Evaluation of robust redhorse (*Moxostoma robustum*) introduction into the Broad River, GA spanning years 1995-2001

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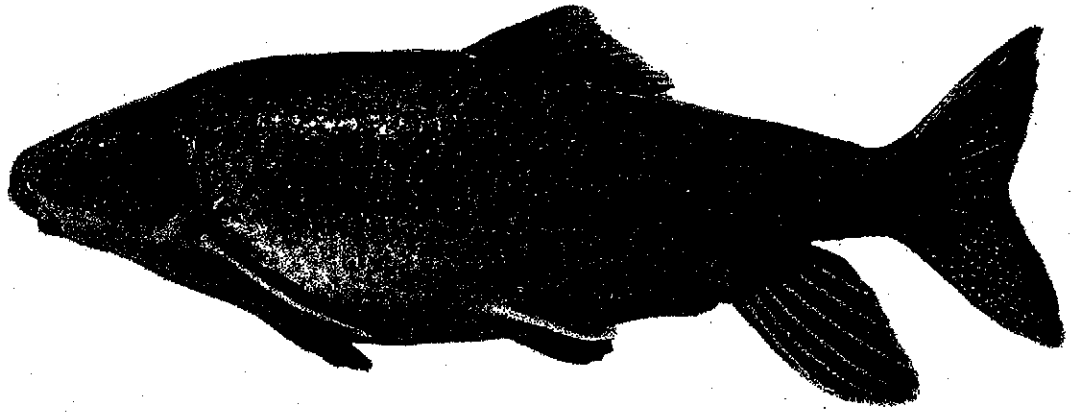

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Executive Summary

A reintroduction effort to establish a self-sustaining population of the robust redhorse, *Moxostoma robustum* (Cope), in the Broad River system (Savannah River Drainage) of Georgia was conducted from 1995 to 1998. During this period, approximately 40,000 individual fish representing 1993, 1995, 1997, and 1998-year classes of artificially propagated Oconee River-derived robust redhorse were released into the Broad River and its major tributaries in Franklin, Madison, and Oglethorpe Counties, Georgia. Monitoring efforts conducted through 1999 within the upper Broad River system failed to detect robust redhorse, other than recently released fish. Beginning in 1999 however, routine monitoring efforts of the GA Cooperative Fish and Wildlife Unit (GA Coop Unit), Georgia Department of Natural Resources, and South Carolina Department of Natural Resources revealed robust redhorse in Clark's Hill Reservoir (on the Savannah River) approximately 100 to 140 km from the initial release points in the Upper Broad River system. Subsequent surveys conducted during 2001 in the Upper Broad River system revealed robust redhorse from two year classes throughout the area encompassing the initial release locations. Since 1999, robust redhorse have been consistently collected from the terminal free-flowing shoal section of the Broad River (Anthony Shoals). Recent collection efforts (2002) in the upper portion of Clark's Hill Reservoir (tail waters of Russell Reservoir) by the GA Coop Unit revealed the presence of several robust redhorse representing two year classes. Survival of 1995, 1997, and 1998-year class fish have now been documented. Visual observations of putative 1993 fish have also been made. Robust redhorse of reproductive age and size now exist within the Broad River-Clark's Hill Reservoir system, however, spawning has not been documented to date. Reintroduction efforts were halted after 1998 with the discovery that Altamaha River Drainage fish (Oconee River) and newly discovered population of Savannah River fish below Augusta, Georgia represent discreet Evolutionary Significant Units (ESU). The existence of an exant population of Savannah River ESU fish coupled with the existence of Altamaha ESU fish within the reservoir system (Clark's Hill) approximately 40 miles upstream from Augusta prompted concern over possible population genetic impacts of the Broad River reintroduction efforts.

Introduction

The robust redhorse, *Moxostoma robustum* (see Appendix I), is a large imperiled catostomid fish native to southeastern Atlantic slope drainages. The species' known native range extends from the Altamaha River drainage in Georgia northward to and including the Pee Dee River drainage in North Carolina and South Carolina (Figure 1). Three known extant wild populations are now restricted to a limited portion of 1) the Oconee River between Milledgeville and Dublin, Georgia, 2) the Ocmulgee River between Macon and Hawkinsville, Georgia and 3) the Savannah River in the Fall Line Zone around and below Augusta, Georgia and North Augusta, South Carolina. A viable wild population of unknown size also persists in the Pee Dee River drainage (North Carolina and South Carolina), where a few individuals have been captured in annual intensive sampling efforts since April 2000.

The robust redhorse is considered an imperiled species because of the large apparent reduction in species' range and abundance. Even if the robust redhorse persists in the Pee Dee as well as the Savannah and Altamaha drainages, abundances are dramatically reduced compared to E. D. Cope's (1870) accounts of fishery catches of the sucker. All remaining populations persist in rivers with flows influenced by hydropower dams. The largest known population, in the Oconee River, displays some evidence of recent juvenile recruitment to the population; for example, we have observed smaller males joining spawning activity during two of the past six years. However, because the population is skewed toward older age classes, concerns remain that spawning or juvenile habitat may be limiting. Effects of flow alteration by dams on population dynamics of the robust redhorse are not known. Potential loss of suitable habitat because of hydrologic alteration, especially for life history stages considered having the narrowest habitat requirements, is a primary management concern.

Robust redhorse, then under the scientific name *Ptychostomus robustus*, were originally collected in 1869 and described in 1870 by Cope. Ichthyologists misapplied this name to the smallfin redhorse (now known as the brassy jumprock, *Scartomyzon* sp. *cf. lachneri* (see Appendix I)). The misapplied name was a problem not recognized until decades later. The next known collection of robust redhorse occurred in 1980 by biologists from the National Academy of Sciences in the Savannah River. At the time of its collection, the identity of the collected fish was unknown. Future studies of this individual and another individual caught in the PeeDee River in 1985 revealed that these fish more appropriately fit the description of robust redhorse written by Cope. In 1991, the collection of the five specimens in the Oconee River occurred during surveys conducted for FERC (Federal Energy Regulatory Commission) re-licensing of Georgia Power Company's Sinclair Reservoir project. The long entangled history of this fish and its effective disappearance from ichthyologists probing eye has resulted in a vast paucity of natural history information about this species. Due to the species apparent lack of abundance and scientists' insufficient knowledge of the species, the U.S. Fish and Wildlife Service listed it as a Species of Special Concern (formally known as a Category 2 species). In addition, the state of Georgia listed this species as Endangered. The discovery of a population of this imperiled species below a hydropower project applying for renewal of a 50-year license propelled the conservation status and potential listing under the Endangered Species Act squarely into the re-licensing discussions. To accommodate concerns of all parties, avoid immediate listing and immediately begin recovery efforts, a Memorandum of Understanding (MOU) was developed involving federal, state, and private partners, including Georgia Power, US Fish and Wildlife Service, Georgia Department of Natural Resources (GDNR), South Carolina Department of Natural Resources (SCDNR), North Carolina Wildlife

Resources Commission, United States Geological Survey, and other utilities and conservation groups. The Robust Redhorse Conservation Committee (RRCC) and the Oconee River Flow Advisory Team were formed in 1995 through this MOU with the purpose of addressing species recovery and specifics of the re-licensing of Sinclair Dam.

Acknowledging that the Oconee River population of robust redhorse was possibly the only significant population within the presumed historical range of the fish it was determined that an establishment of additional populations via artificial breeding and stocking was essential for the preservation of the species. The goal of the RRCC was to identify potential river systems for reintroduction of robust redhorse and to implement a breeding and stocking program utilizing the existing Oconee River population as the source.

After an assessment of potential riverine systems in Georgia suitable for reintroduction, it was determined that the Broad River system in northeast Georgia would be the initial site of reintroduction (Figure 2). This river occurs in the hypothesized historic range of the robust redhorse, contained habitat similar to the Oconee River, and was free of significant impoundments, all characteristics that made it an appropriate candidate for a reintroduction effort.

The first propagation effort began with artificial spawning projects in 1992 and 1993. The release of captively-propagated robust redhorse began with a modest effort in March 1995, followed by a larger releases in November 1996, October and November 1997, and into 1998. Brood fish obtained from the Oconee River were utilized to establish a population of fingerling redhorse for release into the Broad River system to create a sustainable population of robust redhorse in the Broad River system.

In 1997 Georgia Power Company biologists collected one robust redhorse in the Savannah River in proximity to the company's Plant Vogtle. After this discovery a series of surveys for robust redhorse were made in the Savannah River near Augusta, Georgia in May and June of 1998. Six individual robust redhorse were captured during collections from October 1997 to October 1998 in the Savannah River. These collections confirmed the existence of a unique population of robust redhorse within the Savannah drainage of which the Broad River was part. The discovery led geneticists to question whether the population robust redhorse from the Savannah River drainage could be genetically distinct from the Oconee River population.

Using fin clips, Wirgin *et al.* (2001) analyzed mtDNA (mitochondrial DNA) control region sequences in robust redhorse from the Altamaha (Oconee and Ocmulgee Rivers) and the Savannah River drainages. Their results confirmed that there is genetic divergence between the two populations in Georgia. This research concluded that reproductive isolation of these two riverine populations is complete and they have been isolated for some time. Because all brood stock for captively-reared fish came from the Oconee drainage, this led to a halt of the stocking program on the Broad River in 1998 before the stocking goal was achieved. The introduction of unique genetic stock of robust redhorse into the Savannah system could create problems for future of the native robust redhorse populations if mixing occurred between these genetically different stocks. In past reintroduction efforts of salmonids, stocked individuals replaced indigenous populations of the same species in just a few generations (Evans and Willox 1991).

The fish that were stocked into the Broad River in 1998 represent the youngest robust redhorse known within the Broad River system. From the beginning of the stocking program, an attempt was made to document the movement and survival of the fish stocked into the

system. While the population targets have not been achieved within this watershed, the work done in this system serves as a valuable learning tool that may prove insightful for future programs aimed at sustaining the robust redhorse as a species. The following document outlines the work put forth and the discoveries made during introduction and monitoring program of the robust redhorse into the Broad River system.

Methods

Rearing / Stocking Methods

The stocking of robust redhorse into the Broad River began in 1995 after the formation of the stocking plan developed by the RRCC. The reintroduction effort began with the capture and spawning of adult robust redhorse from the Oconee River. Researchers collected brood fish using boat-mounted electrofishing gear. Once collected, these brood fish were returned to temporary spawning facilities constructed on the banks of the Oconee River at river mile 91.7 in Laurens County, Georgia. Eggs were taken from gravid females or from females induced to ovulate via hormone injection. Eggs were mixed with sperm for fertilization. The fertilized eggs produced at the spawning facility were distributed to several incubation facilities, including Warm Springs Regional Hatchery operated by the US Fish and Wildlife Service, McDuffie State Fish Hatchery and Richmond Hill Fish Hatcheries operated by GDNR, and University of Georgia (UGA) Whitehall Fisheries Lab operated by the Georgia Cooperative Fish and Wildlife Research Unit at the University of Georgia (GA COOP). After hatching, fry were transported to various fish hatcheries throughout the state of Georgia for the grow-out phase. These fish were raised in warm water rearing ponds, until their prospective release dates.

Rearing success of robust redhorse was highly variable from year to year due to high mortality rates of juveniles and scarcity of brood fish in the Oconee River. Despite the discontinuation of the stocking program in the Broad River, the capture and spawning of brood fish and the rearing of robust redhorse juveniles still continues as part of the recovery program for the Oconee and Ocmulgee Rivers (Altamaha River drainage) and the Ogeechee River Drainage. Recently (2001 and 2002), low rearing success was due in part to a lack of brood fish availability, possibly indicating a decline in the Oconee River mainstem population.

Before release, each fish was fitted with a binary coded-wire tag in different locations to facilitate aging of captively-reared fish recaptured after their release into the wild. Tag placement for each stock year was unique. In 1995 fish, tags were placed in the left cheek musculature, in 1996 fish in the right cheek musculature, in 1997 fish near the dorsal fin base on the right side, and 1998 fish near the anal fin base on the right side. Fish were transported to stocking sites in oxygenated tanks. Tank water was tempered to near receiving water temperature, and all stockings were point releases of large numbers of individuals. Stockings were generally carried out within 48 hours of removal of fish from grow-out ponds. This process was repeated annually until the discontinuation of the stocking program for the Broad River.

Stocking Chronology

Stocking occurred from 1995-1998, at various sites within the Broad River Watershed in Franklin, Madison, and Oglethorpe Counties, Georgia (Figures 3-6). Eight sites were selected for stocking in the Broad River System over the course of the program (Table 1). Most fish stocked in the Broad River Watershed, with the exception of those stocked in 1995 (the first year of the program) and some fish in 1998, were phase I fingerlings (age: 0+ year).

In 1995, the fish stocked were phase II (age: 2+ years, from the 1993 year class) and in 1998 a some fish were also phase II fish (from the 1996 year class).

In 1995, 545 fish were stocked into the Broad River Watershed at three locations (Figure 3). The 1995 stocking included 195 individuals released into the North Fork of the Broad River at Highway 51 in Franklin County, 250 released into the South Fork of the Broad River at Highway 22 in Madison County, and 100 released into the South Fork of the Broad River above Watson Mill dam at Watson Mill State Park on the Madison/Oglethorpe County line.

In 1996, 1,274 phase I fingerlings were stocked at two sites in Franklin, Madison, and Oglethorpe Counties (Figure 4). The Hudson River (a tributary of the Broad River) was stocked with 1,124 individuals at U.S. Highway 29 in Madison County, and 150 individuals were stocked at the same Watson Mill Park site as in 1995.

In 1997, over 25,000 robust redhorse phase I fingerlings were released at six sites within the Broad River Watershed (Figure 5). Stockings included the release of 3,000 fingerlings into the Middle Fork of the Broad River at Atkinson Bridge Road in Franklin County, 926 fingerlings at the Highway 51 site on the North Fork of the Broad River, 9,900 into the North Fork of the Broad River downstream of the low-head dam at Highway 145 in Franklin County, 4,300 into the Hudson River at Highway 106 in Madison County, 5,731 into the Hudson River at Highway 29 (stocked also in 1996), and 1,350 into Hannah Creek at Hannah Creek Church Road in Franklin County.

In the final year of stocking (1998), 6,567 individuals representing 2 year classes were released (Figure 6). These fish included 3,226 phase II fish (from 1997 year class) and 2,738 phase I fingerlings (from the 1998 year class). Stockings included 5,339 fish in the Hudson

River at Highway 106, 621 at North Fork of the Broad River at Highway 51, 246 fish at North Fork Broad River at Highway 145, and 361 at Hannah Creek at Hannah Creek Church Road. Stocking was discontinued after 1998, because of concerns over stocking fingèrlings from a different Evolutionarily Significant Unit (ESU; Oconee River fish) into the Savannah River Drainage (as explained above).

Monitoring Methods by UGA, Institute of Ecology Personnel

A variety of methods and equipment have been used to monitor stocked robust redhorse within the Broad River Watershed. The method used depended on river conditions, size of the area to be sampled, and habitat conditions present within the sampling reach. In wadeable areas, surveys utilized a Smith-Root™ backpack electrofisher, Model 12 (BPEF). In addition, seine hauling and grid shocking was employed on a limited basis in habitats that were appropriate for the technique. When habitats were unsuitable for BPEF, a 14-foot aluminum johnboat and an 18-foot canoe were equipped with electrofishing equipment and utilized for surveys. The johnboat was used mainly to shock in deep, swift runs and in other areas less suitable for canoes. The canoe was especially effective while sampling in a downstream direction during low river stages. Pulsed DC outputs were used on these shocking units and output voltages varied, ranging from 400 to 800 volts.

The anodes used on the shocking boats were of three types. The johnboat array consisted of one or two anode rings with stainless steel cable droppers, each attached to a fiberglass pole (Wisconsin-type). Two different canoe arrays were used. One design consisted of four pieces of stainless steel cable connected to the output via 16-gauge electrical wire and suspended from the ends of a "Y" shaped array fashioned from one inch PVC pipe. The second design consisted if a single Wisconsin-type anode ring and droppers. In all cases, the boat's

hull served as the cathode via a grounding connection to the electrofishing unit. A BPEF was used for canoe shocking and in some cases using a johnboat, however most johnboat electrofishing employed a Smith-Root™ 2.5 GPP unit.

Grid shockers were used below the low head dam on the North Fork of the Broad River at Highway 145 where water conditions precluded sampling by other means and on sandbars to attempt collection of small individuals at night. Grid shocking involved the use of Smith-Root™ 2.5 GPP electroshocking unit connected to 1.5 x 8 meter or 1.5 x 0.5 meter grids fashioned from stainless steel cables and separated with PVC spacers. AC and full power setting were used to sample areas identified as typical juvenile sucker habitat.

The locality, time of day, river conditions, sampling method, and duration (person hours and shocking time) were recorded on standardized field sheets. All small *Moxostoma spp.* (>10cm) and a size series of larger *Moxostoma spp.* were retained for growth and diet studies. In addition, a subset of *Scartomyzon rupiscartes* (striped jumprock), brassy jumprock, *Erimyzon oblongus* (creek chubsucker), and *Hypentelium nigricans* (northern hog sucker) were retained for a comparative analysis of catostomid prey items in the watershed. Most other fishes were kept and returned to the lab for confirmation and are accessioned at the Georgia Museum of Natural History. Specimens not preserved were identified in the field and released. Standard lengths (SL) were recorded on all large *Moxostoma* and *Scartomyzon* species and information concerning species abundance was noted. Robust redhorse captured during surveys were measured and released with a small subset preserved for growth and feeding studies.

In an attempt to locate coded-wire tags in the collected fish without reducing the integrity of the specimens' tissue, initial recaptured robust redhorse were radiographed at the

Royston Animal Veterinary Clinic. Tags in all radiographed fish were successfully located (Image 1). Codes on the tags allowed us to assess hatchery source and stocking locations of each individual from the 1997 year class after the tag was removed and analyzed. Only fish collected and not released from the 1997 year class were used to determine stocking location and migration distances (see below). Coded-wire tags for 1993 and 1995 year class were used for year class designation only, therefore no stocking localities could be determined from these fish.

Monitoring of the stocked redhorse populations began in December 1996 with a concentration of monitoring effort at previous stocking locales (Table 2). High flows shortly after the initial stocking in 1996 prevented more extensive surveys that year. Locations of all Institute of Ecology collection locations are found in Figure 7.

In 1997, a more extensive and complete monitoring effort was conducted. Seine hauling has demonstrated efficiency in sampling suckers in other river systems (BJF pers observation) and was employed in the Broad River on a limited basis in 1997. It was primarily employed in slow, shallow water downstream of point bars and in slack water areas just below sand bars on the inside bends of the river. Hannah Creek, a second order tributary to the main stem of the Broad River, enters the Broad River approximately one river mile south of the confluence of the Broad River and the Hudson River and was selected as a site to study the dispersal of recently introduced juvenile robust redhorse. Visual surveys of this stream suggested that habitat was suitable for small robust redhorse and electrofishing surveys indicated a high species richness (24 species). Post-stocking surveys were conducted downstream of the introduction point to determine if recently introduced fish migrated downstream of the introduction point and if so at what rate was the migration occurring.

Upstream movement was not investigated initially because of a low concrete sill in the streambed that blocked upstream migration of the stocked robust redhorse. However, subsequent releases of fingerlings occurred during higher stage conditions that would have allowed passage of fish above the sill. In addition, 300 fish were released on the upstream side of this sill. Both the upstream and downstream sections were monitored for the presence of robust redhorse. From the stocking of robust redhorse in 1997 to the end of the year, approximately 20,000 additional shocking seconds were contributed to the total sampling effort to determine migration of these released individuals.

Sampling conducted during the 1998 field season focused on segments of the mainstem of the Broad and Hudson Rivers and Hannah Creek, using similar techniques employed in the 1997 field season. Sampling and monitoring in 1999 focused on the Broad River near the crossing of Highway 281, Hannah Creek, Anthony Shoals, and the Hudson River. Surveys conducted on Hannah Creek used kick seining and BPEF. Surveys conducted on the Broad River, the Hudson River, and at Anthony Shoals used either a boat electrofisher (boat EF) or a modified canoe shocker. Collections were focused only on robust redhorse, and no voucher collections were retained.

Sampling and monitoring in 2000 was limited to some observational work on the North Fork of the Broad River and collections at Anthony Shoals. Collections at Anthony Shoals were conducted using a boat EF. As in 1999, collections were species specific for robust redhorse, and no voucher collections were retained.

Sampling and monitoring in 2001 focused on the Hudson River, the Broad River near Highway 281, and Anthony Shoals. All collections were conducted using a modified canoe shocker or boat EF. Collections were species specific for robust redhorse, and no voucher

collections were retained. Robust redhorse collected from 2000 and later were photographed with a digital camera and were measured and weighed.

The cumulative sampling and monitoring effort leading up to the release of fingerlings in October of 1997 consisted of 125 person-hours, 15 unique collection days, and over 26,000 seconds of shocking time. During the 1998 field season, 262 person-hours and 126,367 shocking seconds were dedicated to the sample effort for robust redhorse (Freeman and Gregory, 1997). Collections conducted during 1999 consisted of 31 person-hours and 8,960 seconds of shocking time. Additional collections conducted on Hannah Creek were conducted using kick seining techniques. Collections occurring during the 2000 season were limited to visual and boat surveys at Anthony Shoals and the North Fork of the Broad River. Collections conducted during the 2001 season consisted of 54 person-hours and 38,844 seconds of shocking time.

Monitoring Methods by GA COOP, GDNR, and SCDNR

The GA COOP conducts long term monitoring of Clark's Hill Reservoir, in conjunction with the Army Corp of Engineer's Lake Russell Pumpback Project. Annual surveys were conducted at these sample locations from 1990-2000 (Figure 8). Collections focused on the northern section of the mainstem of the reservoir. The majority of collections were made using gill nets. The gill nets used were standard 240 feet in length, with a graduated gill mesh that ranged in size from 1/4inch to 4 1/2 inches. These nets were set surface down, in approximately 8-10 feet of water. Nets were set, and left for a period of approximately 18-24 hours.

Collections conducted by the GDNR focused on the western portion of Clark's Hill Reservoir and employed gill nets for collections (Figure 9). Eleven Stations were distributed in

creek channels and main channels of the Little River, Georgia, limb of the reservoir. The remaining nine stations were located on the Savannah River limb, both in creek channels and in the main channels. Nets were set suspended from the shoreline and left for approximately 18-24 hours. The nets consisted of three panels that were approximately 30.5m each. The panel mesh size was 190mm, 317mm, and 444mm.

Collections conducted by SCDNR were conducted using 200-foot gill nets, suspended from the shoreline, in approximately 1-6 feet of water. The nets consisted of three panels that were approximately 20.5m each. The graduated panel mesh size was 190mm, 317mm, and 444mm. Nets were set for a duration of 18-24 hours. Collections were conducted annually and focused on the eastern sections of the reservoir (Figure 9). The emphasis of these surveys was mostly eastern creek channels flowing into the reservoir. Four stations were located on the Little River, South Carolina, limb of the reservoir. The remaining stations were located on the southern section of the Savannah River limb of the reservoir.

All specimens collected by GDNR, SCDNR, and the GA COOP were retained on ice and later stored in a freezer. All robust redhorse collected were sent to the Institute of Ecology, UGA, to gather information located on the embedded coded-wire tags, diet analysis, movement, confirmation of year class, and other life history traits (Tables 3 and 4).

Microhabitat Usage of Juvenile Robust Redhorse

Habitat parameters were recorded at sites where robust redhorse were retained. Habitat parameters included water depth and velocity, bed sediments, stream flora and substrate, and water quality measures. Macrohabitat structure was surveyed in the Hudson River from the Highway 106 bridge downstream to the Highway 281 bridge on the Broad River during early fall 1998, when low water level and low turbidity allowed for more accurate assessment of

benthic conditions. Habitats were mapped using a Global Positioning System (GPS, March II, Corvallis Microtechnology) and a laser range-finder to measure lengths of habitat units (e.g., riffles and pools). GPS data points were differentially corrected using post-processing software (PC/GPS, ver. 3.3) and entered into an ArcView GIS database. Reach maps were constructed by plotting position information on digital raster graphs (DRGs, based on USGS 1:24,000 topographic quad maps) using ArcView. Habitat polygons were digitized in ArcView and scored based on features (e.g., depth, current velocity, substrata).

Diet Analysis Methods

Of the fish collected, 35 were selected for diet analysis. Robust redhorse analyzed for gut contents were processed at the Institute of Ecology, UGA. A subset of juvenile robust redhorse and series of other catostomids collected during surveys were also retained for diet analysis. Specimens used in the diet study were weighed and measured (standard and total lengths) prior to removing the digestive tract. The gut contents of these specimens were keyed to the lowest taxonomic level possible. Some prey items were not identifiable due to the advanced stage of digestion. When discernable, life stages of the prey item organisms were identified.

The entire digestive tract was initially preserved in 10% formalin, rinsed, and later placed in 70% ethanol. The total length of the gut was measured and segments were uncoiled. Gut contents in lengths of gut ranging from 50-120 mm were rinsed from the digestive tract into a small petri dish with 70% ethanol. Individual food items were observed using microscopy. Identification and confirmation of bivalves were made based on the number of hinges. A series of bivalve hinge lengths were analyzed for robust redhorse prey size selection tendencies. All gut contents were retained in ethanol after identification.

For juvenile robust redhorse and other catostomids an anterior portion of the gut was removed, preserved, and examined for diet analysis. Contents of the gut were placed on a counting slide and all recognizable material was counted under 10X magnification using light microscopy. Recognizable material was grouped by gross taxonomic categories and counted. These counts were averaged by species and converted to percentages and expressed as such (Freeman and Gregory, 1997).

By analyzing prey items in the guts of numerous species of catostomids, comparisons can be made between species. This will allow us to recognize if other species of fish are consuming the same types of prey as robust redhorse consume in areas where robust redhorse are not found. In addition, a comparison of adult and juvenile robust redhorse may enlighten the differences or similarities within their diet.

Fish Migration and Growth Analysis Methods

Based on information derived from the interpretation of coded-wire tags removed from collected specimens, distances of migrations downstream from their stocking sites were calculated for all specimens from the 1997 year class. Using ESRI's ArcView®, collection points were plotted on a map and total migration lengths from stocking points to recapture point were calculated (Appendix II).

A comprehensive study of growth rates for robust redhorse has not been conducted. Data from collected robust redhorse gathered by GDNR, SCDNR, GA COOP, and the Institute of Ecology were grouped based on age class, and used to obtain average lengths and weights. These fish were collected from various areas within Clark's Hill Reservoir, Anthony Shoals, and within the Broad River Watershed (Appendix III). These data were also used to construct a

length-weight relationship for recaptured Broad River robust redhorse and compared to recently captured wild-lived robust redhorse from the Pee Dee River (Figure 13).

Results

Stocking

A total of 39,247 robust redhorse were stocked at 8 locations within the Broad River Watershed from March 1995 to December 1998. Stocking locations included two sites on the South Fork of the Broad River, one on the Middle Fork, and two on the North Fork of the Broad River. Two sites were located on the Hudson River and the last site was located on Hannah Creek.

Tagging, Monitoring, and Recapture Chronology

Surveys conducted by the Institute of Ecology in the Broad River system failed to collect any wild and few captive-reared robust redhorse in 1997, 1998, and 1999. The exception was a few collections made immediately after stocking (see below). However, more than twenty fish species were collected during the sampling and monitoring period, including other large species of adult catostomids, i.e. *Moxostoma* and *Scartomyzon* species. The sizes of other species of catostomids minimally overlapped recently released robust redhorse, but would have overlapped with stocked robust redhorse a few years after their stocking. This finding may suggest collection methods may not have maximally targeted 2-3 year robust redhorse, but should have been sufficient to capture fish older than 3 years (Figure 10). Grid shocking techniques were effective at collecting smaller catostomids. *Hypentelium* and other small bodied fish were collected with boat EF, however boat EF was not efficient for collecting small robust redhorse. Collections of other catostomids show that the sampling techniques were effective at collecting fish that were occupying similar habitat as robust redhorse. In addition,

collections within the surveyed reaches containing robust redhorse commonly contained other catostomid species.

Monitoring of juvenile robust redhorse migration began within 24 hours after 300 fingerlings were released into Hannah Creek just downstream of Hannah Creek Church Road. This effort resulted in 29 individual robust redhorse collected downstream of the release point the day after their release. Seven of the twenty-nine specimens were retained from these collections to assess diet of juvenile robust redhorse. In addition, 37 juvenile robust redhorse were retained from the stocking truck that expired prior to stocking.

The first capture of a stocked adult robust redhorse occurred on 1 February 1999 in a gill net set by the GA COOP (Table 2). Between 1 February 1999 and 19 October 1999, the GA COOP collected 25 robust redhorse at various points in the northern portion of the reservoir (Figure 8). GDNR also collected 12 robust redhorse specimens between 10 November 1999 and 14 November 2000. SCDNR collected two additional specimens on 8 December 1999 at station 4 and 5. There were no other known collections of robust redhorse at the SCDNR stations prior to 1999 or in 2000. This monitoring program will continue into the 2001 and 2002 season.

On 3 May 2000, at Anthony Shoals near the mouth of the Broad River eight robust redhorse were collected. On 16 May 2001, again at Anthony Shoals, four robust redhorse were captured and estimated to come from the 1997 year class. The next collection of mature redhorse occurred on 12 August 2001 at the same locale. Three of the fish captured on this date were from the 1997 year class and one came from the 1995 year class.

On the 12 July 2001, one mature robust redhorse (from 1997 year class) was captured in the mainstem of the Broad River less than one mile upstream of the Highway 281 crossing. On

the same day, another robust redhorse was observed, but not captured, downstream of where the first fish was collected. This fish was considerably larger than the first and was estimated to be of the 1995 year class. On 19 July 2001, a large robust redhorse (estimated to be from the 1993 year class) was observed in the same proximity as the previous two. The collection of a 1997 year class robust redhorse on 6 September 2001 on the Hudson River was the last recapture during the 2001 season. The most recent collections of robust redhorse have been within Clark's Hill Reservoir. On 28 October 2002, the GA COOP collected three robust redhorse in gill nets, two females and one male. The male was from the 1998 year class and both females were from the 1997 year class. Both females had readily discernable ova, and ova were enlarged in one ovary in one of these individuals. These fish would have been 6 years old in the spring of 2003 and likely have been candidates for spawning. Another female robust redhorse was collected from Clark's Hill Reservoir by the GA COOP on 2 December 2002. Other robust redhorse have been collected by the GA COOP in Clark's Hill Reservoir, but the data from these other collections are not currently available.

Thirty-nine robust redhorse were collected between 1 February 1999 and 14 November 2000 by GDNR, SCDNR, and the GA COOP at points within Clark's Hill Reservoir. The total number of all robust redhorse documented within the Broad River/Clark's Hill Reservoir system was forty-eight during this same time period.

No collections of robust redhorse were made at the following stations: GA COOP stations 1-1, 1-3, 2-2, 2-3, 3-2, 3-3, and 4-1; GDNR stations 1-10, 12-14, and 16; and SCDNR stations 1, 2, 3, 6, 7, and 8, All station locations were summarized in Figures 8 and 9, and Table 6.

Stocked Fish Migration

Based on information derived from the coded-wire tags removed from the specimens collected, distances of migrations downstream were calculated for all specimens collected from the 1997 year class (Table 6). Coded-wire tag interpretations were not conducted on fish collected from the 1995 stock class (released in 1996), as tags did not have unique codes. However, since 1995 year class fish (released in 1996) were released in the Hudson River at Highway 29 or at the South Fork of the Broad River at Watson Mill State Park (with the majority of those being released in the Hudson River) minimum and maximum migration distances can be estimated. The minimum migration location of those individuals from the 1995 year class recaptured where those collected at Anthony Shoals, 51 river kilometers downstream from the release site on the South Fork and 76.5 river kilometers downstream of the Hudson River release site. Those individuals from the 1995 year class collected in Clark's Hill had a possible minimum migration of 51 river kilometers for those released in the South Fork and a maximum migration of 95.7 river kilometers for those released in the Hudson River. Fish from the 1997 year class had an average migration of 103.1±2.55 km (mean ± SE) from stocking locations to their collection location.

Juvenile robust redhorse migration

Recaptured juvenile fish were concentrated near the release points, but individuals were also captured varying distances downstream from the release point. The recovery of an individual 2610 feet downstream of the release point, within 24 hours after its release indicates that at least some released individuals move rapidly away from the release site. Additional surveys also noted the presence of robust redhorse downstream of the release point with no documented movement upstream (Freeman and Gregory, 1997).

Microhabitat Usage of Juvenile Robust Redhorse

Robust redhorse collected by survey crews were found in water depths ranging from 54-67cm and in current velocities ranging from 0.01 to 0.3 m/s. Descriptions of collection sites for juvenile robust redhorse also suggest that recently released individuals may be selecting deeper, slow moving water over sand substrate and may show some affinity for cover along the margins of stream banks.

Macrohabitat mapping allowed comparisons of two reaches where robust redhorse were stocked in the Hudson River (reach length: 11.9km) and Broad River (reach length: 10.1km). Stream widths in the Hudson vary from a minimum of 20m to greater than 60m in shoals. Stream widths are somewhat greater in the Broad, ranging from a minimum width of 32m to more than 75m in shoals. Water depths in both reaches (at low water stage during the survey) vary considerably and range from 20cm to greater than 1.5m. Macrohabitat in both rivers is dominated by flowing pools (55% Hudson, 80% Broad). The dominant substrate in both rivers across all macrohabitats is coarse sand mixed with fine gravel. Valves of dead *Corbicula fluminea* were extremely abundant. The largest difference between the two rivers was the amount of complex habitat. Complex areas are mixtures of exposed bedrock and boulders, usually with *Podostemum ceratophyllum* (riverweed), coarse gravel and either moderate to swift currents in shoals and runs, or deep flowing pools with boulder and bedrock substrata adjacent to shoal areas. The Hudson River has 4.5 times as much complex habitat as the nearby reach of the Broad (136,183m^2 and 30,187m^2, respectively) (Freeman 1998).

Gut Analysis

Results of diet analysis on robust redhorse collected from Clark's Hill Reservoir identified 23 different types of invertebrates representing five different phyla (Table 4). Four

of the 36 adult robust redhorse used for gut content analysis had no identifiable items in their gut. Prey items in the Phylum Arthropoda comprised 95% (9196 of 9675 items) of all items identified during the gut analysis. The second most abundant Phyla present were prey items from the Phylum Mollusca, comprising an additional 4% of the food items identified (398 of 9675 items). When looking at a more detailed level of classification, the most abundant food item in the guts of collected individuals were chironomid larvae, comprising 84% (8141 of 9675 items identified). The second most abundant group of identified items in the collected redhorse guts was in the subclass Ostracoda (aquatic crustaceans with a two-part, hinged carapace). This group comprised 7% (681 of 9675 items) of all items identified. Although not always the most abundant item in a single individual's gut, chironomid larvae and bivalves were present in almost all individuals.

Dates when fish were collected for the gut analyses varied and spanned all seasons of the year (refer to Table 6 for summary of collection locations of individual fish used for the gut analysis). However, the majority of collections occurred in the fall months (24 of the 37 total collections). Collections of robust redhorse were grouped seasonally and analyzed for this report. Specimens 17-40 were collected in the fall, 1, 2.1, and 2.2 in winter, 3.2-12 in spring, and 13-16 during the summer (Table 5).

All specimens collected during the fall months contained larval chironomids, except specimen 21, which had no identifiable items in its guts. Specimens collected in fall also tended to have increased numbers of bivalve (*Corbicula spp.)* parts in the gut cavity. The three specimens collected in the winter months were all from the 1995 year class. The only unusual appearance of items in the gut from the winter months was an abundance of Zygoptera (damselfly larvae) in one individual's gut. Five specimens were collected during the spring

months of 1999. Specimens 3.2 and 8 were from the 1995 year class. All specimens collected with contents in their guts contained some larval chironomids. Two individuals had a diet with large amounts of ostracods. This influx of ostracods may represent a seasonal variation in diet, but possibly show a difference in ostracod abundance in the portion of the reservoir these fish inhabited. Five specimens were collected in the summer months of 1999. All specimens were from the 1997 stock class. None of these fish had high invertebrate abundances.

From the data presented in this report, there appears to be no relationship between size of fish (total length) or gut length and presence of *Corbicula spp.* or chironomids (*Corbicula*: R^2=0.008 and 0.123; chironomids: R^2=0.085 and 0.079, respectively). These results suggest that fish size and prey selection may not be related for individuals of this size (233 – 450 mm TL).

Juvenile Feeding and Life History Studies

Juvenile robust redhorse collected were found in water depths ranging from 54 cm to 67 cm and in current velocities ranging from 0.01 to 0.3 m/s (Freeman and Gregory, 1997, J. Harper, unpublished Senior Thesis). The gut contents contained 44.8 % cladocera and 37.9 % chironomids indicating that juveniles may be feeding on both planktonic and benthic food sources soon after release. The gut contents of juvenile robust redhorse that were removed from the stocking truck (died prior to stocking) were examined and found to contain on average over 90% cladocerans (Figure 11).

Other Catostomids Feeding and Life History Studies

Other species of catostomids fell into a variety of size classes (Figure 10). Dipterans (chironomids) were the primary prey item for both striped jumprock (n = 12) and brassy jumprock (n = 11) analyzed from Institute of Ecology surveys (Figure 12). The notchlip

redhorse (*Moxostoma collapsum* (see Appendix I); n = 16) was foraging on mostly cladocerans. Creek chubsuckers consumed mostly cladocerans and copepods. Northern hog suckers were foraging mostly on bivalves and some chironomids. Chironomids were the only significant prey item found in all species and individuals used for this study.

Growth of Stocked Fish

A length weight regression using 38 of the recaptured redhorse produced a power function with a significant R^2 value ($R^2 = 0.963$; Figure 13). There were 11 fish were identified as age 2 fish, 26 fish collected that were identified as age 3 fish, 15 collected that were age 4, and a single specimen was collected that was identified as an age 6 fish. Fish collected that were age two fish had a mean total length of 365.4 ± 9.4mm and weight of 637.6 ± 40.0g. (Appendix III). Fish collected that were age 3 had a mean total length of 418 ± 86.1mm and weight of 896.6 ±185.9g. Fish collected that were age four had a mean total length of 443.3 ± 4.0mm and weight of 1129.7 ± 35.0g. No fish were collected that were identified as age 5 fish. A single age 6 fish measured 570mm and weighed 1814g, which was caught at Anthony Shoals in 2001.

Discussion

Reintroduction of robust redhorse into the Broad River Watershed was apparently successful. Almost 40,000 robust redhorse were released and some of these individuals have survived to spawning age. Although stocked individuals were captured in Clark's Hill (an area with no spawning habitat), some individuals have returned to upstream areas where spawning is possible (i.e. Anthony Shoals).

Collections of robust redhorse from the Broad River and its tributaries were largely unsuccessful until the 2001 season. Past efforts have shown that the collection of robust

redhorse might be difficult in even relatively small tributaries. For example, in 1995 DNR biologists sampled for robust redhorse 24-48 hours after approximately 200 fish were accidentally released into Dennis Creek and recovered none. The relatively small number of fish stocked into the system in 1995 and 1996 may explain why no robust redhorse were caught early in the sampling efforts. While sampling under ideal conditions in 1997, the Institute of Ecology crew surveyed a site where less than 24 hours earlier 300 juveniles were released and only recovered 29 individuals. In addition, high water events occurring during the winter of 1996 and 1997 may have moved these young fish downstream of the stocking areas shortly after their release. Non-fingerling robust redhorse were not collected from the Broad River or its tributaries from 1995-2000, except collections occurring directly after stocking events on Hannah Creek. While survival success was confirmed with the collection of the stocked fish in Clark's Hill Reservoir, the utilization of the Broad River and its tributary waters by mature robust redhorse was not documented in the monitoring years 1996-2000.

The size frequency of all fishes collected from 1995-1998, captured during all boat electrofishing surveys ranged from 2-105 cm. The size frequency of all notchlip redhorse, brassy jumprock, and striped jumprock captured on Broad River boat surveys indicated that our equipment and methods were particularly effective at sampling these species with lengths ranging from 12-50 cm (Freeman and Gregory, 1997). These sizes overlap in the length ranges of introduced robust redhorse (6-12 cm) and the size frequency of captured fishes indicates that collection of these fish should have been possible if fish densities were high enough (Freeman and Gregory, 1997). Individuals from the 1993 and 1995 year class would have reached a minimum size of at least 300 mm total length, a size easily sampled with a boat EF.

Habitat Analysis

Quantifying and mapping macrohabitat structure in the mainstem reaches targeted for reintroducing robust redhorse should allow a better understanding of the potential of these reaches to support populations. For example, the number, size, and distribution of patches of complex habitat may strongly influence the availability of benthic invertebrate prey as well as suitable habitat for fishes. Patches of shallow sediment and flowing-pool or run habitats that lack complexity may fail to provide sufficient prey resources or refuges from predators for juvenile redhorse. Conversely, complex habitat patches may support higher prey production (because of greater substrate stability, particularly for filter-feeding invertebrates) as well as structural cover for foraging redhorse. The amount and dispersion of gravel-shoal habitats would also influence availability of spawning habitat for a re-established robust redhorse population. Our initial mapping shows more extensive patches of complex habitat in the Hudson River than in the upper Broad River mainstem, and a predominance in both systems of flowing pools (Freeman 1998). The presence of robust redhorse is more likely to occur in these more complex habitats. For example, the two fish captured by Institute of Ecology personnel on 6 September 2001 were collected in habitat analyzed and categorized as complex for this project. Other collections of robust redhorse by BJF have also occurred in complex habitats, suggesting a correlation of this fish's presence and complex habitat.

Diet Analysis

An analysis of food habits of captured robust redhorse indicate that this species feeds on a wide range of organisms. Dipteran larvae, specifically chironomids, numerically dominated the gut contents. Chironomids are also the dominant food item in both jumprock species

(*Scartomyzon* spp.) analyzed. *Moxostoma collapsum* had gut contents dominated by cladocerans, dipterans, and bivalves.

The species of invertebrates that were most abundant in the digestive tract of the specimens analyzed are typically associated with lentic habitats. Invertebrates that typically inhabit lotic habitats were noticeably low in abundance, including members of the orders Plecoptera, Tricoptera, Ephemeroptera, Hemiptera, Tricoptera, and Odonata. These invertebrates were observed in the guts of collected individuals, yet in most instances were not abundant. Dipterans (Chironomidae and Culicidae) are observed in a wide variety of habitat types and throughout all seasons. There were numerous individuals with mollusks in their guts, most of the mollusks were bivalves, although a few snails were observed in some individual's gut contents. All bivalves observed were members of the genus *Corbicula*, an exotic species introduced into the United States. This organism is extremely successful in colonizing many types of habitats. Ostracods another common item in robust redhorse gut contents are organisms that also occupy a wide range of habitat types. Members of this subclass are often highly abundant when found. Ostracods that occupy riverine habitats are dorso-ventrally flattened. However, all ostracods observed were robust in appearance and likely a reservoir species. Based on these findings, it can be assumed that the robust redhorse collected were residents of the reservoir at the time of capture.

There is no research for robust redhorse dietary habits and little data pertaining any catostomid inhabiting the Savannah drainage. Barwick and Hudson (1985) conducted research on notchlip redhorse dietary habits downstream of Hartwell Reservoir (upstream of Lake Russell on the Savannah River on the northeast Georgia / northwest South Carolina border). Results from this research indicated that the notchlip redhorse, collected in September, fed

primarily on tricopterans and chironomids. Based on total weight, tricopterans were dominant, yet chironomids were numerically dominant. The numerical dominance of chironomids in notchlip redhorse was also observed in robust redhorse collected for this study. Although chironomids may be numerically dominant in many robust redhorse guts, the importance of other food items may be underestimated because of their relatively low numbers. For example, bivalves *(Corbicula spp.)* were observed in many specimens, yet never highly abundant. Adult robust redhorse from the Oconee River also had large numbers of *Corbicula* present in the gut (BJF personal observation).These organisms are significantly larger prey items, and likely contribute greater nutritional support to the robust redhorse. Seventy-five percent of robust redhorse had at least one *Corbicula* hinge present in its gut. This result is not surprising considering the modified pharyngeal arches of this species, which are used to crush bivalve shells and other hard materials. The importance of other food items is hard to infer from available data, but it is clear that robust redhorse at this particular life stage will consume a large range of invertebrates.

Diet Analysis of Juvenile Robust Redhorse

The gut contents of juvenile robust redhorse retained from stocking trucks were dominated by cladocerans (Figure 11). The only other significant taxon present were dipterans. These fish expired prior to stocking; therefore, results of diet analysis can only be used to identify feeding habits in rearing ponds. Phytoplanton and zooplankton blooms are initiated by fertilization of ponds shortly before hatched larvae are transferred to holding ponds. The vast majority of fish stocked in the Broad River system were from Walton Hatchery, which uses ground water to supply its rearing facility. Ground water is typically void of zooplankton. With no running waters feeding these rearing ponds, it is expected that these ponds probably do

not harbor significant populations of benthic macroinvertebrates. Therefore, the food base in the rearing ponds may be limited.

The seven juveniles collected from Hannah Creek only spent a small amount of time in the stream before recapture, yet showed a change of diet. Within 24 hours of their stocking, these fish increased the diversity of prey items consumed, taking advantage of new prey items found in the riverine system. Their diet consisted of a large amount of dipterans and cladocerans, similar to the diet of those juveniles from the stocking trucks. These recently released fish also had some plecopterans and *Corbicula* in their gut contents. Since chironomids are larger than cladocera and our data are based on numerical counts, it is assumed that chironomids may be a more important food item than the cladocera (Freeman and Gregory, 1997). Data collected from robust redhorse juveniles obtained from Hannah Creek are helpful in identifying prey selection tendencies shortly after stocking. Macroinvertebrates consumed by robust redhorse collected from Clark's Hill Reservoir appear to be different from those consumed by juvenile robust redhorse collected from Hannah Creek. The most striking difference in diet between the juveniles in Hannah Creek and adults captured from Clark's Hill Reservoir is large range of foods consumed by the adults as compared to the juveniles. Acknowledging that these specimens were collected in different types of habitats, a direct comparison is difficult to ascertain.

Other related species such as notchlip redhorse, and both striped and brassy jumprock each had gut contents that were composed of a large percentage of chironomids, a finding that is also supported by other researchers. Meyer (1962) reported that prey item selection of *Moxostoma erythrurm* (golden redhorse), silver redhorse (*Moxostoma anisurum*), and *Moxostoma macrolepidotum* (shorthead redhorse) included chironomids (91%), Ephemeroptera

(62%), and Tricoptera (18%) in order of frequency of occurrence of all specimens analyzed. Barwick and Hudson (1985) reported that silver redhorse (notchlip redhorse on the Atlantic Slope) were foraging mainly on dipterans representing three families, with chironomids being the most abundant. Although each fish species had a diet dominated by dipterans, their diets were variable and most species had some cladocerans in their gut contents. Of the other species of catostomids examined, northern hog suckers and notchlip redhorse had a large quantity of *Corbicula* within their gut contents.

Migration

The population of robust redhorse recovered from Clark's Hill Reservoir migrated great distances (some fish over 140 river kilometers) from the original stocking locations. It is uncertain whether this is typical for the species or simply a response to high flows shortly after stocking. Russell Dam (upstream) and Clark's Hill Dam (downstream) apparently block movement throughout the remainder of the Savannah River system, so it is not known how far stocked fish may travel. Also, we don't know if the movements recorded are normal behavior or simply that of pond-reared fish released into fluvial habitats. The apparent absence of stocked robust redhorse post stocking in the Broad River and the rather sudden appearance of 2 year classes in Clark's Hill Reservoir suggest a directed movement by many individuals. The appearance of larger individuals in 2001 may suggest that some individuals may be migrating up the Broad River from Clark's Hill Reservoir. Bradford and Grutin (2000) reported similar observations while observing migration of endangered razorback suckers (*Xyrauchen texanus*). However, catostomids of eastern North America evolved under dramatically different hydrological conditions than western species and exhibit significant differences in

physiological adaptations (Walsh *et. al.*, 1998). Therefore, these similarities must be taken with some caution.

These recent collections of robust redhorse in the Broad River have life-history implications in relation to the utilization of river corridors, impoundments, and tributaries. Because fingerling and intermediate size-class robust redhorse were not found throughout the study years 1996-2000 in the Broad River and its tributaries, excluding immediate post-stocking collections, it may be assumed that these fish are moving rapidly downstream to deep river and/or reservoir waters immediately after release. Further research is required to gain a greater understanding of this species migration patterns.

Habitat Utilization and Association

Distribution of robust redhorse in Clark's Hill Reservoir is difficult to ascertain. Results of collections made indicate robust redhorse are distributed throughout the reservoir. All captured robust redhorse from the reservoir were stocked individuals. The Broad River enters the reservoir as a northwestern limb below the Lake Russell Dam. Some specimens were collected on what is the mainstem of the reservoir (11 specimens). Most of the fish collected from the mainstem were at the GA COOP station 3 (8 of the 11 fish captured). This station was located just upstream of the confluence of the Savannah and the Broad Rivers. It should be noted that two GA COOP stations were located directly on the Broad River arm of the reservoir and no collections of robust redhorse were made at these stations. The recaptured, stocked fish appear to be using medium size creek channels for foraging and refuge areas, for example 14 of the 25 fish captured from February through October we caught at one of the nets at station 4, located on the Russell Creek arm of the reservoir. Most fish collected were of the 1997 year class and appear to be migrating within the reservoir.

Data collected from the 29 juvenile robust redhorse collected in Hannah Creek suggests that recently released individuals may be selecting deeper, slower moving water over sand and may show some affinity for cover along the margins of stream banks. It appears these fish prefer downstream migration possibly using high flow events to trigger migration or push fingerlings downstream. This downstream migration appeared to end in Clark's Hill Reservoir where a barrier eliminated any further migration and where most of the stocked fish were later recaptured.

Despite the small number of robust redhorse collected in the Broad River system, some generalizations can be made. Recently stocked individuals were collected only shortly after release, then disappeared from the catch in the "release reaches" of the Upper Broad River system. Monitoring in subsequent years should have detected older individuals (2-3 years after their release) if they were present in the "release reaches" as their sizes would have been similar to other sucker species captured in the surveyed reaches. Robust redhorse collected in 2001 in the "release reach" were observed with other species (brassy jumprock and notchlip redhorse) and occupied areas of complex habitat. This habitat is similar to Anthony Shoals (the last flowing shoal habitat on the river, and a possible spawning site for robust redhorse in the Broad River system). Robust redhorse have been consistently collected and observed in Anthony Shoals from March 1999 through August 2001.

Stocked robust redhorse continue to utilize the habitat provided by Clark's Hill Reservoir. In fact, three additional specimens were collected in Clark's Hill Reservoir by the GA COOP on 28 October 2002 and one more specimen was collected on 2 December 2002. The non-native bivalve (*Corbicula spp.)*, a robust redhorse prey item, is also present in numbers large enough to support a population of adult robust redhorse in the Broad River

system. Therefore, the utilization of the reservoir habitat may be a predisposed life history trait for larger pools that was previously unobserved in Oconee and Savannah populations of the robust redhorse rather than a matter of resource limitation. Conversely, the presence of robust redhorse in the reservoir may indicate a need for this species to migrate downstream to utilize habitats not occurring above the Fall Line. Additionally, a significant amount of habitat within the lower Broad River was not sampled during the previous five years due to limited access and resources. Habitats within this lower reach could harbor mature or sub-mature robust redhorse. Collection efforts from this reach of river in the future could provide valuable information for understanding the movement and habitat utilization of robust redhorse within the Broad River System. At a minimum Anthony Shoals and other complex habitats identified in the "release reach" should be visited during likely times of spawning to record possible spawning events by mature robust redhorse.

Problems facing robust redhorse in the Broad River Watershed

The majority of stocking programs in the United States have focused on introductions of game species, primarily salmonids. While many programs were deemed a success, some researchers reported negative impacts associated with introduction efforts. Indigenous populations of lake trout (*Salvelinus namaycush*) were replaced by hatchery-stocked fish in just a few generations (Evans and Willox 1991). A potential problem could also occur with the stocked robust redhorse if stocked individuals bypassed Clark's Hill dam and mixed with the wild populations of robust redhorse farther south in the Savannah River drainage. This problem is of particular concern because the stocked individuals in the Broad River are from a different ESU than those wild individuals lower in the Savannah River drainage.

Another potential factor that may hinder the stocked population in the Broad River is the introduction of an exotic species, the flathead catfish (*Pylodictis olivaris*). This species is a known fish predator that has severely impacted other catostomid populations. Bradford and Grutin (2000) addressed these concerns while investigating reintroduction efforts of the razorback sucker, by stating that the introduction of non-native species was implicated in the near extirpation of razorback suckers from the lower Colorado River. Marsh and Brooks (1989) specifically identified channel catfish (*Ictalurus punctatus*) and flathead catfish as intense predators of juvenile razorback suckers (*Xyrauchen texanus*). Results from their research revealed that 90% of the flathead catfish and 55% of the channel catfish collected 2 days after a razorback sucker stocking event had juvenile suckers in the gut cavity. It is safe to assume that flathead catfish are creating a definite threat for juvenile robust redhorse stocked in the Broad River Watershed. Because robust redhorse did not evolve in a system with flathead catfish and other non-native predators, these stocked fish may be at a disadvantage for avoiding these "new" predators. Juvenile razorback suckers, which also evolved in a reduced piscivorous habitat, did not initially avoid predators as easily as northern hog suckers which did evolve in a more intense piscivorous ecosystem (Johnson *et al.* 1993). Introduced predators along with stocking stresses greatly decrease the survival of stocked individuals.

Altered flows influenced by hydropower dams in this system and probable altered migration patterns because of dams are two factors that need to be addressed when learning more about this species in a system that is greatly influenced by man. Although this study could not directly address these issues, collections of robust redhorse in Clark's Hill Reservoir suggest that at least some fish would have moved beyond the barrier provided by Clark's Hill dam. Altered flows may affect different life stages of robust redhorse and flow may affect

migration patterns of this species. The affect of regulated flows on this species needs to be thoroughly studied.

Conclusions

The reintroduction effort in the Broad River Watershed has involved many different stakeholders. Almost 40,000 robust redhorse were introduced into the system, before stocking efforts were halted. Even though stocked fish faced a change in food resources and predators after stocking, some individuals have survived to spawning age and have been seen in potential spawning sites. The true test of this effort will be told in the future, when these individuals begin to spawn. Research on this species, especially looking at habitat use and needs, migration, and spawning habitat and success are just a few items that may help future reintroduction efforts.

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Table 1. Robust redhorse stocking sites, dates, and total individuals released into the Broad River Watershed from 1995-1998.

Stocking Locale	Stocking Dates	Stocked (Total)
South Fork Broad River at Highway 22	3/9/95	250
South Fork Broad River at Watson Mill State Park	8/9/95, 11/21/96	250
Middle Fork Broad River at Atkinson Bridge Rd.	11/24/97	3,000
North Fork Broad River at Highway 145 (below dam)	11/10/97, 11/19/97, 11/21/97, 12/4/98	15,800
North Fork Broad River at Highway 51	3/9/95, 11/20/97, 11/18/98	1,742
Hudson River at Highway 29	11/21/96, 11/21/97, 11/25/97	6,855
Hudson River at Highway 106	11/20/97, 11/25/97, 11/4/98, 11/10/98, 11/18/98	9,639
Hannah Creek at Hannah Creek Church Rd.	10/10/97, 11/20/97, 11/25/97, 12/4/98	1,711
		Total: 39,247

Table 2. Dates, locations, and methods used during surveys for robust redhorse (*Moxostoma robustum*) and other sucker species conducted by personnel of the Institute of Ecology, UGA. Numbers in parentheses after presence/absence indicate the number of robust redhorse captured or observed. BPEF refers to backpack electrofishing.

Collection ID	Location	Date	Collection method	*Moxostoma robustum*
BJF 95-63	Broad River approximately 0.5 mile downstream of Hwy 172 bridge	10/2/1995	seine haul	absent
BJF 95-84	Broad River at vicinity of mouth of Vineyard Creek	12/2/1995	boat EF	absent
BJF 95-85	Broad River near Vineyard Creek	12/4/1995	boat EF	absent
BJF 95-86	Broad River at Vineyard Creek up to Cornell Dairy, downstream below creek	12/6/1995	boat EF	absent
BJF 95-87	Broad River upstream of Vineyard Creek / Cornell Dairy	12/13/1995	boat EF	absent
BJF 96-01	Broad River above Vineyard Creek	1/14/1996	boat EF	absent
BJF 96-02	Broad River, downstream Vineyard Creek about 300m	1/15/1996	Boat EF	absent
BJF 96-36	Broad River at Peyton Ferry Farm, along bar opposite Vineyard Creek mouth, and up vineyard creek	6/23/1996	seine haul	absent
BJF 96-65	Hudson River at Hwy 29 downstream	12/26/1996	BPEF	absent
MBG 97-08	Hudson River at Hwy 29 to the Broad River at Hwy 281	3/19/1997	canoe EF	absent
BJF 97-06	Broad River above and below the mouth of Vineyard Creek	3/30/1997	canoe EF	absent
BJF 97-31	Broad River from 1st shoal upstream Blue stone Creek down to Hwy 281	7/21/1997	boat EF	absent
MBG 97-67	Broad River at Hwy 281 from bridge upstream to first set of shoals	7/22/1997	boat EF	absent
BJF 97-43	Broad River upstream from Hwy 281	8/26/1997	boat EF	absent
MBG 97-79	Hudson River at Hwy 29 downstream to confluence with the Broad River	9/8/1997	boat EF	absent
MBG 97-80	Middle Fork Broad River at Hwy 145 upstream from bridge	9/8/1997	BPEF	absent
RPC 97-01	Broad River from Hannah Creek to Hudson River	9/17/1997	boat EF /seine	absent
RPC 97-02	Broad River from Hwy 281 downstream	9/17/1997	boat EF / seine	absent
RPC 97-03	Broad River from Hannah Creek to Hwy 281	9/19/1997	boat EF	absent
MBG 97-82	South Fork Broad River from upstream of Watson Mill State Park to the State Park.	9/23/1997	boat EF	absent

Table 2. continued.

Collection ID	Location	Date	Collection method	*Moxostoma robustum*
MBG 97-91	South Fork Broad River from Hwy 22 downstream approximately 0.5 miles.	10/3/1997	BPEF	absent
BJF 97-54	Broad River at sand bar opposite mouth of Vineyard Creek	10/6/1997	grid shocking	absent
BJF 97-56	North Fork Broad River below old dam for Franklin Springs water intake	10/10/1997	grid shocking, and BPEF	absent
BJF 97-57	Hannah Creek near release site	10/11/1997	BPEF	present (29)
BJF 97-72	Hannah Creek from junction with the Broad River upstream	11/10/1997	BPEF	absent
RPC 97-18	Hannah Creek from its mouth upstream	11/13/1997	BPEF	present (3)
RPC 97-19	Hannah Creek from mouth upstream to bridge at Hannah Creek Church Road	11/19/1997	BPEF	present (3)
RPC 97-20	North Fork Broad River past confluence with Middle Fork, past CR 171	11/20/1997	boat EF	present (1)
RPC 97-21	Hannah Creek from confluence with Broad us to Hannah Creek Church Rd. and 50m us of bridge	12/2/1997	BPEF	present (4)
RPC 97-22	North Fork Broad River from 145 bridge down to island shoal (4th shoal)	12/9/1997	boat EF	absent
MBG 97-107	Hannah Creek	12/16/1997	BPEF	present (2)
MBG 98-03	Hannah Creek, 150m upstream and 250m downstream from unnamed tributary	2/25/1998	BPEF	absent
MBG 98-04	Hannah Creek from 300m down stream of unnamed tributary on river left to confluence with Broad River	2/26/1998	BPEF	absent
MBG 98-05	Hannah Creek at Hannah Creek Church Road	2/26/1998	BPEF	absent
KJI 98-04	Hudson River at Hwy 29 to Hwy 281 on the Broad River	3/31/1998	BPEF	absent
KJI 98-05	Hudson River at Hwy 29 and Broad River at spotted sucker spawning gravel bar	4/2/1998		absent
KJI 98-06	Hannah Creek from mouth of unnamed tributary downstream	5/12/1998	BPEF	absent
KJI 98-07	Hannah Creek from Hannah Creek Church Rd. bridge downstream and upstream	5/14/1998	BPEF	absent
KJI 98-09	Broad River from first rocky bend downstream of Hannah Creek to Hwy 281	5/20/1998	boat EF	absent

Table 2. continued.

Collection ID	Location	Date	Collection method	*Moxostoma robustum*
MBG 98-19	Broad River, reaches 6, 7, 8, upstream from Hwy 281 bridge	6/2/1998	boat EF	absent
MBG 98-20	Broad River, reaches 9, 10, 11, upstream from Hwy 281 bridge	6/7/1998	boat EF	absent
MBG 98-21	Broad River, reaches 12-15, upstream from Hwy 281 bridge	6/8/1998	boat EF	absent
MBG 98-22	Broad River, reaches 1, 5, upstream from Hwy 281 bridge	6/11/1998	boat EF	absent
KJI 98-11	Broad River from Hwy 281 downstream to 2 km	6/14/1998	boat EF	absent
KJI 98-12	Broad River downstream from Hwy 281 bridge 1.5km	6/15/1998	boat EF	absent
KJI 98-13	Broad River reaches 16-19 upstream from Hwy 281 bridge	6/16/1998	boat EF	absent
KJI 98-14	Broad River from ca. 500-2000m downstream from Hannah Creek	6/17/1998	boat EF	absent
KJI 98-15	Broad River and Hudson River ca 500m u.s. from mouth of Hannah Creek	6/18/1998	boat EF	absent
KJI 98-16	Hudson River, reach 1&2	6/21/1998	boat EF	absent
KJI 98-17	Hudson River, upstream from confluence with Broad River 1-4 km	6/22/1998	boat EF	absent
KJI 98-18	Hudson River reaches 6-8	6/23/1998	boat EF	absent
KJI 98-19	Broad River 1000-2000m us from mouth of Hannah Cr., reaches 23-24	6/25/1998	boat EF	absent
MBG 98-34	North Fork Broad River	6/25/1998	canoe shocker	absent
MBG 98-35	North Fork Broad River	6/28/1998	canoe shocker	absent
KJI 98-21	Broad River reach 25	6/30/1998	boat EF	absent
KJI 98-22	Middle Fork Broad R. Atkinson Bridge	7/13/1998	boat EF, BPEF	present (1)
KJI 98-23	Hudson R., Hwy 106	7/14/1998	canoe shocker	absent
KJI 98-24	North Fork Broad River, below Hwy 145 dam	7/15/1998	canoe shocker	absent
KJI 98-25	North Fork Broad River at Hwy 51	7/22/1998	canoe shocker	absent
HSW 98-41-2	Broad River at Vineyard Creek	8/6/1998	grid shocking	absent
BJF 98-38	Broad River in the vicinity of Hwy 281	9/5/1997	boat EF	absent

Table 2. continued.

Collection ID	Location	Date	Collection method	*Moxostoma robustum*
MBG 98-81	Hudson River in the vicinity of Hwy 106	11/9/1998	BPEF	present (5)
MBG 98-82	Hudson River approximately 1 mile downstream of Hwy 106	11/10/1998	BPEF	present (1)
MBG 98-91	Hudson River at Hwy 106	12/4/1998	BPEF	present (4)
MBG 98-94	Hudson River at various locations	12/9/1998	BPEFF	present (3)
MBG 99-01	Hannah Creek from rockface to approximately 100 m	1/12/1999	BPEF	present (1)
BJF 99-03	Hannah Creek at downstream of Hannah Creek Church Road	3/2/1999	BPEF	absent
BJF 99-07	Broad River, approximately 1+ mi upstream mouth Vineyard Creek	4/12/1999	observation	absent
BJF 99-16	Hannah Creek, midpoint- downstream 200m+	6/7/1999	seine hauls	absent
BJF 99-28	Hudson River, 2.5 miles upstream from Hwy 29	7/28/1999	BPEF	absent
BJF 99-29	Hudson River from US Highway 29, down Broad River to mouth of Hannah Creek	8/8/1999	canoe EF	absent
BJF 99-30	Broad River, from 300m downstream mouth Hannah Creek, downstream to GA Highway 281	8/9/1999	canoe EF	absent
BJF 00-13	Broad River at base of Anthony Shoals, 9.77 air miles NE of Tignall, GA city center.	5/3/2000	boat EF	present (8)
BJF 01-13	Broad River at Anthony Shoals	5/16/2001	boat EF	present (4)
BJF 01-15	North Fork Broad River just downstream Franklin Springs Dam.	6/20/2001	BPEF, spot sampling	absent
BJF 01-16	North Fork Broad River from Franklin Springs Dam downstream to Hannah Creek.	7/11/2001	canoe EF	absent
BJF 01-17	Broad River below Hannah Creek to just below Hwy 281	7/12/2001	canoe EF	present (2)
BJF 01-18	Broad River at GA Hwy 281.	7/19/2001	canoe EF	present (1)
BJF 01-22	Broad River at Anthony Shoals	8/12/2001	boat EF	present (6)
BJF 01-36	Hudson River from Hwy 106 to Hwy 29.	9/6/2001	boat EF	present (2)

Table 3. Summary of robust redhorse collected from Clark's Hill Reservoir and other areas within the Broad River Watershed (1999-2001), these data include some specimens captured and released. Lengths given are all total lengths unless otherwise noted.

Specimen	Date	Collector	Station	Length (mm)	Weight (g)	Gut Length (mm)	Method of Collection	Stock Year
1	02/01/1999	GA COOP	4-2	404	878	620	Gill Net	1995
2.1	02/18/1999	GA COOP	3-1	407	869	560	Electrofishing	1995
2.2	02/18/1999	GA COOP	3-1	420	908	690	Electrofishing	1995
3.1	04/05/1999	GA COOP	4-2	312 (SL)	350	N/A	Gill Net	1997
3.2	04/05/1999	GA COOP	4-2	422	1044	600	Gill Net	1995
3.3	04/05/1999	GA COOP	4-2	220	117	260	Gill Net	1997
8	05/10/1999	GA COOP	1-2	450	1450	610	Gill Net	1995
9	3/12/1999	GA COOP	AS	N/A	1050	N/A	Electrofishing	1995
10	06/24/1999	GA COOP	2-1	352	540	490	Gill Net	1997
11	06/15/1999	GA COOP	4-2	233	139	380	Gill Net	1997
12	06/15/1999	GA COOP	4-2	324	391	440	Gill Net	1997
13	08/17/1999	GA COOP	4-3	353	650	625	Gill Net	1997
14	08/17/1999	GA COOP	4-3	373	575	605	Gill Net	1997
15	08/17/1999	GA COOP	4-3	372	700	615	Gill Net	1997
16	08/17/1999	GA COOP	4-3	387	750	620	Gill Net	1997
17	09/22/1999	GA COOP	4-3	317	425	470	Gill Net	1997
18	09/22/1999	GA COOP	4-4	386	675	680	Gill Net	1997
19	09/22/1999	GA COOP	4-4	361	600	640	Gill Net	1997
20	09/22/1999	GA COOP	4-4	368	600	550	Gill Net	1997
21	10/19/1999	GA COOP	3-4	386	750	380	Gill Net	1997
22	10/19/1999	GA COOP	3-4	391	750	690	Gill Net	1997
23	10/19/1999	GA COOP	3-4	349	500	595	Gill Net	1997
24	10/19/1999	GA COOP	3-4	401	875	620	Gill Net	1997
25	10/19/1999	GA COOP	3-4	354	525	260	Gill Net	1997
26	10/19/1999	GA COOP	3-4	393	825	575	Gill Net	1997
27	11/10/1999	GDNR	20	390	780	505	Gill Net	1997
28	11/10/1999	GDNR	19	377	635	580	Gill Net	1997
29	11/10/1999	GDNR	18	401	755	680	Gill Net	1997
30	11/10/1999	GDNR	17	387	657	540	Gill Net	1997
31	11/10/1999	GDNR	17	405	750	620	Gill Net	1997
32	11/10/1999	GDNR	17	385	690	N/A	Gill Net	1997
33	11/11/1999	GDNR	15	419	958	780	Gill Net	1997
34	11/11/1999	GDNR	15	415	905	580	Gill Net	1997
35	12/08/1999	SC DNR	5	N/A	750	720	Gill Net	1997
36	12/08/1999	SC DNR	5	N/A	700	720	Gill Net	1997
**	5/3/2000	UGA Ecology	AS	442	N/A	N/A	Electrofishing	1997
**	5/3/2000	UGA Ecology	AS	386	N/A	N/A	Electrofishing	1997
**	5/3/2000	UGA Ecology	AS	403	N/A	N/A	Electrofishing	1997

Table 3. continued.

Specimen	Date	Collector	Station	Length (mm)	Weight (g)	Gut Length (mm)	Method of Collection	Stock Year
**	5/3/2000	UGA Ecology	AS	398	N/A	N/A	Electrofishing	1997
**	5/3/2000	UGA Ecology	AS	418	N/A	N/A	Electrofishing	1997
**	5/3/2000	UGA Ecology	AS	423	N/A	N/A	Electrofishing	1997
**	5/3/2000	UGA Ecology	AS	401	N/A	N/A	Electrofishing	1997
37	11/14/2000	GDNR	19	440	949	650	Gill Net	1997
38	11/15/2000	GDNR	18	447	1120	780	Gill Net	1997
39	11/14/2000	GDNR	11	430	770	550	Gill Net	1997
40	11/14/2000	GDNR	19	410 (SL)	760	780	Gill Net	1997
**	5/16/2001	UGA Ecology	AS	365 (SL)	N/A	N/A	Electrofishing	1997
**	5/16/2001	UGA Ecology	AS	355 (SL)	N/A	N/A	Electrofishing	1997
**	5/16/2001	UGA Ecology	AS	365 (SL)	N/A	N/A	Electrofishing	1997
**	5/16/2001	UGA Ecology	AS	373 (SL)	N/A	N/A	Electrofishing	1997
**	6/18/2001	UGA Ecology	NF Broad	450	N/A	N/A	Electrofishing	N/A
**	7/12/2001	UGA Ecology	Broad	455	N/A	N/A	Electrofishing	1997
**	8/12/2001	UGA Ecology	AS	455	1247	N/A	Electrofishing	1997
**	8/12/2001	UGA Ecology	AS	447	1260	N/A	Electrofishing	1997
**	8/12/2001	UGA Ecology	AS	461	1418	N/A	Electrofishing	1997
**	8/12/2001	UGA Ecology	AS	570	1814	N/A	Electrofishing	1995
**	9/6/2001	UGA Ecology	Hudson	450	N/A	N/A	Electrofishing	1997
**	10/28/2002	GA COOP	Clark's Hill	480	1692	N/A	Gill Net	1998
**	10/28/2002	GA COOP	Clark's Hill	491	1694	N/A	Gill Net	1997
**	10/28/2002	GA COOP	Clark's Hill	514	1850	N/A	Gill Net	1997
**	12/2/2002	GA COOP	Clark's Hill	526	2240	N/A	Gill Net	N/A

** These individuals were released or not used for gut analyses.
AS = Anthony Shoals on the Broad River.

Table 4. Information from coded-wire tags removed from juvenile robust redhorse stocked into the upper Broad River from 1995 through 1998 and recaptured in Clark's Hill Reservoir during 2/01/1999-11/14/2000.

Fish no.	Year class	Tag no.	Date stocked	Hatchery	Pond no.	Batch	Roll no.	Phase (I or II)	No. stocked	Stocking location
3.1	97	9402	11/21/1997	Walton	12	L	A55 D55/60	I	2000	Middle Fork of the Broad River at Atkinson
3.3	97	10421	11/24/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
4	97	10586	11/24/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
10	97	4292	11/25/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 29
12	97	10458	11/24/1997	Walton	12	M	A55 D55/60	I	3000	Hudson River at Hwy 29
13	97	11705	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
14	97	11226	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
15	97	5338	11/21/1997	Walton	12	J	A55 D55/57	I	1900	North Fork below dam at Franklin Springs
16	97	10458	11/25/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
17	97	1154	11/25/1997	Walton	12	N	A55 D55/60	I	1900	North Fork below dam at Franklin Springs
18	97	11172	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
20	97	5354	11/21/97	Walton	12	J	A55 d55/57	I	1900	North Fork below dam at Franklin Springs
21	97	10405	11/24/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
22	97	11077	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29

Table 4. continued.

Fish no.	Year class	Tag no.	Date stocked	Hatchery	Pond no.	Batch	Roll no.	Phase (I or II)	No. stocked	Stocking location
23	97	11173	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
24	97	10678	11/24/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
26	97	10538	11/24/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
27	97	11132	11/25/1997	Walton	12	N	A55 D55/60	I	3000	Hudson River at Hwy 106
28	97	11154	11/25/97	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
29	97	10714	11/25/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
30	97	11189	11/25/1997	Walton	12	N	A55 d55/58	I	3000	Hudson River at Hwy 29
31	97	10661	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
32	97	9797	11/21/1997	Walton	12	H	A55 D55/61	I	1900	North Fork below dam at Franklin Springs
33	97	5788	11/21/1997	Walton	12	J	A55 D55/58	I	3000	North Fork below dam at Franklin Springs
34	97	11098	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
36	97	10418	11/25/1997	Walton	12	M	A55 D55/58	I	3000	Hudson River at Hwy 106
37	97	10722	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
38	97	11226	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
39	97	11178	11/25/1997	Walton	12	N	A55 D55/58	I	3000	Hudson River at Hwy 29
40	97	5194	11/21/1997	Walton	12	J	A55 D55/58	I	1900	North Fork below dam at Franklin Springs

Table 5. Summary of gut contents in specimens of robust redhorse collected from Clark's Hill Reservoir (1999-2000). Specimens 1, 3.2, 16, and 21 had no identifiable content in the gut and are not included. Individuals 1-2.2 were collected in the winter, 3.2-12 were collected in the spring, 13-16 were collected in the summer, and 17-40 were collected in the fall.

Robust redhorse specimen number

	WINTER		SPRING					SUMMER			FALL																					
Food Item	2.1	2.2	3.3	8	10	11	12	13	14	15	17	18	19	20	22	23	24	25	26	27	28	29	30	31	33	34	35	36	37	38	39	40
Phylum Nematoda																1					1		2					1	2		15	
Phylum Bryozoa																				34												
Bryozoa (Statocyst)																							1									
Phylum Annelida																																
Class Oligochaeta											2																					
Phylum Arthropoda																																
Order Acarina	1	39	6	2	9		5	9																								
Order Cladocera									2	1		3	4	1	2	9					1							3				
Genus Daphnia														1																		
Subclass Copepoda								9	1	1	2		1		1	2			6						1	8	1	19			5	1
SubClass Ostracoda			456		13	100				5	1	1	7	4	23	10		2	2		22			2				17		3		27
Order Isopoda																										1		1				
Order Amphipoda		30																			3					14	23	8				
Superfamily Hydracarina										2					13		7	5		2	1	2	6	4		1	1	1	1			
Order Ephemeroptera																														1		
Order Odonata																												2				
Family Anisoptera		1			1																											
Family Zygoptera		17																														
Order Plecoptera																										1		7				
Order Hemiptera																																
Order Megaloptera		6																														
Order Trichoptera	3	2	2	1	3	4	2		1				1															1				
Order Coleoptera					8											2					4											
Order Diptera													1	1		1	1											1				
Diptera pupae													1			2																
Family Culicidae																														2		
Family Chironomidae	2	97	12	17	56	141	38	1	13	2	8	25	103	122	9	13	5	2	7	34	1208	919	620	74	1158	1616	36	792	639	201	224	739
Phylum Mollusca																																
Class Gastropoda		13	1		17																									2		
Class Bivalvia	[illegible]	19	1		2	19		[illegible]			7	7	63	2	3	10	1			9	10	21	21	13	72	12	32	28	1	5	19	10
Unknown	4		2		2			12	1				1																			

Table 6. Summary of collection stations for robust redhorse in Clark's Hill Reservoir, fish identification, diet, and estimated migration distances.

Station	Location UTM 16	Fish id	Date collected	Year class	Major food items (>25% of contents)	Stocking location (date)	Migration distance (km)
GA COOP Station 1-2	352701E, 3764440N	8	5/10/99	1995	chironomids	N/A	at least 24.3*
GA COOP Station 2-1	353073E, 3763728N	10	6/24/99	1997	chironomids	Hudson at Hwy 29	93.1
GA COOP Station 3-1	354325E, 3760830N	2.1	2/18/99	1995	trichopterans unknown items	N/A	at least 20*
		2.2	2/18/99	1995	chironomids zygopterans	N/A	at least 20*
GA COOP Station 3-4	354325E, 3760830N	21	10/19/99	1997	no identifiable content	Hudson at Hwy 106	101.8
		22	10/19/99	1997	ostracods hydracarina	Hudson at Hwy 29	90.8
		23	10/19/99	1997	chironomids	Hudson at Hwy 29	90.8
		24	10/19/99	1997	chironomids hydracarina	Hudson at Hwy 106	101.8
		25	10/19/99	1997	hydracarina	N/A	at least 90.8*
		26	10/19/99	1997	chironomids copepods	Hudson at Hwy 106	101.8
GA COOP Station 4-2	355143E, 3763760N	1	2/1/1999	1995	no identifiable content		at least 22*
		3.1	4/5/99	1997	N/A	MF Broad at Atkinson Rd.	107.4
		3.2	4/5/99	1995	no identifiable content	N/A	at least 22*
		3.3	4/5/99	1995	ostracods	N/A	at least 22*
		11	6/15/99	1997	chironomids ostracods	N/A	at least 93.4*
		12	6/15/99	1997	chironomids	Hudson at Hwy 29 (11/24)	93.4
GA COOP Station 4-3	355143E, 3763760N	13	8/17/99	1997	unknown items	Hudson at Hwy 29	94.3
		14	8/17/99	1997	chironomids	Hudson at Hwy 29	94.3

Table 6. continued.

Station 4-3 cont		15	8/17/99	1997	ostracods	NF Broad at Franklin Springs	101.7
		16	8/17/99	1997	no identifiable content	Hudson at Hwy 106	105.3
		17	9/22/99	1997	chironomids *Corbicula sp.*	NF Broad at Franklin Springs	101.7
GA COOP Station 4-4	355143E, 3763760N	18	9/22/99	1997	chironomids	Hudson at Hwy 29	94
		19	9/22/99	1997	chironomids *Corbicula sp.*	N/A	at least 94*
		20	9/22/99	1997	chironomids	NF Broad at Franklin Springs	101.4
GDNR Station 11	379334E, 3731655N	39	11/14/1999	1997	chironomids	Hudson at Hwy 29	141.8
GDNR Station 15	369216E, 3743882N	33	11/11/99	1997	chironomids	NF Broad at Franklin Springs	125.3
		34	11/11/99	1997	chironomids	Hudson at Hwy 29	117.9
GDNR Station 17	359434E, 3755350N	30	11/10/99	1997	chironomids	Hudson at Hwy 29	95.2
		31	11/10/99	1997	chironomids	Hudson at Hwy 29	95.2
		32	11/10/99	1997	N/A	NF Broad at Franklin Springs	102.6
GDNR Station 18	356398E, 3753748N	29	11/10/99	1997	chironomids	Hudson at Hwy 106	111.8
		38	11/15/00	1997	chironomids	Hudson at Hwy 29	100.8
GDNR Station 19	352604E, 3757796N	28	11/10/99	1997	chironomids	Hudson at Hwy 29	90.8
		37	11/14/00	1997	chironomids	Hudson at Hwy 29	90.8
		40	11/14/00	1997	chironomids	NF Broad at Franklin Springs	98.2
GDNR Station 20	353868E, 3762181N	27	11/10/99	1997	chironomids bryozoa	Hudson at Hwy 106	102.5
SCDNR Station 4	UTM17 375089E, 3748025N	35	12/8/99	1997	chironomids *Corbicula sp.*	N/A	at least 114.8*
SCDNR Station 5	UTM17 387280E, 3738185N	36	12/8/99	1997	chironomids	Hudson at Hwy 106	140.5

* - The coded-wire tag from this individual was unusable for determining stocking location and migration distances. Using the most southern stocking location for the year the individual was stocked a minimum migration distance was calculated.

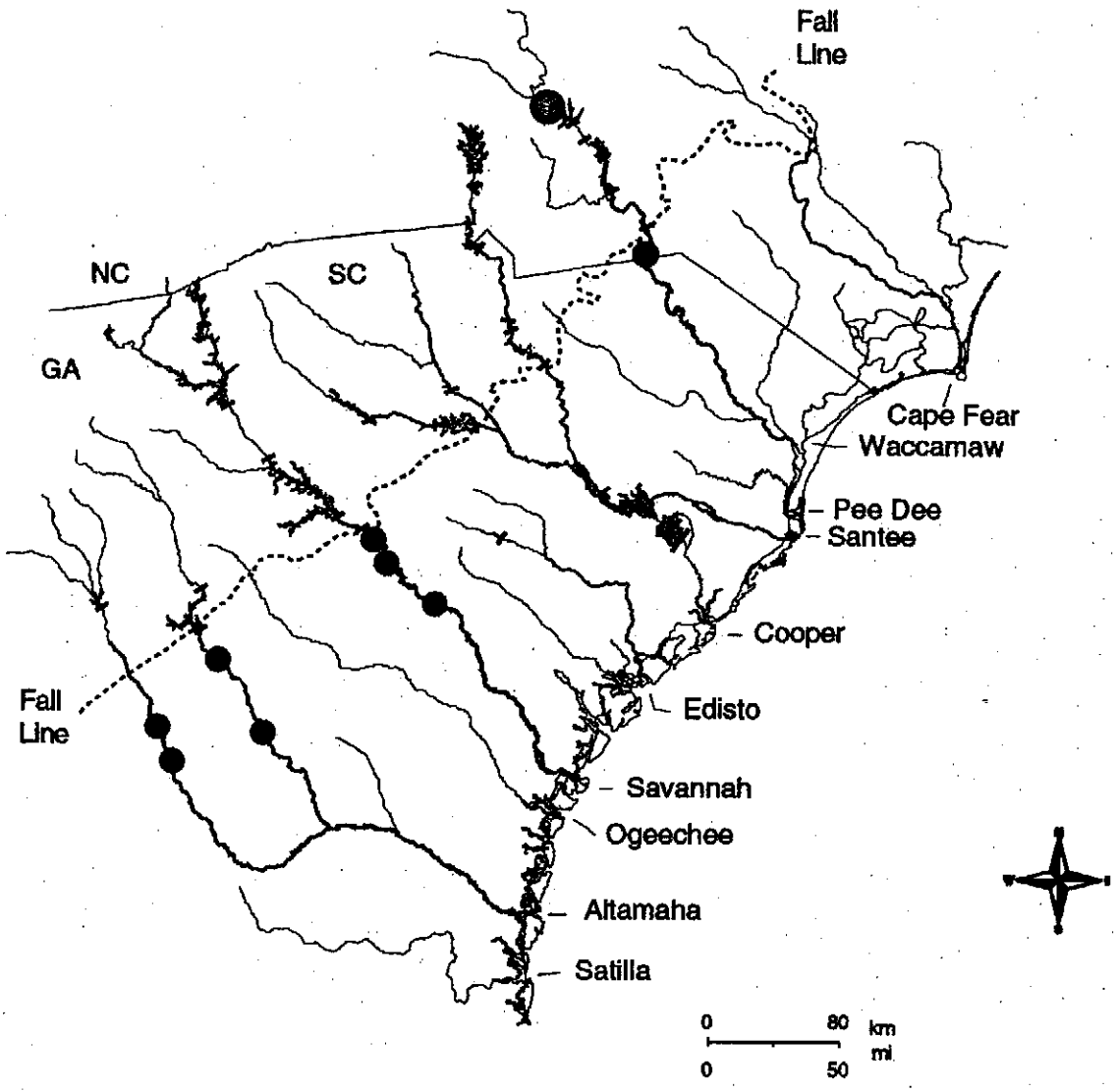

Figure 1. Presumed range of robust redhorse (*Moxostoma robustum*) in the Altamaha, Savannah, and Pee Dee River drainages. The yellow circle represents the location of the original collection by Cope in 1869. Red circles represent approximate limits of known wild populations. (R.E. Jenkins, B.J. Freeman, and J.E. Evans, unpublished data).

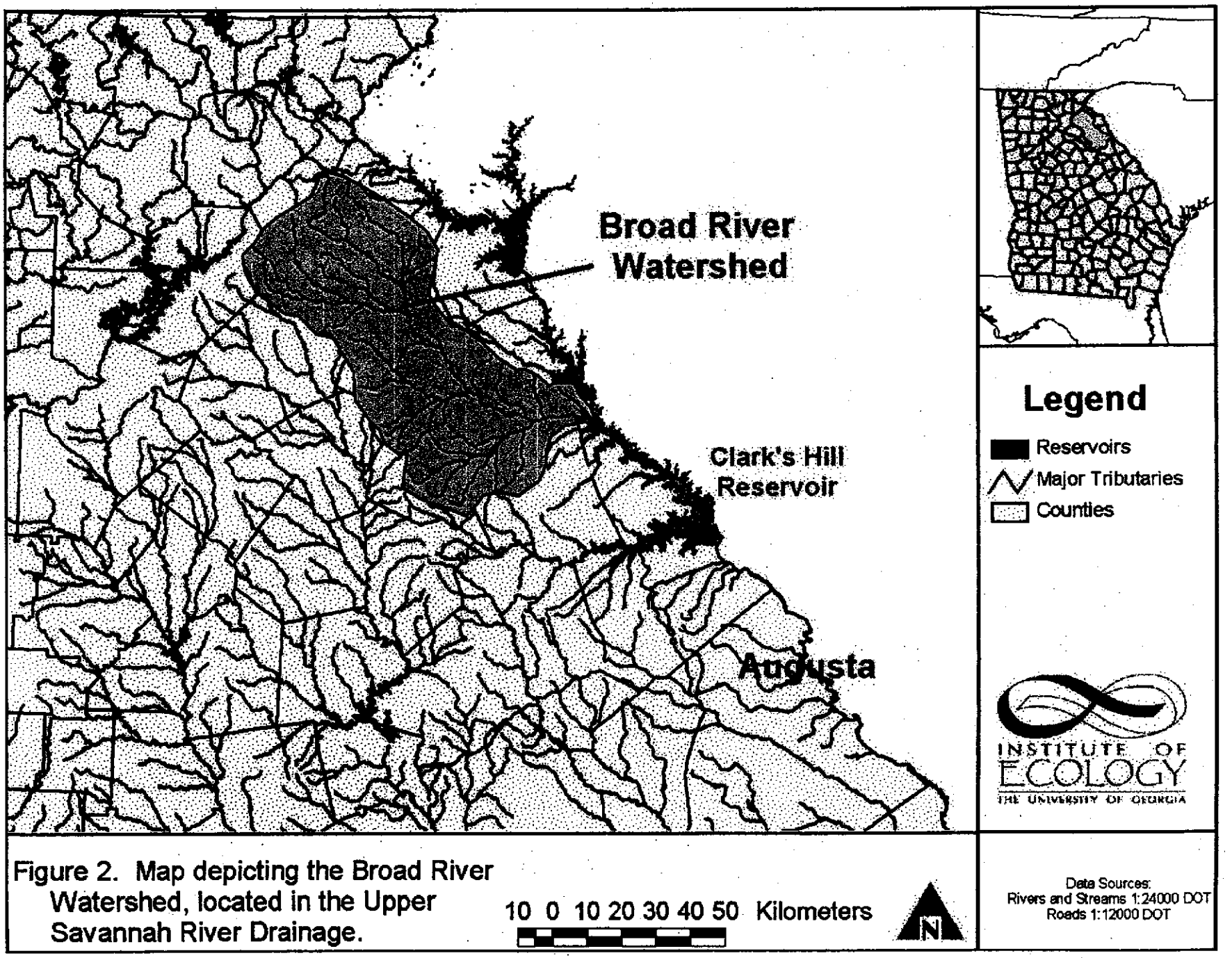

Figure 2. Map depicting the Broad River Watershed, located in the Upper Savannah River Drainage.

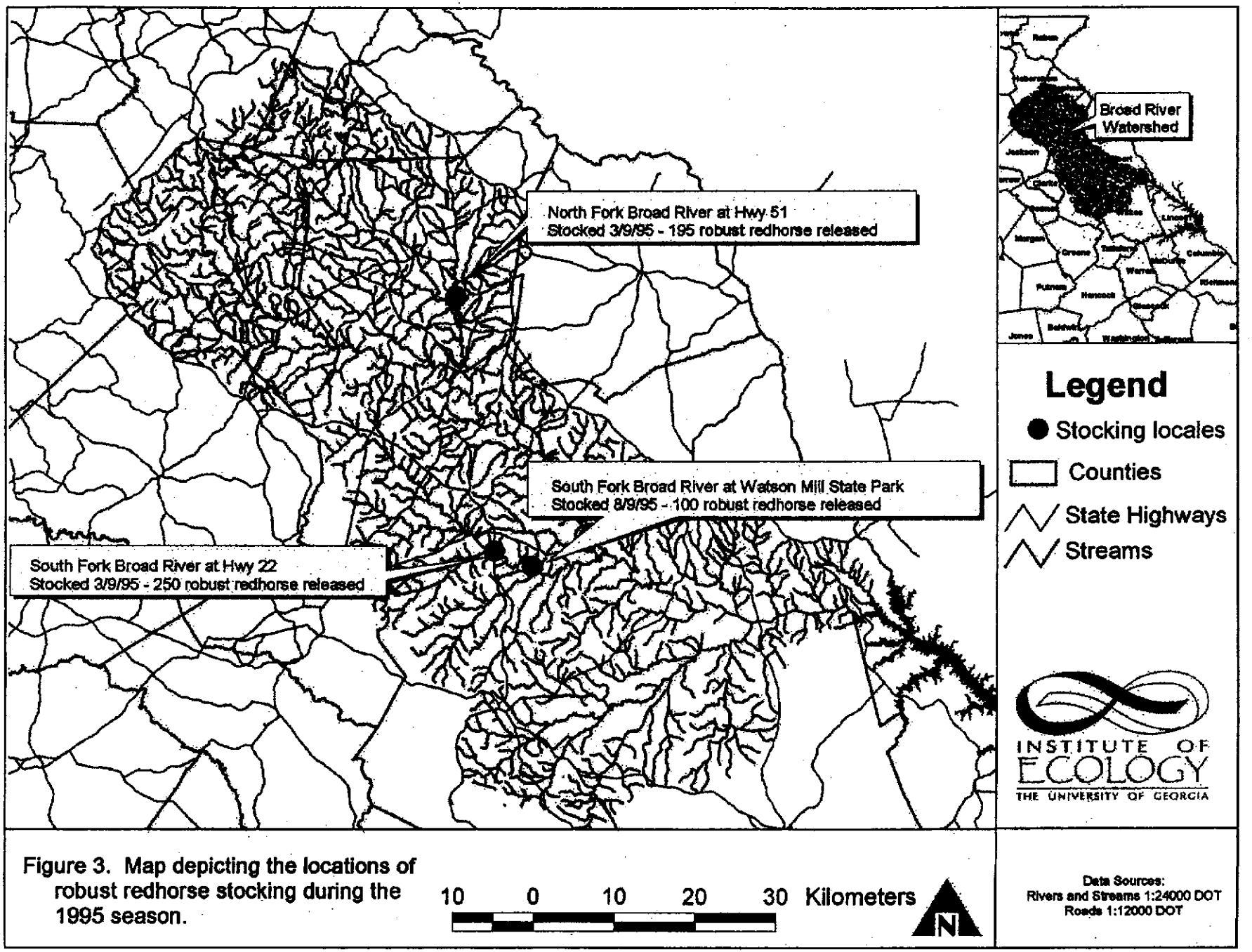

Figure 3. Map depicting the locations of robust redhorse stocking during the 1995 season.

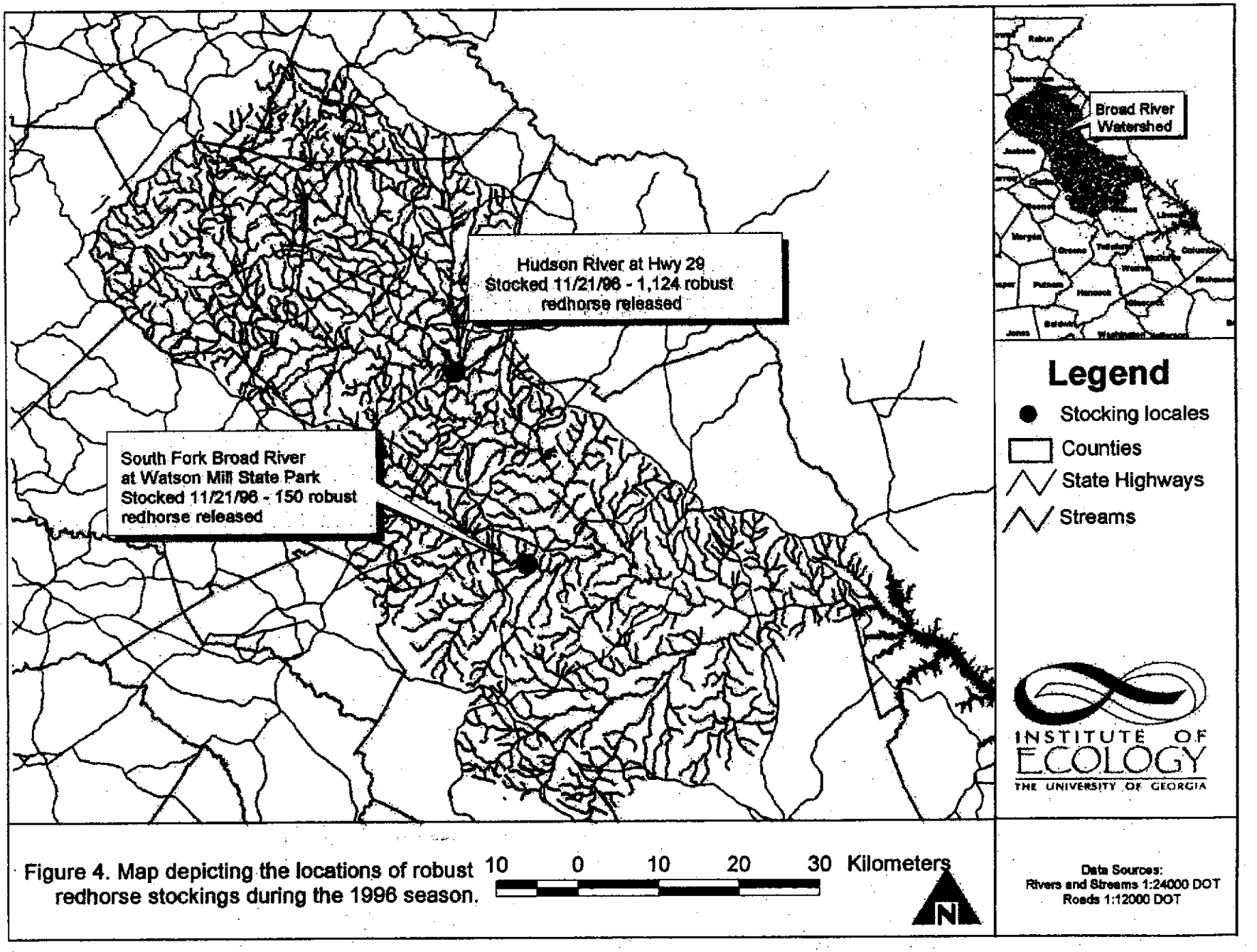

Figure 4. Map depicting the locations of robust redhorse stockings during the 1996 season.

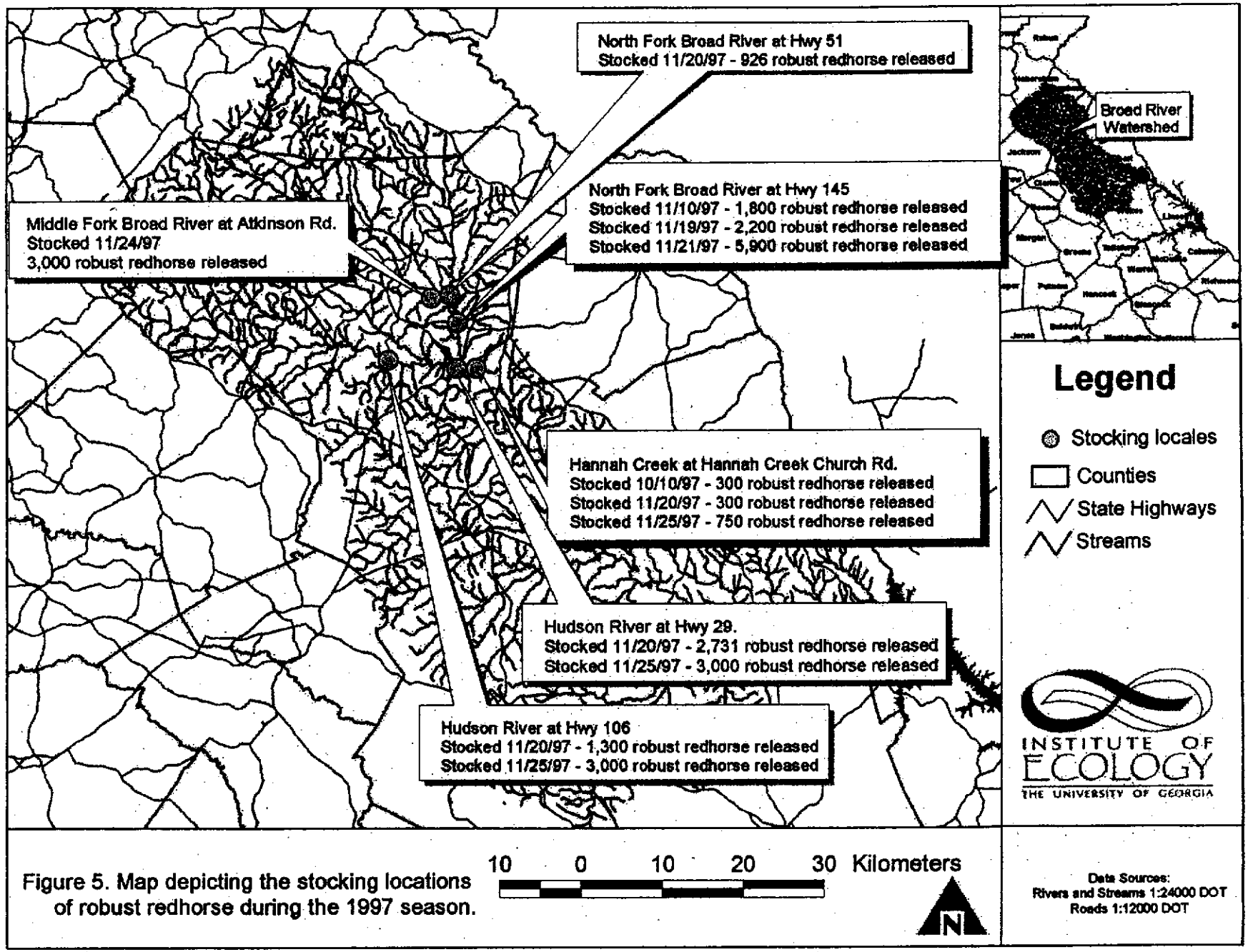

Figure 5. Map depicting the stocking locations of robust redhorse during the 1997 season.

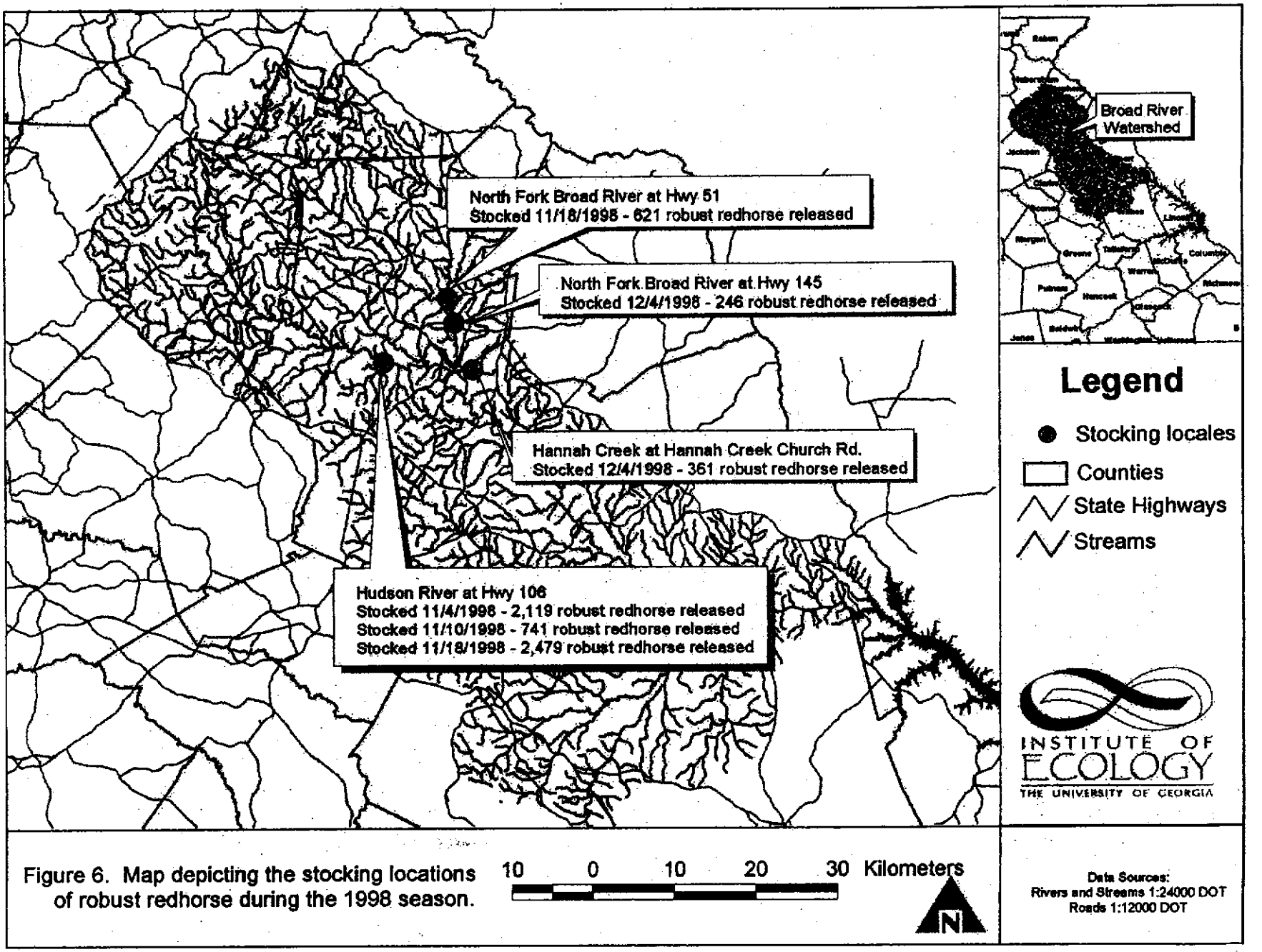

Figure 6. Map depicting the stocking locations of robust redhorse during the 1998 season.

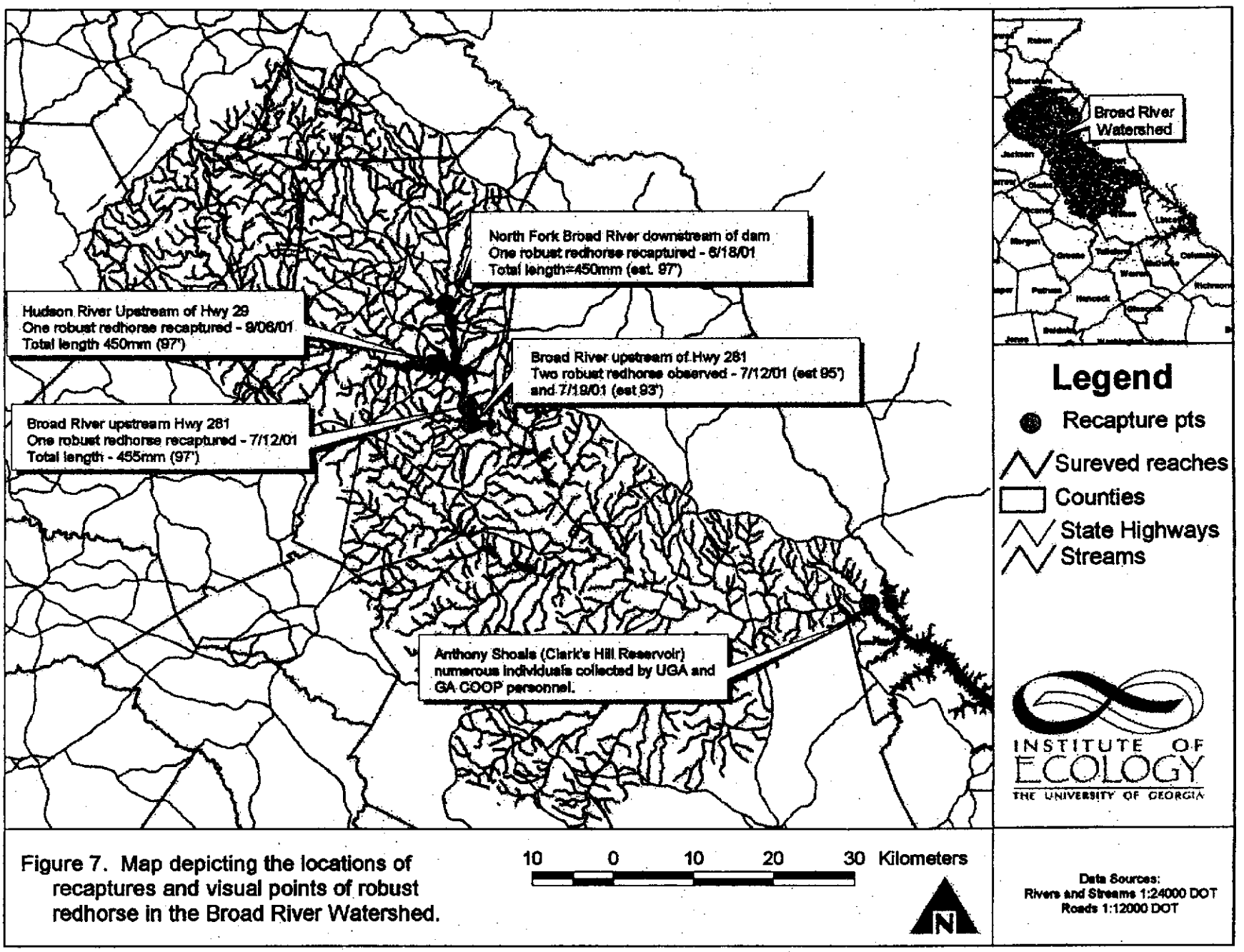

Figure 7. Map depicting the locations of recaptures and visual points of robust redhorse in the Broad River Watershed.

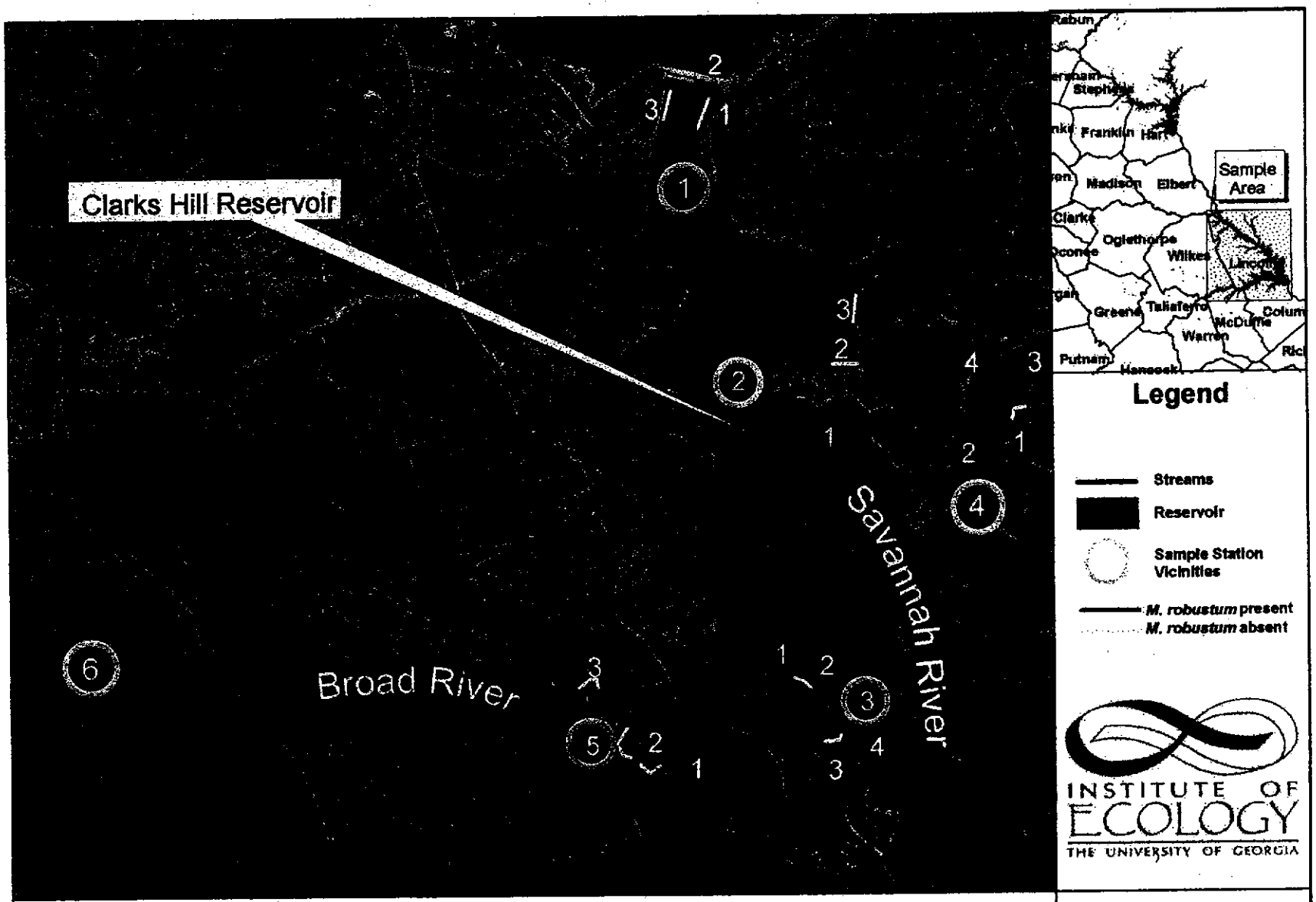

Figure 8. DOQQ black and white image depicting the location of GA COOP sample stations within Clark's Hill Reservoir. Red and yellow lines indicate positions of gill nets (nets are not to scale).

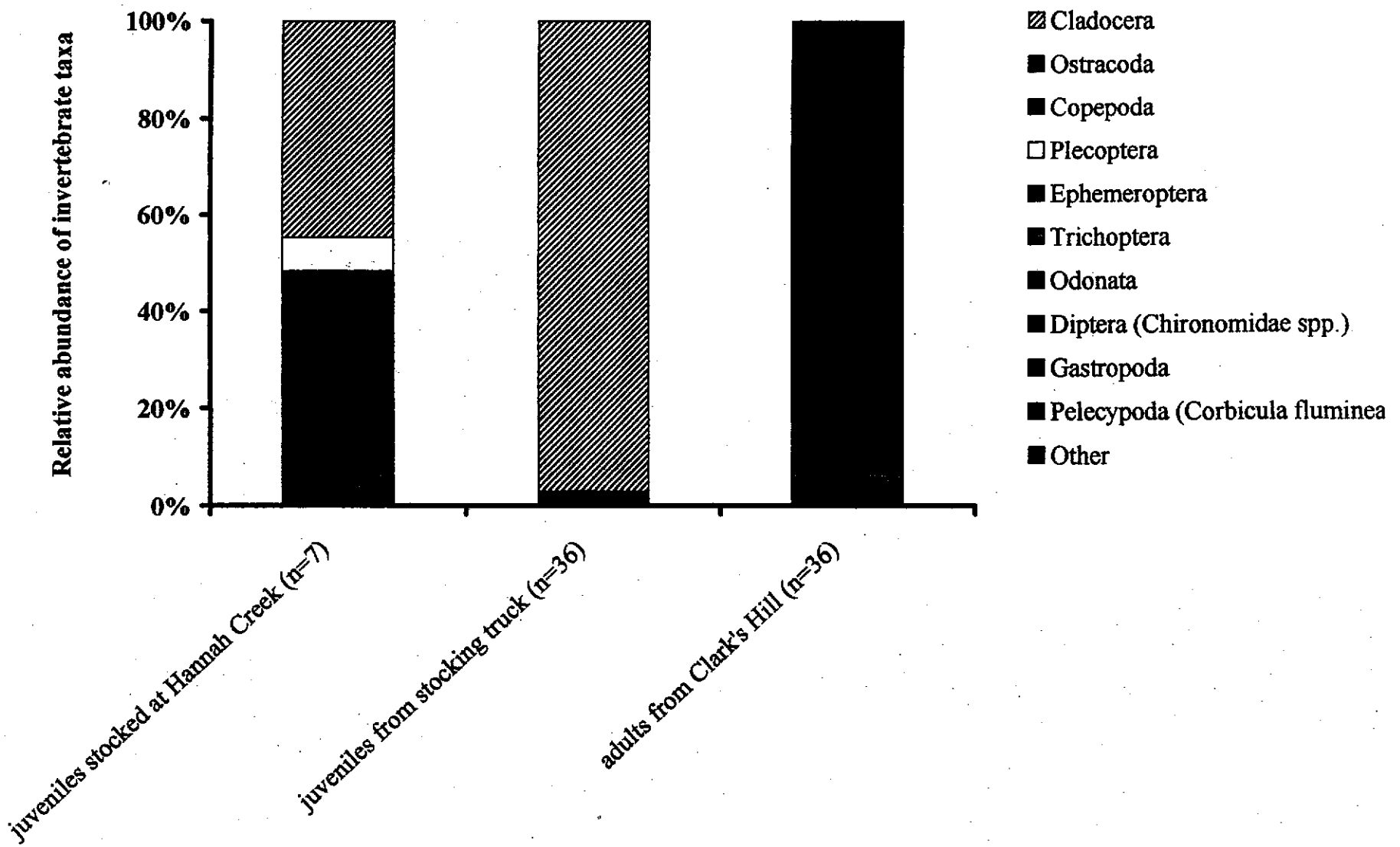

Figure 11. Summary of food habit analysis of robust redhorse collected within the Broad River Watershed and Clark's Hill Reservoir and from the stocking truck.

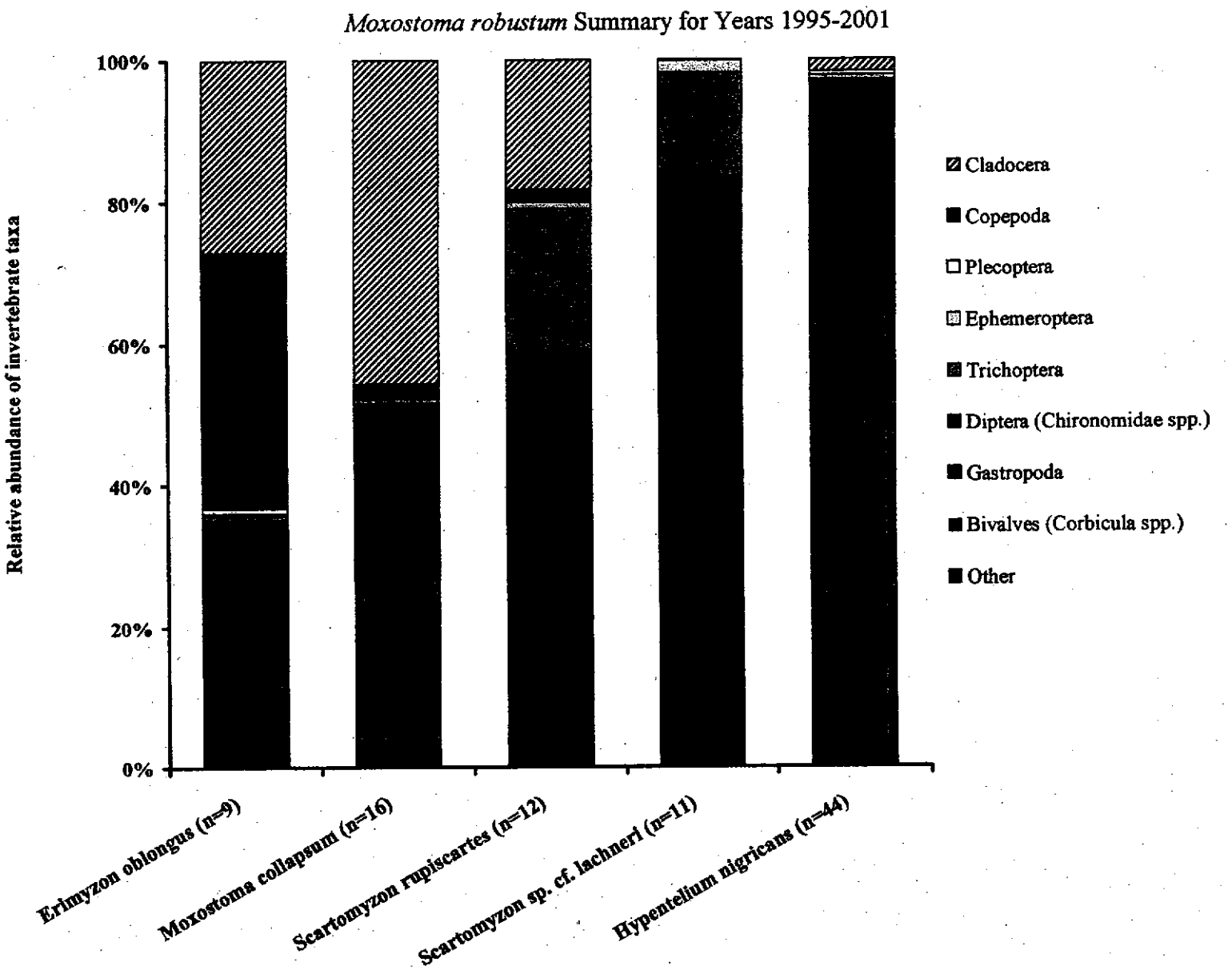

Figure 12. Summary of food habit analysis of catostomids collected in the Broad River and Hannah Creek.

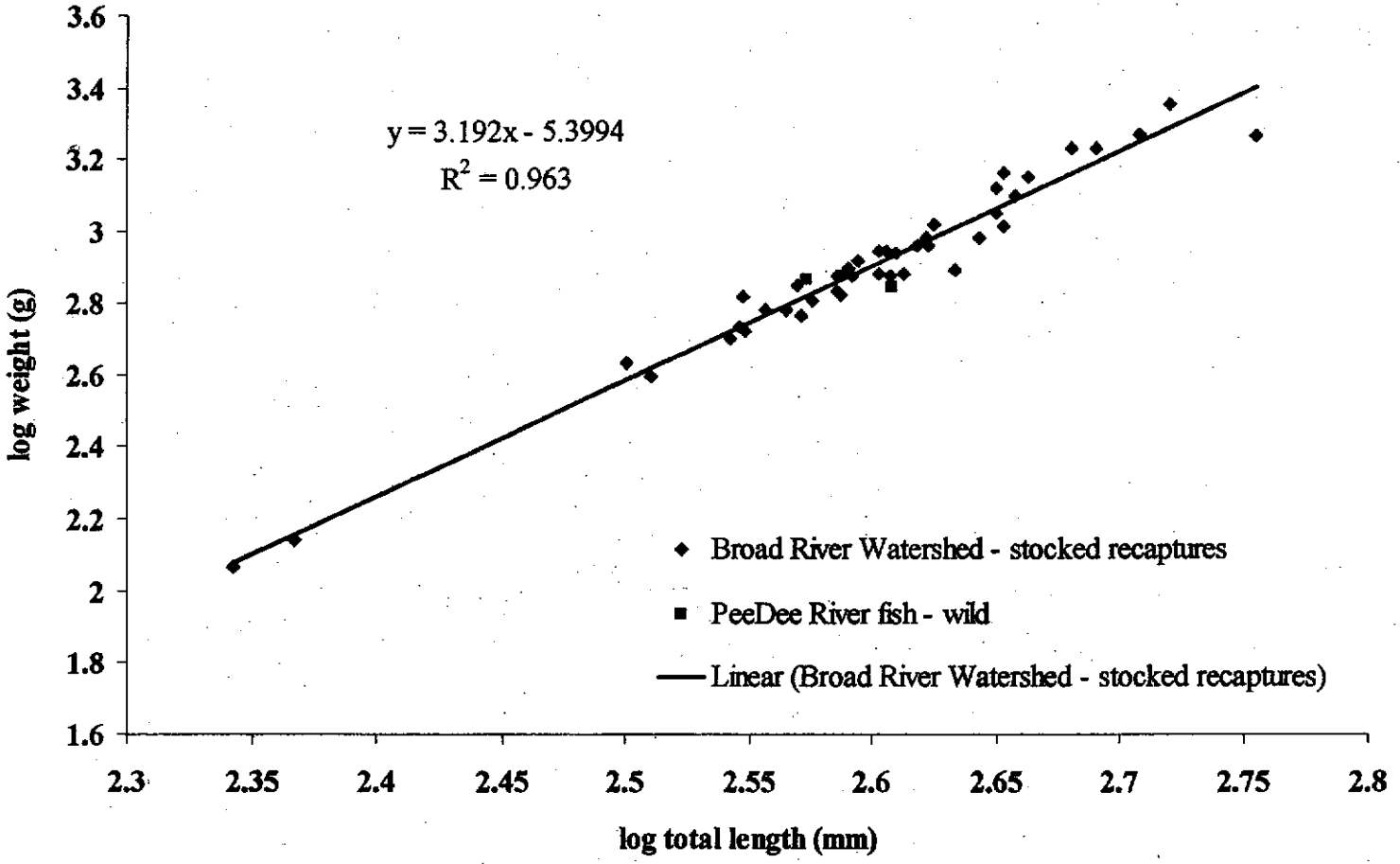

Figure 13. Linear regression of log weight (grams) and log total length (mm) of recaptured individuals. Two wild fish from the Pee Dee River drainage shown for comparison.

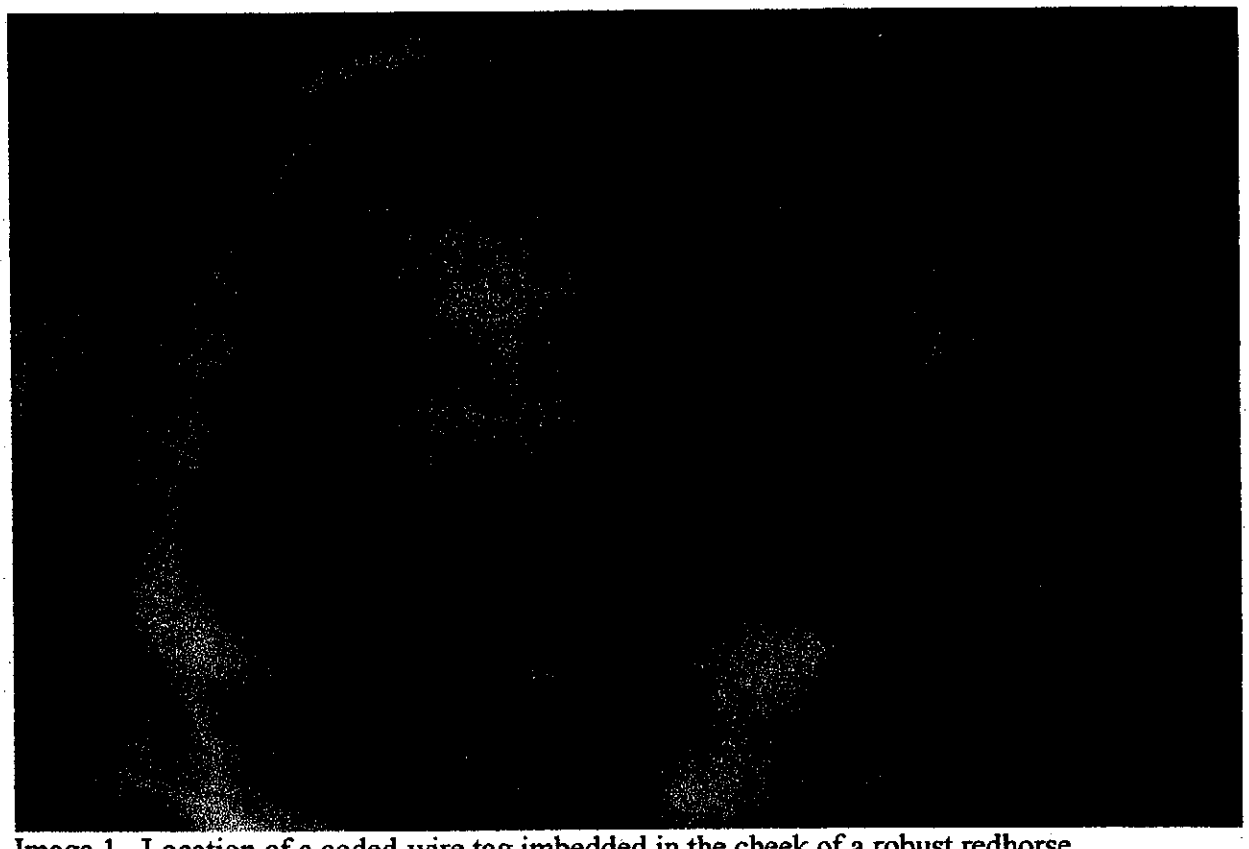

Image 1. Location of a coded-wire tag imbedded in the cheek of a robust redhorse.

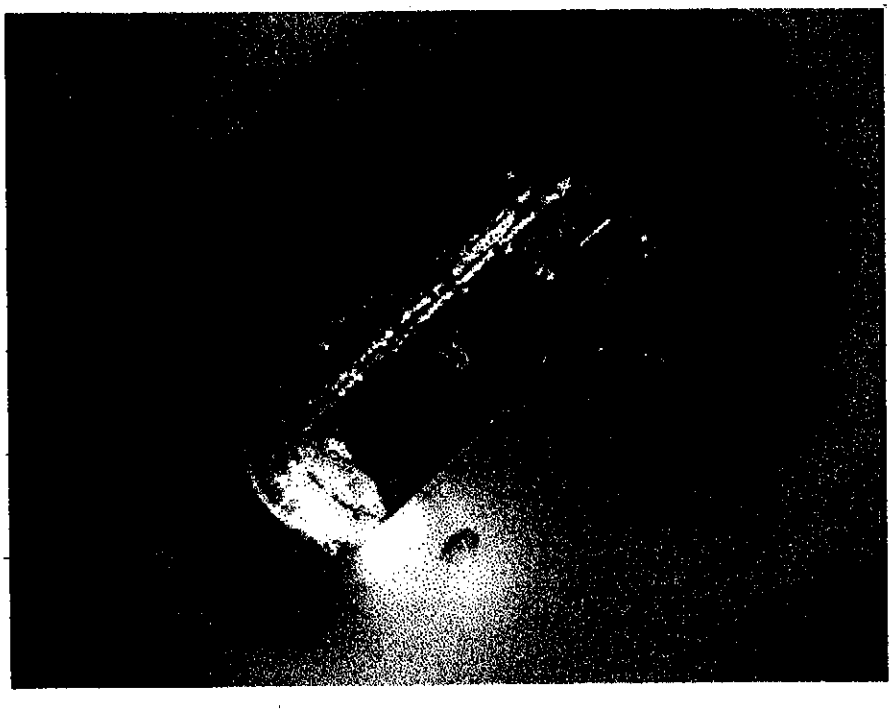

Image 2. A microscopic photo of a coded-wire tag embedded in a robust redhorse specimen. Coded-wire tags are approximately 2mm in length.

Appendix I. Taxonomy of catostomid references within this manuscript.

At present the following combinations of fish names do not appear in the "Common and Scientific Names of Fishes from the United States and Canada, Fifth Edition" (1991): brassy jumprock (*Scartomyzon sp. cf. lachneri*), robust redhorse (*Moxostoma robustum*), and notchlip redhorse (*Moxostoma collapsum*). The taxonomy of both the brassy jumprock and robust redhorse is explained in the introduction. The notchlip redhorse was formerly grouped with the silver redhorse, and will be re-elevated under its new common and previous scientific name in the Sixth Edition of Common and Scientific Names of Fishes from the United States and Canada (R.E. Jenkins, personal communication).

Appendix II. Distances from stocking locations to collection sites within Clark's Hill Reservoir. Distances listed are in river kilometers. Within the reservoir distances were calculated by using the most direct route to each station. Distances in bold denote distances stocked fish have traveled.

Collector	Station number	North Fork Broad at Hwy 51	North Fork Broad near Hwy145, Franklin Springs	Middle Fork Broad at Atkinson Rd	Hudson River at Hwy 106	Hudson River at Hwy 29	Hannah Cr. at Hannah Cr. Church Rd.	South Fork Broad at Hwy 22	South Fork Broad at Watson Mill
GA COOP	1-1	155.5	102.9	109.5	106.5	95.5	95.7	78.6	24.1
GA COOP	1-2	155.7	103.1	109.7	106.7	95.7	95.9	78.8	24.3
GA COOP	1-3	155.5	102.9	109.5	106.5	95.5	95.7	78.6	24.1
GA COOP	2-1	153.1	100.5	107.1	104.1	**93.1**	93.3	76.2	21.7
GA COOP	2-2	153.4	100.8	107.4	104.4	93.4	93.6	76.5	22
GA COOP	2-3	153.6	101	107.6	104.6	93.6	93.8	76.7	22.2
GA COOP	3-1	151.4	98.8	105.4	102.4	91.4	91.6	74.5	20
GA COOP	3-2	151.2	98.6	105.2	102.2	91.2	91.4	74.3	19.8
GA COOP	3-3	150.9	98.3	104.9	101.9	90.9	91.1	74	19.5
GA COOP	3-4	150.8	98.2	104.8	**101.8**	**90.8**	91	73.9	19.4
GA COOP	4-1	153.7	101.1	107.7	104.7	93.7	93.9	76.8	22.3
GA COOP	4-2	153.4	100.8	**107.4**	104.4	**93.4**	93.6	76.5	22
GA COOP	4-3	154.3	**101.7**	108.3	**105.3**	**94.3**	94.5	77.4	22.9
GA COOP	4-4	154	**101.4**	108	105	**94**	94.2	77.1	22.6
GA COOP	5-1	145	92.4	99	96	85	85.2	68.1	13.6
GA COOP	5-2	144.7	92.1	98.7	95.7	84.7	84.9	67.8	13.3
GA COOP	5-3	144.6	92	98.6	95.6	84.6	84.8	67.7	13.2
GDNR	1	197.1	144.5	151.1	148.1	137.1	137.3	120.2	65.7
GDNR	2	196.4	143.8	150.4	147.4	136.4	136.6	119.5	65
GDNR	3	208.9	156.3	162.9	159.9	148.9	149.1	132	77.5
GDNR	4	213.9	161.3	167.9	164.9	153.9	154.1	137	82.5
GDNR	5	190.7	138.1	144.7	141.7	130.7	130.9	113.8	59.3
GDNR	6	219.3	166.7	173.3	170.3	159.3	159.5	142.4	87.9
GDNR	7	224.7	172.1	178.7	175.7	164.7	164.9	147.8	93.3
GDNR	8	225	172.4	179	176	165	165.2	148.1	93.6
GDNR	9	212.8	160.2	166.8	163.8	152.8	153	135.9	81.4

Appendix II. continued.

Collector	Station number	North Fork Broad at Hwy 51	North Fork Broad near Hwy145, Franklin Springs	Middle Fork Broad at Atkinson Rd	Hudson River at Hwy 106	Hudson River at Hwy 29	Hannah Cr. at Hannah Cr. Church Rd.	South Fork Broad at Hwy 22	South Fork Broad at Watson Mill
GDNR	10	207.7	155.1	161.7	158.7	147.7	147.9	130.8	76.3
GDNR	11	201.8	149.2	155.8	152.8	**141.8**	142	124.9	70.4
GDNR	12	184.6	132	138.6	135.6	124.6	124.8	107.7	53.2
GDNR	13	181.6	129	135.6	132.6	121.6	121.8	104.7	50.2
GDNR	14	172.4	119.8	126.4	123.4	112.4	112.6	95.5	41
GDNR	15	177.9	**125.3**	131.9	128.9	**117.9**	118.1	101	46.5
GDNR	16	161.7	109.1	115.7	112.7	101.7	101.9	84.8	30.3
GDNR	17	155.2	**102.6**	109.2	106.2	**95.2**	95.4	78.3	23.8
GDNR	18	160.8	108.2	114.8	**111.8**	**100.8**	101	83.9	29.4
GDNR	19	150.8	**98.2**	104.8	101.8	**90.8**	91	73.9	19.4
GDNR	20	151.5	98.9	105.5	**102.5**	91.5	91.7	74.6	20.1
SCDNR	1	190.1	137.5	144.1	141.1	130.1	130.3	113.2	58.7
SCDNR	2	191	138.4	145	142	131	131.2	114.1	59.6
SCDNR	3	181	128.4	135	132	121	121.2	104.1	49.6
SCDNR	4	174.8	122.2	128.8	125.8	114.8	115	97.9	43.4
SCDNR	5	189.5	136.9	143.5	140.5	129.5	129.7	112.6	58.1
SCDNR	6	189.5	136.9	143.5	**140.5**	129.5	129.7	112.6	58.1
SCDNR	7	191.3	138.7	145.3	142.3	131.3	131.5	114.4	59.9
SCDNR	8	196.8	144.2	150.8	147.8	136.8	137	119.9	65.4
	Anthony Shoals	136.5	83.9	90.5	87.5	**76.5**	76.7	59.6	**51.0**

Appendix III. Preliminary growth tables (weight and total length) of robust redhorse collected from Clark's Hill Reservoir, Anthony Shoals, and the Broad River.