The
Conservation and Restoration of the Robust Redhorse
Moxostoma robustum

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This report, and more importantly the conservation and restoration efforts for the robust redhorse described herein, could not have been possible without the cooperation and contributions of many agencies, private companies, environmental organizations, and individuals. The list of cooperators for this project would necessarily be long and most likely incomplete. The author has attempted to identify cooperating organizations, but not necessarily individuals, where appropriate within the body of this report.

The material for this report was gathered from a multitude of sources, including licensing documents and reports, complete and incomplete project reports, Robust Redhorse Conservation Committee updates, letters, personal communications, and oral presentations. Some of the study summaries presented were necessarily based on draft reports or incomplete data. These instances were identified where appropriate. The reader should exercise appropriate judgment regarding the interpretation and distribution of that material. 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 in whole or part, exactly as it appeared in the original document.

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1. INTRODUCTION

From 1991 - 1996, Georgia Power's Sinclair Hydroelectric Project (FERC No. 1951) was relicensed through the Federal Energy Regulatory Commission (FERC). Sinclair Dam impounds the Oconee River in central Georgia to form Lake Sinclair. 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.

This relicensing effort represented the first hydro project relicensing using the new Applicant Prepared Environmental Assessment Process (APEA), as authorized by the Energy Policy Act of 1992. This process included the submission of a Draft Environmental Assessment (DEA) with the final license application, in lieu of the usual Exhibit E, or Environmental Report.

During the beginning of the licensing process 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 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 APEA process fostered stakeholder inputs and agreements during licensing, and the Endangered Species Act contained provisions to encourage stakeholder partnerships to conserve imperiled species and their habitats.

Several stakeholder partnerships and agreements were formulated during and independent of the licensing process. The first, and perhaps most important of these to be covered in this report, was the creation of the Robust Redhorse Conservation Committee (RRCC). The RRCC was given the responsibility to implement research, conservation, and restoration actions for the robust redhorse. Other agreements included a negotiated flow agreement for the Oconee River designed primarily to enhance habitat for the robust redhorse, and the Robust Redhorse Flow Advisory Team for the Oconee River (Advisory Team). The Advisory Team was given the responsibility of reviewing data to monitor the effectiveness of the new flows and if necessary, make recommendations to the FERC regarding any future flow modifications for the Oconee River.

The new license for the Sinclair Project, issued by the FERC on 19 March 1996, required the submission of a report every two years to the FERC. The license stated that 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. Per license requirements, this document represents the first of such reports.

This report is not intended to be a fully detailed accounting of every aspect of the conservation and restoration of the robust redhorse. However, much progress has been made during the last few years and many organizations and individuals have contributed to the project. Some progress has been made through trial and error. It is reasonable to expect mixed success during the early years of a conservation effort for a largely unknown species.

The author believed that it is necessary, at least for this initial report, to provide enough background and appropriate details to enable the reader to fully understand the magnitude of this conservation effort, as well as the growing base of knowledge and the logical progression of work. This report begins with the discovery of the robust redhorse, and some coverage is given to the early years of the conservation effort. The bulk of this report is devoted to actions that have occurred since the creation of the RRCC in 1995.

2. REDISCOVERY AND COOPERATION

2.1 Rediscovery of the Robust Redhorse *Moxostoma robustum* in the Oconee River, Georgia

The following information regarding the rediscovery of the robust redhorse was reprinted almost verbatim from a fact sheet detailing the collection and early extent of knowledge about the species. This information can be located in many reports and publications written by many individuals during the last few years, although the original fact sheet continues to be one of the more complete and explanatory sources on the rediscovery of this species. Mr. James Evans of the GA Department of Natural Resources, Wildlife Resources Division (GDNR) initially drafted the fact sheet, relying on his extensive personal experience with the robust redhorse, personal communication with other scientists, and the following unpublished manuscripts:

Jenkins, R.E., and B.J. Freeman. Systematics of the molar-toothed redhorse suckers (Moxostoma carinatum) and the rediscovered M. robustum of the south Atlantic slope (Pisces: Catostomidae).

Jenkins, R.E. Systematics of the brassy jumprock (Scartomyzon braesius, new species; formerly called Moxostoma robustum) of the south Atlantic slope (Pisces, Catostomidae).

"Five large catostomids were collected from the Oconee River below Sinclair Dam near the mouth of Commissioner Creek on 8 August 1991. Meristic characteristics did not correspond precisely to any known species and average length exceeded that of all catostomid species known to occur in the Altamaha River drainage. Preserved specimens were sent to Dr. Henry Bart, then curator of the Auburn University fish collection. He indicated that these fish might belong to what was then believed to be an undescribed species known to ichthyologists by only two existing specimens - one collected from the Savannah River, Georgia/South Carolina in 1980, and a second from the Pee Dee River, North Carolina in 1985. Informal names applied at the time to the species represented by the two Savannah/Pee Dee specimens were the bighead redhorse and the Savannah River redhorse."

"The status of this species was being investigated by Dr. Robert Jenkins of Roanoke College, Virginia; by personnel from the National Fisheries Research Center in Gainesville, Florida; and by Dr. Byron Freeman, curator of the University of Georgia fish collection. All investigators subsequently concluded that the Oconee, Savannah, and Pee Dee river specimens represented a single species. Prior to the discovery of the Oconee River population, during the period 1981 - 1990, ichthyologists, biologists, and consultants in Georgia and the Carolinas had been consulted and portions of the Savannah River were sampled in an effort to obtain more specimens. None were found."

"Initially, the Oconee, Pee Dee, and Savannah River specimens were believed to represent a new species, probably an Atlantic slope form of the river redhorse *Moxostoma carinatum*. The species is now believed to have been described by master naturalist Edward Cope in 1870 from specimens collected from the Yadkin River, North Carolina and given the scientific name *Ptychostomus robustus* (*Ptychostomus* is synonymous with the present genus designation *Moxostoma*). Cope's original type specimens were apparently lost and later workers erroneously labeled specimens of other species as types. The scientific *P. robustus*, which Cope had intended to be applied to the robust species represented by the Oconee, Pee Dee, and Savannah river specimens, was instead misapplied by later revisionists of the Catostomidae to a smaller species. This smaller species, sympatric with the larger more robust form, has since 1956 been known in the scientific literature, incorrectly, as *Moxostoma robustum* - the smallfin redhorse. As a result of these investigations, the scientific name *Ptychostomus* (*Moxostoma*) *robustus* will be transferred as *Moxostoma robustum* (Cope) (robust redhorse) to the species known from the Oconee, Pee Dee, and Savannah river specimens. The smallfin redhorse will be placed in the jumprock genus (*Scartomyzon*) and given the common name brassy jumprock (Jenkins and Freeman, in preparation)."

"Subsequent to the discovery of the Oconee River population of robust redhorse, investigations by Jenkins and Freeman into the status of this species included a review of "gray literature" such as federal aid reports, state fisheries reports, and biological surveys as well as studies of museum fish collections. In a further attempt to locate other remnant populations, the Pee Dee and Yadkin rivers in North Carolina, the Ogeechee and Broad rivers in Georgia, and the Savannah River, Georgia/South Carolina, were sampled by personnel from a variety of agencies as well as by companies with hydropower interests in these rivers."

To date, the only one other population of robust redhorse outside the Oconee River has been discovered. In October 1997, a single adult robust redhorse was caught from the Savannah River about 50 river miles downstream from Augusta, GA. During a June, 1998 survey of the Savannah River near Augusta, GA, four adult robust redhorse were captured. A more detailed accounting of this discovery is presented in a later section of this report.

"Skeletal remains of an additional specimen from the Savannah River were discovered at the University of Georgia. Pharyngeal teeth from the robust redhorse have also been found at an archeological site near Brier Creek, Georgia (Savannah River drainage). Anecdotal reports of large redhorse suckers persist from portions of the species former range, specifically from the Pee Dee and Yadkin rivers, North Carolina, and from the Savannah, Ogeechee, and Ohoopee rivers in Georgia. The general consensus of most authorities is that small, isolated remnant populations of the species could exist in one of these rivers, or perhaps elsewhere. All authorities agree that the species is in danger of extinction, perhaps within the next decade, and that recovery efforts should be initiated as soon as feasible (Jenkins and Freeman, in preparation)."

Some literature indicates that spawning runs of catostomids, and probably the robust redhorse, were declining in the late 1800s. Scientists believe that the most likely early causes for these declines may have been overfishing and excessive siltation from wide-spread land clearing and related agricultural practices. In more recent times, threats to native riverine fish populations have been associated with pollution and continued sedimentation of spawning and rearing habitats, construction of dams and associated changes in hydrologic regimes, and rapidly expanding populations of introduced predator species, including flathead *Pylodictis olivaris* and blue *Ictalurus furcatus* catfishes. The exact reasons for the apparent decline and range restriction of the robust redhorse are as yet unknown.

"Other significant findings to date from literature reviews, museum research, and field investigations on the Oconee River and elsewhere are outlined below.

1). The historic range of the species is believed to be the Piedmont and upper Coastal Plain areas from the Altamaha River drainage in Georgia through the Carolinas to at least the Pee Dee River, North and South Carolina. The known range of the Oconee River population is from approximately 1.6 km below the GA Hwy. 22 bridge at Milledgeville downstream to about 18 km above Dublin, a distance of approximately 85 km. Several attempts to collect additional specimens from the Oconee River below Dublin were unsuccessful. A review of available data and anecdotal information from throughout the Altamaha River drainage, including the Oconee River above Lake Sinclair, has produced no verifiable evidence of the presence of this species outside the area delineated above. It is probably reasonable to assume, however, that isolated individuals could exist in the Oconee River below Dublin or perhaps even in the Altamaha River.

2). Preferred habitat for non-spawning adults is typically in deeper, moderately swift areas in or near outside bends, often in association with accumulations of woody debris. Spawning behavior is apparently similar to that of the river redhorse and seems to occur over both deep and shallow water gravel patches from late April to early June at water temperatures from 18 - 24 C.

3). Recaptures of tagged fish indicate significant variability in movement patterns among individuals. Most individuals seem to migrate very little but movements of up to 27 km have been noted. Estimated population size is 1,000 - 3,000 adults based on Peterson and Chapman mark-recapture estimates.

4). Analysis of stomach contents indicates a diet consisting almost entirely of Asiatic clams (*Corbicula* sp.) which are crushed with large molariform pharyngeal teeth. Similar dentition is found in two other species of redhorse, the river redhorse (*Moxostoma carinatum*) and the copper redhorse *(M. hubbsi*).

5). A preliminary age and growth investigation indicated that over 90% of the population is between 15 and 26 years of age although a few fish as young as 5 - 6 years of age have been collected. Age and growth studies using various bony structures have shown other members of this family to be generally long-lived.

6). Length-frequency analysis of 239 robust redhorse collected from August 1991 to June 1994 shows little evidence of significant recruitment in recent years. Total length range is 424 to 722 mm, yet about 75% of the sample lies between 600 and 660 mm, or within a 60 mm (2.4 inch) range. Four individuals from this group (506, 492, 482, and 424 mm) may have been juveniles with the remainder clearly adults."

2.2 The 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 several river systems within the species' former range.

This stakeholder partnership approach to recovery was selected in lieu of possible listing under the Endangered Species Act (ESA) in part because a large number of private landowners and companies would necessarily be involved in the conservation of this species. Another partial reason for this approach was that conservation actions have often been delayed for various reasons upon the announcement of a proposal to federally list a species under the ESA. With this partnership approach, however, research and conservation actions could begin almost immediately, saving potentially invaluable time for the robust redhorse. Other advantages to this approach include a cooperative, instead of confrontational, environment for the parties involved. This appears to foster more rapid and efficient conservation actions. The MOU provides that the USFWS would ultimately evaluate the effectiveness of these recovery efforts. If the USFWS determines that the survival and enhancement of the robust redhorse can not be accomplished with this or other similar approaches, the USFWS may initiate listing action under the ESA.

Membership of the RRCC is representative of a diverse group of interests and expertise. Current members of the RRCC include the Georgia Department of Natural Resources (GDNR), South Carolina Department of Natural Resources (SCDNR), North Carolina Wildlife Resources Commission (NCWRC), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey - Biological Resources Division (USGS), U.S. Forest Service (USFS), U.S. Army Corps of Engineers (USACOE), Georgia Power Company, Duke Power Company, Carolina Power and Light, and the Georgia Wildlife Federation. The MOU provides for "cooperator" status to be assigned to agencies, organizations, or individuals that are interested in the conservation of the robust redhorse but do not want formal representation on the RRCC.

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.

Most of the contents of this report are the direct result of actions taken or directed by the RRCC or its members. Several work items are being planned and conducted at present, which will be discussed during later sections of this report.

2.3 The Flow Advisory Team For the Oconee River

Negotiated Flow Agreement for the Oconee River

The primary focus of negotiations during the relicensing of the Sinclair Project was the potential flow requirements of the robust redhorse, especially the early life stages. During the relicensing of the Sinclair Hydroelectric Project, Georgia Power and EA Engineering, Science, and Technology had completed numerous studies on the robust redhorse. These included surveys for the availability of gravel spawning substrates, monitoring of spawning activity, surveys for young-of-year and juvenile robust redhorse, characterization of spawning habitat, and the development of habitat suitability criteria for the Oconee River. Other studies conducted during relicensing that were useful in these negotiations were an assessment of the fluvial geomorphology of the Oconee River, a description and evaluation of the floodplain, wetlands, and oxbow connectivity, boat passage, and a comprehensive instream flow study that utilized the Instream Flow Incremental Methodology (IFIM). Primary negotiating parties included Georgia Power Company, the Wildlife Resources Division and the Coastal Resources Division of the GDNR, the USFWS, and the National Marine Fisheries Service (NMFS).

The negotiating parties realized that even though there was little evidence of recent recruitment, the only population of robust redhorse known at that time persisted, for unknown reason(s) downstream of the Sinclair Project. The general consensus among the negotiating parties was that little information was available that pointed to specific causes for the apparent lack of recruitment in the Oconee River population. The FERC staff encouraged a tiered, incremental approach to a flow agreement for the Sinclair Project, instead of large-scale, sweeping changes to the existing flow regime. Initial flow modifications would need to be evaluated with respect to the robust redhorse and other fish species. Future modifications of the flow regime would necessarily be based on the best available information, and all members of the Advisory Team would need to agree on the best course of action.

A negotiated flow agreement was finalized in 1995 prior to the submittal of the license application. 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 for spawning and early rearing for robust redhorse and anadromous species.

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.

The Flow Advisory Team

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 largely 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 shared memberships and administration. The current members of the Advisory Team are the GDNR, USFWS, USGS, Georgia Wildlife Federation, and Georgia Power. The Advisory Team is to be coordinated by Georgia Power Company for the life of the license, unless it is determined that the Advisory Team is no longer necessary. This may occur if the appropriate federal agency declares the robust redhorse extinct, or recovered and no longer in need of special protection.

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, the Advisory Team may petition the FERC with its recommendations. These recommendations would then be subject to appropriate FERC evaluation and approval.

The Advisory Team has not yet made any formal determinations regarding the adequacy of the negotiated flow agreement for the Oconee River with respect to the robust redhorse. It would be difficult to attempt to make such a determination at the present time, partially because of the short time the flow agreement has been in effect. The following paragraphs explain the rationale behind the previous statement.

The flow agreement was finalized during 1995, the same year that formal studies began investigating hypotheses relating to robust redhorse recruitment in the Oconee River. The Reproductive and Recruitment Success studies that involve collection of larval and juvenile fishes from the Oconee River have been ongoing since 1995. Data collected during 1995 under the previous Sinclair flow regime suggested very low abundance of larval robust redhorse. It was unclear, however, whether the observed abundance was an accurate representation of the population of larval fishes in the river, or if some unknown sampling deficiency could have influenced the catch.

Although finalized in 1995, the flow agreement for the Oconee River was not actually 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 would 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 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. At the conclusion of sampling this fall (1998), the Advisory Team will have 2 years each of pre- and post-flow agreement data available on larval and juvenile robust redhorse abundance and distribution in the Oconee River. Temperature and flow data from several locations in the Oconee River will also be available, as will the results of many other studies that have been directed at the requirements of the early life stages of robust redhorse. Thus, it is anticipated that the Advisory Team will begin formal analysis and decision making at the conclusion of the 1998 recruitment study.

Preliminary results of the larval fish collections and other studies have been encouraging. During 1997, the first year fully under the new flow regime, sampling results suggested relatively large increases in larval robust redhorse abundance compared to 1995 and 1996 (research summaries provided in later sections of this report). The reader is cautioned that the numbers of robust redhorse larvae captured still seem very low, and some aspects of sampling equipment and locations are still under development. These results, though encouraging, should not yet be interpreted as evidence of definitive improvement in the reproductive success of the Oconee River population.

Flow stability may be important for the successful completion of spawning and survival of early life stages of many riverine species. The negotiated flow agreement provides higher minimum flows throughout the year and run-of-river flows during May and early June. This schedule was designed to provide maximum flow stability during spawning and early rearing for the robust redhorse. In addition, spawning conditions for other species such as striped bass should be improved. Although studies to date have not revealed the exact causes or mechanisms affecting robust redhorse recruitment in the Oconee River, run-of-river flows during the May and early June should be suitable for riverine species.

Research projects have attempted a logical and systematic testing of early hypotheses potentially related to reproduction and recruitment of robust redhorse in the Oconee River. Research summaries presented later in this report indicate that a few hypotheses relating to the potential direct effects of the operation of Sinclair Dam on robust redhorse have been at least partially refuted. Of course, much research remains to be conducted to determine specific mechanisms that influence recruitment, possibly through discreet and indirect effects.

Although much data will soon be available to the Advisory Team, several factors can not be overlooked that may contribute some confusion to the analysis. One factor is the natural variability in both hydrologic regimes and fish populations. As an example, the second year of the new flow regime (1998) was probably influenced by the global weather phenomenon known as El Nino, which contributed to prolonged high water conditions during the winter and spring throughout the southeastern United States.

Another factor that the Advisory Team may need to consider when evaluating the new data is the interruption of run-of-river flows for collection of broodfish during the May spawning season (on the Oconee River) of robust redhorse. Low flows for broodfish collection are currently critical to the overall recovery efforts for the robust redhorse, and every attempt is made to minimize the duration and frequency of these events. It is unknown, however, whether any effects associated with the interruptions of run-of-river flows are positive or negative, although it is clear that the provision of low flows can contribute to more rapid warming of river temperatures than would be the case under run-of-river conditions.

3. CONSERVATION STATUS AND ACTIONS

3.1 Status of the Oconee River Population of Robust Redhorse

The age and size structure of the Oconee River population appears to have advanced slightly, but remains similar to original estimates made in 1994. Most of the data available for this population has been gathered in conjunction with broodfish collection efforts. Fish collected are double anchor tagged, measured, weighed, the location noted, and other items of interest recorded. The population evidently remains mostly composed of older adult individuals about 60 - 70 cm total length, with little evidence of recruitment into the population. However, 1 - 3 immature specimens of about 42 cm total length have been captured each year since 1992. This work and work by other researchers has to date failed to capture robust redhorse less than 42 cm.

Population estimates based on mark-recapture studies conducted during 1995 and 1996 estimated the adult population to be 2,439 and 1,746, respectively. These data appeared to indicate a decline in numbers, but this conclusion could not be made with confidence because of the high variance associated with the estimates. Survival estimates from 1995 to 1996 were nearly 1, which indicated excellent survival between years. Electrofishing catch rates have declined since 1994. However, many factors, including water stage and temperature at the time of sampling can influence catch rates of robust redhorse and contribute to variance.

These data suggest that the Oconee River robust redhorse has not begun a drastic decline. Length-frequency analysis continues to indicate a cause for concern, as was the case during the early years of this project. Robust redhorse remain the number one species in terms of abundance in certain sections of the Oconee River. However, the catch may be biased as the researchers were usually targeting robust redhorse. Unfortunately, flathead catfish are regularly collected within these same sections, and may eventually pose predation problem for juvenile robust redhorse.

Plans are to continue monitoring the Oconee River population for significant recruitment. The projects currently funded and planned for the near future will hopefully discover the reasons for the lack of juvenile fish in the Oconee River, and shed light on the most likely causes for the widespread decline of this species throughout the Atlantic slope drainages. With this information and knowledge of specific requirements of the early life stages and productive hatchery techniques, it is hoped that enhancement of the Oconee River population and the eventual recovery of the robust redhorse will be realized.

3.2 Research Summary

The following section summarizes formal research that has been aimed along two basic lines of investigation: 1) culture techniques for robust redhorse, and 2) the ecology and biology of the robust redhorse in the Oconee River. No effort was made to distinguish projects among these two investigation lines for this report because in many cases, information gained was relevant to both. These summaries are not intended to be detailed reports, but simply to provide the reader with sufficient information to understand the need and rationale for each project as related to the overall goals of the recovery effort, and to present significant results of each project. Many projects were continued for multiple years, but these summaries are presented in chronological order to enable the reader to understand the logical progression of the projects based on knowledge gained and the systematic testing of early hypotheses.

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 at the University of Georgia, and at the Georgia Cooperative Fish and Wildlife Research Unit, also located at the University of Georgia. Sperm cryopreservation, nutrient requirements of early life stages, and water quality for production are just a few examples. 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 bulk of the research 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 also contracted for the age, growth, and maturation studies. It is doubtful that many of these projects could have been successfully completed without the additional funds and enormous amount of in-kind services provided by the Georgia Department of Natural Resources, the United States Fish and Wildlife Service, the University of Georgia, and volunteer participation. 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.

Many portions of the following text were included verbatim from submitted research reports, summaries, and electronic communications.

3.2.1 1995 Research Summaries

Project 1. Hormone Induced Ovulation of Robust Redhorse *Moxostoma robustum*

To facilitate recovery of the robust redhorse, adult broodfish from the only known Oconee River population were used to produce offspring for research and reintroduction purposes. However, initial attempts to spawn robust redhorse, by both natural and artificial means, were largely unsuccessful. Some eggs were produced from female fish that were "running ripe" at the time of collection, but these numbers were far below what was needed for a valid effort at recovery. It became apparent that artificial spawning, and the development of a reliable and efficient hormone treatment regime was vital to the success of the recovery program.

The initial research project for developing a hormone treatment regime for robust redhorse propagation was conducted during spring, 1995. The objectives of this project were to:
1) evaluate the effectiveness of five different hormones in inducing robust redhorse to ovulate,
2) determine the optimum treatment dosage for the most effective hormones or hormone combination, and
3) determine if robust redhorse spawn intermittently.

A temporary broodfish holding and spawning facility was constructed on the banks of the Oconee River at Beaverdam Wildlife Management Area (WMA). The spawning facility originally included nine circular holding tanks that were aerated and supplied with a continuous flow of river water from electrical pumps. The site at Beaverdam WMA was selected because it was relatively close to the area of broodfish collection, which would greatly minimize transport and holding times of adult broodfish.

The study involved testing five hormone treatments, administered via injection, on female robust redhorse, along with a control group that were subjected to injections of a sterile saline solution. Hormones and dosage rates were selected based on a review of scientific literature, personal communication with other researchers, and product information provided by the manufacturers. Broodfish were returned to the Oconee River upon completion of each spawning trial.

Broodfish were collected with boat-mounted electrofishing gear from May 1 to May 3, 1995. A total of 33 females were collected, but only 21 of these were used in the study, based on a determination of appropriate spawning condition for hormone treatments. A total of 58 males were collected, all with free flowing milt. Seventeen males were transferred to holding tanks for egg fertilization.

Nine of the 17 females injected with hormones ovulated, but none of the fish in the control group ovulated. Eggs collected per female ranged from 1,485 to 86,295. It appeared that robust redhorse are capable of intermittent spawning, as some of the females released additional eggs one day after initial collection.

This work indicated that Ovaprim, Carp Pituitary Extract (CPE), and Human Chorionic Gonadotropin (HCG) were effective for inducing ovulation and increasing spawning success of broodfish. However, specific dosage rates and treatment intervals needed to provide optimum results were unknown.

About 800,000 eggs were produced from both natural and artificially induced females. The eggs were transported to McDuffie Fish Hatchery, Warm Springs Fish Hatchery, and Whitehall Fisheries Lab for incubation. About 71,000 fry were produced and shipped to grow-out ponds at various hatcheries. Pond inventory from November 30 - December 1, 1995 indicated that about 40,000 (56%) fry had survived to fingerling stage.

Project 2. Spawning Behavior of Robust Redhorse in the Oconee River, Georgia

Some field observations from the Oconee River indicated that the robust redhorse may construct redds in gravel substrate, but these observations were not thoroughly documented. Whether robust redhorse construct redds or not could be important in determining reasons for limited recruitment in the Oconee River population. The specific objectives of this project were to:

1) document spawning-related behavior prior to and during the spawning act, and
2) identify specific habitat conditions associated with the spawning sites.

Three reaches of the Oconee River were surveyed by boat for spawning robust redhorse and/or suitable spawning sites. These surveys focused on known gravel deposits and areas that were shallow enough to allow direct observation. High flows and turbidity hindered the survey effort. However, spawning robust redhorse were observed from 14-22 May 1995, at a gravel bar near the Avant Mine site at about river mile 120. Documentation of spawning behavior was recorded with both video and still photography. Water velocity, depth, substrate, water temperature, and other variables were recorded at spawning sites.

Spawning was observed from dawn to dusk, and occurred over small to medium-sized gravel. Water velocity ranged from 35 - 60 cms and daytime water temperature fluctuated around 25 C during observation. It appeared that male robust redhorse were very territorial and would actively defend their staging position on the gravel bar against other males. Females staged in a pool upstream of the gravel bar, and when ready, moved onto the gravel bar between two males. Gametes were released as the three fish pressed into each other, with caudal and anal fins plowing into the gravel substrate. One group of spawning fish included three males and two females, and spawning behavior was often violent and aggressive as non-participating males butted participating males with their snouts. This behavior was consistent with some other species of the genus *Moxostoma*.

The Laurens County section of the Oconee River has at least one active spawning population and suitable habitat to support other breeding groups. Spawning habitat, based on observable activity, is moderate to swift, shallow water over loose gravel substratum.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River, GA

From the first efforts to document the status of the robust redhorse in the Oconee River, it appeared that the population was skewed toward larger, older individuals. Robust redhorse had been observed spawning in the Oconee River, however, many efforts directed at collecting juvenile or young-of-year (YOY) fish were unsuccessful. This combination of circumstances suggested reproductive or recruitment failure in recent years. Data regarding spawning success, distribution and abundance of larvae, and estimates of larval growth and mortality were needed to determine if the scarcity of juvenile robust redhorse is related to recruitment failure or other non-biological factors. Specific objectives for this task were to:

1) document spawning activity,
2) determine reproductive success,
3) determine growth and mortality of larval life stages sampled from the Oconee River

Pushnets, D-ring nets, light traps, and seines were used to sample larval fishes from about a 51 km reach of the Oconee River from May 10 to December 8, 1995. Depth, water velocity, turbidity, water temperature, and dissolved oxygen were recorded for each sample. Fish samples were preserved in 10% buffered formalin and returned to the laboratory where they were examined for the presence of larval and juvenile robust redhorse. After picking, twenty percent of the sample residues were re-examined to determine to efficiency of project personnel extracting larval fish.

Six hundred twenty-two samples were collected from the Oconee River that contained 45,698 larval and juvenile fishes, representing 11 families. Six larval robust redhorse were identified from these samples. Most of these (5) robust redhorse were caught in late May with pushnets. These larvae were 13-14 mm total length, with five being collected at night, directly upstream of a suspected spawning site.

Larval and juvenile suckers of other species were relatively abundant in the samples. However, density estimates for robust redhorse larvae ranged from 0.0 to 13.4 per 1000 m^3 of water sampled. It appeared that the chosen gear types were effective at sampling larval fishes from the Oconee River. Each gear seemed to work better during different flow conditions, but based on the numbers and diversity of fishes collected, it seemed that most of the sampling gear worked well most of the time.

A D-ring net was deployed nine times about 1-3 m downstream of spawning fish at the Avant Mine site. Four nets contained no eggs, the other nets contained 81, 1, 1, 9, and 2 eggs. Considering the known fecundity of robust redhorse from Project 1, it appeared that the eggs may be buried in the gravel during the spawning act, preventing most egg drift. This also suggested that newly hatched larvae would probably also remain buried in interstitial spaces within the gravel substrate until all yolk material had been absorbed.

This study suggested that larval and juvenile life stages of robust redhorse were rare in the Oconee River. However, it was unclear whether the scarcity of larval and juvenile robust redhorse in the samples was strictly a function of abundance, or if other sampling and biological considerations contributed to the low catch rates. Growth and mortality of larval robust redhorse could not be estimated because of insufficient numbers of larvae collected.

Project 4. Surveys for Additional Populations of Robust Redhorse

Robust redhorse were known only from a small reach of the Oconee River between Milledgeville and Dublin, Georgia. Recovery efforts would benefit from the discovery of other remnant populations within the suspected former range of this species. Such a population would provide additional information about the habitat requirements, and possibly lend clues regarding the apparent recruitment failure in the Oconee River. These status surveys may also provide information on the occurrence of flathead and blue catfish, two recently introduced, highly predatory species that are expanding their range. Introduced catfish predation can negatively affect native sucker populations. The primary objective of this project was to locate other remnant populations of robust redhorse.

Preliminary surveys for robust redhorse were planned for the Broad River and Brier Creek, two major tributaries of the Savannah River. Historical collections of robust redhorse are known from the Savannah River near Augusta. Robust redhorse remains were also identified from a shell midden in the floodplain of Brier Creek. However, only the Broad River could be sampled during 1995 because of time constraints associated with fund availability and acquiring the necessary sampling gear.

Eight collections were made with boat-mounted electrofishing gear in Madison and Elbert Counties, GA, during December 1995 and January 1996. Several sucker species were collected including silver redhorse, northern hogsucker, and jumprock, but no robust redhorse were collected. Carpsuckers were seen but not captured. Silver redhorse were particularly abundant, as were Asiatic clam *Corbicula* sp. *Corbicula* sp. are a food item of robust redhorse. Flathead catfish were also collected, having been introduced into Clarks Hill Reservoir in 1964. However, most individuals were small and flathead density appeared low. The existence of flathead catfish within the drainage for many years, and the abundant and diverse sucker population in the Broad River, suggested that flathead catfish may have limited success colonizing the upper Broad River system.

Preliminary sampling in the Broad River indicated that suitable habitat and a forage base were available for robust redhorse. Brier Creek was believed large enough to support robust redhorse, and records exist of a prehistoric population. The researchers suggested Brier Creek should remain a priority for future robust redhorse surveys.

3.2.2 1996 Research Summaries

Project 1. Effects of Temperature and Water Flow on the Incubation and Survival of Robust Redhorse eggs and larvae

Although robust redhorse spawning was documented in the Oconee River, it appeared that the abundance of larvae and juveniles was low. This suggested that environmental conditions may be unsuitable for incubation of eggs and larvae. Little was known about the early life history requirements of robust redhorse, and temperature and water flow are two of the most critical factors influencing the survival of fishes during early life stages.

This project was designed to provide information regarding optimum incubation parameters for robust redhorse eggs and larvae. If temperature and/or flow conditions were problematic within the Oconee River, this project could help provide information for a solution, and help determine factors needed in other rivers that are prospective stocking sites for establishing reproducing populations.

In addition, egg to fry survival rates had been very low under laboratory conditions. Data gathered from this project could be useful in establishing more efficient hatchery protocols for producing robust redhorse fingerlings. Specific objectives of this project were to:
1) examine incubation success through a range of flow rates and turbulence levels, and
2) examine the effects of water temperature on incubation success.

Fertilized robust redhorse embryos obtained from the hormone-induced ovulation work conducted earlier in the spring were used for this study. An incubation system that allowed control of water temperature and flow velocity for replicate groups of embryos was constructed. Water flow treatments ranged from a low flow rate that produced no turbulence to a high flow rate that produced high turbulence for the incubating eggs. Five temperature treatments were used, which included 15, 19, 23, 27, and 30 °C. Six replicates were to be used for each flow rate at each temperature. Surviving larvae were counted and examined for deformities immediately after each trial was completed.

Surprisingly, the robust redhorse embryos were positively buoyant when introduced to the study chambers. This was the first, and only, time that positive buoyancy had been noted during incubation. A control group of embryos placed in McDonald hatching jars also floated. It was thought this buoyancy could have occurred as a result of changes in internal gas pressures within the embryos during transport or tempering. Because of this buoyancy problem, data regarding temperature effects reflect all flow treatments combined. Data collected on the effects of flow and turbulence was deemed not statistically defensible by the researchers, and was presented only in support of, and as a guide to, future studies dealing with temperature and flow effects on incubation.

The highest survival was encountered at 23 °C and decreased as water temperature increased or decreased. None of the 4,800 embryos subjected to 30 °C survived, and deformities were most prevalent at 27 °C and 15 °C. Incomplete spinal development was the most common deformity. This type of deformity would almost certainly result in death.

In sustained flow treatments survival was extremely low for the high-flow, high-turbulence levels. No strong relationship was observed between survival and flow rate when embryos were transferred to low turbulence treatments at the start of hatching.

The highest survival rates occurred at 23 °C (32%) and 19 °C (23%). Similarly, deformities were lowest at 19 °C (3%) and 23 °C (4%). These data suggest possible optimum incubation temperature around 23 °C, and that temperatures higher than 27 °C or lower than 19 °C would likely contribute to significant mortality. Water temperature data collected at the spawning facility during broodfish collection efforts ranged from 17.3 to 26.1 °C. Therefore, it is possible for wild-spawned robust redhorse larvae to be exposed to high, possibly detrimental water temperatures in late May.

Sustained flow versus reduced flow treatments indicated robust redhorse fry may experience higher mortalities when exposed to adverse conditions after hatching. This research indicated that yolk-sac fry may be a critical developmental stage relative to environmental conditions. This suggested that robust redhorse fry could be susceptible to mortality if displaced from the gravel before the yolk-sac is fully absorbed.

Even though unexpected problems affected this study, the information provided was useful in many ways to the overall goals of the recovery effort. The results of this project suggested that yolk-sac fry are the most vulnerable life stage, and that physical and/or biological processes affecting the substrate during their presence is worthy of future study.

Project 2. Swimming Performance of Larval and Juvenile Robust Redhorse: Implications for recruitment in the Oconee River, GA

One hypothesis for the apparent lack of recruitment in the Oconee River robust redhorse population was negative impacts of hydropeaking flows on early life stages. Hydrological conditions downstream of peaking facilities can be highly variable, and may influence water depth, velocity, and temperature, and possibly other factors involving the spawning substrate. The variability in depth and velocity is of particular importance, especially for those fishes that may require relatively shallow and slow habitat conditions during early life stages. Therefore, the swimming ability of a species, and its ability to maintain position in desired habitats, may be a critical factor to survival.

Through laboratory experiments, this project attempted to document the swimming ability of three size classes of larval robust redhorse under varying flow conditions. A literature review provided information regarding the swimming ability of robust redhorse relative to other fishes. The overall goal of this project was to test the hypothesis that larval robust redhorse could tolerate typical low-velocity currents that occurred during power generation at Sinclair Dam. Specific objectives were to:
1)measure prolonged swimming speeds of three size-classes of larval and juvenile robust redhorse in a gravity-flow current flume, and
2)determine the availability of larval fish rearing habitat, defined by current velocity, varied between minimum and peaking flow releases at Sinclair Dam during May and June when early life stages of robust redhorse would be most vulnerable to flow.

Swimming Performance
About 1,000 newly hatched robust redhorse larvae were randomly selected from those available from the artificial spawning efforts. Swimming performance was measured by determining the failure velocity (FV50). Mean total length of the three size classes was 13.1, 16.2, and 20.4 mm. Swim-up typically occurred at about 11 mm total length. Water temperature was kept constant for each size class of fish tested, but was increased with increasing size classes to simulate water temperature that the specific size class would have experienced in the Oconee River during May and June. The range of current velocities tested was 3.6 - 6.7 cm/s, and the mean increment between test velocities was 1.1 cm/s. For this project, current velocity and fish score (pass/fail) were synonymous with toxin dosage and animal survival in toxicity experiments.

Larval and juvenile robust redhorse often responded to increases in current velocity by laying on the bottom of the swim tube. Once the fish started swimming, swimming behavior was more similar to striped bass *Morone saxatilis* than larval and juvenile Colorado squawfish *Ptychocheilus lucius*. Robust redhorse exhibited photopositive behavior when positioning within the swim tube.

The proportion of robust redhorse that successfully completed a 1 hour swimming trial at a prescribed velocity decreased as velocity increased for each size class tested. Prolonged swimming speeds increased with length for larval and juvenile fish. However, the increase in swimming performance from 13.1 to 16.2 mm fish was greater than the increase from 16.2 to 20.4 mm fish. FV50 values were estimated for both 30 minute and 60 minute intervals.

Swimming speeds of yolk-sac (13.1 mm = 6.9 cm/s, 5.3 BL/s) and larval robust redhorse (16.2 mm = 10.6 cm/s, 6.5 BL/s; 20.4 mm = 11.7 cm/s, 5.7 BL/s) were among the highest reported for early life stages. Prolonged swimming speeds were greater than striped bass (lowest reported), but less than Colorado squawfish (highest reported). Swimming performance of larval robust redhorse was high, as expected.

Rearing Habitat Modeling

Four study sites were used to assess the effects of peaking flow releases on rearing habitat availability in the Oconee River at seven river discharges (500 - 6,000 cfs). PHABSIM models developed by EA Engineering during relicensing studies for Sinclair Dam were used to estimate robust redhorse rearing habitat, using swimming performance data gathered as part of this project. Mean Weighted Usable Habitat (WUH) was calculated at seven discharges for each of the four study sites, and was based on the swimming performance of the 13.1 mm size class larvae. Regression analysis was used to evaluate the relationship between discharge and rearing habitat.

Availability of larval robust redhorse rearing habitat was relatively low at the Avant Mine, Georgia Railroad Bridge, and Highway 57 study sites at all river discharges. The greatest mean WUH estimates were calculated for the Dublin site at 4,000 - 6,000 cfs. Relationships between mean WUH and discharge were not significant at the Avant Mine, Georgia Railroad Bridge, or the Highway 57 study sites. However, a positive relationship was evident between discharge and habitat availability for Dublin study site. These data suggested that peaking flows did not cause current velocity to limit larval robust redhorse rearing habitat in the Oconee River. High discharge was actually related to increased rearing habitat at Dublin, the furthest site downstream from Sinclair Dam.

These results indicated that even though WUH was not correlated with discharge (at three sites), the position of appropriate rearing habitat was dynamic during changing discharges. The conclusion that hydropeaking events at Sinclair Dam did not limit available larval habitat assumes that larval fish can move as the habitat moves within the River. Although the quantity of larval robust redhorse habitat (based on depth and current velocity) was estimated during this project, the quality of this habitat remains unknown.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River, GA (Year 2)

This project was a continuation of similar work performed during 1995, with intentions to build on information learned during the initial phase of this project. The objectives for this project were modified slightly, based on 1995 sampling results and new hypotheses regarding the fate of eggs and larvae within the gravel substrate. The 1996 objectives for this project were:

1) document continued spawning activity,
2) determine abundance of larvae in spawning sites, and
3) determine the abundance of larvae in the Oconee River

Weekly sampling of larval and juvenile fishes was conducted during approximately the same time frame as 1995, again using pushnets, D-ring nets, light traps, and seines. A benthic pump was used at the spawning site to determine if eggs were being deposited in the gravel, and to quantify the abundance of eggs and larvae. Water depth, velocity, temperature, turbidity, and dissolved oxygen were again collected for each fish sample. Handling of samples was similar to the previous study. Twenty percent of the sample residues were re-examined to determine to efficiency of project personnel extracting larval fish.

The catch of larval and juvenile fishes in 1996 was similar to, but slightly lower than the catch from the same reach of river during 1995. Four hundred twenty-two samples were collected that contained 38,715 larval and juvenile fishes that represented 11 families. Cyprinids comprised about 90% of the sample by number, and as in 1995, Catostomids were well represented in the catch.

Some robust redhorse eggs and larvae were collected at the spawning site with the benthic pump, but in very low numbers. A laboratory experiment helped determine that the benthic pump was about 33% effective in sampling fertilized robust redhorse eggs from gravel substrate, which may partially explain the low catch.

Only three larval robust redhorse were caught in icthyoplankton drift samples, which led to much lower estimates of density (1.5 - 3.5 per 1000 m3 of water) than in 1995 (0.0 - 13.4 per m3 of water). The 1995 density estimates were obtained during early to mid May, and the density estimates for 1996 were obtained during late May and early June. Whether these density estimates represented actual differences in larval robust redhorse abundance, or the estimates reflected temporal differences in fish collection was unclear. Densities of larval robust redhorse sampled from the gravel substrate also appeared low. These low estimates may have been be a reflection of sampling efficiency, however, overall densities of larval robust redhorse in the Oconee River seemed low relative to the large numbers of spawning adults frequenting gravel areas.

Thirty-six juvenile silver redhorse were collected during 1996, but no robust redhorse juveniles were collected. Early assumptions were that robust redhorse and silver redhorse occupied the same or similar habitats, and would behave similarly with regard to avoidance of sampling gears. If these assumptions were true, differences in catch rates should reflect actual differences in species abundance. However, juvenile robust redhorse have demonstrated extremely wary behavior in the laboratory, and have proven difficult to capture in hatchery ponds. Differences in behavior and/or habitat preference may partially explain reduced catch rates of robust redhorse juveniles from the Oconee River, or the actual numbers of juvenile robust redhorse may be extremely low.

Another possibility for the apparent differences in abundance may be spawning time as related to river conditions. Silver redhorse spawn earlier in the spring than robust redhorse, possibly when river conditions would be less affected by hydro operations. During May when robust redhorse typically begin spawning, peaking ability at Sinclair Dam can be extremely important to the Southern Electric system. Other projects conducted during 1996 attempted to determine the possible relation between generation flows, habitat stability, and robust redhorse recruitment.

3.2.3 1997 Research Summaries

Project 1. Effects of Temperature and Water Flow on the Incubation and Survival of Robust Redhorse Eggs and Larvae (year 2)

Initial work for this project was begun in 1996, however, unexpected problems with egg buoyancy prevented statistical analysis and confidence in portions of the study. This project was designed to repeat the initial flow and temperature study with redesigned flow chambers, as well as confirm and refine results obtained during 1996. Specific objectives were to:
1) refine estimates of optimum temperature for incubation of eggs and fry,
2) determine optimum flow rate for hatching success of eggs and development of larvae,
3) evaluate interactive effects of flow and temperature on survival of eggs and larvae,
4) determine if eggs from early-, peak-, and late-spawning fish, and from different parental crosses, respond similarly to the effects of temperature and flow.

Complete analysis of this project was not available for this report, however, preliminary data appeared to confirm earlier results. Narrower ranges of temperatures tested indicated that water temperatures around 21 - 23 °C may be optimum for survival of eggs and larvae. These data also showed that higher tested flows resulted in higher mortalities to both eggs and larvae than the lower flows tested. In addition, some flow trials resulted in good egg incubation, but were lethal to fry. These results appeared to confirm earlier suspicions that yolk-sac fry were more fragile than either eggs or swim-up fry.

Project 2. Effects of Gravel Quality and Percent Fine Sediment on the Hatching and Survival of Robust Redhorse Eggs

This project represented the next logical step in a series of studies designed to address the apparent lack of recruitment of robust redhorse in the Oconee River. Previous projects have documented continued spawning, egg deposition in the gravel, and that survival to emergence (STE) was low. Sedimentation has been shown to negatively affect survival of salmonid eggs and larvae. It was believed that examination of some of these same factors in the Oconee River could further narrow the possible causes for low STE of robust redhorse. The goal of this project was to determine if the low abundance of larvae and observed absence of juvenile robust redhorse were related to poor incubation habitat

in terms of gravel quality and percent fine sediment. The specific objectives of the project were to:
1) determine the size(s) of gravel most suitable for survival of robust redhorse larvae,
2) evaluate the effects of fine sediment on STE,
3) determine if suitable-sized gravel is present in the Oconee River in high enough concentrations to permit high STE.

To determine gravel size most suitable for survival of larvae, five treatments of various-sized gravel were used that represented the range of gravel sizes available in the Oconee River. A fixed volume of fertilized robust redhorse eggs would be incubated in each gravel treatment. The substrate producing the highest percentage of larval emergence would be considered optimum size for robust redhorse STE.

To determine the effects of percent fine sediment on STE, treatments would involve fixed volumes of fertilized eggs placed 6 - 15 cm deep in separate trays of optimum-sized gravel. Other projects have determined that robust redhorse eggs are usually buried between 6 - 15 cm in the gravel substrates during the spawning events. These treatments were inoculated with 25%, 50%, or 75% fines. Three replicates of each treatment combination were evaluated. Water temperature and flow was be controlled to mimic the conditions present in the Oconee River during the time of the experiment.

Preliminary results indicated that peak emergence occurred on day 16, somewhat later than occurred during normal hatchery operations. Results also indicated that lower percentages of fines in the gravel contributed to greater STE. Preliminary conclusions of this project were that gravel quality, in terms of size and amount of fine sediments present in the Oconee River, may affect STE of robust redhorse.

Project 3. Substrate Stability and Spawning Behavior of Robust Redhorse in the Oconee River

Substrate Stability
The purpose of this project was to continue narrowing the focus of the research into the possible causes of low recruitment in the Oconee River, based on what had been learned from previous projects. Other projects have pointed to the early life stages of robust redhorse as the possible bottleneck for this population. The physical characteristics of spawning sites and the stability of these areas during spawning may be important factors in recruitment process from yolk-sac larvae to emergent fry. Specific objectives of this project were to:
1) characterize physical attributes of known spawning sites,
2) estimate potential change in physical habitat from hydropower operations at Sinclair Dam,
3) estimate the potential for physical movement of gravel to reduce STE,

Gravel mobility was assessed by calculating and comparing shear stresses on the gravel bed during various hydropower operations. United States Geological Survey rating curves for the Avant Mine site were collected, and additional channel and bed composition surveys were conducted. Direct observations of particle movements were conducted with tracer gravel studies, and evaluated across a range of hydro operations. In addition, scour chains were used to assess the amount of scour and fill that might occur during hydro operations. A model was developed to help describe potential gravel movements at various flow regimes.

This project also attempted to assess any change in fine sediment composition of gravel areas during hydro operations. Freeze core substrate samples were used to describe these changes. Bed sediment transport was measured with pit-fall traps and modified Whitlock-Vibert boxes. Suspended sediment was measured with rising stage samplers.

Preliminary results of this study indicated that gravel patches were relatively stable across a 2,000 cfs flow event. Habitat modeling of the study site showed that shear velocities remained relatively low over gravel habitat, although shear velocities at higher modeled discharges could pose problems for emerging larval suckers. Freeze core samples documented that robust redhorse eggs are distributed to depths greater than 9 cm below the substrate surface. Fine sediments within the core samples were not abundant, although it appeared the repeated spawning acts may help to displace much of the finer sediments from the substrate.

Spawning Behavior of Robust Redhorse

Results of previous studies suggested that robust eggs were buried in gravel substrates during spawning events. The possibility that repeated spawning events at the same site may dislodge or damage already deposited eggs was worthy of investigation. This project was to document the mechanics of egg burial, and further characterize microhabitat of known spawning areas. Specific objectives of this project were to:

1) determine the mechanics of egg burial and any effects of repeated spawning acts on the same site,
2) identify the commencement of spawning at known and suspected spawning sites in the Oconee River,
3) determine if shifts in spawning activity occur with changes in water stage,
4) determine if cyprinids previously seen near spawning areas were feeding on drifting eggs or larvae.

During April and May, 1997, at the Avant Mine site, robust redhorse were observed exhibiting pre-spawning behavior (swirling and porpoising). Frequent high flows associated with rainfall events and the usually high spring turbidity hindered efforts at direct visual observation. At times, hydro-acoustic equipment was used to monitor robust redhorse activity. Most spawning activity was observed in water less than 75 cm deep, although the researchers were unable to directly observe fish in deeper water.

An underwater microphone was used to record sounds made by spawning redhorse. Recordings were made during observed spawning events, and were diagnostic for the presence/absence of spawning fish. Sounds result from the displacement and agitation of gravel during the spawning act. The sounds were usually intense enough to be heard out of water. Some investigators could feel the vibrations in the gravel bed. The microphone has the potential to help monitor spawning activity during conditions where direct observation is impossible.

Bannerfin shiners *Cyprinella leedsi* observed near the spawning site were collected with seines. Bannerfin shiners appear to be drift feeders, and stomach content analysis of the captured fish indicated that the shiners were actively feeding on robust redhorse eggs and larvae.

Preliminary data indicated robust redhorse eggs were usually highly concentrated in localized areas. These data also suggested at least some eggs were not buried during spawning events, or were possibly dislodged by other spawning events.

Researchers determined that robust redhorse were spawning during times of high flow and turbidity that would have prevented direct observation. These data also suggested that robust redhorse were spawning during discharges in excess of 2,300 cfs. This preliminary evaluation indicated that robust redhorse may successfully spawn in a wide range of flow conditions.

<u>Project 4. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River (year 3)</u>

This project was a continuation of larval fish sampling that began in 1995. The purpose of this project was to help determine whether the causes of the apparent recruitment failure in the Oconee population is biological or environmental. Monitoring the abundance and distribution of larval and juvenile robust redhorse in the Oconee River is also a critical component of the work necessary for determining the effects of the new flow regime at Sinclair Dam. The specific objectives for this project were to:
1) determine abundance of larval robust redhorse in spawning sites, and
2) determine the abundance of larval and juvenile robust redhorse in the Oconee River.

As in the previous two years, this project involved the use of multiple gear types to collect larval and juvenile fishes from the Oconee River, including pushnets, light traps, and seines. Water temperature, depth, velocity, turbidity, and dissolved oxygen were again measured for each sample collection.

Preliminary results for this project indicated that 25 larval and post-larval robust redhorse were captured. Nineteen were caught with pushnets, five with seines, and one was caught in a light trap. This catch, during the first year under the new flow regime, more than doubled the highest abundance estimate from previous years. Peak density (# per 1000 m3 of water) estimates for 1995, 1996, and 1997 were 13.4, 3.4, and 32.1, respectively. No YOY robust redhorse were captured, so there was still little evidence of recruitment to the adult population. It could not be determined whether the observed increase in larval density was a true reflection of larval abundance, or if sampling efficiency improved. However, these results were encouraging.

Project 5. Age, Growth, and Maturation of Robust Redhorse

Age, growth, and age at maturation data were lacking for the robust redhorse, and also for its believed closest relative, the river redhorse *Moxostoma carinatum*. This project would help determine some critical aspects of robust redhorse biology, including the age of sexual maturity, typical and maximum longevity, reproductive potential of the species during a given year, and reproductive potential over the life span of individuals. These data would also provide valuable information on the age structure of the Oconee River population. Accurate age structure information could be important by allowing determination of environmental conditions in the Oconee River when strong and weak year-classes were produced. The river redhorse was included in this study partially because large sample numbers of robust redhorse of varying sizes are not currently available, and it was suspected that published accounts of age, growth, and maturation of river redhorse were erroneous.

Other researchers have demonstrated the validity of using opercles for long-lived fish. Opercles were the primary hard structures used during this project for aging redhorse, although a few lapillus otoliths were aged to determine similarity with opercles. Preliminary work by Dr. R.E. Jenkins on robust and river redhorse opercle bones indicated that one major annulus was formed on the opercle during each year. All available (38), wild-caught, adult specimens of robust redhorse were used for developing age-growth relationships, in addition to pond-reared juveniles. About 500 specimens of river redhorse were to be used. The opercle method was validated using 1) known-age fish, 2) marginal increment analysis, and length-frequency analysis. Length-frequency analysis may only be useful for younger redhorse because of extensive overlap in adult fish size. Specific objectives of this project were to:

1) determine year-class of all wild caught robust redhorse,
2) age at each annulus,
3) sexual differences in growth, if any,
4) age and size at maturation by sex,
5) length-weight relationship,
6) geographic variation in growth,
7) comparison of ages determined by opercles, otoliths, and scales, and
8) morphological growth trajectories

This project is currently incomplete, but preliminary results indicated that opercles were a valid structure for aging robust redhorse. For fish age 10 years and older, scale ages were slightly to grossly underestimated relative to opercle ages. Scales may be acceptable to about age 5. Beyond age 5, the use of scales may lead to underestimation of robust redhorse ages.

Mean age of the 34 Oconee River specimens used for aging was 18; 17.4 for males and 19.1 for females. The youngest fish were an age 4 male and an age 10 male. Ages 11-15 were represented by 6 fish, ages 16-20 by 14, and ages 21-25 by 12 fish. These data suggested an older-aged population with little recruitment. Survival to adulthood occurred unevenly across years. Year classes of the 34 fish span 1967 - 1988. Of these 22 years, 13 are represented by 1-5 fish. Age at maturation is probably 4-5 for males and 5-6 for females.

Back-calculation of lengths-at-age indicated length increase to be moderate in year 1, relatively rapid in years 2-5, and generally slowing to little or no advancement of length in ages 15-25.

The heaviest fish, a gravid female, was collected by EA Engineering, Science, and Technology on 22 May 1993. This fish was reported to be 8 kg (17.64 lb) and 682 mm TL. The longest robust redhorse was 732 mm TL, caught during spring 1995. The largest reported river redhorse was a female taken from the Elk River, Missouri, in April, 1986. That fish weighed 7.743 kg (17 lb 1.12 oz) and was 812.8 mm in total length.

Oconee River adult females were larger than males on average, which is typical of redhorses. The quadratic equation for the length-weight relationship of the 38 fish was: $Wt = 729.3805 - 11.2276(SL) + 0.0333\ SL^2$, $R^2 = 0.733$.

Project 6. Genetic Investigation of the Oconee River Robust Redhorse Population

One of the original questions concerning the lack of recruitment in the Oconee River population centered around the numbers (est 1,000 - 3,000) of adults using a few known and suspected spawning sites. There seemed to be a good possibility for inbreeding, or at least a probability of low genetic diversity, within the Oconee River robust redhorse population. Recovery efforts for other species have often been heavily criticized for initiating stocking programs without genetic characterization of wild and hatchery stocks. In order to successfully establish other reproducing populations, or restock the Oconee River if necessary, answers regarding of the genetic diversity of the robust redhorse could be valuable. Specific objectives of this project were to:
1) determine if the Oconee population contains single or multiple genetic stocks,
2) compare nuclear DNA of hatchery and native stock,
3) determine the extent of inbreeding within the Oconee River population.
4) Develop rapid and sensitive PCR-based approach to identify young life stages of robust redhorse from a mixed sucker species, early life stage collection.

Preliminary results indicated genetic diversity of the Oconee River robust redhorse population to be on the low end of normal range when compared to other species. As of October, 1997, no significant evidence of inbreeding in the Oconee population.

Investigators continue to collect tissues samples for use in this project. Funding for this project was provided to Dr. Ike Wirgin of New York University by EPRI, Duke Power, and Carolina Power and Light.

Project 7. Surveys for Additional Populations of Robust Redhorse

Candidate stream reaches within the hypothesized historic range of the robust redhorse were prioritized using a variety of data sources. Based on the initial work, the Savannah River system and the Ohoopee River in Georgia, and the Broad River system in North Carolina emerged as primary candidates for remaining populations. Streams would be surveyed with electrofishing gear. The objectives of this project were to:

1) survey likely stream reaches for other remnant populations of robust redhorse.
2) conduct habitat assessments of stream reaches.

Surveys of the stream reaches included assessment of access potential, gross habitat assessment, and fish collection. One sampling trip was made to the Savannah River in the vicinity of U.S. Highway 301. High water levels prevented a thorough habitat assessment, and hindered fish collection efforts. A few spotted suckers *Minytrema melanops* were collected, but no robust redhorse.

Brier Creek in the Savannah River system was sampled in the fall. Fish abundance appeared low, and no suckers were captured. Relatively high water levels may have influenced electrofishing catch rates, but were suitable for a general habitat assessment. This reach was characterized as a lowland river swamp, with a poorly defined and braided channel. Little habitat was encountered that would be considered suitable robust redhorse spawning habitat.

The Ohoopee River was scheduled for survey, but high flow conditions prevented sampling efforts. However, information regarding boat and vehicle access was noted, as were reports of potential spawning shoals.

The upper Broad River system (Santee River drainage) in North Carolina was also sampled. Anecdotal reports of "large, redhorse suckers" spawning in the Rocky Broad River had been received. Spawning redhorse were observed in May, 1997, in the Rocky Broad River, but were identified as black redhorse *Moxostoma duquesnei*. No robust redhorse were observed.

The Green and Rocky Broad Rivers in North Carolina was sampled in November, 1997. This was actually part of a large, cooperative effort involving several individuals, agencies, and private companies. No robust redhorse were captured, although several other species of suckers were collected.

3.2.4 1998 Research Summaries

The following projects are either ongoing or will be attempted during 1998.

Project 1. Effects of Temperature and Flow on Incubation of Robust Redhorse Eggs and Larvae

This project is 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. Early attempts at some portions of this project achieved varied success. Less successful attempts often resulted from unforeseen and/or uncontrollable factors. Slight modifications and refinements were made to these studies based on information gained during previous studies. Modifications include a narrowing of the range of temperatures tested, and further investigation into the interactive effects of water temperature and flow on early life stages.

Project 2. Effects of Gravel Quality and Percent Fine Sediment on the Hatching success of Robust Redhorse Eggs

This project is a continuation of a similar project conducted during 1997. During 1997, the percentages of fine sediment inoculated into the gravel treatments were 25, 50, and 75%. To determine the critical level of percent fines in the spawning substrate this project will focus on substrate composition containing 5, 10, 15, and 20% fine sediment.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River (Year 4)

This project is a continuation of earlier work to document the abundance and distribution and larval and juvenile robust redhorse in the Oconee River. This project is also 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 include sampling of tributary streams to the Oconee River, and deep water, main channel seining. Other aspects of larval and juvenile fish collection will remain essentially the same.

Project 4. Age, Growth, and Maturation of Robust Redhorse

This project is a continuation of the age and growth project described in the previous section. The goals and objectives remain unchanged. The continuation is primarily to allow time for dealing with many new specimens of river redhorse, juvenile (pond reared) robust redhorse, and developing adequate age-growth relationships for these species.

Project 5. Genetic Investigation of the Oconee River Population of Robust Redhorse

This project is a continuation of the project started in 1997 by Dr. Ike Wirgin at New York University, and is again funded by Duke Power, CP&L, and EPRI. The goals and objectives of this project are essentially unchanged from those described in the previous section of this report, although samples from the Savannah River will be included.

Project 6. Surveys for Additional Populations of Robust Redhorse

A Georgia Power crew collecting fish samples for routine radiological analysis near Plant Vogtle downstream of Augusta GA, captured a single adult robust redhorse from the Savannah River in October, 1997. In addition, a South Carolina Department of Natural Resources biologist reported the probable, but unconfirmed, observation of a robust redhorse during fish sampling on the Savannah River near Augusta, GA. These occurrences prompted the RRCC to organize large-scale sampling efforts to determine the location and extent of any native robust redhorse population in the Savannah River. Sampling was planned to be conducted during two separate occasions for different reaches of the Savannah River during spring 1998.

On 20 - 21 May 1998, seven electrofishing boats sampled primarily two areas: 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. The Georgia Department of Natural Resources, the Institute of Ecology and the Cooperative Fish and Wildlife Research Unit at the UGA, Georgia Power Company, Army Corps of Engineers, Tulane University (LA), Kleinschmidt Associates, and Roanoke College (VA) supplied equipment and/or personnel for these surveys.

During the two days, the boats accumulated more than 15 hours (total pedal time) of electrofishing effort in search of robust redhorse. Effort was concentrated on sections with meander bends, areas as similar as possible to those areas in the Oconee River where robust redhorse occur. V-lip redhorse and spotted suckers were relatively abundant, and a few carpsuckers were captured from furthest downstream location on 20 May. No robust redhorse were captured. 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 be captured. It is possible, but unknown, if these observations were robust redhorse. Another, but probably less intensive survey of these reaches will most likely be conducted in 1998 during the typically low-flow period of September - November.

On 3- 4 June 1998, the Savannah River was sampled in the Augusta shoals area between the City of August diversion dam and the New Savannah Bluff Lock and Dam. This reach of the Savannah River is characterized by shallower water and more shoals and rocky/gravely substrate than the downstream reaches sampled. The Corps of Engineers provided low flows of about 6500 cfs during the sampling period, about half of which would flow through the sampling area. The Georgia and South Carolina Departments of Natural Resources, the UGA Institute of Ecology, EDAW, Inc, Georgia Power Company, Duke Power, Roanoke College, and the North Carolina Museum of Natural Science provided equipment and/or personnel to assist in these surveys. A total of five electrofishing boats participated during the two day search for robust redhorse.

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. The fish were scheduled to be released at the capture site on 8 June 1998.

The location of other robust redhorse in the Savannah River is significant. The extent and condition of this population is unknown at present, but it is encouraging that other individuals exist outside the Oconee River. The discovery of this population will undoubtedly be a topic requiring much discussion of the RRCC, and some effort will most likely be directed at broodfish collection from Savannah River during 1999.

3.3 Broodfish Collection, Fingerling Production, and Reintroduction

After the robust redhorse was rediscovered in the Oconee River in 1991 and the significance of this discovery was established, attempts were made to spawn this species during the springs of 1992, 1993, and 1994. Obviously, dealing with a fish whose biology and early life history requirements were almost completely unknown to the scientific community was a daunting task, even with the depth of professional and experienced personnel that participated in the early years of this project.

Some (400) fertilized eggs were obtained during 1992 after holding a few adult robust redhorse in tanks at Warm Spring Regional Fisheries Center. All eggs died within two days. During spring 1994, the focus was on collecting ripe broodfish for transportation to Warm Springs. Again, some eggs were produced and hatched, but none survived to fingerling stage. It was not until the spring of 1995 and more formal experiments with hormone induced ovulation that significant robust redhorse production was realized. The following section provides summary information regarding the production of eggs, fry, and stockable fish. In most cases, very detailed records were kept regarding production, pond stocking, pond harvest, transport, and reintroduction to other streams.

3.3.1 1993 year-class

A small number of eggs and fry were produced in the spring of 1993 and survived in ponds to the fingerling stage. The RRCC decided that better survival in the wild might be achieved if these fish were raised in captivity for two growing seasons, believing that the larger size of phase II fish would reduce vulnerability to predation.

From 9 March to 9 August 1995, About 545 robust redhorse juveniles from the 1993 year-class were reintroduced into the Broad River system, Georgia, at several locations. More specifically, 250 juveniles were released into the South Fork of the Broad River at Georgia Hwy 22, 195 juveniles were released into the North Fork of the Broad River at Highway 51, and 100 juveniles were released into the South Fork of the Broad River at Watson Mill State Park. The Broad River system was chosen as the initial reintroduction site primarily for the following reasons: 1) suitable habitat and food source, 2) non-existent or reduced densities of introduced catfish predators, 3) adequate access for future sampling to determine survival, 4) local support from environmental organizations, and 6) relatively undeveloped watershed with good water quality and no hydropower development.

Another creek within the Oconee River drainage was inadvertently stocked with a small number of fish from the 1993 year-class. During June 1995, the dam on a rearing pond at Walton State Hatchery broke and released about 200 juveniles into Dennis Creek. Dennis Creek is a tributary of Little River, which ultimately flows into Lake Sinclair.

These juveniles were apparently from a single mating. This occurrence prompted the consideration of Little River as a site for future stockings to enhance the gene pool, making the assumption that some of these original fish would survive to reproducing age.

3.3.2 1995 year class

The primary goal of the broodfish collection efforts during the spring 1995 was to provide enough adult robust redhorse to meet requirements of the new hormone induced ovulation studies. A specific fry production goal was not established prior to this work, largely because rearing space was not a limiting factor.

A single electrofishing boat was used to collect broodfish from the Oconee River. Two additional boats were used to transport broodfish from the capture site to the temporary hatchery and holding facility near the boat ramp at Beaverdam Wildlife Management Area. Previous work indicated that catch rates increased at low flows, and flows necessary for broodfish collection efforts were coordinated through the Georgia Power Company Control Center in Atlanta, Georgia.

From 1 - 3 May 1995, 58 male and 33 female robust redhorse (that appeared to be good candidates for spawning) were collected. Fertilized eggs (about 800,000) from 17 matings were transported to three hatchery facilities for incubation. These facilities were the McDuffie State Fish Hatchery (GA WRD), Warm Springs Regional Fish Technology Center (USFWS) and Whitehall Fisheries Laboratory (UGA). Attempts were made to maintain incubation temperatures at 22 - 24 °C. From these eggs, about 73,000 fry were produced. Overall survival from egg to swim-up fry was about 9%. Survival at the three hatcheries varied from 18% at Warm Springs to less than 1% at McDuffie. The exact causes for the high mortalities remain unknown, although it is suspected that one incident of rapid temperature elevation at the McDuffie hatchery may have resulted in the loss of almost all fry from this facility.

From 19 May to 26 June, about 70,000 fry were transported to rearing ponds at the Walton and McDuffie State Hatcheries and the USFWS Bo Ginn hatchery in Georgia, and to the McKinney Lake hatchery in North Carolina.

During 30 November and 1 December 1995, all ponds were drained and about 40,000 robust redhorse fingerlings were recovered for an overall survival rate of about 57%. Survival rate varied among the ponds and ranged from 39 - 84%. Survival did not appear correlated to stocking rate. These fingerlings were restocked at reduced densities to be grown a second year. It was believed that an additional year of growth, and thus additional size, would reduce the fingerling's vulnerability to predators and enhance overall survival when reintroduced to wild streams in the fall of 1996.

During November 1996, only about 3,104 phase II robust redhorse fingerlings were harvested from the grow-out ponds at the various hatcheries. Overall survival from phase I to phase II was about 8%, and individual pond survival ranged from 86% at

Walton hatchery to less than 1% at several ponds at the McDuffie and BoGinn hatcheries.

Varyied mortality was experienced at all ponds under various environmental conditions and handling procedures. No consistent pattern was revealed among the different hatcheries and ponds, and the primary causes of mortality were unknown.

During November, 1996, about 1,424 total robust redhorse juveniles (1995 year class) were stocked into the Broad River system, Georgia. More specifically, 150 juveniles were released into the South Fork of the Broad River upstream from Watson Mill State Park, and 150 juveniles were released into the North Fork of the Broad River near the community of Franklin Springs, GA. About 1,124 juveniles were released into the Hudson River near its junction with the Broad River.

About 1,377 juveniles were stocked into ponds at the Piedmont Wildlife Refuge to start building a refugial population of robust redhorse. The small number of remaining fingerlings were retained at McDuffie hatchery or sent to the UGA.

3.3.3 1996 year class

Collection and transportation of broodfish to the temporary spawning facility was conducted as in 1995. Flows for broodfish collection were again coordinated through the Georgia Power. Broodfish were collected and spawned on three occasions from 29 April to 23 May 1996. A total of 12 females and 21 males were used to produce a total of 477,119 eggs. (Twenty-four crosses were made, but some of these crosses experienced high mortalities for unknown reasons. It was unclear how many crosses contributed significantly to the fry production. It appeared that the third spawning attempt near the close of the natural spawning window produced the fewest fry). A portion of the total egg production was used in various early life history studies.

After incubation, about 98,000 (about 30% survival from egg to swim-up) fry were collected for transport to Walton and McDuffie State Fish Hatcheries. About 2,000 fry were retained by the UGA for use in ongoing studies. The bulk of the fry were stocked into four rearing ponds at the two hatcheries during June, 1996. These ponds were harvested during February, 1997, and there was essentially no survival from any of the ponds. About 400 fingerlings reared at UGA's Whitehall Lab represented the only production for the 1996 year class. Most of these fingerlings were transferred to the SCDNR hatchery at Cheraw in March, and a small number were retained at Whitehall Lab for use in other research.

3.3.4 1997 year class

Broodfish collection resumed during 12 - 14 May and 19 - 22 May 1997 and methods were similar to previous years. Fish were spawned at the Beaverdam WMA temporary hatchery using the hormone induced ovulation techniques developed through research projects. Largely because of the widespread failures of the 1996 year-class, the fry production goal was increased to 200,000.

A total of 126 robust redhorse were collected during May, 1997, and 61 (48%) fish were female and two (1.6%) were juveniles. Fifty-three fish were recaptures from previous collection efforts. A total of 30 females and 45 males were transported to the spawning facility. Eight females were spawned without the use of hormones and produced 79,491 eggs. Eight females also underwent hormone treatments (Ovaprim), and the spawning rate for these fish was 100%. Artificially induced ovulation produced 280,683 eggs, for a total 1997 egg production of 360,174. About 65,000 of these eggs were shipped to UGA and Warm Springs Fish Technology Center for use in various research projects. The remaining eggs were shipped to McDuffie hatchery, UGA, and Warm Springs. A portion of these eggs were also used for early life history studies.

From the eggs used solely for production purposes, about 189,167 fry were produced. This represented a tremendous improvement in production efficiency since work was begun with egg and larval rearing requirements. Survival from egg to emergent fry was 11% in 1995, 30% in 1996, and 67% in 1997.

Greg Looney of the USFWS, in cooperation with other researchers, developed handling procedures and hatchery protocol for use in robust redhorse production. These procedures should prove valuable for hatchery managers and others involved in rearing this species, and will hopefully contribute to greater survival rates from egg to fingerling.

During late May and early June, 1997, 182,127 fry were transferred to 12 grow-out ponds at Burton, McDuffie, Walton, and Richmond Hill State Fish Hatcheries in Georgia, and Dennis Center and Campbell hatcheries in South Carolina. After one growing season, about 34,974 fingerlings were harvested from these ponds, resulting in an overall survival rate of about 19%. Individual pond survival ranged from 76% to 0%.

Because earlier attempts at rearing these fish to phase II for reintroduction were not successful, only about 20% of the 1997 year class was held back for a second growing season. An additional 1,770 fingerlings were stocked into ponds at the Piedmont Wildlife Refuge to supplement the existing refuge population of robust redhorse. All remaining fish were reintroduced to the wild.

During November, 1997, about 24,256 fingerlings of the 1997 year-class were reintroduced to the Broad River system, GA. Original sites stocked during previous years were restocked, and several new sites within this river system were stocked for the first time. New sites were selected in the North and South Forks of the Broad River, Hudson River, and Hannah Creek.

The Ogeechee River was a new reintroduction drainage for 1997. The Ogeechee River was originally selected as a potential stocking site because it remains the largest Georgia river without significant, current predation issues. In addition, the Ogeechee has a diverse sucker population, good water quality, and a good mussel population. However, the Ogeechee River may be more suitable as a site for raising future broodfish than developing a reproducing population because of limited spawning habitat for robust redhorse. During December, 1997, about 1,762 fingerlings were reintroduced to the Ogeechee River at Mayfield and Jewell Mill.

3.3.5 1998 year-class

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. 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 enabled river temperatures to approach 25 C or higher. Earlier experience indicated that these river temperatures may not be conducive to successful artificial spawning.

During the broodfish collection 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 or had other problems, and only four were successfully spawned. Of these four females, one fish spawned three times, and the other three fish spawned twice each. A total of 142,662 fertilized eggs were produced from 10 matings. These eggs were then transported to McDuffie, Warm Springs, Dennis Center, and the UGA for rearing and research.

4. REINTRODUCTION MONITORING

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 has received the most significant stockings over the last few years and was the first system to be checked for success. The upper sections of the Broad River have received slightly more effort than the lower sections. During 1997, investigators collected silver redhorse, but could find no robust redhorse. Flathead catfish were also absent from the collection in the upper Broad River which was encouraging.

On 10 October 1997, about 200 Phase I fingerlings were stocked into Hannah Creek below a low-head dam. The next morning, investigators made a search of the creek. A total of 30 fingerlings were located within 2,610 feet downstream of the release site. The largest fingerling was found the furthest downstream, and had moved through a beaverdam and pool. Fingerlings were found in both slow and fast current areas, so a preliminary estimate of juvenile habitat preference could not be made. However, there were few predators present.

As of May 1998 monitoring is continuing on the Broad River system with a variety of gears. Investigators have delineated 500 m reaches of this system with GIS, and are systematically sampling these reaches on a weekly basis. No robust redhorse juveniles have been captured. However, two fish were momentarily stunned, but not captured during recent sampling that are believed to have been robust redhorse juveniles. One fish was estimated to be about 15 inches long and the other fish was about 6 inches in length (Dr. B.J. Freeman, personal communication). The Broad River system has thusfar received fish from the 1993, 1995, and 1997 year-classes. Although not conclusive, this report, indicating potential survival from two separate year-classes, was encouraging.

The lack of positively locating stocked fish during the early monitoring efforts should not necessarily be interpreted as non-survival. Juvenile robust redhorse have proven difficult to capture in closed systems even when their presence is certain. Additionally, the apparent lack of juvenile robust redhorse in the Oconee River has prevented researchers from developing a clear sense of preferred habitat for early life stages of this species. The Broad River system still appears to be one of the better introduction sites.

5. PUBLICITY, EDUCATION, AND OUTREACH

All parties involved with this project realized during the early stages that publicity, education, and outreach could be critical to helping the recovery effort succeed. Because this was a relatively new approach to conservation of imperiled species, it was necessary to attempt to fully explain the rationale and methods of this approach to the media and the public. Effective publicity regarding the robust redhorse recovery would help heighten awareness of imperiled species and the importance of aquatic habitats, and hopefully showcase the effectiveness of diverse stakeholder partnerships for conservation and management of wildlife. Fortunately, media interest regarding this recovery effort remains high.

The following is a short listing of some of the written publicity efforts to date. The intent is not to document <u>all</u> articles, but simply to provide the reader information regarding the extent and diversity of publicity efforts.

- *Back from the brink*. Atlanta Journal-Constitution
- *Monumental effort gives robust redhorse a chance*. Macon Telegraph
- *Agencies out to save states' robust redhorse*. Atlanta Journal-Constitution
- *Robust redhorse conservation committee organized*. Bulletin of the Edison Electric Institute
- *Cooperative effort aimed at rare fish*. Royston News Leader
- *Robust redhorse may be coming back*. The Clayton Tribune
- *Georgia Power making progress protecting rare fish species*. The Citizen Weekly
- *Robust redhorse fingerlings*. Southern Company Environmental Review
- *A rosier future for the robust redhorse*. Athens Daily News
- *The mystery fish*. 10-page feature article in Southern Wildlife Magazine
- *Cooperative recovery effort aimed at rare fish*. Highlights, an internal publication of the Georgia Wildlife Resources Division
- *Developing stakeholder partnerships for the management of imperiled fish species: a case study*. Proceedings of the Waterpower '97 conference, Atlanta, Georgia
- Short article in Popular Mechanics magazine

Numerous oral reports have been presented for professional societies, civic clubs and organizations, and internal planning and review meetings by nearly every individual involved with the recovery effort. It would be nearly impossible to keep track of each and every presentation, particularly those made for university student classes and other internal agency/company updates. The following is a sampling of the types and diversity of known organizations that have received presentations about the robust redhorse. Presentations have been made more than once to many of these organizations.

- American Fisheries Society (AFS)
- Southern Division AFS
- Georgia Chapter AFS
- Alabama Chapter AFS
- South Carolina Chapter AFS
- North Carolina Chapter AFS
- North American Lake Management Society
- Southeastern Fishes Council
- Waterpower '97
- Edison Electric Institute Biologists' Task Force
- Auburn University Student Seminars
- The University of Georgia Student Seminars
- Quad-utility Biologist Meetings
- Villa Rica, GA Lions Club
- Roswell, GA Garden Club
- Camp Creek Middle School, Atlanta, GA
- Peach County High School
- Bryan Middle School

As stated earlier, media interest regarding the robust redhorse remains high and publicity has been considerable. In addition to the items listed above several television spots have been aired by local stations, and the Georgia Public Television network included the robust redhorse in a documentary of the state's rare and endangered wildlife. Coverage of some aspects of the recovery effort could also be viewed on multiple occasions on Cable News Network (CNN) during 1997. The Georgia Department of Natural Resources is also producing documentary films on the historic decline and recovery efforts, with funding provided by the Georgia Wildlife Resources Division Fisheries Section, GA WRD Non-game program, and Georgia Power Company. Copies of these videos should be available in the near future.

6. WHERE DO WE GO FROM HERE?

During the past few years, the RRCC has learned a great deal about the biology and requirements of the robust redhorse through the cooperative efforts of many agencies, universities, private utilities, conservation groups, and individuals. We have learned how to produce eggs through hormone-induced ovulation, have achieved greater survival rates from egg to fry, and are working to find solutions to other problems with fingerling production. Numerous studies have and are being conducted on age and growth, genetics, and the early life stage requirements of this species in relation to Sinclair Dam and other environmental factors that are necessary for evaluating the new flow regime. Reintroduction sites continue to be evaluated, and several reintroductions have been made within the historic range of this species. A Candidate Conservation Agreement is currently being developed to help facilitate reintroduction efforts in other drainages. Another population of robust redhorse has been located in the Savannah River that could serve as another source of broodfish for the recovery efforts, although the status and extent of this population is presently unknown. While we can not yet say that this species is recovered, we can say that significant progress has been made in the conservation and restoration of robust redhorse. The RRCC should be able to proceed with the knowledge gained during these initial efforts and hopefully accelerate the recovery process.

For 1998 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. The Advisory Team should soon have sufficient data to begin formal analysis of the flows for the Oconee River, and make decisions regarding the adequacy of present flows or the need for modifications in the flow regime.

Primary issues for focus in the near future are the recently discovered Savannah River population, reintroduction site evaluation and monitoring survival of stocked populations, predation, habitat degradation, more efficient culture of fingerlings, and enhancing communication among participating organizations and individuals.

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