGS software, version 1.4 (Spiegelhalter *et al.* 2006) to jointly fit the model estimating capture probabilities of tagged and untagged robust redhorse and the mean abundance of robust redhorse in sample transects. All models were fit based on 500,000 iterations with 250,000 burn in (i.e., the first 250,000 MCMC iterations were dropped) and diffuse priors. We evaluated the relative fit of 4 candidate models: (1) capture probabilities differed between tagged and untagged fish ($\hat{p}_i \neq \hat{r}_i$), (2) capture probabilities of tagged and untagged fish were equal ($\hat{p}_i = \hat{r}_i$), (3) mean robust redhorse abundance was a function of transect length, and (4) mean robust redhorse abundance was constant among transects (irrespective of transect length). The relative fit of models was assessed using Deviance Information Criterion (DIC) (Spiegelhalter *et al.* 2002) with lower values indicating better approximating models. We considered models with ΔDIC values less than 5 as plausible and reported their parameter estimates and 95% Bayesian credibility intervals, which are analogous to 95% confidence intervals (Spiegelhalter *et al.* 2002).

Results

Eight transects were sampled during this study; they ranged in length from 0.50 to 2.24 km in length and contained between one and eight radio-tagged robust redhorse (Table 1). A total of 7.46 hours of effort was expended during these sampling events. A mean (±SD) of 0.66 ± 0.22 hours of effort was spent per km of transect, 1.5-5.7 times greater than the amount of effort recommended by sampling guidelines outlined for this species (Robust Redhorse Conservation Committee 2002). Only one radio-tagged robust redhorse and six untagged individuals were captured during these sampling events (Table 1). An additional 82 catostomids were captured; this catch consisted of notchlip redhorses *Moxostoma collapsum* (*n* = 10), spotted suckers *Minytrema melanops* (*n* = 46),

Table 1. Sample dates, locations, lengths (km), effort (hrs), and catch statistics of radio-tagged and untagged robust redhorse and other catostomid species collected in electrofishing transects in the Ocmulgee River, Georgia.

Sample date	Start point (rkm)	Transect length (km)	Effort (hrs)	Radio-tagged robust redhorses in transect	Radio-tagged robust redhorses captured	Untagged robust redhorses captured	Notchlip redhorses captured	Spotted suckers captured	Brassy jumprocks captured	Quillbacks captured
2/23/2007	393.95	2.24	0.77	8	0	2	4	10	0	0
2/23/2007	240.95	0.75	0.40	1	0	0	0	0	0	0
2/23/2007	236.57	1.00	1.07	1	0	0	0	1	0	1
2/23/2007	233.98	0.50	0.40	1	0	0	0	1	0	0
3/2/2007	393.95	2.24	1.51	7	0	2	6	15	12	0
3/8/2007	393.95	2.24	1.51	6	0	0	0	11	8	0
4/5/2007	393.95	1.49	1.05	4	1	0	0	0	0	0
6/19/2007	393.95	1.50	0.75	2	0	2	0	8	5	0

brassy jumprocks *Moxostoma* sp. cf. *lachneri* (n = 25), and quillback *Carpiodes cyprinus* (n = 1) (Table 1).

Radio-tagged robust redhorse did not seem to exhibit an immediate response to the sampling efforts. Movement was detected only two times out of the 30 possible encounters between radio-tagged individuals and the electrofishing boat. The signal for the single captured radio-tagged fish did increase in strength as the fish was brought to the surface and netted. Movement was observed for another radio-tagged fish that was initially occupying shallow water (1.0 m) in the proximity of the shoals at the upstream limit of the transect (Figure 9) on 8 March 2007. This fish moved across the river channel several times before taking up a position about 0.1 km downstream in water 2.0 m deep that contained large woody debris. Changes in signal strength or other indications of movement were not noted for any of the remaining individuals while sampling was in progress.

Some movement was observed when the tracker relocated fish at the conclusion of sampling activities. Within 1-2 hrs of the conclusion of sampling activities, the majority of radio-tagged robust redhorse were occupying positions within a mean distance of 0.15 km (SE =0.05; range: 0.0 – 0.80 km) of their location prior to sampling. However, this movement was not directional as demonstrated by the mean displacement not differing from zero (t_{21} = -0.02; p = 0.99). A similar pattern was observed upon relocating radio-tagged robust redhorse 24 hrs and 3-5 days after sampling. Individuals had moved mean distances of 0.19 km (SE = 0.05) and 0.23 km (SE = 0.14) from their original position after 24 hrs and 3-5 days respectively. However, this movement also was not directional during either time interval ($t_{30} \leq 1.58$; $p \geq 0.12$). The single recaptured radio-tagged individual was released at the boat ramp. This fish returned to within 200 m of the position from which it was captured and remained in that location for approximately three weeks before being relocated upstream in the tailrace of Lloyd Shoals Dam.

Multiple exposures to sampling activities did not seem to alter the behavior of radio-tagged robust redhorse (Figure 10). Numerous individuals were exposed to sampling efforts a second ($n = 7$), third ($n = 5$), and fourth ($n = 3$) time over the course of the study. The activity levels of these fish, expressed as the sum of absolute movement and displacement over the 3-5 day monitoring period, were not different than that after their initial exposure to sampling activities and did not differ among subsequent exposures (absolute movement: $F_{3,12} = 0.49$, $P = 0.70$; displacement: $F_{3,12} = 0.62$, $P = 0.62$).

Ultimately, the behavior of radio-tagged robust redhorse did not seem to be affected by boat-mounted electrofishing (Figure 11). Radio-tagged fish, including individuals used in this study, were relocated over 24-hr ($n = 85$) and 3-5-day ($n = 262$) periods without exposure to sampling activities during the course of a year-long telemetry study in the Ocmulgee River (see Grabowski and Jennings, *in press*). The absolute movement and displacement of individuals 24 hrs (absolute movement: $t_{83} = 0.13$; $p = 0.90$; displacement: $t_{69} = -1.00$; $p = 0.32$) and 3-5 days (absolute movement: $t_{144} = 1.19$; $p = 0.12$; displacement: $t_{110} = -1.37$; $p = 0.17$) after sampling did not differ from the movement patterns of undisturbed fish over similar time intervals.

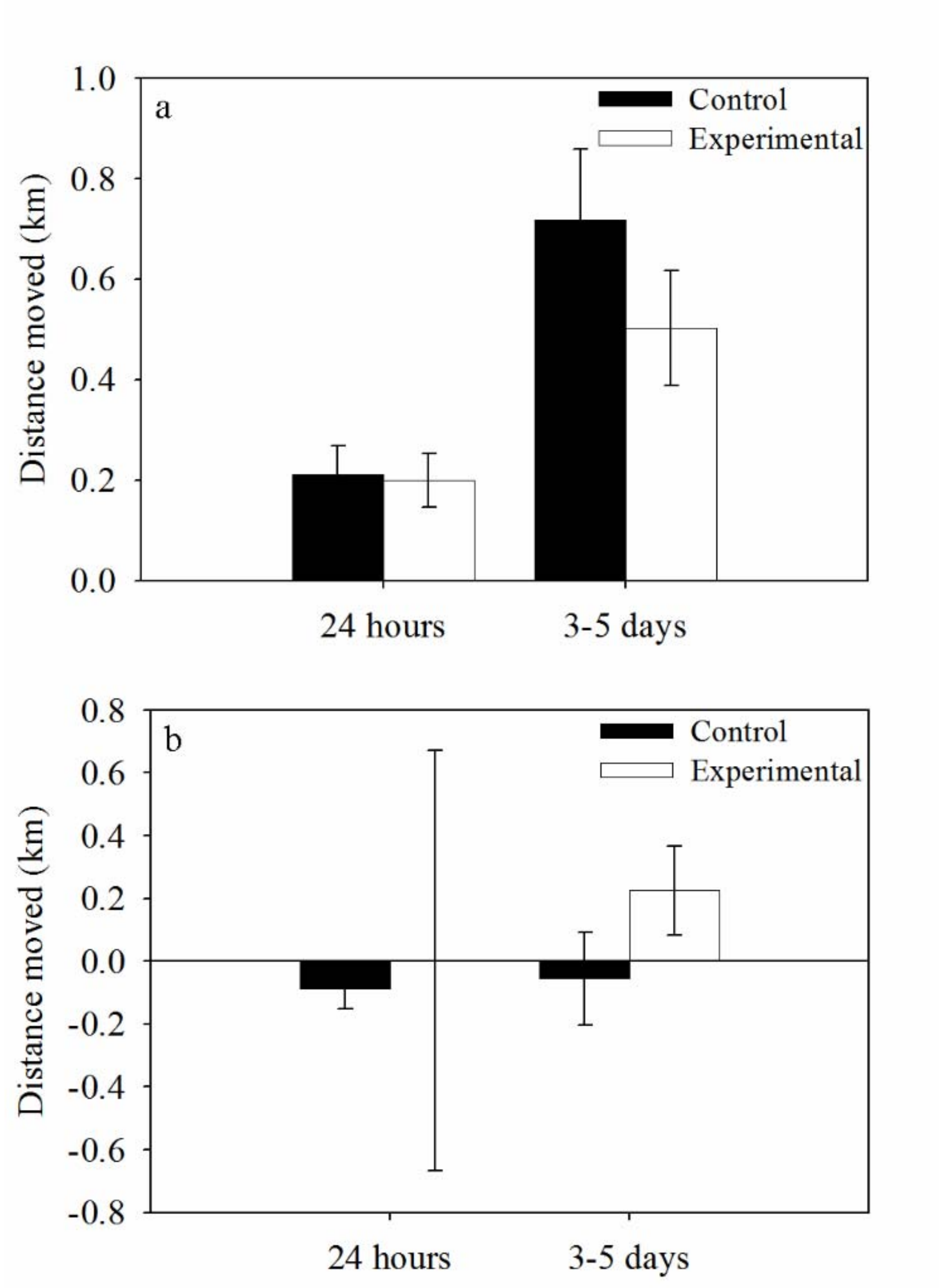

Figure 10. Mean absolute movement (a) and displacement (b) of radio-tagged robust redhorse in the Ocmulgee River, Georgia over a 3-5 day period after their first, second, third, and fourth exposures to sampling activities. Error bars represent standard error.

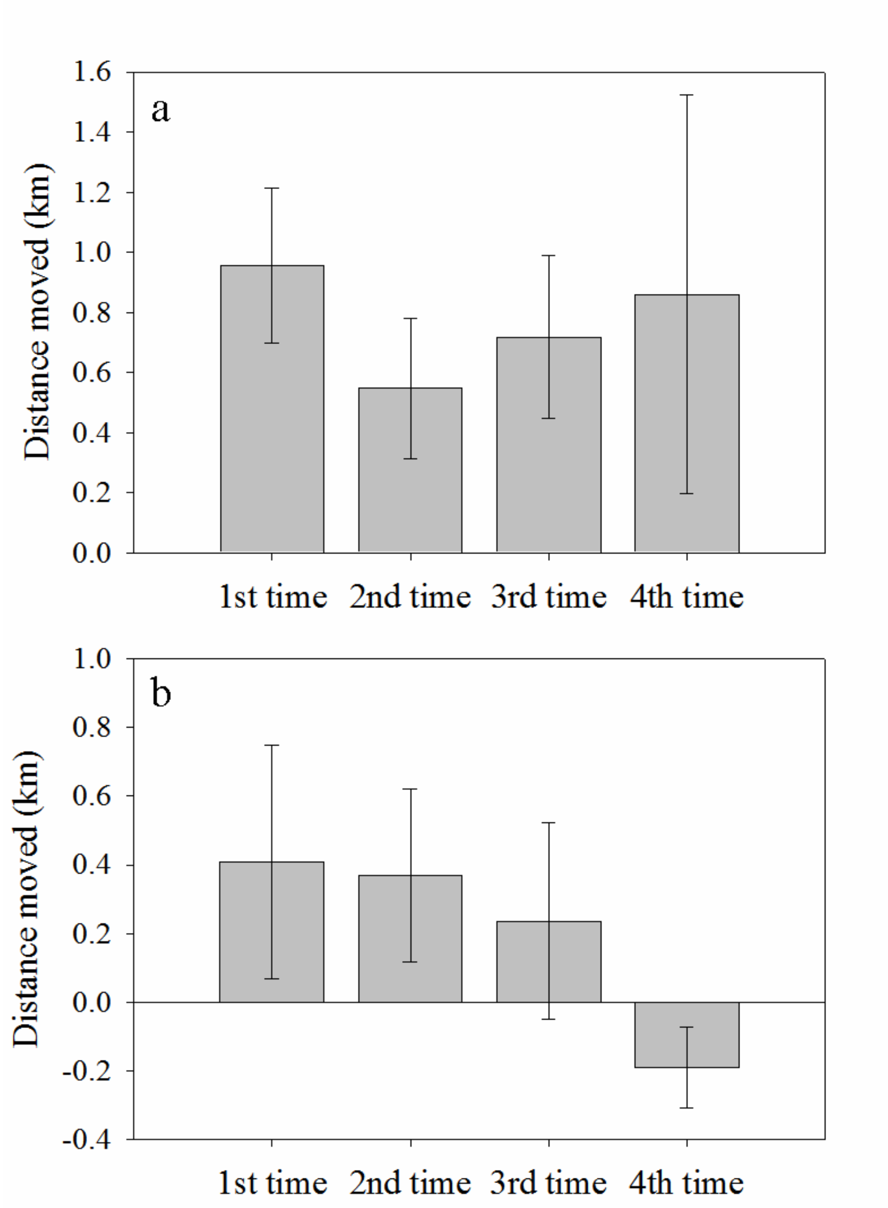

Figure 11. Mean absolute movement (a) and displacement (b) over a 24-hour and 3-5 day period of radio-tagged robust redhorse in the Ocmulgee River, Georgia. Fishes that were exposed to sampling effort are represented within the experimental treatment group. The control group contains observations made at the appropriate time intervals during a one-year telemetry study of these individuals (Grabowski and Jennings, *in press*). Error bars represent standard error.

Model selection criteria indicated support for two of the candidate models. The best approximating model for estimating robust redhorse capture probability and abundance modeled capture probabilities as equal between tagged and untagged robust redhorse and modeled mean abundance as equal across transects (Table 2). The second best approximating model differed from the best by modeling capture probabilities as differing between tagged and untagged fishes. Estimates of capture probabilities from the best approximating model averaged 0.031 with 95% Bayesian credibility intervals of 0.002- 0.111. In contrast, capture probability estimates from the second best fitting models were 0.062 and 0.055 for tagged and untagged fish, respectively. The standard deviations for these were relatively large and suggested that these estimates were unreliable. Mean robust redhorse abundance estimates per transect were 86.3 and 179.7 for the best and second best models, respectively. However, the standard deviations were relatively large and suggest that these values be interpreted with caution.

Discussion

Robust redhorse did not exhibit a significant response to boat-mounted electrofishing sampling activities. Most fish did not exhibit behavioral changes during or after single or repeated sampling events. This lack of response was unexpected as the species has been observed to be somewhat wary and sensitive to disturbance, at least under captive conditions (D. Wilkins, South Carolina Aquarium, *personal communication*). Observations in streams and smaller rivers have indicated that other catostomids are wary and can be difficult to approach when not spawning (Jenkins and

Table 2. Mean deviance ($\overline{D}$), deviance at mean parameter values ($\hat{D}$), effective number of parameters (*p*D), DIC, and ΔDIC, for the candidate models for estimating robust redhorse capture probability (p), and the abundance of untagged robust redhorse (N) in transects in the Ocmulgee River, Georgia.

Model[1]	$\overline{D}$	$\hat{D}$	*p*D	DIC	ΔDIC
p(.) N(.)	27.670	25.947	1.724	29.394	0.000
p(tagged, untagged), N(.)	27.850	23.875	3.975	31.825	2.432
p(tagged, untagged), N(transect length)	25.170	15.903	9.267	34.437	5.044
p(.), N(transect length)	26.810	19.157	7.653	34.463	5.070

[1](.) indicates that the parameter was modeled as a constant.

Table 3. Parameter estimates, standard deviation, and upper and lower 95% credibility intervals for confidence set of models of robust redhorse abundance and capture probability.

Parameter	Estimate	Standard deviation	Lower	Upper
Untagged fish abundance	86.34	135.8	6	532
Probability of capture	0.031	0.030	0.002	0.111
Untagged fish abundance	179.7	242.8	2	873
Probability of capture, tagged fish	0.062	0.042	0.008	0.167
Probability of capture, untagged fish	0.055	0.093	0.001	0.351

Burkhead 1993; T. B. Grabowski *personal observation*). There are several possible explanations for the observed lack of response of radio-tagged robust redhorse in the Ocmulgee River. Robust redhorse occupy relatively deep water, typically > 2.0 m (Grabowski and Isely 2006, Grabowski and Jennings, *in press*). As such, they may be out of reach of the electric field generated by a boat-mounted electrofisher, particularly if they are on or near the river bottom (Reynolds 1996). Alternatively, robust redhorse may be stunned by the electricity but may not readily float to the surface, possibly because they become entangled in cover. Robust redhorse are rarely, if ever, found far from cover as demonstrated by this and other radio telemetry studies (Grabowski and Isely 2006, Grabowski and Jennings *in press*, R. Hiese, North Carolina Wildlife Commission *personal communication*). The lack of movement we observed may be a result of some individuals becoming entrapped in structurally complex refuges, and thus prevented from rising to the surface or being carried downstream. The observed similarity of behavior between fish exposed to sampling activities and the "control" dataset of the movement of individuals over similar time periods as well as the consistent behavior of individuals exposed to multiple exposures would seem to suggest the fish were not being affected by the electric field.

Regardless of the reason(s) for the lack of an observed behavioral response in robust redhorse, the implication to conservation efforts is that electrofishing does not appear to be a particularly effective method for capturing this species. Robust redhorse capture probabilities are considerably lower than those reported for smallmouth bass *Micropterus dolomieu* (Odenkirk and Smith 2005, Dauwalter and Fisher 2007) and other common sportfish species such as largemouth bass *Micropterus salmoides*, bluegill

Lepomis macrochirus, and crappie *Pomoxis* spp., as well as nongame fishes, such as common carp *Cyprinus carpio*, gizzard shad *Dorosoma cepedianum*, or threadfin shad *Dorosoma petenense* (Bayley and Dowling 1990, 1993, Bayley and Austen 2002). Many of these studies have suggested that catostomids, such as redhorses, may be underrepresented in samples taken with boat-mounted electrofishers. Bayley and Austen (2002) report a mean capture probability of 0.03 for catostomids captured with a boat-mounted electrofisher in Midwestern lakes. They found that only ictalurid catfishes had a lower capture probability (mean: 0.0018) out of 11 common warmwater taxa. The capture probability reported here for robust redhorse is comparable to that reported for catostomids by Bayley and Austen (2002), despite deeper water, higher current velocities, and potentially lower conductivity encountered in this study. The low sample sizes of robust redhorse in this study suggests a high level of uncertainty regarding the precise probability of capturing robust redhorse with electrofishing gear; however, the capture probability is likely low based on this study and the observations of others. Further research to refine these models would be useful, but the results of this study suggest that the effort recommended for the standard electrofishing mark/recapture surveys used to monitor populations of this species are insufficient and greater effort must be expended to ensure more accurate estimates.

Accounting for the behavioral reactions of fish to sampling gear (Fréon 1993) and the capture probability of a species, particularly ones that are rare or difficult to sample is an important component of study design. Failing to do so will likely result in consistently underestimating population sizes. Although a conservative approach is desirable in the management of threatened or endangered species, underestimating population size can be a hindrance to recovery. For example, in the case of robust redhorse, some combination of behavioral responses and habitat selection seem to render the species difficult to capture. Low capture probability results in high sample variance, which lowers data quality and ultimately influences conservation decision-making (Peterson and Rabeni 1995). However, determining the success of stocking programs, estimating the status of known populations, or establishing the presence or absence of this species in other Atlantic Slope drainages is heavily dependent upon electrofishing surveys (DeMeo 2001, Robust Redhorse Conservation Committee 2002). This is a common theme amongst the conservation programs for imperiled catostomids throughout North America (Cooke *et al.* 2005) and perhaps other cryptic riverine species. There are potential remedies such as employing alternative gear types to which the target species may be more vulnerable, increase gear efficiency through the use of radio-tagged "guide fish" (Grabowski and Jennings *in review*), or approaching the problem differently (e.g., the use of occupancy models; MacKenzie *et al.* 2003, 2006, Royle and Dorazio 2006) that resource managers can incorporate to account for low capture probabilities.

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Appendix B

Ocmulgee River Gear Trials 2007-08

By

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Presented at the 2008 Annual Meeting of the Robust Redhorse Conservation Committee
Boomer, NC

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Ocmulgee River Gear Trials
Fall 2007

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Introduction

Robust redhorse are a sucker species native to the Altamaha River basin that has been the subject of intensive conservation and recovery efforts for the past two decades. While new information is gained annually about the reproductive behavior, habitat use, and population dynamics of the species, the most challenging aspect of managing populations is collecting adequate and accurate population data. Several groups including USGS, GA-DNR and GPC have conducted sampling surveys throughout the Oconee and Ocmulgee Rivers in hopes of collecting large numbers of individuals to aid in population estimation, produce a genetically diverse broodstock, and understand collection methodologies and target sampling areas. Unfortunately, the cryptic nature of the species has led to consistently low and highly variable catch rates in all sampling efforts. Given this result, we have endeavored to find alternate sampling methodologies to provide a more consistent data source for population evaluation and estimation. Below I describe the first of several proposed studies designed to test alternate gear types and sampling methods.

Study Site

The study site for the preliminary gear trial was a x.xx km stretch of the Ocmulgee River downstream of Lloyd Shoals Dam and upstream of the Georgia Highway 16 Bridge (Figure 1). This section of river has historically been sampled by GA-DNR and GPC personnel for robust redhorse, has a known robust redhorse population, and is one of the sites of juvenile stockings.

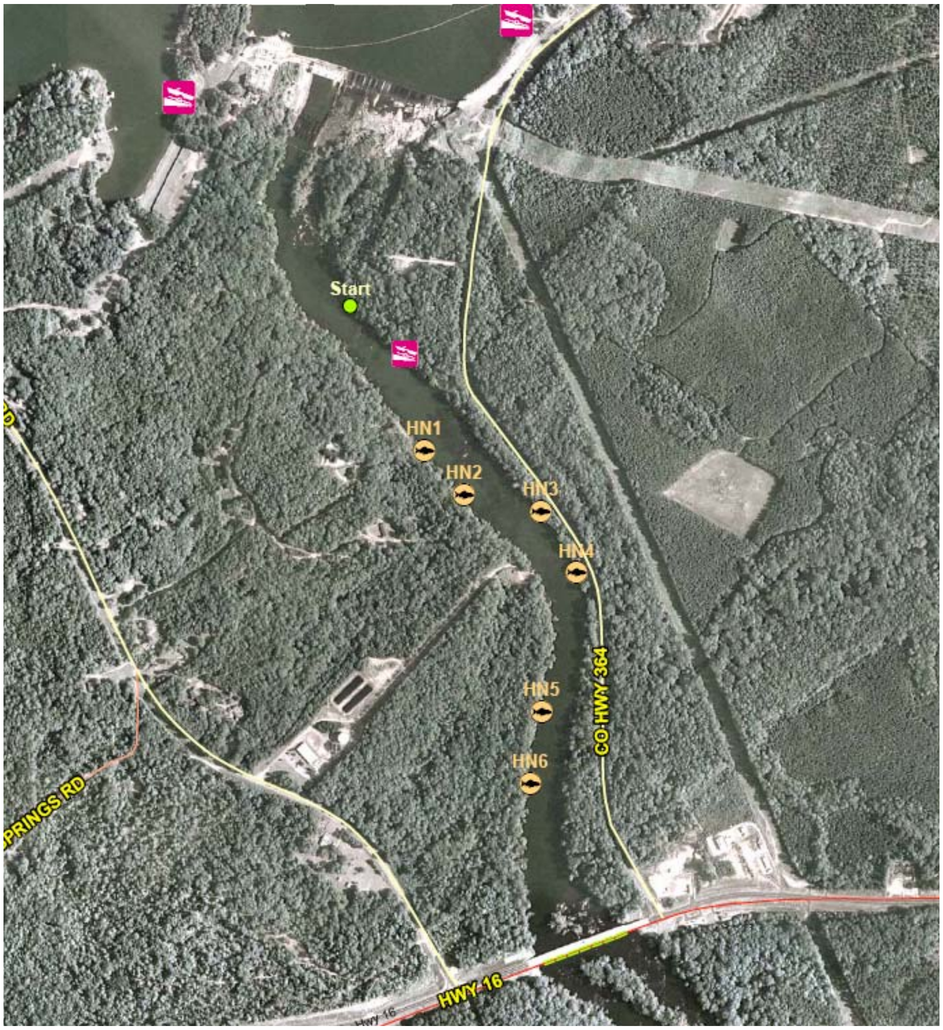

Figure 1. The Ocmulgee River below Lloyd Shoals Dam, Georgia. The "start" location indicates the uppermost boundary for electrofishing surveys, while the Hwy. 16 bridge depicts the lowermost boundary. Hoopnet locations (labeled HN-1 through HN-6) are marked for reference.

Methods

An electrofishing survey was conducted in the study reach on October 15, 2007 with Georgia DNR utilizing their standardized electrofishing survey methodologies. That pre-manipulation survey resulted in the capture of two robust redhorse suckers and served as a control for the following experiment.

Six sampling sites were selected based on proximity to robust redhorse collection locations or habitat similarity to those locations where robust redhorse have been previously collected within the reach. These six sample sites were fixed throughout the fall 2007 experiment.

Weighted double-throated hoopnets were set individually at each of the six sampling sites for each of three treatment nights during a one-week period from October 23-30, 2007. Net sizes varied in diameter (0.5, 0.75, and 1m diameters), and net depths and volumes were proportionate to hoop diameters. Hoopnets were secured to stable woody debris or to large overhanging branches using approximately 15 meters of nylon rope and were stretched down-current in areas of slight downstream flow. Additional weights were attached to nets as needed to ensure that each net sank to the river bottom and remained open. Flow was stable at approximately 330cfs during the experiment, and water temperatures ranged from 19.9 to 22.9C.

The experimental design consisted of an unbaited set night, a set night after 3 consecutive days of corn baiting at each site, and a final set night after 6 consecutive days of corn baiting and the addition of one of two bait bags added to each net. Corn baiting events consisted of spreading approximately 2.5kg of dried whole kernel livestock feed corn in the immediate vicinity of each hoopnet set location. On the last net night, bait bags filled with either high-fat content cat food or dried molasses/mixed grain/soy cakes were placed at random in each hoop net.

Following the netting experiment, a second electrofishing survey was conducted in the reach following GA-DNR standardized sampling procedures. This survey was designed to determine if the corn baiting had attracted robust redhorse to the area and/or concentrated robust redhorse in previously baited locations.

Results

The GA-DNR standardized electrofishing survey conducted on October 15, 2007 yielded two adult robust redhorse. One specimen was captured immediately upstream of the HN-1 netting site, and the other was captured at the HN-6 site. No additional data were collected on either specimen, as this control survey was solely intended to determine if robust redhorse were within the study area.

No robust redhorse were captured in hoopnets, regardless of baiting treatment, and no suckers of any species were collected during the netting experiment. Catch rates of other species varied greatly, but generally increased with increased corn bait duration and addition of bait bags (Figure 2).

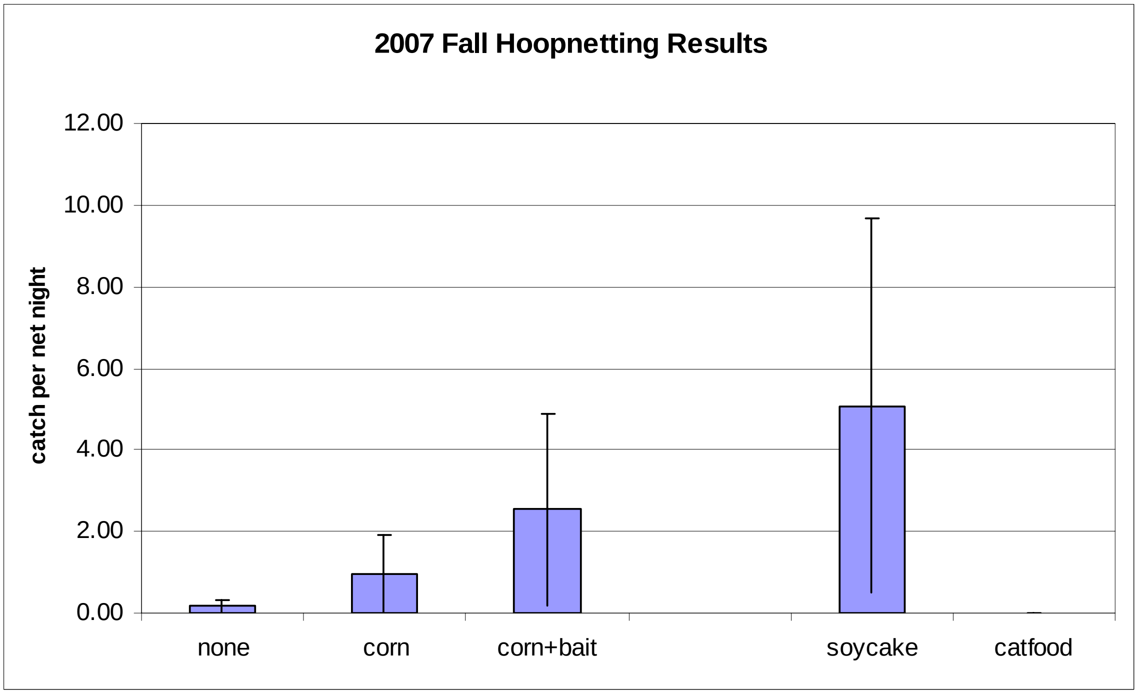

Figure 2. Hoopnet catch rates as a function of variable bait combinations utilized during the gear trial study. Catch rates generally increased with increased baiting, and soy cakes were preferred over cat food by species captured.

GPC utilized GA-DNR standardized electrofishing sampling methods within the reach after seven consecutive days of localized baiting at hoop net locations. The follow up electrofishing survey resulted in the capture of two adult robust redhorse (421mm and 496mm TL) within the reach; one immediately upstream of the HN-1 net site and at the location of the previous electrofishing capture, and the other upstream of the HN-5 net site and immediately downstream of the Butts County water intake structure.

Discussion

Adult robust redhorse continue to utilize available habitat within a relatively small river reach below Lloyd Shoals Dam. Despite stocking efforts resulting in over 14,000 juveniles being introduced into the river, no juvenile robust redhorse were collected. While habitat in the reach may be limited, we would expect more individuals to recruit to our electrofishing gear as they continue to grow within the system.

Hoop netting trials require tremendous effort and logistical preparation, which may be unwarranted due to lack of collection of robust redhorse in our samples. Baiting hoopnets with corn or with corn in combination with other attractants also seems unwarranted, especially during fall. Although anecdotal evidence suggests that anglers have successfully baited suckers into areas to increase catch rates, that method in not confirmed with our electrofishing results.

Robust redhorse remain a very elusive species, and sampling the species continues to be difficult. While our study cannot confirm or refute the use of hoopnets or baiting as viable collection alternatives, it seems that GA-DNR's standardized electrofishing strategy in the best known approach to collection of the species and provides the best consistent source of collection records to date.

Our future plans for robust redhorse collection will include use of baited or un-baited hoopnets during spring, when robust redhorse are actively aggregating and migrating to spawning sites. We also plan to utilize other gears as available (such as trammel nets and electrofishing in conjunction with trammel-netting) during spring aggregation and migration. Additionally, we plan to continue to monitor the Ocmulgee population using electrofishing methods at known collection locations and hope to identify additional habitats (such as gravel bars) that attract spawning aggregates.

APPENDIX C

Plate Index and associated maps showing the location of gravel bars in the Oconee River from the 2005-2007 GPC survey

Plate Index

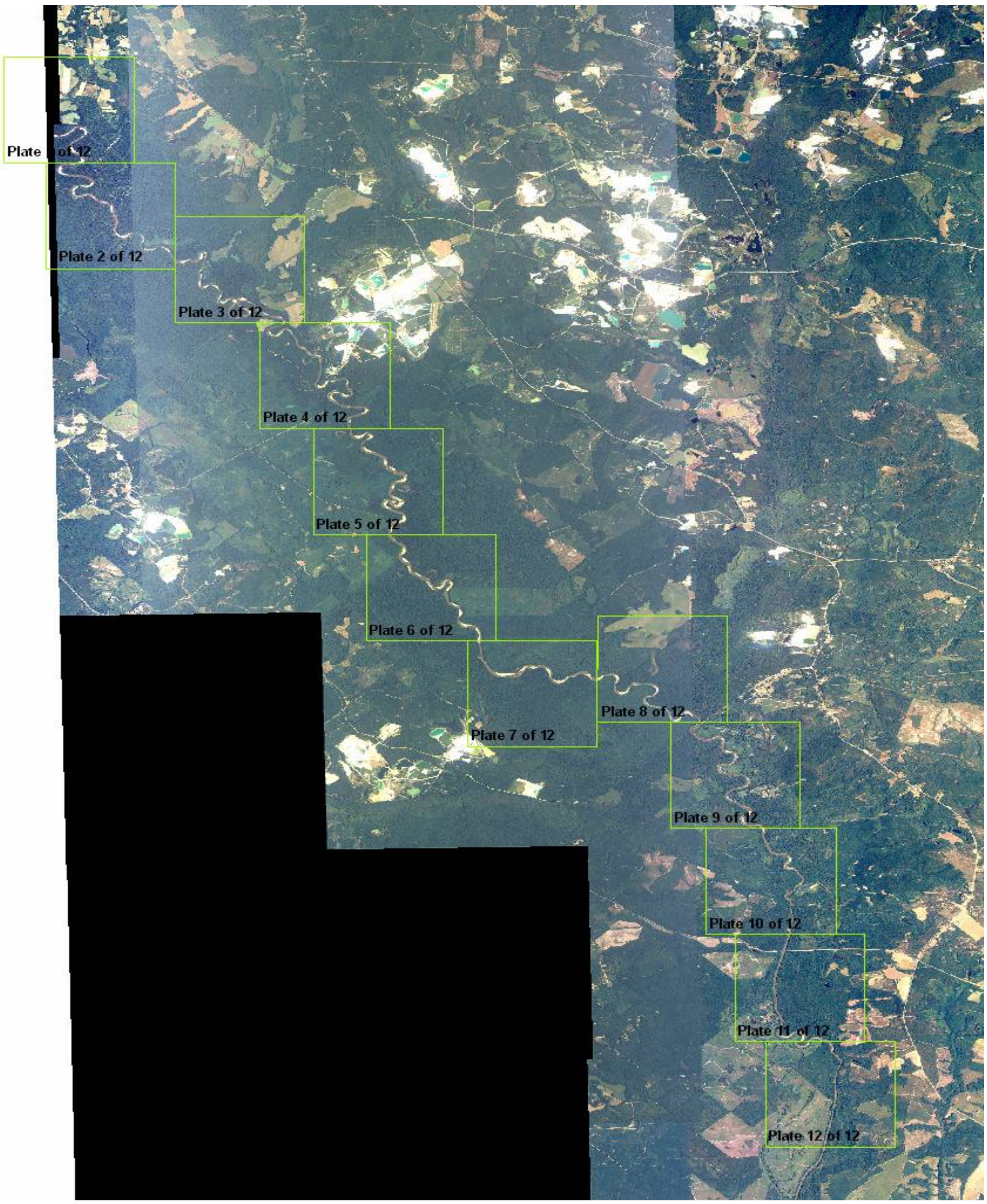

Plate 1

Plate 2

Plate 3

Plate 4

Plate 5

Plate 6

Plate 7

Plate 8

Plate 9

Plate 10

Plate 11

Plate 12