The
Conservation and Restoration of the Robust Redhorse
Moxostoma robustum

Volume 2

April 2000

prepared for the

Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

prepared by

A.S. Hendricks
Georgia Power Company
Environmental Laboratory
Smyrna, Georgia

GEORGIA POWER
A SOUTHERN COMPANY

ACKNOWLEDGEMENTS

This report was based on the work of many individuals and organizations that form the Robust Redhorse Conservation Committee. The author has attempted to identify cooperating organizations, but not necessarily individuals, where appropriate within the body of this report. Special thanks are due to the hatchery managers and personnel that contributed to the successful culture of robust redhorse, and also to the organizations that provided funding, services, and materials. The author also thanks the individuals that provided helpful comments and suggestions on a draft of this report.

TABLE OF CONTENTS

1. INTRODUCTION

This report is the second report in a series of bi-annual reports required by the FERC license for Georgia Power Company's Sinclair Hydroelectric Project (FERC No. 1951). The new license for the Sinclair Project, issued by the FERC on 19 March 1996 (effective date 1 May 1996), required the submission of a report every two years to the FERC. The license stated these reports should document the status of the robust redhorse and provide a determination regarding the adequacy of flow releases in meeting the needs of the robust redhorse.

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. Information presented in this report, *Volume 2*, is limited mainly to conservation activities that occurred from June 1998 through April 2000. When appropriate, some information on currently planned activities is presented. The format of this report generally follows that of the *Volume 1* to facilitate a chronological review of pertinent events and information.

The material for this report was gathered from a multitude of sources, including complete and incomplete project reports, Robust Redhorse Conservation Committee updates, letters, personal communications, and oral presentations. Some of the study summaries presented are necessarily based on draft reports or incomplete data. To decrease possible confusion that may result from the author's personal interpretation of some events or study results, some portions of text in this report were adopted whole or part, exactly as it appeared in the original document. Some basic background information initially presented *Volume 1* has been included in this report for readers that may be unfamiliar with the robust redhorse.

1.1 Sinclair Project

Sinclair Dam, a 45 megawatt hydroelectric project 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 to serve as the lower reservoir for Georgia Power's Wallace Dam pumped storage project.

During the early stages of relicensing in 1991, a rare fish was "rediscovered" in the Oconee River downstream of the Sinclair Project by biologists working for the Georgia Department of Natural Resources, Wildlife Resources Division. The fish was eventually

Figure 1. State of Georgia showing major rivers within the historic range of the robust redhorse.

identified as the robust redhorse *Moxostoma robustum*. Subsequent reviews by many agencies and individuals suggested that conservation and restoration actions should begin immediately for this species. The relicensing process fostered stakeholder input and the Endangered Species Act contained provisions to encourage stakeholder partnerships to conserve imperiled species and their habitats.

1.2 Robust Redhorse *Moxostoma robustum*

The robust redhorse was originally described in 1870 by master naturalist Edward Cope from specimens collected in the Yadkin River, NC. Unfortunately, Cope's original specimens were lost, and labels were mistakenly applied to another species. During the next 100 years or so, the real 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. The two existing specimens were believed to belong to an undescribed species of redhorse. The discovery of the Oconee River population of robust redhorse helped to unravel the history of this species.

In August 1991, five of the large, unrecognized suckers were collected from the Oconee River 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 fish collection, and Dr. Robert Jenkins of Roanoke College, Virginia, worked to unravel the mystery. They concluded the five specimens from the Oconee River were the same species as the two existing specimens that had been collected in 1980 and 1985. They further concluded that all specimens belonged to the species originally described by Cope in 1870. The currently accepted historic range consists of southeastern Atlantic slope rivers, extending from at least the Altamaha River system in Georgia to the Pee Dee River system in North and South Carolina.

2. ADMINISTRATIVE ACTIVITIES

2.1 Robust Redhorse Conservation Committee

The Robust Redhorse Conservation Committee (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 former range. The primary goals of the RRCC are to implement research and conservation measures, enhance recruitment in the existing Oconee River population, and re-establish robust redhorse populations in appropriate river systems within the species' former range.

The RRCC is the overall vehicle directing recovery of the robust redhorse, and has determined priority avenues for necessary research and action. Through formal annual meetings and innumerable informal meetings among members and other interested parties, the RRCC has identified impediments to the recovery effort, designed and conducted research related to those impediments, and formulated solutions or plans for dealing with those impediments. 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.

As was the case for *Volume 1*, most of the contents of this report are the direct result of actions taken or directed by the RRCC or its members. Because the original, known population of robust redhorse was located in Georgia, the vast majority of conservation activities have taken place in Georgia. However, state agencies and private utility companies in North and South Carolina, as well as federal agencies, are members of the RRCC and have participated in conservation activities in those states.

The full RRCC has typically met for two days in October of each year to discuss research results, conservation activities, administration, and the overall progress of the conservation effort. Meetings consist of presentation and group discussion, and attendance has usually been 30 – 40 individuals. The next annual meeting of the RRCC is scheduled for October 11-12, 2000, at the Charlie Elliott Wildlife Center near Mansfield, GA. The past two meetings of the RRCC have been facilitated by Ms. Terry DeMeo, under contract with the United States Fish and Wildlife Service. The following sections present some of the major activities and administrative duties of the RRCC from June 1998 – April 2000.

MOU Renewal

The Memorandum of Understanding that originally established the RRCC expired on December 31, 1996, but was renewed by current members through December 31, 1999. In September 1999, the MOU was distributed to members for renewal with a five year extension. Current members of the RRCC are the Georgia Department of Natural

Resources, South Carolina Department of Natural Resources, North Carolina Wildlife Resources Commission, U.S. Fish and Wildlife Service, Georgia Power Company, Duke Power Company, Carolina Power and Light, Georgia Wildlife Federation, U.S. Army Corps of Engineers, USGS-Biological Resources Division, and the U.S. Forest Service. Another organization, the Georgia River Network, also signed the MOU and became a member as of January 1, 2000. The expiration date for the current MOU is December 31, 2005.

Elections

A Search Committee was formed at the 1997 RRCC meeting and charged with finding a new Chair to replace James Evans (GDNR – Wildlife Resources Division), who had served as the Chair since the formation of the RRCC. The Search Committee was also charged with developing a process to select the new Chair.

The Search Committee realized that the conservation effort had outgrown the ability of one person to manage and direct the whole project. The Search Committee appropriately developed three leadership positions, the Chair, Chair-elect, and the Project Manager.

The Search Committee selected Scott Hendricks (Georgia Power Company) to be the 2nd Chair of the RRCC. The RRCC approved this selection at the 1998 annual meeting. His term began immediately and is scheduled to run through October 2000.

The Search Committee believed that because close coordination with hatchery personnel was essential, it was important for the Project Manager to be employed by the GDNR. James Evans moved easily into the Project Manager position and was responsible for much of the necessary planning and organizing, and has remained an integral part of the conservation effort.

The Search Committee was then charged with finding a Chair-elect that would serve one year in that position before taking over as Chair. The Search Committee selected Ms. Terry DeMeo (UGA Institute of Government). The selection of Ms. DeMeo was approved by the RRCC at the 1999 meeting. Her term as the 3rd Chair of the RRCC will begin October 2000 and expire October 2002.

Technical Advisory Group (TAG)

The RRCC quickly identified the need for a small, core group of individuals that would handle the bulk of the daily activities related to the conservation effort. The current members of the TAG are James Evans (GDNR-Wildlife Resources Division), Chris Skelton (GDNR – Non-game and Natural Heritage Program), Greg Looney and Mark Bowers (U.S. Fish and Wildlife Service), Dr. Jay Shelton (UGA School of Forest Resources), Dr. Byron Freeman (UGA Institute of Ecology), Dr. Cecil Jennings (USGS –

Coop Fish and Wildlife Research Unit at UGA), Scott Hendricks (Georgia Power Company), and Ms. Terry DeMeo (UGA Institute of Government).

The TAG officially met many times during 1999 to facilitate planning and implementation for the ever-growing robust redhorse project. This frequent communication among the TAG members also helped maintain focus on the goals of the RRCC, and work toward priority activities established by the full RRCC at the annual meeting. One of the larger tasks of the TAG was to understand and deal with the new genetic information that had become available.

The discovery of a Savannah River population of robust redhorse was reported in *Volume 1*, when a single robust redhorse was incidentally captured in the fall of 1997. This capture prompted additional surveys, and additional robust redhorse were located in the Savannah River near Augusta. Dr. Ike Wirgin of the New York University school of medicine analyzed genetic samples from the Oconee and Savannah Rivers and concluded these populations were genetically distinguishable. Dr. Wirgin has worked with striped bass, sturgeon and other species, and cautioned the RRCC against intentional mixing of the two populations.

This information quickly complicated existing reintroduction efforts for the Broad River, GA, which is in the Savannah River drainage (Figure 1). The Broad River was one of the first reintroduction sites for robust redhorse, and stocked fish were from the Oconee River which was the only known population at that time. Available historical evidence, fishery data and museum records, and several recent surveys specifically targeting robust redhorse in the Savannah River indicated it was unlikely for a robust redhorse population to exist in significant numbers in the Savannah River.

The TAG wanted a better understanding of the genetic information and invited Dr. Wirgin and several other fishery genetics experts to meet and discuss the implications of the genetic differences between the Oconee and Savannah River populations. The other geneticists included Dr. John Epifanio (President – AFS Genetics Section), Dr. Don Campton (USFWS), and Dr. Eric Hallerman (Virginia Tech). The TAG also sought advice about how to proceed with propagation of robust redhorse to ensure that appropriate genetic diversity was captured in the offspring that resulted from the artificial spawning attempts. The meeting was particularly important as fish produced from Oconee River stock had been recaptured in Clarks Hill reservoir, upstream of the Savannah population near Augusta.

There did not appear to be a firm consensus among the group regarding the potential harm to the Savannah River population through introgression. It was noted that there were several hydroelectric dams and many river miles between the two populations that could further reduce any potential for meaningful introgression. However, the group recommended the RRCC not do take irreversible actions in the absence of good information about the potential outcome. This TAG used the information from this meeting to make informed stocking and culture recommendations to the RRCC. The

RRCC modified these recommendations slightly, and decided against continued stocking of the Broad River, at least until better information could be developed.

Development of Culture Protocols

The culture of robust redhorse fingerlings has been challenging, and successful year classes have been produced partly because of failures that identified specific needs in the process. Because culture takes place at many hatcheries, the RRCC saw the need for standardized protocols for specific steps in the process.

Greg Looney of the U.S. Fish and Wildlife Service, Dennis Young of the Department of Natural Resources, and several other individuals developed protocols based on considerable experience with the robust redhorse. Current protocols include 1) Spawning , 2) Egg Incubation and Fry Rearing, 3) Fingerling Production, 4) Phase II Production, and 5) Pond Harvest and Hauling. These protocols will be updated as new information is developed, and are expected to facilitate more efficient culture of robust redhorse.

Conservation Strategy

The conservation effort for robust redhorse has expanded in recent years and the members of the RRCC saw the need to develop an overall guidance document, or roadmap for the project. The original MOU formed the RRCC and provided some general goals, but did not offer details for implementing the conservation effort.

An initial version of the Robust Redhorse Conservation Strategy, drafted by Mike Nichols of Georgia Power Company, was reviewed by the RRCC member organizations. The Strategy was subsequently approved in March 2000, by Scott Hendricks, current Chair of the RRCC. The Strategy describes the extent of current knowledge of robust redhorse status and 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 RRCC may revise the Strategy as new information becomes available.

The Strategy is also intended to promote voluntary conservation initiatives and stakeholder partnerships for conserving and reintroducing the robust redhorse within its historic range. One of the long-term conservation goals described in the Strategy is the establishment of self-sustaining populations throughout the species' historic range. The RRCC recognized that reintroduction at some sites could be complex and involved several organizations. Therefore, the Strategy describes a process for developing reintroduction plans, site selection, and other considerations. In some cases, Conservation Agreements with Assurances may facilitate reintroduction of the species. The Endangered Species Act contains provisions designed to encourage such creative partnerships between public and private sectors and among government agencies to conserve imperiled species and their

habitat (Endangered Species Act, 2(a)(5)), and the Strategy is intended to be consistent with these provisions.

Conservation Agreements

In some situations, reintroduction plans for specific sites may be facilitated by using Conservation Agreements with Assurances as described in 64 Federal Register 32706 (1999). Conservation Agreements include assurances for non-federal participants that their conservation efforts will not incur additional regulatory obligations in excess of those agreed upon in the specific Conservation Agreements. Conservation Agreements may also address other conservation needs and actions at the specific project sites by defining goals, timelines, and commitments by the parties to the Agreement. Conservation Agreements should also identify pertinent facts about the site, such as existing wild populations, available habitat, and if necessary, describe assurances given to non-federal property owners as a party to the Conservation Agreement.

Georgia Power Company, the U.S. Fish and Wildlife Service, and the Georgia Department of Natural Resources have been drafting a Conservation Agreement to reintroduce robust redhorse into a reach of the Ocmulgee River, GA (Figure 1). The reach is between river miles 230.9 and 250.2, bounded on the downstream end by a low head dam at Juliette, Georgia, and on the upstream end by Lloyd Shoals Dam, a hydroelectric facility owned and operated by Georgia Power Company. A few robust redhorse have been found downstream of the low head dam at Juliette, but recent robust redhorse surveys did not locate the species between the two dams.

The objective of this particular Agreement is to facilitate reintroduction of this species into a specific reach of the Ocmulgee River. The habitat is believed suitable and this action should create an additional population and extend the known range of the robust redhorse. The Agreement would also provide assurances to Georgia Power Company, as a party to the Agreement, that the U. S. Fish and Wildlife Service will not require additional conservation measures or restrictions at this location beyond those specified in the Agreement, should the robust redhorse become listed under the Endangered Species Act at some point in the future. The Agreement currently contains commitments from Georgia Power for maintaining dissolved oxygen downstream of Lloyd Shoals Dam, a telemetry study, and some monitoring of the introduced fish.

The Agreement has not yet been finalized and approved by all parties, but approval is expected in the near future. Additional benefits from implementing this conservation agreement include the development of essential information on the biology and life history of robust redhorse, including possible migratory behavior and potential identification of habitat utilized by young-of-year and juvenile robust redhorse.

Robust Redhorse Aquarium Exhibit

The South Carolina Aquarium in Charleston is under construction. Ms. Terry DeMeo developed a proposal that would establish a permanent refugial population at the Aquarium. A robust redhorse exhibit could benefit the conservation effort through education, awareness, and outreach. The exhibit may also facilitate certain research projects and perhaps create an additional source for robust redhorse broodfish. The South Carolina Department of Natural Resources and the Aquarium have discussed the proposal and it is likely to become a reality during 2000.

Robust Redhorse Symposia

Members of the RRCC organized a robust redhorse symposia at the 1999 annual meeting of the American Fisheries Society. The meeting was held 29 August 1999 through 2 September 1999 in Charlotte, NC. The titles and presenters are listed below, and the presentation abstracts can be viewed on the American Fisheries Society web site at http://www.fisheries.org/Meetings/Recent_AFS_Annual_Mtgs/annual99/program/wedsymposia2.htm.

Biology, Ecology, and Restoration of Imperiled Fishes in Atlantic Slope Drainages: The Robust Redhorse Case History

September 1, 1999
Organizers: Cecil A. Jennings, Scott Hendricks, James W. Evans,
James L. Shelton, Byron J. Freeman, and Greg Looney
Moderators: Cecil A. Jennings and James L. Shelton

- Discovery, rediscovery, species status, and distribution of the robust redhorse *Moxostoma robustum*
  Robert E. Jenkins, Byron J. Freeman, and James W. Evans

- Partnerships in recovery - a cooperative approach to the management of an imperiled species
  James W. Evans

- Age, growth, and maturation of the river and robust redhorses *Moxostoma carinatum* and *M. robustum*
  Robert E. Jenkins, Mark D. Clements, Stephanie C. Moore, James W. Evans, Gregory L. Looney, and Byron J. Freeman

- Population structure and genetic diversity in robust redhorse from the Oconee and Savannah rivers
  Isaac Wirgin, Lorraine Maceda, Tim Oppermann, and Joseph Stabile

- An assessment of robust redhorse reproductive and recruitment success in the Oconee River, GA
  Cecil A. Jennings, Carl R. Ruetz, III, and Rebecca E. Cull

- Effects of fine sediment on survival to emergence of larval robust redhorse
  Erik W. Dilts, Cecil A. Jennings, and James L. Shelton, Jr.

- Contaminant impacts to early life stages of the robust redhorse from the lower Oconee River
  Peter J. Lasier, Parley V. Winger, Kurt J. Bogenrieder, and James L. Shelton, Jr.

- Developing propagation techniques for robust redhorse
  James L. Shelton, Jr., Timothy A. Barrett, and Gregory L. Looney

- Short and long-term storage of sperm of the robust redhorse *Moxostoma robustum*
  Gregory L. Looney, William R. Wayman, and Terrence R. Tiersch

- A rocky road to recovery - successes, failures, and the future of conservation efforts for the robust redhorse
  A. Scott Hendricks

2.2 Flow Advisory Team for the Oconee River

The MOU that established the RRCC included provisions for creating additional working groups to address specific issues related to the conservation and restoration of robust redhorse. The first of such groups, created by an agreement drafted by Georgia Power Company, was the Robust Redhorse Flow Advisory Team for the Oconee River (Advisory Team). The Advisory Team functions under the overall umbrella of the RRCC with some shared memberships and administration. The current members of the Advisory Team are the GDNR, USFWS, USGS-BRD, Georgia Wildlife Federation, and Georgia Power Company.

The primary responsibilities of the Advisory Team are to monitor the effectiveness of the flow changes and other environmental conditions on the robust redhorse in the Oconee River. The agreement provides that the Advisory Team may review flow data from the Oconee River, studies developed by the RRCC, and other pertinent information related to the robust redhorse to help determine any necessary changes to the negotiated flow agreement. 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 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 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.

Table 1. Negotiated flow agreement for Sinclair Hydroelectric Project.

MONTH	FLOW and 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) to be utilized depending on the amount of inflow to the reservoir

[B] - From June 1 -10, units will be operated run-of-river unless electric system demands necessitate normal peaking operation

The agreement also provided for an increase in generation scheduling from 5 to 7 days per week. This was done to reduce the extended low flow periods that previously resulted from little weekend generation.

Flow Suitability

Although finalized in 1995, the flow agreement for the Oconee River was not implemented until June 1996, as requested by the RRCC. This request was made largely because of the natural variability associated with aquatic systems. It was believed that one year of data under the existing flow regime may not be representative of baseline conditions, making it difficult to fairly evaluate the new flow regime. By delaying the implementation of the flow agreement, it was possible to collect an additional year of reproductive and recruitment success data under the existing flow regime.

Consequently, 1997 was the first year of data collection under the new flow agreement. However, the extreme hydrological variability during the past several years, combined with the low numbers of the larval robust redhorse collected, have complicated the interpretation of these data and fair evaluation of the flow agreement. For example, the winter of 1997 through the spring of 1998 was influenced by the weather phenomena known as El Nino. Heavy rains, high discharges and river levels were common throughout the spring. This was immediately followed by severe drought (La Nina) that extended through 1999.

Substantially more larval robust redhorse were captured during 1997, the first year of full implementation of the flow agreement, than were captured during 1995 and 1996 under the previous flow regime. During 1998 however, the number of larval robust redhorse collected was similar to years prior to the flow agreement (see Research Summaries). It should be noted that less than 50 larval robust redhorse have been collected during any

single year. Undoubtedly, there are many factors that may influence the abundance of larval robust redhorse and our ability to catch them. These factors include natural weather and flow conditions which may directly affect reproduction and recruitment. These factors also affect the capture efficiency of the sampling gear.

The general opinion of the Flow Advisory Team is that the evidence provided by current research and monitoring of robust redhorse does not indicate that a modification of the current flow agreement is necessary. It appears that larvae of some species may be more numerous in the river after implementation of the flow agreement. This suggests positive benefits of the flow agreement for some species, although these data are not yet fully evaluated.

It is clear that larval fish sampling may not provide the information necessary to fairly evaluate the flow agreement, at least as it relates to robust redhorse. The RRCC is taking new steps to gain information that should help to evaluate the flow agreement. A discussion of the identified knowledge gaps, and the steps being taken to fill those gaps is presented in the next section on the status of the Oconee River population.

3. CONSERVATION STATUS AND ACTIONS

3.1 Status of the Oconee River Population

Much of the information on the status of the Oconee River population has been based on electrofishing catch during spring broodfish collection. From 1994 to 1999, these data appeared to indicate a decline in electrofishing catch rates, although catch rates were similar during the last three years. These data also showed a shift in the length frequency of the catch toward larger individuals, which suggested an aging population. Length frequencies for 1999 showed a slight shift to a smaller mean length. Very few juveniles and no young-of-year have been sampled during broodfish collection or other studies on the Oconee River. The large mean length of captured individuals, and the apparent lack of juvenile fish suggested nearly complete recruitment failure of robust redhorse within the last decade or two.

The above information prompted the RRCC to develop culture techniques and begin reintroduction of robust redhorse in other river systems. At the same time, research continued in the Oconee River to attempt to answer the many questions and uncertainties regarding population size, distribution, and recruitment. One or two juvenile fish, measuring around 400-420mm, have been captured during most years. This seemed to indicate there was at least some recruitment occurring. Questions raised by this information included "how much recruitment is necessary to maintain a genetically diverse population over the long-term, and could this level of recruitment be considered normal for this long-lived species?

The repeated appearance of robust redhorse near 400 mm indicates that smaller individuals do exist in the Oconee River system. The minimum size of stocked fish that have been recaptured in other systems, with electrofishing gear, has also been around 400 mm. This fact is puzzling because robust redhorse substantially less than 400 mm can be collected from ponds with electrofishing gear, indicating this size should be vulnerable to electrofishing gear. Small specimens of other sucker species have also been collected from rivers containing robust redhorse, yet the smaller robust redhorse have not been collected.

This may indicate that we have not yet found the preferred habitat for smaller juveniles within the Oconee River system. It could also indicate that we are unable to effectively sample the appropriate habitats. In either case, current and future research is being designed to address the dynamics of the Oconee River population.

A capture-recapture study and Jolly-Seber population modeling was recently completed for the Oconee River. The results of this study indicated the Oconee River population should persist for many generations, even though the total numbers of adults may be relatively low. The researchers caution that this conclusion is applicable only to the portion of the Oconee River sampled during the study, and is of course subject to the

limitations and assumptions of the sampling and the model. This study will be discussed in more detail later in this report.

3.2 Surveys for Other Robust Redhorse Populations

For the first several years during the RRCC's existence, it was commonly thought the Oconee River could contain the only remaining population of robust redhorse. This seemed reasonable, considering the extensive survey work on southeastern rivers. It also seemed unlikely that a fish as large as adult robust redhorse could be missed during sampling. However, habitats associated with adult robust rehorse in the Oconee River (swift, moderately deep waters with accumulations of woody debris) are difficult to sample effectively. The robust redhorse has also proven somewhat cryptic and difficult to collect even in pond environments.

The RRCC identified several rivers that could contain other populations of robust redhorse. These included the Ocmulgee, Ogeechee, Altamaha, and Ohoopee rivers in Georgia, and the Savannah River, Georgia-South Carolina. Other rivers identified for potential surveys included the Upper Broad River in North Carolina, the Lynches River in South Carolina, and the Pee Dee River system, North and South Carolina. Figure 2 describes the known distribution of robust redhorse through October 1999.

Savannah River, GA-SC

The Savannah River, Georgia-South Carolina, is one of the most thoroughly sampled rivers in the southeast and only 2 historical records of robust redhorse existed for this system. However, in October 1997, a single adult robust redhorse was collected by a Georgia Power Company crew conducting routine fish tissue monitoring in the Savannah River downstream of August, GA near Plant Vogtle. This confirmed collection, in addition to a few anecdotal reports of large sucker sightings, indicated the Savannah River should be a top priority for robust redhorse surveys.

20-21 May 1998
Seven electrofishing boats participated in robust redhorse surveys of the Savannah River from the New Savannah Bluff Lock and Dam to about 12 river miles downstream, and from Vogtle Electric Generating Plant downstream to about Little Hell Landing. These reaches of the Savannah River are typically wide and deep, and represented a much more difficult sampling task than the Oconee River. Efforts were concentrated in meander bends with snags, habitat that resembling that found in the Oconee River. Participating organization included the Georgia Department of Natural Resources, University of Georgia (Warnell School of Forest Resources, Institute of Ecology, and the Coop Fish and Wildlife Research Unit), Georgia Power Company, U.S. Army Corps of Engineers, Tulane University, Kleinschmidt Associates, and Roanoke College (Virginia).

The crews accumulated over 15 hours of electrofishing pedal time but did not capture or positively identify a robust redhorse. Some boats working the upper area just downstream from the New Savannah Bluff Lock and Dam reported observing a few large suckers in the electrical field, but these fish were not captured. However, even with coordinated flows from the U.S. Army Corps of Engineers, the river level was still high and presented less than ideal sampling conditions.

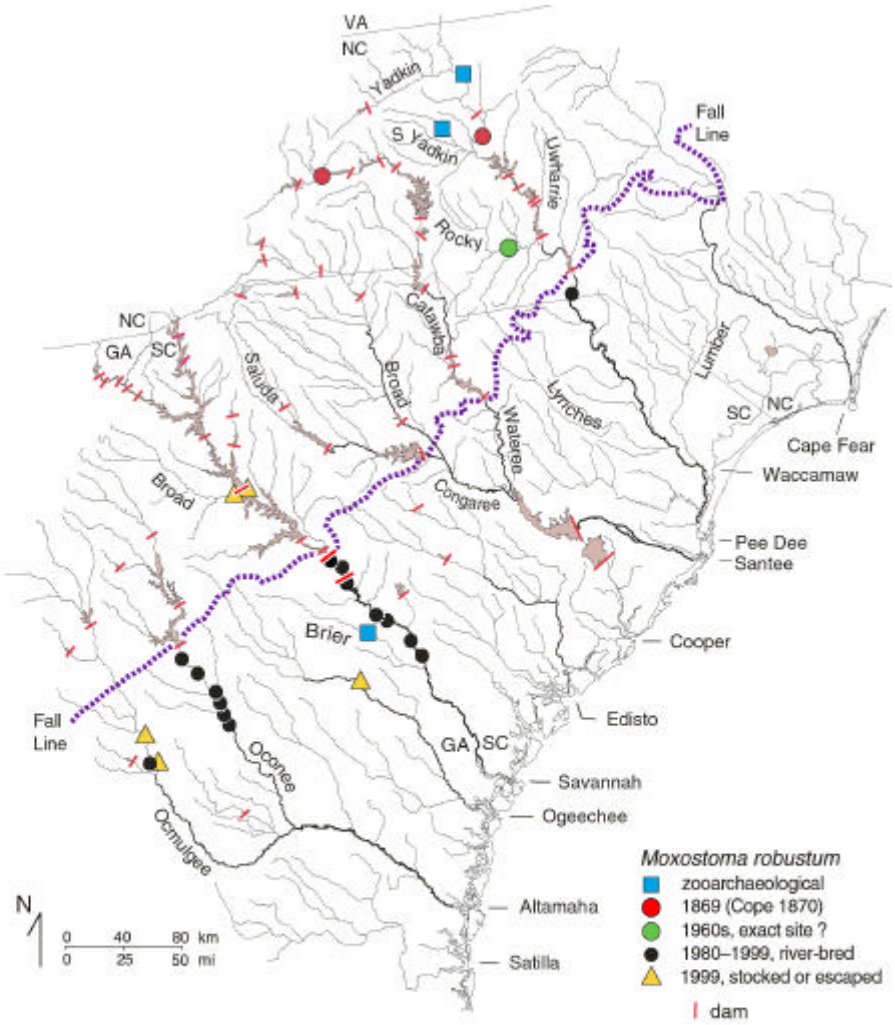

Fig. 00. Records of *Moxostoma robustum*. Number of specimens by drainage or system: Pee Dee 5; Santee 1; Savannah 42 (sites of the 4 record symbols crossed by dam symbols are below the dams); Ogeechee 1; Oconee 870 (detail in Fig. 00); Ocmulgee 4. Triangles represent artificially bred fish captured after stocking or escape from rearing ponds. Fall Line drawn from Anonymous (1963a–c) and Harris and Zullo (1991). Dams shown mainly for larger streams (south of Cape Fear drainage).

Map by R. E. Jenkins, B. J. Freeman, and J. W. Evans (October 1999)

Figure 2. Known distribution of robust redhorse records through March 2000.

3-4 June 1998
Five electrofishing boats participated in a robust redhorse survey of the Savannah River near Augusta, GA, from the Augusta canal diversion dam downstream to about the New Savannah Bluff Lock and Dam. This reach was essentially the portion of the river that flows parallel to the Augusta canal. The river is wide in this reach and habitat was characterized by shallow, rocky shoals and shallow pools between rock ridges. Sampling is somewhat difficult and it was necessary to coordinate flows with the U.S. Army Corps of Engineers. Crews included personnel from the GDNR, SCDNR, Institute of Ecology (UGA), EDAW, Inc, City of Augusta / Richmond County (GA), Georgia Power Company, Duke Power Company, Roanoke College (VA), and the Museum of Natural History from North Carolina State University.

The five boats accumulated over 12 hours of electrofishing pedal time. Four adult female robust redhorse were captured and several more adult fish were observed. Most of these fish were collected in the rocky habitats, within site of the Interstate 20 bridge crossing the river. Fish length ranged from 620-675 mm TL with a mean of 645 mm TL. Fish weight ranged from 3.66-5.11 kg with a mean of 4.13 kg. Four adult female robust redhorse were captured during the two days sampling, with a few additional reports of large suckers seen escaping the electric field. The captured fish were transported to McDuffie Hatchery for spawning attempts. It appeared that these fish were overripe, and no usable eggs were collected. All fish were Floy and PIT tagged, and fin clips were collected for genetic analysis. The fish were released at the capture site on 8 June 1998.

15 October 1998
A GDNR crew conducting routine sampling on the Savannah River captured a single robust redhorse that was 575 mm TL and weighed 2.9 kg. This fish was captured 11 miles downstream of U.S. Hwy 301 in deep water in a straight reach of the river. This location was about 42 river miles downstream of the location where Georgia Power collected a fish in October 1997, and about 98 river miles downstream of the Augusta shoals area where spawning fish were collected in the spring.

24-28 May 1999
Five electrofishing boats, mostly with the same personnel as previous Savannah River surveys, participated in a robust redhorse survey in the Augusta Shoals reach. These boats accumulated over 16 hours of electrofishing pedal time. Twenty-three robust redhorse were collected that ranged from 501-655 mm and weighed from 1.70-4.32 kg. Some of these fish were held for propagation purposes before being returned to the river. Results of this spawning attempt is discussed later in this report.

SCDNR also reported a single robust redhorse observation from the lower reaches of the Savannah River, incidentally observed during sampling for other projects in 1999.

May-June 2000
A status survey is tentatively planned for the Augusta Shoals reach. Attempts at spawning will not be attempted until permanent stocking locations for Savannah River fish can be identified.

Ocmulgee River, GA

22-25 June 1999
Six electrofishing boats participated in an initial robust redhorse survey of the Ocmulgee River from Lloyd Shoals Dam near Jackson, GA, downstream to about Hawkinsville, GA. This reach is separated by a low-head dam near Juliette, GA. Participating crews were from the GDNR, UGA, United States Fish and Wildlife Service, and Georgia Power Company. These boats accumulated over 27 hours of electrofishing pedal time during the survey. Two wild adult robust redhorse and two escaped juvenile robust redhorse were captured in the lower portion of the sampled reach. The two juvenile fish contained coded-wire tags, which indicated they had escaped from a pond population on the Piedmont National Wildlife Refuge, most likely during a high flow event. At capture, these fish were 440 and 448 mm, which was substantially larger than fish of the same age that remained in the ponds. It is unknown how many fish escaped or how many may have survived. However, this survey did confirm the existence of an unknown number of natural robust redhorse in the Ocmulgee River downstream of the Juliette Dam. No robust redhorse were located between Juliette Dam and Lloyd Shoals Dam.

Ogeechee River, GA

September-November 1999
Several electrofishing boats accumulated over 10 hours of pedal time in the Ogeechee River, mostly during the fall. These surveys were conducted largely by the GDNR, and some of the pedal time accumulated was in conjunction with standardized sampling surveys. No naturally produced robust redhorse were captured or observed. However, one juvenile robust redhorse was captured about 2 miles downstream of the U.S. Hwy 25 bridge, south of Millen, GA. This fish did contain a micro coded-wire tag. Tag information indicated this fish was part of the group stocked into the Ogeechee river near Jewell, GA in December of 1997. Length and weight at capture was 387 mm and 820 gm, respectively.

Pee Dee River, NC/SC

26-28 April 2000
Several reaches of Pee Dee River have been sampled in recent years without locating robust redhorse. John Crutchfield (Carolina Power and Light) organized an intensive fish

survey for the reach of the Pee Dee River from the Blewett Hydroelectric Plant in North Carolina downstream to about Cheraw, South Carolina. This reach is about 23 river miles in length.

The study plan listed Carolina Power & Light Company, North Carolina Division of Water Quality, North Carolina Wildlife Resources Commission, North Carolina Museum of Natural Sciences, North Carolina State University-USFWS Cooperative Research Unit, South Carolina Department of Natural Resources, and the U.S. Fish & Wildlife Service as potential cooperators in the survey.

The author received phone and email messages on 27 April 2000 that indicated a single, adult robust redhorse female had been captured during the survey. The collection was made near the site of the 1985 record from the Pee Dee River. No other details were available at the time of the printing of this report.

Broad River, South Carolina

The South Carolina Department of Natural Resources has made tentative plans to survey for robust redhorse surveys in the Broad River drainage, South Carolina, during 2000. Several other organizations may participate in these surveys.

3.3 Research Summary 1998 - 1999

Much of the research during 1998 – 1999 continued to focus on a) the Oconee River population of robust redhorse and identifying factors that could be contributing to the presumed low recruitment, and b) culture techniques for more efficient production of stockable robust redhorse fingerlings. Among these broad topics were studies that targeted spawning habitats and substrate composition, contaminants, cryogenics, and genetic characterization. Monitoring of reproductive success in the Oconee River and evaluating hatchery pond survival were also prominent studies.

The following summaries are not intended to be detailed reports, but simply to provide the reader with brief descriptions of current research projects and major results and findings, if available. Many projects were continuations of previous studies that were presented in *Volume 1*, where it was desirable to have multiple years of data. Some projects were new and based on results of previous or similar studies.

In addition to formally funded research, much less-publicized investigation and observation has been conducted within the laboratories at the USFWS Warm Springs (GA) Regional Fish Technology Center, the Institute of Ecology and the Cooperative Fish and Wildlife Research Unit at the University of Georgia, and other southeastern laboratories. Other informal studies have undoubtedly been conducted at the many

hatcheries that have served as rearing centers for robust redhorse. Although little information regarding much of this work is provided in this report, the information gained from this work is potentially critical for formulating relevant and efficient research plans.

The bulk of the funding for the following research projects was provided by Georgia Power Company. The Georgia Department of Natural Resources, Natural Heritage Program has also funded studies for enhancing survival in hatchery facilities. These funds were from the newly created wildlife auto tag program for Georgia. Duke Power, Carolina Power and Light, and the Electric Power Research Institute also contracted with Dr. Ike Wirgin of New York University for genetic research on the robust redhorse. The United States Geological Survey and United States Fish and Wildlife Service also provided funds for research.

The bulk of the research discussed in the following section was conducted by Dr. Cecil A. Jennings of the Georgia Cooperative Fish and Wildlife Research Unit (UGA), Dr. James L. Shelton of the Warnell School of Forest Resources (UGA), Dr. Byron J. Freeman of the Institute of Ecology (UGA), and Gregory L. Looney of the Warm Springs Fish Technology Center (USFWS). Dr. Robert E. Jenkins of Roanoke College, Virginia was previously contracted for the age, growth, and maturation studies. It is doubtful whether some of the projects could have been successfully completed without the in-kind services and personnel provided by the Georgia Department of Natural Resources, the U. S. States Fish and Wildlife Service, the U.S. Army Corps of Engineers, the University of Georgia, Georgia Power Company, and other volunteer labor.

Effects of Temperature and Flow on Incubation of Robust Redhorse Eggs and Larvae

This project was a partial continuation of work done in 1996 and 1997 aimed at developing more efficient techniques for hatchery production of robust redhorse. In addition, this project would have some applicability to the success of early life stages of robust redhorse in the Oconee River.

Survival of eggs and swim-up fry was tested in hatching jars at temperatures from 19-25° C, and at flow rates of 200-1600 mls/s. Reduced flow and mid-range temperature treatments from 21-23° C resulted in the lowest deformity rates for larvae. The sustained flow treatment resulted in the highest deformity rates at all temperature treatments. Overall mean survival was low, although temperatures of 21-23° C also provided the highest survival. The higher flow rates resulted in the lowest survival rates.

Results suggested that reduced flow rates of 200 – 400 mls/s and moderate temperatures of 21-23° C were optimal for incubation. In addition, eggs were much more tolerant of changes in flow that larvae.

Effects of Gravel Quality and Percent Fine Sediment on the Hatching success of Robust Redhorse Eggs

This project was a continuation of a similar project conducted during 1997, was undertaken to try to address the low density of robust redhorse larvae in the Oconee River. Early hypotheses for the low densities observed were a) biologically senescent population, which was proven incorrect, b) low quantity of spawning habitat, which does not appear to be a major factor, and c) low quality of spawning habitat. Amounts of sediment in gravel spawning habitat has been proven an important factor in reproductive success of other lithophilic spawners.

During 1997, the percentages of fine sediment inoculated into the gravel treatments were 25, 50, and 75%. Results showed that peak emergence from the gravel occurred at 16-17 days after fertilization, and that greater amounts of fine sediment were related to reduced survival to emergence. Reduced survival was caused by increased egg or fry mortality within the substrate. Earlier emergence of fry, possibly related to reduced hyporheic dissolved oxygen at the higher sediment treatment rates, may have also contributed to increased mortality.

To refine the estimate of the critical level of percent fines in the spawning substrate, this project also evaluated substrate containing 5, 10, 15, and 20% fine sediment. Results again showed that increasing amounts of fine sediment were related to decreased survival to emergence of robust redhorse larvae. At 0% fine sediment survival was 60%, but survival decreased to 10% at 25% fine sediment.

Earlier studies noted that the gravel substrates in the Oconee River were often composed of 25-50% fine sediment. The model developed during this study suggested that 8% or less of wild robust redhorse larvae may survive to emergence at these levels of fine sediment. The high percentage of fine sediments could be a significant limiting factor to recruitment of robust redhorse in the Oconee River. Restorative actions, including artificial spawning beds, flushing flows, sediment traps may deserve consideration in the future.

Reproductive and Recruitment Success of Robust Redhorse in the Oconee River

This project was a continuation of earlier work to document the abundance and distribution and larval and juvenile robust redhorse in the Oconee River. This project is of fundamental importance for documenting any changes in recruitment that may result from the new flow regime at Sinclair Dam or other unknown and possibly uncontrollable factors. Modifications to this project for 1998 included sampling of tributary streams to the Oconee River, and deep water, main channel seining.

This project has employed a variety of sampling gears to collect larval and juvenile robust redhorse. However, smaller sizes of robust redhorse have proven to be relatively rare in

the Oconee River, very difficult to catch, or both. The table below presents larval robust redhorse density estimates from the Oconee River, 1995-1998. Two years of data were collected prior to the implementation of the Sinclair flow agreement. Low sample numbers, and extreme variability in the natural hydrology of the Oconee River complicates the interpretation of these data. A density estimate was not yet available from the 1999 samples.

Maximum densities of robust redhorse in the Oconee River (from Dilts 1999)

Date	Volume Sampled (cubic meters)	Density Estimate	Comments
1995	1000	13	Pre flow agreement
1996	1000	7	Pre flow agreement
1997	1000	33	*ROR spring flow
1998	1000	10	*ROR spring flow; wet spring
1999	1000	NA	*ROR spring flow; drought spring

* Run-of-river

Some robust redhorse larvae do emerge from the gravel although the exact numbers are unknown. Larval and juvenile monitoring will continue in the Oconee River to try to develop a data set suitable to evaluate the current flow agreement for the Oconee River.

Age, Growth, and Maturation of Robust Redhorse

This was a continuation of the age and growth project described in *Volume 1*. The goals and objectives remain unchanged. The additional time was needed to clean and update the robust redhorse capture database. The database includes capture and recapture history for Oconee River robust redhorse, including date, location, length and weight at capture, and how many times an individual fish may have been used for propagation. A clean and well-formatted database would allow the determination of natural growth between years, size and age at maturation by sex, whether individual robust redhorse spawn annually, and other life history and biological details.

Genetic Investigation of Robust Redhorse

This project was a continuation of the research project first presented in *Volume 1*, that was started in 1997 by Dr. Ike Wirgin at New York University. Duke Power, Carolina Power and Light, and EPRI have continued the funding of this work. The objectives of this project for 1998 were to 1) determine if there were multiple stocks in the Oconee River, 2) evaluate genetic similarity of the Oconee and Savannah River population, and 3) compare the genetic diversity of the hatchery production to the adult Oconee River population.

Preliminary conclusions were that the Oconee River contained a single stock of robust redhorse, and that there were fixed genetic differences between the Oconee and Savannah River populations of robust redhorse. Dr. Wirgin suggested these two populations may have become reproductively isolated about 400,000 years ago and cautioned the RRCC against mixing the two populations. This information prompted the meeting with several geneticists that was discussed in an earlier in this report.

Upon discovery of the two wild robust redhorse in the Ocmulgee River, GA during a 1999 survey, fin clips were sent for genetic analysis. Although sample size was small, no significant genetic differences were found between the Oconee and Ocmulgee fish.

Effects of Contaminants of Robust Redhorse Eggs and Larvae

The study objective for 1998 was to determine the effects of known toxins on eggs and larvae of robust redhorse. Treatments included exposure to one contaminant, a 96-hour exposure, and cumulative exposures. Contaminants included, but were not limited to copper, zinc, cadmium, and ammonia. The results indicated that robust redhorse eggs and fry were more tolerant of exposure to some common contaminants than many other fish species.

In 1999, this study included analysis of the toxicity of depositional sediments, pore water chemistry, presence of organic contaminants and trace cations, and other physical characteristics from known spawning areas of robust redhorse. Water chemistry was generally within expected ranges. However, zinc concentrations in the sediment were significantly elevated at some sites, and manganese concentrations were elevated in some pore water samples.

Robust redhorse eggs, yolk-sac fry, and swim-up fry were then exposed to samples of sediment, pore water, and surface water from several Oconee River sites. Control treatments were also conducted. Although sediments from a few sites were found to be toxic to robust redhorse eggs in transition to yolk-sac fry, the researchers considered the overall effects of the sediment bound contaminants to be insignificant to early life stages of robust redhorse.

Although this study found no PCBs in the Oconee River, an independent study did find PCBs in robust redhorse eggs. The significance of PCBs relative to robust redhorse reproductive success is unknown, and subsequent studies to address this issue were proposed for 2000.

Observations of Robust Redhorse Spawning Habitat and Behavior in the Oconee River, GA

Most observations were made at the one of the major know spawning locations, near the Avant Kaolin Mine downstream of Milledgeville, GA. The gravel bars are maintained from a lens in an eroding outside bend. This site has changed significantly during the last five years.

Observations of spawning substrate characteristics were made by using a nitrogen freeze-core method. This method allowed the determination of the composition of the substrate by particle size and the depth that robust redhorse eggs were buried in the substrate. Robust redhorse eggs appeared to be buried slightly deeper than some other sucker species. A hydrophone was also used to listen to and record the sounds of gravel disturbance associated with spawning events. This tool could be used to identify additional spawning areas, which may be especially useful during turbid, spring conditions.

Development of Cryogenics for Robust Redhorse

This project confirmed that robust redhorse semen could be frozen and stored for at least one week. After thawing, mean motilities were 50% in 1997 and 30% in 1998. Males typically produce more than enough semen to fertilize eggs for propagation, the rest can be stored to prevent loss of genetic material. Fully developed, cryogenics could be a particularly important piece of information to further the recovery effort.

Preliminary Results of Hatchery Pond Monitoring

Volume 1 described some of the fry and juvenile mortality problems associated with robust redhorse stocked into hatchery ponds for rearing to stockable size. Juvenile mortality was severe at times and did not seem consistently related to any known factors. Mortality events did not seem consistently related to any single hatchery, handling techniques, or geographic region. There was often little or no evidence of mortality, which made it difficult to estimate when the problems occurred or what factors may have been involved.

To attempt to address this issue, the Georgia Department of Natural Resources Non-game Program funded a long-term study to help determine the best hatchery procedures for

raising robust redhorse. This study included intensive monitoring of water quality, plankton, invertebrates, and feed and fertilizer rates. Robust redhorse were also collected weekly from the ponds during the growing season to track abundance and growth.

Preliminary results indicate pond mortality may be related to growth rate. This of course is related to fulfilling the nutritional requirements of the fish. The fish consumed mainly cladocerans and copepods up to about 4 weeks of age. Commercially available feed was present in gut contents as early as week 4. Commercial feed, as a percentage of gut contents, ranged from 25-100 percent by the end of the growing season. This study suggests that robust redhorse can be raised on commercial feed. However, successful transition to commercial feed at the 4-5 week age may be critical to pond culture of robust redhorse.

Microchemistry Analysis of Robust Redhorse Otoliths

This study was new in 1999 and attempted to determine if robust redhorse may spend some time in brackish water. One puzzle that led to this project was the almost annual collection of juvenile robust redhorse (about 400 mm) from the Oconee River, but no collection of fish between 14mm and 400mm. Previous work by the USGS showed the robust redhorse to have considerable tolerance for salinity. Duke Power Company pursued microchemistry analysis of a few otoliths that were available, with specific interest in the strontium/calcium ratio (strontium concentrations are much greater in seawater than in fresh). It is normal for the strontium/calcium ratio in different planes of the otolith to be similar for a purely freshwater fish.

The analysis of robust redhorse otoliths from three fish (3) collected from the Oconee River showed wide differences in the strontium/calcium ratio across the otoliths. This suggests that these fish had been exposed to an environment with elevated strontium concentrations during some portion of their lives. This study was limited to a very small sample size, and this finding is preliminary. However, this topic deserves further investigation.

Population Dynamics of the Oconee River Population

A robust redhorse capture-recapture study was conducted in the Oconee River from Milledgeville, GA to near Lowery, GA, from October 1999 to February 2000. Jolly-Seber population models were used to estimate population size, recruitment, and survival. The population estimate was 607 (S.E. 138) robust redhorse greater than 417mm total length (smallest size captured during the study). This estimate was limited to that portion of the Oconee River from about Black Creek downstream to Dublin, GA. Year-to-year survival estimates were high at about 60%, and annual recruitment estimates ranged from 5 to 57% of the estimated population.

The models predicted robust redhorse would persist in the study reach over the next 100 years, though the mean number of individuals was variable. Two hundred simulations were run, and no estimate of population size was less than 100 individuals and some estimates were as high as 1,200 fish greater than 417mm total length.

Initially, the current estimate of 607 fish appears to conflict with an earlier population estimate of 1000 – 4000 individuals that was based on catch data obtained in conjunction with broodfish collection. The disparity seems to be the result of differences in the calculation of the estimate, and not necessarily a decline in population number. For example, the population estimate for the current study was limited to a specific section of river, whereas the previous estimate was expanded to encompass a larger reach of river. When the raw catch data from each source was treated similarly, the estimates were also similar. Overall, the information from the Oconee River is encouraging, and indicates that variable numbers of fish recruit to the population and their subsequent chances of surviving are good.

3.4 Broodfish Collection, Fingerling Production, and Reintroduction

The collection of wild, adult robust redhorse for use as broodfish, and the subsequent culture operations to produce stockable fingerlings is critical the overall conservation efforts for the robust redhorse. When possible, Georgia Power Company provides flows from Sinclair Dam that are suitable for broodfish collection in the Oconee River. During the last several years, the RRCC has refined the steps necessary for broodfish collection, and has refined culture techniques and enhanced the survival potential of eggs and fry. With these refinements, less adult broodfish have been necessary to achieve egg production goals. This in turn means less variation from run-of-river flows during the spring spawning season in the Oconee River and less disturbance to spawning fish. The following section builds on information presented in *Volume 1*, where individual year-classes were tracked from production to stocking.

1995 and 1997 year-classes

About 100 fish from the 1995 and 1997 year classes were being held at a few hatcheries in Georgia for extended growth. During February 1999, these larger juveniles were released into the Oconee River. This represented the first re-introduction of robust redhorse into the Oconee River.

1998 year-class

Oconee River

Attempts at broodfish collection during 1998 were met with many difficulties. The far-reaching weather phenomenon know as El Nino most likely influenced the abnormally high amounts of rainfall in Georgia during the winter and early spring 1997-98. The Oconee drainage seemed particularly wet, as the Oconee River reached flood stage on several occasions. Extended high reservoir inflows and expectations of continued rainfall within the basin prevented the provision of low flows from Sinclair Dam for most of the spring. These conditions made it impossible to conduct the usual early surveys to check the location and spawning condition of robust redhorse. As a consequence of high flows, only one broodfish collection and spawning effort was possible beginning on 18 May. By the end of this period, low flows provided from Sinclair Dam for broodfish collection enabled river temperatures to approach 25° C or higher. Previous studies indicated these river temperatures may be near the upper end of the range conducive to successful artificial spawning.

During the broodfish collections effort between 18 - 20 May, 14 female and 17 male robust redhorse were transported to the temporary hatchery at Beaverdam WMA. Some females were overripe and four were successfully spawned. Of these four females, one fish was spawned three times, and the other three fish were spawned twice each. A total of 142,662 fertilized eggs were produced from 10 matings.

About 17,000 eggs were shipped to the University of Georgia for ongoing research projects and the remaining 125,000 were shipped to various hatcheries for production. About 56,000 fry were produced for an egg to fry survival rate of 44%. These fry were shipped for pond rearing at several hatcheries and other available facilities in Georgia and South Carolina.

Of these fry, and an estimated 43,000 were actually stocked into hatchery ponds for grow-out. About 13,030 survived the summer and were harvested in the fall of 1998 for a 30% average survival rate from stockable fry to fingerling. This survival figure can be misleading because much of the mortality observed during 1998 occurred as complete mortality at just a few ponds. In one pond mortality appeared related to DO depletion. Causes were unclear in other ponds, but the intensive monitoring study currently underway should provide some insight and solutions for this phase of production. Growth rate and condition were clearly better than in previous years, and were relatively consistent across hatcheries.

About 6,326 fingerlings were then added to the refugial population at the Piedmont National Wildlife Refuge. The remaining 6,000 fingerlings were stocked into the Broad River system, GA at previously stocked locations.

Savannah River

As described earlier in this report, the first attempt to collect robust redhorse broodfish from the Savannah River occurred in the spring of 1998. Four adult fish, all female, were collected near the Augusta Shoals reach on 3-4 June. All four appeared to be overripe and no eggs were available for collection. Interestingly, these fish exhibited less spawning related injuries than adults from the Oconee River. The body form was similar to Oconee fish, although the head of the Savannah fish appeared smaller relative to body size. Fish were released at the capture site after being weighed, measured, and tagged for future identification.

1999 year-class

Oconee River

During the spring of 1999, flow and weather conditions on the Oconee River were nearly ideal for broodfish collection. Catch rates were similar or slightly higher than 1998, and 23 females and 17 males were collected. Fifteen of the females and 14 of the males were used to obtain 21 crosses. About 567,578 fertilized eggs were produced and shipped to various hatcheries for culture and research purposes, which was the highest number produced to date with artificial techniques.

Significant mortality of fry was experienced at Warm Springs National Fish Hatchery, GA, that was presumably caused by a *Costia*-like organism. This was the first known occurrence of this type of infection in robust redhorse culture. The untreated eggs were believed to be the source of the organism. Warm Springs staff subsequently evaluated methods for egg disinfection, and are considering installing a UV system to prevent future outbreaks. The recently developed hatchery and hauling protocols may also be revised to help control infection problems.

In addition, significant mortality occurred at several hatchery ponds, possibly related to the high temperatures, drought conditions, and associated dense algae blooms during the summer. From October – December 1999, about 24,000 fingerlings were harvested. Fish were then stocked according to priorities established at the RRCC meeting in October. About 10,328 fish were stocked in the Ogeechee River, and 4,000 were stocked into the refugial population at Piedmont National Wildlife Refuge. Remaining fish were distributed to several hatcheries for Phase II production.

Savannah River

River conditions were also favorable on the Savannah River and 23 broodfish were collected. Gametes from three females and four males were used to produce 4 crosses. About 53,016 eggs were produced from the Savannah River. These eggs produced about 10,000 fry that were shipped for grow-out at the Dennis Center, SC, and Burton Hatchery, GA. About 3,200 Phase I fingerlings were stocked into a newly available pond on the Fort Gordon military installation near Augusta, GA. About 1,400 Phase I fingerlings were restocked at Burton Hatchery for Phase II production.

3.5 Monitoring of Introduced Populations

Broad River, GA

A critical component in the recovery effort for the robust redhorse is to monitor the success of the re-introduced populations. The Broad River system received the majority of fingerlings available for wild stocking during the last several years. Stockings occurred annually from 1995 to 1999 with fish from the 1993, 1995, 1997, 1998, and 1999 year classes. Monitoring efforts aimed at tracking the survival and distribution of stocked fish were largely unsuccessful. Fish could often be located in the first few days post-stocking, but quickly disappeared from the catch. The lack of recapture was not necessarily interpreted as non-survival or failure, but it was discouraging.

On 1 February 1999, researchers from the University of Georgia were sampling the Clarks Hill Reservoir (78,000 acre mainstem impoundment of the Savannah River, upstream of Augusta, GA) with electrofishing and gillnet gear as part of a project unrelated to robust redhorse. The researchers, however, were familiar with the conservation efforts and were able to positively identify a juvenile, robust redhorse among their catch. The fish was 404mm total length and weighed 878 grams. A micro coded-wire tag was present, confirming the fish had been produced in a hatchery. Tag information revealed that this fish was a member of the 1995 year class produced from the Oconee River. Juvenile robust redhorse were subsequently caught from with both gear types in almost every month of 1999. All fish were confirmed to be members of the 1995 and 1997 year classes. Complete data describing the age, size, and capture locations were unavailable for this report.

The recapture of stocked fish was very significant to the conservation effort. This provided the RRCC with several interesting pieces of information: 1) hatchery robust redhorse could be used to intiate and build additional populations of robust redhorse, 2) though most likely not the ideal habitat for robust redhorse, reservoir environments could potentially be used to support robust redhorse, 3) hatchery produced fingerlings survived in the presence of a substantial flathead catfish population, 4) movement of juveniles may be much greater than previously believed. The fish appeared to be plump and healthy at time of capture.

4. WHERE DO WE GO FROM HERE?

For 2000 and beyond, it is anticipated that the RRCC will continue to identify impediments to the recovery, and create task groups and formulate solutions to effectively deal with those impediments. Significant progress has been made toward the conservation of robust redhorse, and the project is expanding quickly. New populations of robust redhorse are being discovered and additional information on the biological and ecological needs of this species is being developed. Additional surveys within the historic range are again a high priority. Several knowledge gaps have been identified, and research is being designed and conducted to fill those gaps.

The RRCC plans to use telemetry to evaluate potential migratory behavior of robust redhorse. An assessment of robust redhorse year-class strength in the Oconee River as related to hydrological conditions and flow is also scheduled for the near future. The recent stocking of a small number of juvenile fish into the Oconee River could potentially yield very valuable information, depending on if, when, and where those fish are recaptured. The monitoring of already introduced populations will surely provide more interesting information, as some of those year-classes approach sexual maturity and begin to seek spawning habitat.

The RRCC recognizes the importance of preparing sound plans for reintroduction, with special consideration of genetic managment. The RRCC has consulted with fishery genetic experts and appears ready to accept these tasks. Conservation Agreements, if necessary, could also be effective tools to extend the range of robust redhorse and create refugial and self-sustaining populations.

The expansion of the territory encompassed by this project, and the related increase in administration, documentation, and planning has made it difficult for most individuals to commit to the responsibilities at the elected levels of the RRCC. In response, the RRCC has discussed ways to fund a permanent staff position for the project. No decisions have been made regarding funding sources or amounts for the position, but this is an important item for consideration.

The stakeholder partnership concept that is the foundation of the RRCC appears to be working to the benefit of the robust redhorse and the organizations involved. New and varied sources of funding have been identified and tapped. Additional populations have been discovered. Much information has been developed and some difficult and controversial issues have been addressed. The next few years will undoubtedly bring some answers and raise many new questions about the robust redhorse. The RRCC, in its current form, should be able to effectively handle upcoming issues related to the conservation of robust redhorse.

REFERENCES

DeMeo, T. 1998. Report of the Robust Redhorse Conservation Committee Annual Meeting. October 28-29, 1998, Social Circle, GA. 63 pp.

DeMeo, T. 2000. Report of the Robust Redhorse Conservation Committee Annual Meeting. October 13-14, 1999, Charlie Elliott Wildlife Center, GA.

Dilts, E. W. 1999. Effects of find sediment and gravel quality on survival to emergence of larval robust redhorse *Moxostoma robustum*. M.S. Thesis, University of Georgia, Athens. 61 pp.

EA Engineering, Science, and Technology. 1994. Sinclair Hydroelectric Project Relicensing Technical Studies (FERC Project No. 1951): Robust redhorse report. Final report to Georgia Power Company.

Evans, J.W. 1997. Developing stakeholder partnerships for the management of imperiled fish species: a case study. pages 490-499 in Waterpower '97, Proceedings of the international conference on hydropower. American Society of Civil Engineers, New York.

Freeman, B.J., B Gregory, and D. Walters. 1998. Ecological studies of the robust redhorse: substrate stability, spawning behavior and surveys for additional populations. Institute of Ecology, the University of Georgia, Athens, GA. Draft report to Georgia Power Company, Atlanta, GA.

Hendricks, A.S. 1998. The conservation and restoration of the robust redhorse *Moxostoma robustum*. Volume 1. Georgia Power Company, Environmental Laboratory. Prepared for the Federal Energy Regulatory Commission. Washington, D.C.

Jennings, C.A., J.L. Shelton, and G.L. Looney. 1998. Culture techniques and ecological studies of the robust redhorse: assessment of reproductive and recruitment success and incubation temperatures and flows. Georgia Coop Fish and Wildlife Research Unit, the University of Georgia, Athens, GA. Final report to Georgia Power Company.

Jennings, C.A., B.J. Hess, J. Hilterman, and G.L. Looney. 2000. Population dynamics of robust redhorse (*Moxostoma robustum*) in the Oconee River, Georgia. Final Project Report—Research Work Order No. 52. Prepared for the U.S. Geological Survey, Biological Resources Division. Reston, Virginia.

Nichols, M.C. 2000. Conservation strategy for robust redhorse *Moxostoma robustum.* Prepared for the Robust Redhorse Conservation Committee.