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Sinclair Hydroelectric Project Relicensing Technical Studies:

(FERC Project No. 1951)

Robust Redhorse Report

FINAL

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EXECUTIVE SUMMARY

Georgia Power Company (GPC) conducted studies during 1993 to investigate various life history aspects of the robust redhorse sucker in the Oconee River downstream of Sinclair Dam. The studies were conducted as part of the Federal Energy Regulatory Commission (FERC) relicensing requirements of Sinclair Hydroelectric Project (FERC Project No. 1951). After discovering the robust redhorse in the Oconee River in 1991, state and federal resource agencies requested GPC to conduct a study specific to this species because of its importance of being a potentially new or unidentified species. The study area for this project encompassed an approximately 70 mile strectch of the Oconee River from Milledgeville to Dublin, Georgia. The 70 mile study area was divided into six study segments with segment 1 being the upstream-most segment and segment 6 being the downstream-most segment. The robust redhorse study was designed to identify actual and potential spawning areas, investigate habitat-use by spawning and non-spawning adults, and survey for juvenile robust redhorse.

Actual and potential spawning areas for robust redhorse were identified during and prior to the spawning season. Similar to the other species of redhorse suckers, the robust redhorse appears to build redds in gravel substrate in which they deposit eggs. Because substrate within the Oconee River study are primarily sand with intermittent patches of gravel substrate, the areas of gravel were mapped to identify potential spawning areas. Gravel deposits were comprehensively mapped in study segments 4, 5, and 6, which encompassed most of the areas where robust redhorse had been previously collected. Gravel areas in the remaining three study segments were identified during other field studies conducted by GPC relative to the relicensing process.

The gravel surveys resulted in identification of more extensive gravel deposits than were previously known to occur in the Oconee River study area. Significant deposits of gravel and gravel-armored point bars were found throughout study segments 4, 5, and 6. Additionally, gravel deposits were found throughout Segment 3. Based on the distribution

and extent of the gravel deposits, a sufficient amount of suitable spawning substrate is available at a wide range of flows in the Oconee River, to support the robust redhorse population.

Habitat-use studies of spawning robust redhorse were concentrated in the portions of the study area where gravel substrate had been located. Boat electrofishing surveys for spawning adults were initiated when the water temperature approached 18° C, which was reported by the resource agencies as the critical temperature triggering spawning activity. The distribution of robust redhorse demonstrated that individuals in spawning condition were present from the middle of Segment 2 downstream to middle of Segment 6. Spawning adults were typically found in mid-channel habitat approximately two-thirds of the way around outside bends in the immediate vicinity of gravel deposits. Robust redhorse in spawning condition were collected at depths of 2 to 14 ft, velocities of 0.5 to 2.5 ft/s, and over substrate of coarse sand or gravel. Fish in spawning condition were frequently collected in the vicinity of cover objects.

Habitat-use studies of non-spawning robust redhorse adults were conducted using boat electrofishing over the entire 70 mile study area. Non-spawning robust redhorse were collected in study segments 3, 4, 5, and 6. Non-spawning adults were typically found in close association with cover over a gravel or coarse sand substrate. Depth use varied from 2 to 8 ft and velocity use varied from 0.5 to 2.5 ft/s.

The habitat-use data collected non-spawning adults was used to develop the habitat suitability criteria that were reported in the Habitat Suitability Ciriteria Interim Report (EA 1994) and will be incorporated into the Oconee River IFIM Study. The data for spawning adults was used along with professional judgement to form the basis of the habitat suitability criteria.

Based on the collection locations of both spawning and non-spawning robust redhorse, there appears to be little movement of fish between spawning and non-spawning areas. Additionally, the microhabitat used by the two lifestages is very similar, with the biggest

difference being that non-spawning adults tend to occur in slightly shallower water. Fish in spawning condition were abundant and tended to occur in groups at the locations they were collected. Non-spawning robust redhorse were less abundant and tended to be in groups of no more than 2 to 3 fish.

Juvenile robust redhorse studies were conducted in the middle and lower portions of the study area corresponding to the locations of the majority of the spawning and non-spawning adults. Extensive daytime and nighttime surveys were conducted using a variety of sampling gear. No juvenile or young-of-year (YOY) robust redhorse were collected, although several specimens of juvenile or YOY of other sucker species were collected. The juvenile survey was subsequently extended to include areas downstream of Dublin Georgia . No juvenile or YOY robust redhorse were collected downstream of Dublin.

1. INTRODUCTION

Georgia Power Company (GPC) conducted studies during 1993 to investigate various life history aspects of the robust redhorse sucker (*Moxostoma robustum* Cope 1870) in the Oconee River downstream of GPC's Sinclair Dam near Milledgeville, Georgia (Figure 1-1). This report is one in a series of reports prepared as part of the Federal Energy Regulatory Commission (FERC) relicensing requirements of Sinclair Dam (FERC Project No. 1951). After discovering the robust redhorse in the Oconee River in 1991, the U. S. Fish and Wildlife Service (USFWS) and the Georgia Wildlife Resources Divsion (WRD) requested GPC to conduct a study specific to this species because of its importance of being a potentially new or unidentified species.

The initial scope of work for the robust redhorse study was designed to: 1) identify actual and potential spawning areas; 2) investigate spawning habitat use; and, 3) develop habitat suitability criteria (HSC) for spawning adults (EA 1993). The study scope objectives were accomplished by: 1) mapping potential spawning habitat prior to the spawning season, 2) monitoring spawning activity at selected sites, and 3) determining the range of spawning areas used by spawning adult robust redhorse within the study area. The scope of work was later expanded to evaluate non-spawning habitat-use and a more intense survey for juveniles. The habitat suitability criteria developed as a result of these efforts were provided in the Interim Habitat Suitability Criteria Report along with the HSC developed for additional species, as part of a separate study (EA 1994). The general results of the habitat-use studies are presented and discussed as part of this report.

The remaining sections of Chapter 1 provide background information on the robust redhorse sucker and its taxonomic status and its status as a candidate for federal listing as an endangered species. Specifically, Section 1.2 discusses the rediscovery and description of the species; USFWS rationale for recommendation of federal endangered species status and restoration efforts are discussed in Section 1.3; and, an overview of robust redhorse studies conducted by GPC is contained in Section 1.4.

Chapter 2 describes the study area and methods used for evaluation of the robust redhorse. Chapter 3 provides study results for the gravel surveys (Section 3.1); spawning adult habitat-use (Section 3.2); non-spawning adult habitat-use (Section 3.3); and, juvenile surveys (Section 3.4). Chapter 4 provides a summary and discussion of the study results.

1.1 BACKGROUND

A series of events have occurred since 1991 that have clarified the taxonomy and systematics of the robust redhorse sucker. These events have resulted in the robust redhorse sucker being considered a rediscovered species. Robust redhorse were initially collected in the Oconee River by the WRD during a fisheries survey in August 1991 (Evans 1993). Prior to these collections, the robust redhorse had not been collected (technically documented) for approximately 122 years (Jenkins 1992). Specimens were retained by WRD and tentatively identified by fish taxonomists from the University of Georgia at Athens (B. Freeman) and the U.S. Fish and Wildlife Service National Fisheries Research Center (N. Burkhead) in Gainesville Florida during the fall of 1991. The robust redhorse was subsequently verified as a rediscovery and described in greater detail (Jenkins and Freeman 1993).

The rediscovery prompted the WRD to conduct surveys for the robust redhorse (1992 to present) as part of the management objectives of this species in the Oconee River. Since 1991, the WRD has conducted occasional robust redhorse surveys with assistance and guidance from Noel Burkhead (USFWS, Gainesville, Florida), Byron Freeman (University of Georgia), and Robert Jenkins (Roanoke College, Virginia).

1.2 DESCRIPTION AND CLARIFICATION OF THE NOMENCLATURE OF THE ROBUST REDHORSE

Because the robust redhorse sucker is not a common, widely distributed species, a brief clarification of the nomenclature and a description of the species is presented. The purpose of this section is to identify and describe the robust redhorse clearly to avoid questions

regarding the identity of the species discussed in this report. The robust redhorse sucker (*Moxostoma robustum* Cope 1870) and the river redhorse (*Moxostoma carinatum*) are the two largest members of the *Moxostoma* group (Catostomidae family--suckers). These species are distinguished from other redhorse species by the presence of well developed molariform pharyngeal teeth (food grinding structures located in the pharynx) and associated specializations for crushing molluscs. Male robust redhorse develop cephalic breeding tubercles that are much larger than other closely related species in the group (Jenkins and Freeman in draft). *Ptychostomus robustus* (Cope 1870) was considered a true redhorse sucker (*Moxostoma sp.*) until the name was misapplied by Robins and Raney in 1956 to a jumprock sucker called the smallfin redhorse then named *Moxostoma robustum*. The smallfin redhorse has subsequently been renamed the brassy jumprock (*Scartomyzon brassieus;* Jenkins and Freeman 1993 in draft abstract). The species name *robustum* has been reassigned to the robust redhorse which is the subject of this report.

The geographic distribution of the robust redhorse has been subsequently redescribed by Jenkins and Freeman (1994 draft). Based on historical records, the robust redhorse was known to inhabit medium and large southeastern Atlantic Slope rivers from the Pee Dee River, North Carolina to the Savannah River in South Carolina and Georgia (Jenkins and Freeman 1994 in draft). The robust redhorse was distributed widely on the Piedmont and upper to middle reaches of the Coastal Plain. An 1870 record from the Santee drainage in North Carolina was attributed to this species.

Current information indicates the robust redhorse is either very rare or extirpated from much of its historic range except in the Oconee River, Georgia. The robust redhorse is known to exist in an uneven distribution in the Oconee River from river mile (RM) 86 to RM 138 with the greatest concentration between RM 100 and RM 107 and between RM 86 and RM 92. (The river miles reported in this document are consistent with those developed by the US EPA Office of Integrated Environmental Analysis.) This area is entirely within the geographic scope (approximately river miles 143 to 73) of the studies being conducted by

GPC as part of the relicensing of the Sinclair Project.

1.3 FEDERAL ENDANGERED SPECIES STATUS

Two inter-agency meetings were held between state and federal resource agencies to discuss the status of the Oconee River robust redhorse population. Based on the first meeting, held on September 3, 1993, it was concluded that the status of robust redhorse was precarious due to lack of evidence of successful reproduction. The WRD and USFWS decided to proceed with an endangered species proposal for the robust redhorse. Several months were required to complete the endangered species proposal. During the proposal development period, the WRD and USFWS began the process of developing a robust redhorse management and recovery plan.

The second meeting, held on December 17, 1993, resulted in the decision that there were sufficient reasons to proceed with establishing endangered species status for the robust redhorse. The USFWS stated that archeological and other records infer that the robust redhorse has experienced massive regional extirpation (Burkhead 1993). To date in the Oconee River, robust redhorse have not been collected downstream of Dublin, Georgia. Age structure, as estimated from hard body parts, indicate the Oconee River robust redhorse population is comprised of individuals that vary in age from 8 to 22 years (Burkhead 1993). Based on a WRD mark and recapture study during 1992-1993, an estimated population size of 1,000 to 2,000 robust redhorse exists in the Oconee River. Evans (1993) reported a high standard error in the population estimate attributed to the small sample size of 36 tagged fish and 5 recaptures. Also, the USFWS suggested potential factors, including biological (e.g., predation by flathead catfish), physical (e.g., fluctuating flows) or physicochemical limitations (e.g., water quality) may be inhibiting successful recruitment of the Oconee River robust redhorse population. Currently, there is a lack of empirical data to support any of these hypothesized factors that may be limiting the robust redhorse population.

In summary, the USFWS rationale for listing the robust redhorse as an endangered species is based on its restricted distribution, reduction in range, and unknown effects of predators and physical or physicochemical attributes of the Oconee River on the species (Evans 1993; Butler 1993). The Oconee River population is the only viable population known to date, although surveys for robust redhorse should be conducted in other river drainages in the southeast (e.g., Broad River, Georgia) in an attempt to locate additional populations. The recovery plan has not been finalized, but preliminary recommendations include establishing new populations in other rivers with artificially propagated stocks (e.g., brood stock in hatchery operations) and continued research on habitat requirements, especially for young-of-year (yoy), juveniles, and spawning. The WRD plans to implement a short-term recovery plan in 1994 due to the emphasis added by the recent elevation of the robust redhorse to protected status in Georgia (Evans 1994--personal communication). The WRD is currently evaluating the best rivers in which to stock hatchery-reared robust redhorse.

An informal robust redhorse research committee of the USFWS recently (7 March 1994) distributed a memorandum that identified critical objectives for robust redhorse recovery and research needs (Walsh 1994). The committee's current objectives include distribution and abundance monitoring, habitat and stream flow assessments, post-spawn studies, behavior and diet studies, culture studies, applied research, and establishment of experimental populations. These topic areas are recognized by the committee as important tools for management and research of the robust redhorse, but currently a mechanism to implement these plans has not been established.

1.4 OVERVIEW OF ROBUST REDHORSE STUDIES CONDUCTED BY GPC

Table 1-1 provides a checklist of activities that were focused specifically at robust redhorse and those that incidentally encountered robust redhorse (e.g., 1992 Oconee River Fish Resource Studies; Table 1-1). The studies summarized in Table 1-1 were conducted from May through December, 1993. Specific tasks were designed to map gravel habitats potentially used for spawning (April-May); monitor spawning readiness (April-May); identify distribution and abundance of spawning robust redhorse and quantify the habitat used for spawning (May-June). The study scope was later expanded to identify the distribution and abundance of non-spawning robust redhorse and quantify their habitat use (August-October); and, identify juvenile robust redhorse and quantify their habitat use (September-December).

Based on the spawning requirements of closely related suckers, gravel substrate is thought to be a requirement for spawning. Gravel deposits in the Oconee River below Sinclair Dam were initially described by the WRD in an 8 January 1992 letter to EA (Evans 1992). Gravel mapping surveys were conducted before and during the early robust redhorse spawning season, 6 to 8 February and 27 to 28 April 1993. The purpose of these surveys was to identify the occurrence of gravel deposits that might function as robust redhorse spawning sites. The spawning habitat studies were then concentrated at locations that were identified to have substantial gravel deposits.

Three field efforts were conducted during April and early May 1993 (Table 1-1) with the objective of monitoring the reproductive and spawning readiness of robust redhorse to ensure that habitat use study was conducted during the peak of the spawning season. Subsequently, fish collections were conducted from 18 to 22 May 1993 with the objectives of determining the range of areas used by spawning robust redhorse within the study area, identifying general macrohabitat characteristics of areas used for spawning, and quantifying the physical microhabitat used by spawning individuals.

Field surveys were conducted from 27 September through 1 October 1993 and 7 to 10 December 1993 with the primary objective of determining the presence of juvenile robust redhorse in the lower reaches of the study area. The lower study area (Segments 4, 5, and 6; Figure 1-2) was sampled because most of the identified spawning habitat and subsequent spawning activity occurred in this portion of the river. This survey targeted specific habitats which were mostly point bars with gravel deposits and relatively shallow, low velocity habitats. These habitats were targeted because these are the preferred habitats of young fish of related species.

Seven surveys to quantify habitat use of all fish species were conducted between mid-May and mid-October 1993 (Table 1-1) for spawning and non-spawning fishes. Ten non-spawning adult robust redhorse were collected during these surveys (Table 1-1). Additionally, three seasonal fish resource surveys were conducted during 1992 that included robust redhorse as incidental catches. Those data are incorporated in this report where appropriate.

Figure 1-1. Location of the Oconee River study area near Milledgeville, Georgia.

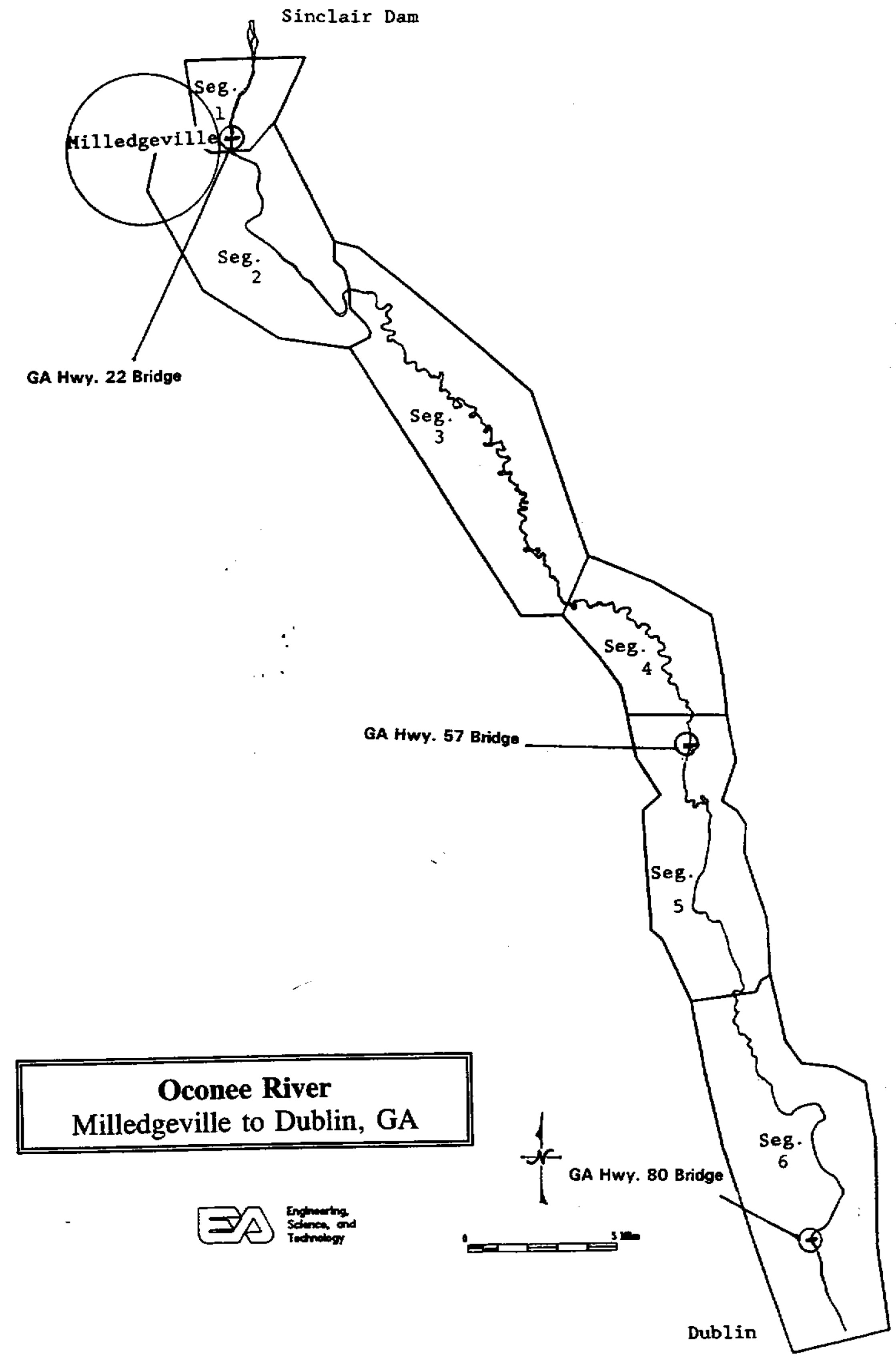


Figure 1-2. Six survey segments of the Oconee River study area.

TABLE 1-1 CHECKLIST OF ROBUST REDHORSE AND ASSOCIATED SURVEYS ON THE OCONEE RIVER, 1992 - 1993

SURVEYS	DATE	GEAR TYPE(S)	DATA COLLECTED	SAMPLE LOCATION	SAMPLE FREQUENCY	NUMBER COLLECTED	SIZE RANGE (mm)	TIME OF COLLECTION
Oconee River Fish Resource Standard Surveys	22-28 JUN 1992 (7 Days)	Boat electro-fishing ~4-6 AMPS ~500-840 V DC	Fish: length, weight, sex. Water: temp., pH, cond., and DO. Habitat: substrate, cover, velocity, bank and channel type.	Fish study segments Kaolin mines to below Hwy 57 bridge RM 95 to RM 121	6 x 30-min reps. at six locations from Milledgeville to Dublin, GA.	10 adults	542 - 630	Daytime 1100 - 1700 hrs
Oconee River Fish Resource Standard Surveys	16-22 SEP 1992 (7 DAYS)	Boat electro-fishing ~4-6 AMPS ~500-840 V DC	Fish: length, weight, sex. Water: temp., pH, cond., and DO. Habitat: substrate, cover, velocity, bank and channel type.	Fish study segments Kaolin mines to below Hwy 57 bridge RM 85 to RM 121	6 x 30-min reps. at seven locations from Milledgeville to Dublin, GA.	16 adults	430 - 687	Daytime 0930 - 1800 hrs
Gravel Mapping	6-8 FEB and 27-28 APR 1993 (4 Days)	Visual, ponar, and probes.	Habitat variables including substrate depth, velocity, riparian, woody debris, bank stability,	Segments 5 and 6 RM 75 to RM 99	Daily mapping, throughout area.	--	--	
Spring Spawning and Anadromous Fish Surveys -- Trip No. 1	26-30 APR 1993 (5 DAYS)	Boat electro-fishing ~3-4 AMPS ~400 V DC	Fish: length, weight, sex. Water: temp., pH, cond., and DO. Habitat: substrate, cover, velocity, bank and channel type.	From Sinclair Dam to Dublin RM 75 to RM 104 Most specimens from between Central RR and Hwy 57 Bridge RM 99 to RM 105	Non-specific daily delineation 8.83 hrs shock time.	8 adults	597 - 677	Daytime 1100 - 1630 hrs
Spring Spawning and Anadromous Fish Surveys -- Trip No. 2	5 MAY 1993 (1 DAY)	Boat electro-fishing ~3-4 AMPS ~400 V DC	Fish: length, weight, sex. Habitat: substrate, cover, velocity, depth bank and channel type.	From Buzzard Is. to Hardwick boat ramp RM 136 to RM 141	Non-specific daily delineation 2.47 hrs shock time.	2 adults	637 - 641	Daytime 1200 - 1700 hrs

TABLE 1-1 (CONT.)

SURVEYS	DATE	GEAR TYPE(S)	DATA COLLECTED	SAMPLE LOCATION	SAMPLE FREQUENCY	NUMBER COLLECTED	SIZE RANGE (mm)	TIME OF COLLECTION
Spring Spawning and Anadromous Fish Surveys -- Trip No. 3	18-22 MAY 1993 (5 DAYS)	Boat electro-fishing ~4 AMPS ~840 V DC	Fish: length, weight, sex, anomalies. Habitat: substrate, cover, velocity, and depth.	From vicinity of Thiele kaolin mines to East Dublin, GA RM 77 to RM 120	Non-specific daily delineation 21.5 hrs shock time	49 adults plus 13 observed	561 - 682	Daytime collections
Young of year and Juvenile Surveys -- diurnal	27 SEP - 1 OCT 1993 (5 DAYS)	25 ft bag seine w/ 1/4 in. mesh and boat electro-fishing	Checklist of all species collected plus length, weight, sex, anomalies,	From Central GA RR to Dublin, GA RM 75 to RM 105	Habitat specific: meanders, shallows, and gravel bars.	4 adults	592 - 645	Daytime collections
Habitat Suitability Non-transect Surveys	5-8 OCT 1993 (4 DAYS)	Boat electro-fishing ~3-4 AMPS ~400 V DC	Fish: length Habitat: substrate, cover, velocity, depth, and distance to complex cover.	Segments 5 and 6 RM 75 to RM 99	Random non-transect sampling.	10 adults	614 - 701	Daytime
Young of year and Juvenile Non-transect Surveys -- nighttime	7-10 DEC 1993 (4 DAYS)	20 ft bag seine w/ 1/4 in. mesh; 10 ft seine w/ 3/16 in. mesh, boat electro-fishing output ~4-5 AMPS ~700 V DC	Checklist of all species collected plus length, weight, sex, anomalies, substrate, cover, and depth for robust redhorse. Water temp., pH, DO, and cond.	From Central GA RR to Hwy 57; and below Dublin between Hwy 16 and Hwy 46 RM 83 to RM 104 and RM 40 to RM 63	Habitat specific: shallows and , gravel bars. 86 seine hauls and 1.25 hrs shock time	0	—	Nighttime 1830 - 0100 hrs
HSC Transect Survey	May 16-22, 1993 (7 days)	Boat electro-fishing ~3-4 AMPS ~400 V DC Seine and Visual	Fish: length, weight. Water: pH,cond.,and DO. Habitat: sub., cover, vel.	RM 115 to RM 140 RM 75 to RM 94	transect orientated	0	—	Daytime

TABLE 1-1 (CONT.)

SURVEYS	DATE	GEAR TYPE(S)	DATA COLLECTED	SAMPLE LOCATION	SAMPLE FREQUENCY	NUMBER COLLECTED	SIZE RANGE (mm)	TIME OF COLLECTION
HSC Transect Survey	June 2-6, 1993 (5 days)	Boat electro-fishing ~3-4 AMPS ~400 V DC Seine and Visual Observation	Fish: length, Water: pH,cond.,and DO. Habitat: substrate, cover velocity	RM 94 to RM 110	transect orientated	0	—	Daytime
HSC Non-transect Survey	July 6-9, 1993 (4 days)	Boat electro-fishing ~3-4 AMPS ~400 V DC and Visual Observation	Fish: length, Water: pH,cond.,and DO. Habitat: substrate, cover velocity	RM 115 to RM 140 RM 75 to RM 99	Non-specific daily delineation	0	—	Daytime
HSC Non-transect Survey	August 9-13, 1993 (5 days)	Boat electro-fishing ~3-4 AMPS ~400 V DC Seine and Visual Observation	Fish: length, Water: pH,cond.,and DO. Habitat: substrate, cover velocity	RM 130 to RM 140 RM 99 to RM 110	Non-specific daily delineation	0	—	Daytime
HSC Non-transect Survey	August 18, 1993 (1 day)	Seine and Visual Observation	Fish: length, Water: pH,cond.,and DO. Habitat: substrate, cover velocity	RM 140 to RM 143	Non-specific daily delineation	0	—	Daytime
HSC Non-transect Survey	Sept. 21-24, 1993 (4 days)	Boat electro-fishing ~3-4 AMPS ~400 V DC Pram and backpack shock and Seine	Fish: length, Water: pH,cond.,and DO. Habitat: substrate, cover velocity	RM 140 to RM 143 RM 115 to RM 123	Non-specific daily delineation	0	—	Daytime

2. METHODS

2.1 DESCRIPTION OF STUDY AREA

The robust redhorse study encompassed approximately 70 miles of the Oconee River from Sinclair Dam downstream to Dublin, Georgia (Figure 1-2) representing both the Piedmont and Coastal Plain physiographic zones. The upper study area is characterized by rock shoals, outcrops, and deep pools typical of the Fall Line. The lower study area is within the upper Coastal Plain physiographic region that begins approximately four miles downstream of Sinclair Dam and is characterized by predominantly sand substrates, alternating sand bars, runs, meanders, occasional gravel beds, and bedrock outcrops.

The study area was divided into six segments by classifying the macro- and mesohabitats as part of the instream flow study being conducted as part of the relicensing process. To provide consistency among the technical reports being prepared as part of the relicensing of Sinclair Project, those segments used in the instream flow study are referenced in this report. General descriptions of the physical habitat of each of the study segments are described in Table 2-1. Gradient is consistent along the study area averaging 1.29 ft/mi, however, gradient in the immediate vicinity of the Fall Line (Segment 1) is significantly higher at 5.69 ft/mi. Numerous small tributaries enter the Oconee River throughout the study area and extensive swamps, oxbows, and floodplains border the Oconee River in the middle and lower study area.

2.2 GRAVEL MAPPING

Gravel mapping was conducted from February 6 to 8 and 27 to 28 April 1993 to document and map the occurrence of gravel deposits. Gravel mapping was conducted by boat throughout Segments 4, 5 and 6 encompassing most of the areas where robust redhorse had previously been collected. Substrate composition was classified via visual examination, ponar grab samples, and probing. Samples for sieve analysis were collected by shovel near the mid-point on point bars and at areas with coarse armor substrate. Occurrence of gravel and non-gravel substrates was documented on mylar map reproductions of the river channel and coded to appropriate data sheets. In addition to substrate type, qualitative descriptions of meso-habitat, amount of woody debris, density of riparian vegetation, water velocity, bank stability, and approximate depth range were recorded.

2.3 FISH AND HABITAT-USE DATA COLLECTION

Two general sampling designs were used to collect habitat-use data for the lifestages of robust redhorse being studied (spawning adult, non-spawning adult, and juvenile). These designs combined fish collection efforts with habitat data collection to document habitat associated with the presence and/or absence (for transect-based sampling) of robust redhorse.

Transect sampling (Section 2.3.1) provided habitat-use data from discrete, quantified areas within homogeneous habitat types, at a fixed position within the stream channel, for spawning and non-spawning adult robust redhorse. The transect-based samples included habitat data collected at the identified sites regardless of the presence/absence of robust redhorse in the transect-specific fish collections.

Non-transect sampling provided habitat-use data for robust redhorse from homogeneous habitat types but was not conducted at pre-selected quantifiable areas. The non-transect based sampling method was designed to only record microhabitat measurements at locations where fish were collected.

Descriptions of fish collection and habitat measurement methods employed are described in the following sections. Fish surveys and gear types are summarized in Table 1-1. The occurrence and location of individual robust redhorse and corresponding microhabitat measurements (e.g., depth, velocity, substrate, cover type) were recorded on location maps

and data sheets. Physicochemical measurements including water temperature, dissolved oxygen, pH, and conductivity were recorded on a daily basis.

Spawning adult robust redhorse surveys throughout the study area were conducted from 26 to 30 April, 5 May, 19 to 23 May, and 18 to 22 May 1993 (Table 1-1). Non-spawning adult robust redhorse surveys throughout the study area were conducted from 9 to 13 August, 21 to 24 September, 5 to 8 October, 21 to 29 October 1993 (Table 1-1). Daytime and nighttime surveys for juvenile robust redhorse in portions of Segments 4, 5, and 6. Due to the unsuccessful results of collecting juvenile robust redhorse within the defined study area, GPC decided to expand the survey downstream of Dublin. Sampling geared specifically for juveniles was conducted 10 miles and 23 miles downstream of Dublin.

2.3.1 Transect-Based Sampling

Transect-based sampling was used to collect data for spawning and non-spawning adult robust redhorse throughout the study area.

Sampling Design: One or two relatively small target areas of 1 to 2 mi in length were selected from aerial photographs prior to sampling within each of the six river segments. The areas sampled were selected to include areas that were representative of the majority of the available habitat within the selected river segment. If possible, sample areas were selected relatively close to boat ramps to minimize boat travel time and maximize sampling effort. Eight cross-channel transects were randomly placed within target habitat areas. Four sample events were conducted at each transect to determine presence of fish and to record associated microhabitat. The four samples were distributed as follows: one sample on the left bank (facing downstream); one sample at one third of the river width; one sample at two thirds of the river width; and one sample on the right bank. Either the right or left bank sample was collected 5 ft from the bank so as not to over-represent the shoreline habitat.

Fish Collection: Sampling gear included boat or pram electrofishing and seining. Electrofishing was conducted with a boat operated, boom-mounted Smith-Root Electrofisher VI or Coffelt VVP-15 pulsator. Boat electrofishing was conducted in an upstream direction along 85-ft long longitudinal transects placed on the cross-stream transect with the up- and down stream ends of the transect marked with floats. One biologist operated the boat while an assistant netted stunned specimens. A third crew member marked, as accurately as possible, the first observed location of a robust redhorse with a weighted, numbered float.

Bag seines (25 ft x 3/8 in. mesh) were deployed in a pivot sweep fashion (arc) from upstream to downstream along transect sample points. The perimeter and middle of sample area were marked with floats or stakes, to delineate the boundaries of the sample.

All captured fish were measured for total length (nearest mm), weighed (nearest gm), and released on site. For fish collected by electrofishing, fish locations were mapped using position of the weight on the bottom of the stream as a locator. For fish collected by seine, multiple habitat measurements were recorded from the area that was seined, because it was not possible to mark the exact collection location.

Microhabitat Measurement: Microhabitat variables were measured for 6 to 8 locations evenly distributed along each electrofishing transect and 3 to 6 measurements within each seine haul area. Microhabitat variables were recorded regardless of the presence or absence of fish. Measurements included water depth, mean water column velocity, dominant substrate type, and dominant cover type using a standardized format. Water depth was measured with a wading rod marked in increments of tenths of feet. Current velocity was measured by means of a transducer type current meter at 0.6 of the distance from the surface to the bottom for depths less than 2.5 ft. Velocities for depths greater or equal to 2.5 ft were averaged by measurements at 0.2 and 0.8 of the distance from the surface to the bottom. Substrate types were characterized visually or by probing the bottom with a wading staff when depths or turbidity exceeded visual estimation. Cover was estimated visually or with a probe depending on the circumstance and coded on appropriate data sheets. Other

information collected and recorded on data sheets included distance to cover, other species collected, and distance to bank.

2.3.2 Non-transect Based Sampling

Sampling Design: Non-transect based sampling was conducted throughout the study area and provided fish habitat-use data for habitat types present in 1 to 2 mile stretches of river, as well as specific habitats where fish spawning or nesting was observed. Homogeneous habitat types were marked either visually or through the use of marker flags or floats to delineate target habitats. Each target habitat was sampled without bias towards physical attributes of the target habitat. For example, shallow sandy substrates with no cover were sampled with similar effort as shallow sandy substrates with cover. Gear types were the same as those described above for transect-based sampling.

Fish Collection: Prior to sampling, each target habitat was inspected visually for uniformity (similar depth, cover, velocity, substrate, etc.). As target habitats were sampled, the collection locations of individual robust redhorse were marked with weighted, numbered floats. The collection location, as marked, was the spot where the fish was first observed, not necessarily the actual capture location. Sampling locations adjacent to previously sampled areas were allowed to remain undisturbed for at least 20 minutes before sampling resumed and fish samples from prior collections were released downstream and away from those areas yet to be sampled. Equipment and sample handling for adult robust redhorse were the same as those described for transect sampling.

The same methods as described for transect-based habitat data collection (Section 2.3.1) to collect microhabitat data for adult (spawning and non-spawning) and juvenile fishes were used, except that habitat data were collected at only one location. Microhabitat variables were measured at the position of each marker-float and weight. During instances when the exact location of individual specimens could not be easily determined, a rectangular habitat grid (dimensions varied depending on cover) was visually centered over the sample location to represent the area of capture. Five evenly placed microhabitat measurements were recorded within the grid that yielded an average value for each microhabitat variable.

2.4 JUVENILE ROBUST REDHORSE SURVEYS

Juvenile robust redhorse surveys focused on specific habitat (e.g., point bars with gravel). Fish collections were conducted using seine nets or boat electrofishing as described for non-transect sampling. Microhabitat data were obtained by non-transect methods previously described. No habitat data were collected if robust redhorse were not collected. Juvenile robust redhorse surveys employed bag seines varying in length from 10 to 25 ft with mesh sizes ranging from 3/16 to 1/4 in. Boat electrofishing was used to sample habitats that were too deep or too densely covered with woody debris to efficiently seine. Methods of boat operation, fish handling, location mapping, and data recording were the same as those described in Section 2.3.1.

TABLE 2-1 DESCRIPTION OF OCONEE RIVER STUDY AREA

Segment 1: Sinclair Dam (RM 0.0) to Highway 22/24 Bridge (RM 4.2)

Segment 1 is in the Fall Zone where the Oconee River is wider and steeper than downstream areas. River gradient averages about five feet per mile in Segment 1 as compared with one to two feet per mile in most downstream segments. The river course is primarily straight, river width averages about 345 feet and low-flow depths are generally four to eight feet except for the rocky shoals (average depth of one foot) and some very deep areas (up to 21 feet). Several small tributaries enter in this segment. Segment 1 is characterized by several long runs of variable depth divided by short rocky shoals. Substrates are varied; bedrock and sand substrates predominate and gravel and cobble are common. Cover in this section is predominately bedrock ledges and boulder with occasional woody debris. An old diversion dam immediately upstream of the Highway 22/24 Bridge constitutes a prominent feature in this segment.

Segment 2: Highway 22/24 Bridge (RM 4.2) to Ginhouse Lake (RM 14.0)

Segment 2 occurs in the upper region of the Fall Line Hills District (Hodler and Schretter 1986), between the Piedmont and upper Coastal Plain, and encompasses the transition from a bedrock-controlled channel to a meandering, sand-dominated, alluvial channel. The river course in Segment 2 is dominated by one 4.4-mile straight reach and the channel is well constrained; gradient in this section averages about two feet per mile. River width averages about 310 feet and depths are generally shallow (averaging two to four feet at low flow) with occasional deeper areas (seven to nine feet) along the banks and infrequent deep runs. Several small tributaries enter in this segment. Segment 2 is characterized by shallow runs with alternating, shifting sand bars and occasional point bars. Substrates are dominated by sand and small gravel, with occasional bedrock outcrops and large boulder substrates occurring primarily in the middle of the segment. Woody debris comprises the dominant cover type but is not abundant throughout the segment; boulders and ledges occur infrequently.

Segment 3: Ginhouse Lake (RM 14.0) to Black Creek (RM 35.3)

In Segment 3, the Oconee River is a sand-dominated, meandering, alluvial river with an extensive low-lying floodplain. River gradient averages about 1.5 feet per mile, river width averages about 270 feet, and depths are highly variable ranging at low flow from an average of two to three feet in shallow runs to seven to nine feet in the deeper portions of meanders. Habitat is generally a repetitive sequence of shallow to moderate depth runs and point bars with steep unstable outside banks. Associated with the point bars are backwater areas which are typically of limited area but which are occasionally large. Substrates are dominated by sand and small gravel, but silt and clay are also abundant and often occur in consolidated masses may appear as broken bedrock, cobble, or gravel. Gravel is common in this segment and is most abundant on the upstream face of point bars, at mid-channel about two-thirds of the distance around meander bends, and in some run areas. Instream cover consists of areas of woody debris, concentrated along the banks on outside banks of meanders and shallow runs between meander bends. About 10 oxbow lakes occur between RM 26.0 and RM 36.0 in this segment which are recently abandoned portions of the river channel and which are connected to the river at low to moderate flows.

Segment 4: Black Creek (RM 35.3) to Vicinity of Highway 57 Bridge (RM 46.5)

Segment 4 is essentially similar to Segment 3, but the channel is somewhat less steep (gradient of approximately one foot per mile), wider (average width is 300 feet), and less sinuous, and the point bars and associated backwaters are less extensive. Two large tributaries enter in this segment; Buffalo Creek (RM 40) and Commissioners Creek (RM 44). As in Segment 3, sand, silt, and small gravel predominate, but large gravel commonly occurs throughout the segment on the upstream face of point bars, at mid-channel about two-thirds of the distance around meander bends, and in some run areas. Oxbows are less frequent in this segment, suggesting a more stable channel.

Segment 5: Vicinity of Highway 57 Bridge (RM 46.5) to Vicinity of Flat Creek (RM 59.8)

In Segment 5, the Oconee River has a relatively straight, geologically-controlled, river channel with a low-lying but narrower floodplain and generally stable banks. Segment 5 is characterized by three straight reaches of river channel which are narrow and relatively deep. These straight reaches are divided by short reaches of wider, meandering river channel with habitat nearly identical to Segment 4. Habitat in this segment is dominated by runs of moderate depth (three to seven feet); alternating runs and point bars occur in the meanders. Gradient is about two feet per mile and channel width ranges from about 235 in straight reaches to about 265 in meanders. Substrate is predominately coarse and fine sand and small gravel with occasional areas of large gravel; areas with bedrock, cobble and boulder substrates occur occasionally. Cover consists almost entirely of woody debris, which is most abundant in meanders. Cypress roots become an important cover feature in the lower reaches of this segment.

Segment 6: Vicinity of Flat Creek (RM 59.8) to Highway 80 Bridge (RM 69.0) at Dublin

Segment 6 of the Oconee River, begins as a short series of meanders with an extensive low-lying floodplain and relatively unconfined channel and ends as a relatively straight and geologically-confined series of reaches. The channel has an average gradient of about three feet per mile, channel width is approximately 250 feet, and with the exception of the upper reaches the banks are stable. Average depths at low flow range from two to five feet throughout the segment. Habitat in the upper reaches of Segment 6 is dominated by alternating runs and point bars; runs of variable depth dominate the lower reaches and short rocky shoals occur infrequently. Substrates in Segment 6 are highly variable; sand, gravel, and bedrock are the primary constituents and cobble occurs occasionally throughout. The banks in this section are steep and instream cover is generally less abundant than upstream segments and consists of snags, log piles, occasional downed trees, and cypress roots.

3. RESULTS

Figure 3-1 is a map showing the location of the six study segments in relation to Sinclair Dam and functions as a key to the distribution of robust redhorse in the study area. The text frequently references locations of individual robust redhorse by river mile and each individual robust redhorse collection location is referenced in Figure 3-2. Figure 3-2 is a nine page enlargement of Figure 3-1. Table A-1 (Appendix A) provides a record of collected or visually observed robust redhorse and it serves as a cross-reference to Figure 3-2 by serial numbers.

3.1 GRAVEL MAPPING

The WRD and USFWS reported that gravel deposits were thought to be critical habitat for spawning robust redhorse (Evans 1992). Figure 3-2 shows the locations of significant gravel or gravel/sand composite substrates encountered during the gravel surveys. The gravel surveys resulted in discovery of more extensive gravel deposits than originally identified by the WRD (Evans 1992). Significant deposits of gravel and gravel armored point bars were found throughout the lower study area between RM 104.4 (Central of Georgia Railroad bridge) and RM 75 (Dublin). Significant gravel deposits occurred in Segment 5 between RM 95 and RM 97 (Figure 3-2, sheet 7 of 9) along the alternating point bars found in Segment 4 between RM 100 and RM 104 (Figure 3-2, sheet 6 of 9), and the upper section of Segment 6 between RM 84 and RM 85 (Figure 3-2, sheet 8 of 9). Deposits of medium to large-sized gravel occurred frequently in the mid-channel areas of meandering reaches of Segments 3 and 4. These deep water (> 5 ft) gravel deposits in Segment 3 were not indicated on Figure 3-2 because their location and extent was not mapped.

Gravel strewn point bars (Figure 3-2, sheets 4 of 9 through 8 of 9) occurred fairly regularly in the meandering sections in the river, while only occasional deposits of gravel were present in straight reaches of the river. Point bar gravel deposits were occasionally dense (approximately 1 to 2 in. deep) and cover about 50 to 75 percent of the upstream end of the exposed bar up to the vegetation line. Typically, clean gravel deposits extend visibly into the river channel when flows were at approximately 1,000 cfs in Segments 4, 5, and 6, but gravel deposits quickly declined compared to that of the exposed bar. The gravel deposits were generally free of fine particles at the upstream end of the point bar, but, gave way to mostly coarse sand and other fine particle substrates downstream of the coarse gravel armor, especially toward the mid-section of each bar.

Other deposits of gravel were identified in mid-stream sections of Segments 3, 4, 5, and 6, but occurred seldom in shallow areas (<5 ft). Deposits of large gravel (32 to 64 mm) have been documented with active spawning nests (redds) in Segment 3 at RM 118.5 (Figure 3-2, sheet 4 of 9) and at RM 104.5 in Segment 4 (Evans 1992; Figure 3-2, sheet 6 of 9). Both areas contained robust redhorse spawning nests in large-gravel deposits between point bars.

The gravel deposits were predominantly monomineralic originating from Piedmont geologic formations. The gravel was composed of quartzite (silicate) and vein quartz minerals. The armored surface of point bars consisted of a range of sizes from fine sand (< 2 mm) to large gravel (58 mm) with trace components of fine and coarse sand, mica, Asiatic clam shell (*Corbicula*), and detritus. Generally, gravel components appeared subangular to subrounded and were predominantly large gravel with poorly sorted fines and pebbles.

Sieve analysis of point bar gravel samples from Segments 4 and 6 provided a more detailed description of substrate composition. The coarse armor (top layer) of point bar gravel deposits were comprised of 38 to 42 percent large gravel (16 to 58 mm), 38 to 42 percent small gravel (2 to 16 mm), 9 percent coarse sand (0.5 to 2 mm), and less than 14 percent fines (< 0.5 mm). The subsurface layer, under the coarse armor, consisted of 12 to 17 percent large gravel, 27 to 41 percent small gravel, 25 to 43 percent coarse sand, and 18 percent or less for fines. Sieve analysis of sediment samples from mid-points along point bars reflect the absence of gravel in point bar areas other than the head of the point bar. Approximately 40 to 73 percent of the mid-point samples consisted of fine sediments (<2 mm) by weight with small gravel (<4 mm) accounting for only five percent of the substrate

or less and no large gravel was present. Ancillary data from the gravel surveys, such as observations on depth patterns, amount of riparian vegetation and woody debris, velocity characterizations, and meso-habitat types, were used to detect potential robust redhorse spawning areas; as well as, assist transect placement for physical habitat simulation for the instream flow studies.

3.2 SPAWNING READINESS

Water temperatures were monitored by GPC from 12 January to 30 July 1993 (Table 3-1, Figure 3-3). Measurements were recorded downstream of Sinclair Dam next to the powerhouse, at the Highway 22 boat ramp (approximately RM 140.7), and at the Hardwick public boat ramp (approximately RM 136) to determine if temperatures were approaching 18 C, which was reported as the critical temperature triggering spawning activity of robust redhorse (Evans 1992). The water temperatures at which robust redhorse spawn were consistent with the range of temperatures reported for other species of redhorse sucker (Becker 1983). Temperature monitoring indicated that the water temperature reached 18 C between 7 through 11 May 1993 in the Oconee River at Milledgeville (Table 3-1).

Boat electrofishing surveys were conducted from 26 to 30 April and on 5 May 1993 in Segments 1, 2, 4, 5, and 6 (Figure 3-1). Eight adult robust redhorse were collected during 28 to 29 April 1993 in Segments 4 and 5 near RM 95-96 and RM 104 (Figure 3-2, sheets 6 of 9 and 7 of 9). Robust redhorse collected during these surveys varied in total length from 597 to 677 mm. The catch consisted of six males, four of which were ripe and running with milt, and one female with mature eggs. Only one individual (645 mm) was classified as undetermined gender. Water temperature at individual collection sites in Segment 4 varied from 19.0 to 19.6 C on 28 April and from 18.9 to 19.4 C in Segment 5 on 29 April 1993. The sexually mature (ripe and/or running) specimens were collected at depths varying from 6.5 to 8.3 ft, velocities ranging from 1.0 to 2.15 ft/s, substrates of large gravel and/or sand, and near cover including sticks or logs. The three sexually immature individuals were collected from depths of 7.6 to 9 ft, velocities ranging from 1.05 to 1.8 ft/s, substrates of small gravel or fine sand, and near cover including downed trees and logs. USGS stream flow gage measurements indicated a flow of 2045 cfs (RM 99) on 29 April 1993.

Two sexually mature adults were collected as far upstream as Segment 2 on 5 May 1993. Figure 3-2, sheet 2 of 9 marks the locations of robust redhorse collected during the 5 May 1993 survey. A male robust redhorse that measured 637 mm was collected near the mouth of Fishing Creek (approximately RM 140) and one female that measured 641 mm was collected about 0.5 mi further downstream (Figure 3-2, sheet 2 of 9). Surface water temperature, measured at the start and end of the day, varied from 20.4 to 22.5 C.

The male robust redhorse was observed resting near the bottom and was subsequently collected from the downstream half of a point bar at a depth of 1.3 ft. The water velocity where the redhorse was observed was 1.18 ft/s and the substrate was predominantly coarse sand and small pebbles. The female was collected at a depth of approximately 7.5 ft near simple woody cover. The mean water column velocity where the female redhorse was collected was 0.82 ft/s and the dominant substrate was coarse sand. The male exhibited well developed cephalic tubercles. The female had numerous bruises and lesions along the right side of its body and was blind in the right eye. The bruises and hemorrhagic lesions were obvious signs of vigorous nest building and mating activity (Jenkins 1993).

3.3 SPAWNING ADULT DISTRIBUTION AND HABITAT-USE

Spawning adult robust redhorse surveys were conducted from 16 to 23 May in study segments 4, 5, and 6. Fifteen observations represented visual observations, while captured specimens included 20 females (16 ripe with eggs) and 37 males (35 running milt). The majority (57 percent) of spawning robust redhorse were captured in Segment 6 between RM 82 and RM 87, followed by 32 percent in Segment 5 between RM 95 and RM 96, 8 percent in Segment 4 between RM 100 and RM 110, and 3 percent in Segment 2 between RM 118 and RM 120 (Appendix A). Figure 3-2 shows the locations of individual spawning robust redhorse.

As mentioned above, gravel substrate was thought to be the dominant substrate used by spawning robust redhorse. Although the point bars represented the largest source of gravel deposits for potential spawning habitat, spawning adults were typically found in mid-channel areas approximately two-thirds of the way around outside bends. Spawning robust redhorse were collected in association with coarse sand (50 percent) and large gravel (41 percent) (Figure 3-4). Most of the robust redhorse were located in the vicinity of gravel deposits, the most likely location for redds. Cover types associated with collected fish included log complexes (39 percent); attached root masses (26 percent), downed trees (10 percent), and no cover (10 percent) (Figure 3-5).

Approximately 52 percent of the redhorse were collected from mean water column velocities of 1.0 to 1.5 ft/s; 31 percent of the observations from 1.5 to 2.0 ft/s; 10 percent of the observations from 0.5 to 1.0 ft/s and 7 percent of the observations from 2.0 to 2.5 ft/s (Figure 3-6).

Depth use varied between 2 to 14 ft (Figure 3-7). Approximately 21 percent of the spawning robust redhorse were collected from depths of 4 to 5 ft, followed by 18 percent at depths of 5 to 6 ft, 17 percent at depths of 6 to 7 ft, and 15 percent at depths of 3 to 4 ft. Spawning and resting robust redhorse were visually observed at depths as shallow as 1.3 ft in Segment 3 and 2, respectively.

Distribution of robust redhorse demonstrated that they were present in pre-spawn and spawning condition from the middle of Segment 2 downstream to the middle of Segment 6 and were typically associated with gravel deposits (Figure 3-2). Aggregations of spawning condition redhorse suckers were collected in the meanders downstream of the Highway 57 bridge near RM 84-88 and RM 94-97 in Segments 5 and 6, respectively (Figure 3-2, sheets 7 and 8 of 9). The surveys of 26 April through 23 May 1993 collected 62 spawning robust redhorse from waters with temperatures varying from 18.9 to 22.5 C at selected locations (Figure 3-3).

3.4 NON-SPAWNING ADULT DISTRIBUTION AND HABITAT-USE

Surveys for non-spawning adult robust redhorse were conducted from 22 to 28 June and from 5 to 8 October 1993 (Table 1-1). The 1993 surveys yielded only 14 non-spawning adults. Therefore, the data from the 26 robust redhorse observations that were collected as part of the Oconee River Fisheries Survey (EA 1993) were combined with the 1993 data to increase the sample size of non-spawning adults. The 1992 fisheries studies utilized a standardized protocol (EA 1993) which yielded 26 robust redhorse during 25 to 27 June and 16 to 22 September.

Non-spawning robust redhorse were not collected in Segments 1 through 2, while 4 individuals (10 percent) were collected in Segment 3 between RM 119 and RM 120; 14 individuals (35 percent) were collected in Segment 4 between RM 100 and RM 109; 11 individuals (28 percent) were collected in Segment 5 between RM 94 and RM 97.5, and 11 individuals (27 percent) were collected in Segment 6 between RM 85 and RM 88.5 (Figure 3-2). Overall, the sample consisted of 2 females, 6 males, and 32 robust redhorse of unidentified gender. The few individuals that were distinguishable by gender were collected in June, whereas the others were collected in September or October. Gender was designated as undetermined when eggs or milt could not be obtained by firmly stripping the gonads externally. Figure 3-2 shows the locations of individual non-spawning robust redhorse.

3.4.1 Non-spawning Adult Habitat-Use

The habitats most frequently associated with non-spawning robust redhorse occurred in the meandering reaches of Segments 4, 5, and 6. Dominant habitat variables were summarized from information provided in Table A-1. Substrates of large gravel were recorded for 49 percent of the observations followed by 44 percent frequency of use for coarse sand (Figure 3-4). Log complexes, which consisted of accumulations of logs and deadfall, were used as cover by 55 percent of the catch followed by 20 percent frequency of use for simple log

cover, 13 percent were associated with no cover, and 8 percent were associated with downed trees (Figure 3-5).

Non-spawning robust redhorse used velocities varying from 0.5 to 2.5 ft/s with 45 percent of the observations collected from average velocities of 1.0 to 1.5 ft/s; 35 percent of the observations from 1.5 to 2.0 ft/s; 12.5 percent of the observations from 0.5 to 1.0 ft/s; and 5 percent of the observations from 0 to 0.5 ft/s (Figure 3-6).

Depth used by non-spawning adult robust redhorse varied from 2 to 8 ft. Approximately 49 percent of the non-spawning robust redhorse were collected from depths of 2 to 3 ft, followed by 43 percent at 3 to 6 ft, and 8 percent at 7 to 9 ft (Figure 3-7).

Delineation of non-spawning robust redhorse occurrence relative to spawning robust redhorse demonstrated that non-spawning robust redhorse were present in generally the same areas as spawning fish; however, none were collected upstream of RM 122 (Segment 3) unlike spawning redhorse which were captured in the upper reaches of Segment 2. Also similar to spawning robust redhorse, a higher frequency of occurrence of non-spawning robust redhorse were collected in the meanders downstream of the highway 57 bridge in Segments 5 and 6 (Figure 3-2, sheets 7 and 8 of 9).

3.5 JUVENILE ROBUST REDHORSE SURVEYS

Daytime surveys were conducted during 27 September to 1 October 1993 and included selected reaches from the Georgia Central RR bridge to East Dublin (RM 103 to RM 77). Nighttime surveys were conducted during 7-10 December 1993 and included areas between RM 103 to RM 100 and RM 88 to RM 83 (upstream of Dublin), as well as selected reaches downstream of Dublin between RM 63 to RM 59 near the Shady Field boat landing located approximately 10 mi downstream of Dublin and RM 49 to 40 at the Highway 46 bridge boat landing about 23 mi downstream of Dublin.

A total of 114 seine hauls and 20.25 hrs of electrofishing were expended in sampling effort in selected habitats within the reaches indicated. No juvenile robust redhorse were collected; although, four adults (Serial numbers 101-104; Figure 3-2) were captured between RM 85 and RM 87 on September 30, 1993 by boat electrofishing (Appendix A; Table A-1). Overall, 25 species were collected from both surveys including many yoy or juveniles of other species (Table 3-2).

Other species of the Catostomidae family (suckers) were collected as yoy during the surveys (Table 3-2). Silver redhorse (*Moxostoma anisurum*), spotted suckers (*Minytrema melanops*), and carpsuckers (*Carpiodes sp.*) were captured in the vicinity utilized by spawning redhorses. Nine yoy silver redhorse were collected in segments 5 and 6 near RM 97 and between RM 86 and RM 87 (Figure 3-2; sheets 7 and 8 of 9).

3.6 SEX RATIO AND LENGTH DISTRIBUTION OF ADULT ROBUST REDHORSE

The average total length for all specimens was 630 mm with minimum and maximum lengths of 561 and 682 mm (Figure 3-8; Table A-1). The average weight of spawning robust redhorse was approximately 5,250 gm with minimum and maximum weights of about 3,600 and 8,000 gm, respectively. Approximately 76 percent of the robust redhorse individuals collected during April and May were considered sexually mature.

The ratio of males to females differed among segments. A total of 57 of 72 total observations were identified by gender and about 65 percent of those were male. Study Segments 5 and 6 yielded the highest number of spawning individuals and the most uneven sex ratios. Ratios of male to female ranked respectively as: 1:1 in Segment 2, 0.5:1 in Segment 3, 0.7:1 in Segment 4, 1.4:1 in Segment 5, and 3.7:1 in Segment 6. The remaining 15 specimens of undetermined gender were nearly evenly divided between Segments 4 and 5 (Table A-1).

The average total length for non-spawning specimens was 611 mm with minimum and maximum lengths of 400 and 701 mm, respectively (Figure 3-9 and Table A-1). The average weight (excluding 10 specimens collected during Oct 5-7, 1993 with weight not recorded) was approximately 3,521 gm with minimum and maximum weights of 1,700 and 5,500 gm, respectively.

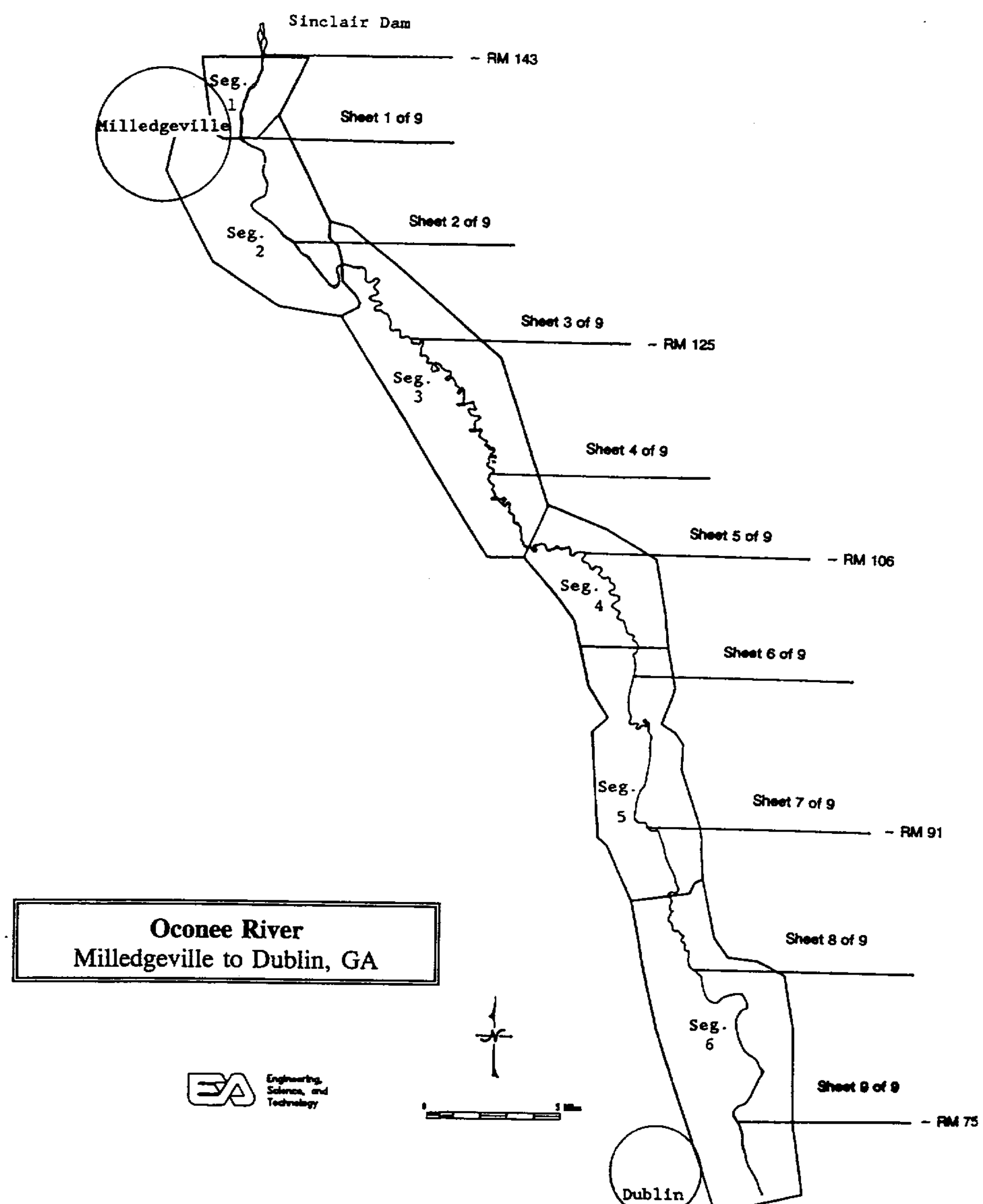
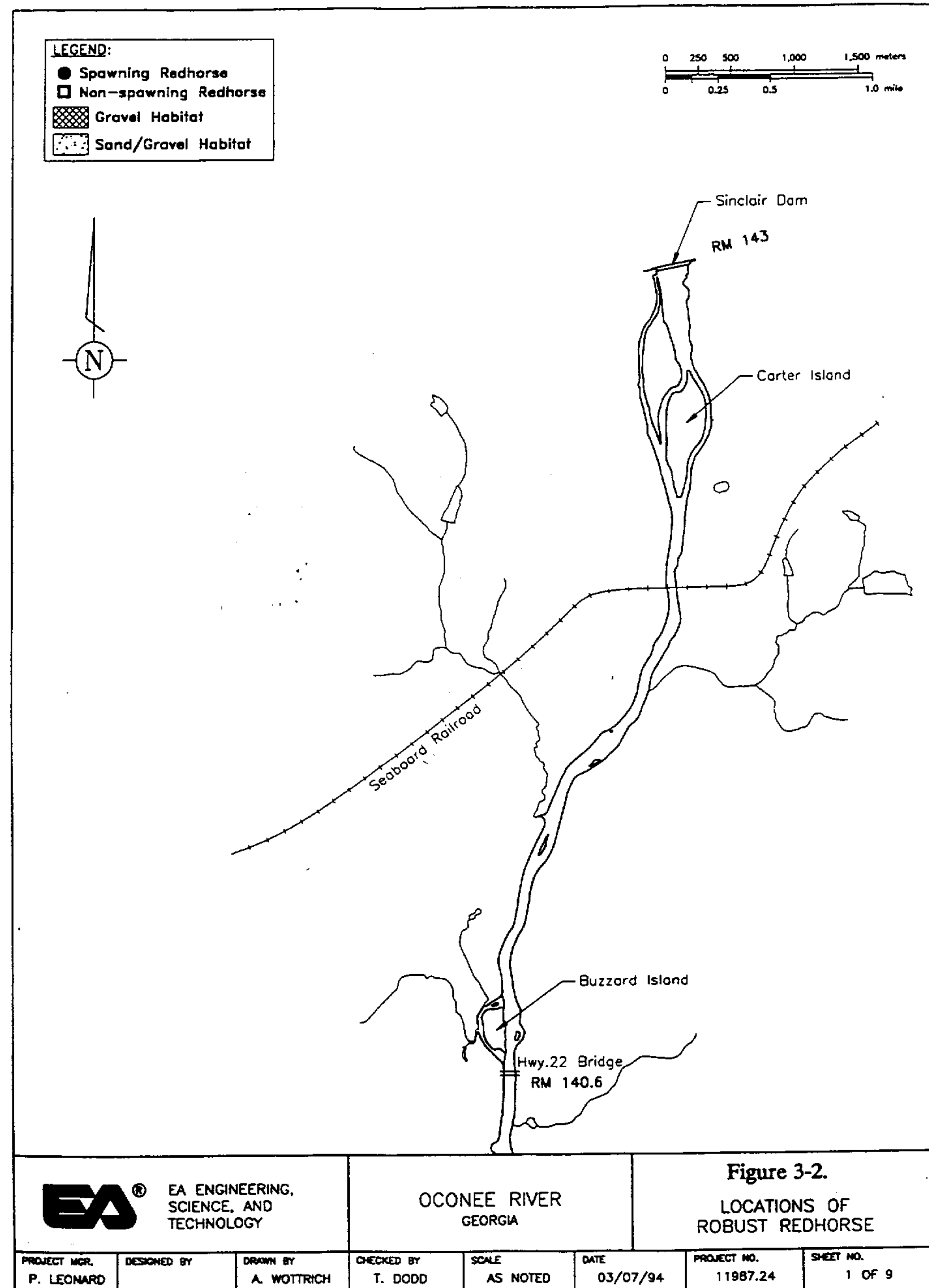
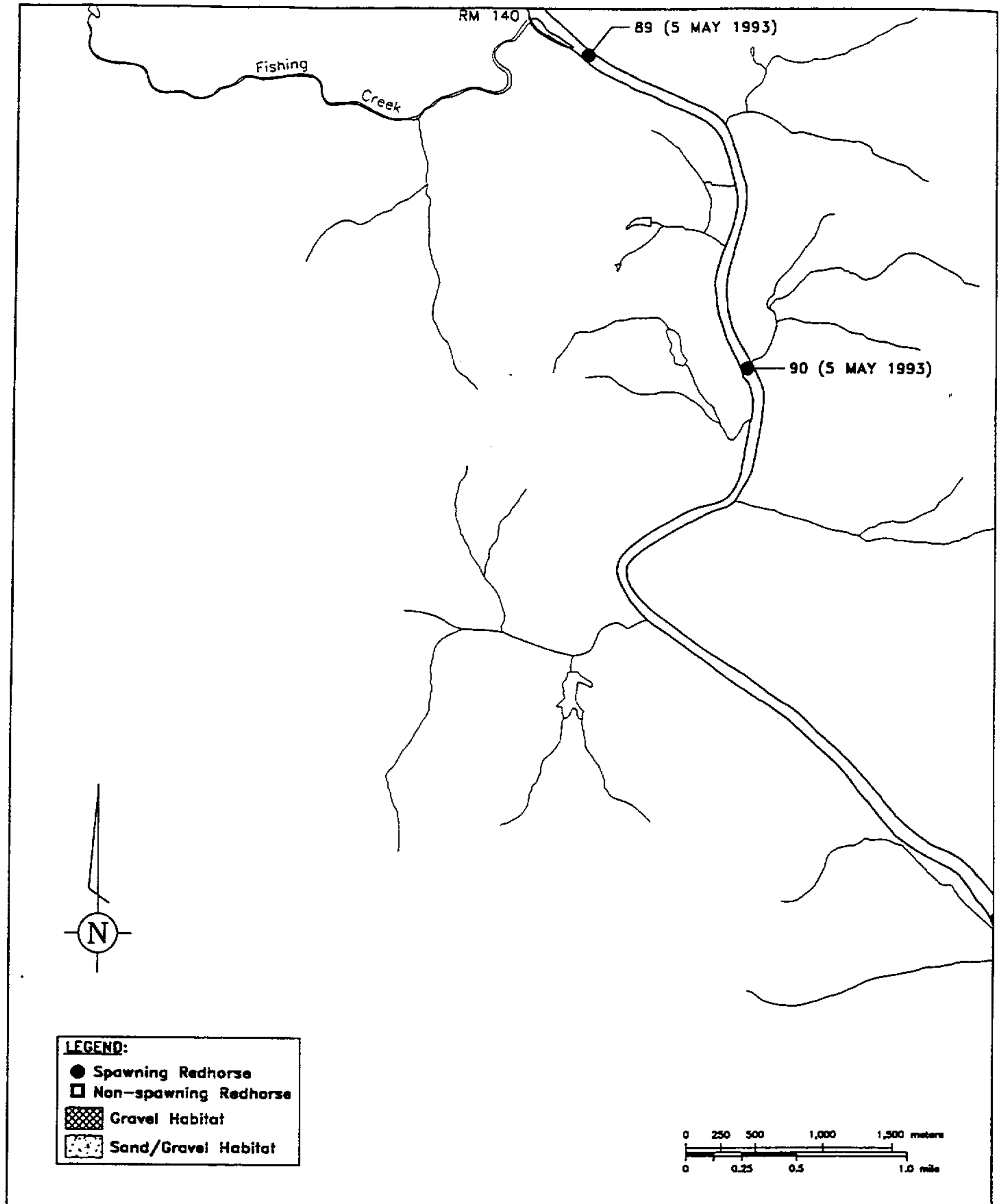


Figure 3-1. Cross-reference map key to robust redhorse captures illustrating river miles (RM) and map sheets as provided in Figure 3-2.





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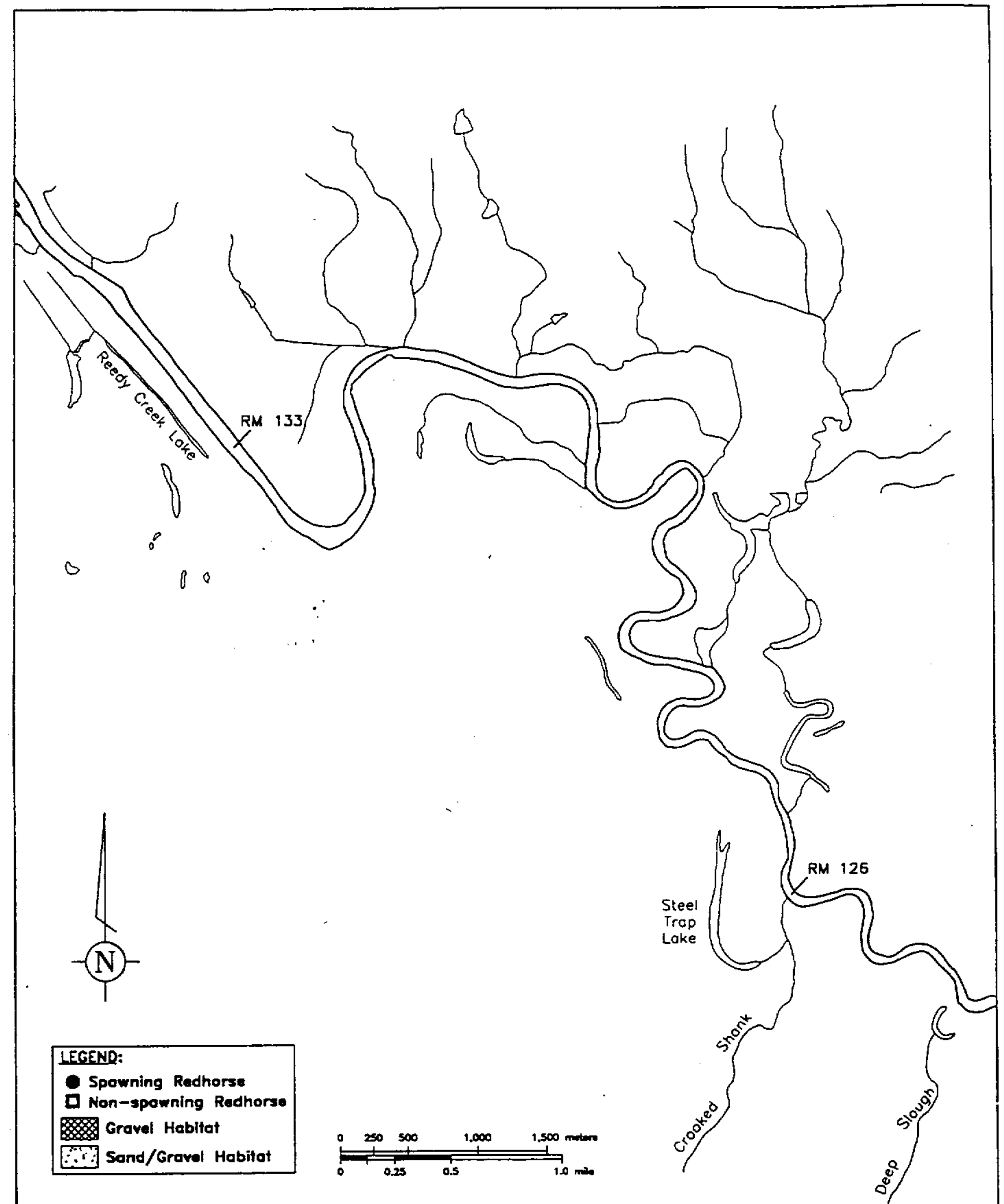
OCONEE RIVER
GEORGIA

Figure 3-2 (cont).
LOCATIONS OF
ROBUST REDHORSE

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO.	SHEET NO.
P. LEONARD		A. WOTTRICH	T. DODD	AS NOTED	03/07/94	11987.24	2 OF 9



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OCONEE RIVER
GEORGIA

Figure 3-2 (cont).
LOCATIONS OF
ROBUST REDHORSE

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO.	SHEET NO.
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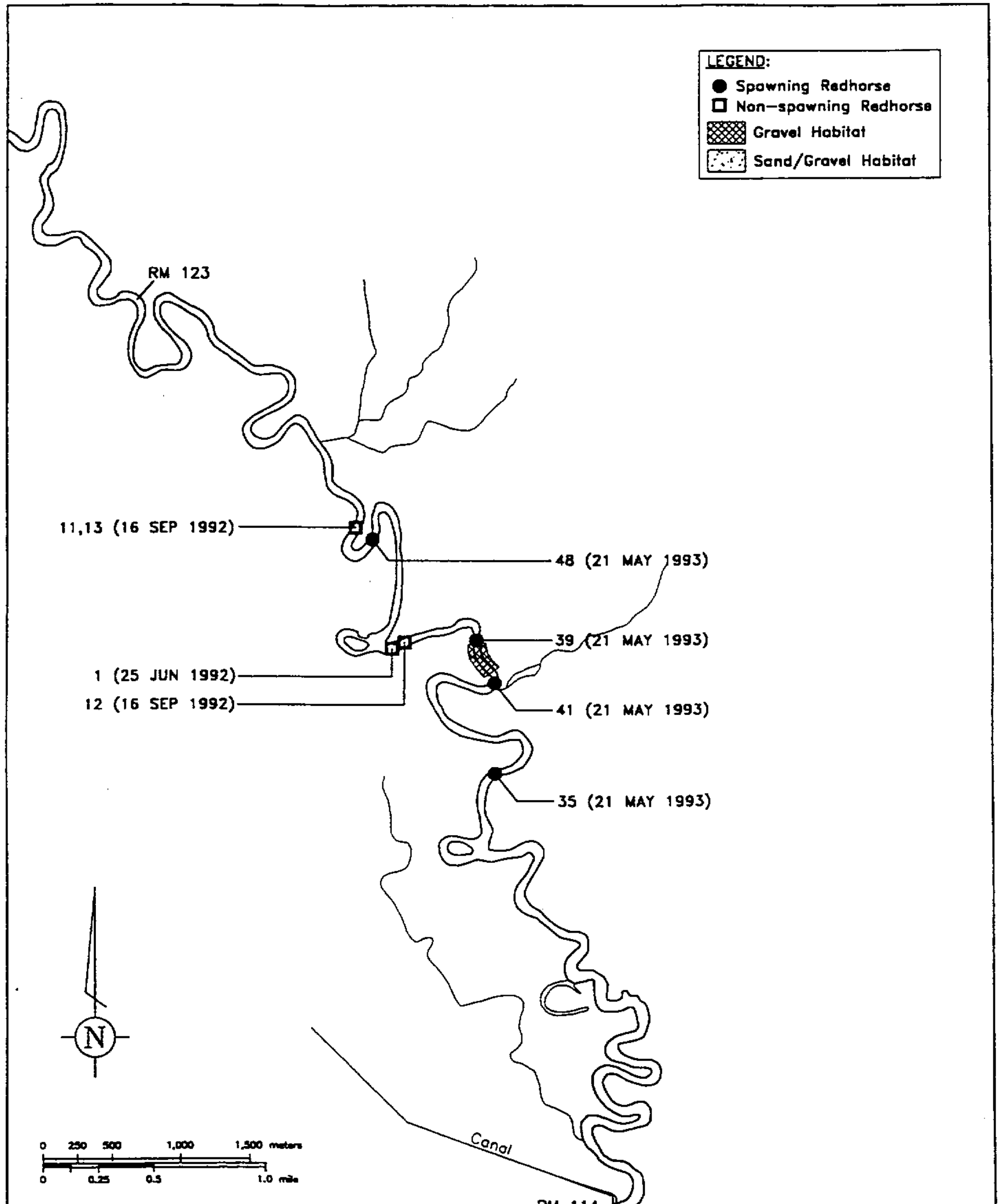

EA ENGINEERING, SCIENCE, AND TECHNOLOGY			OCONEE RIVER GEORGIA			**Figure 3-2 (cont).** LOCATIONS OF ROBUST REDHORSE	
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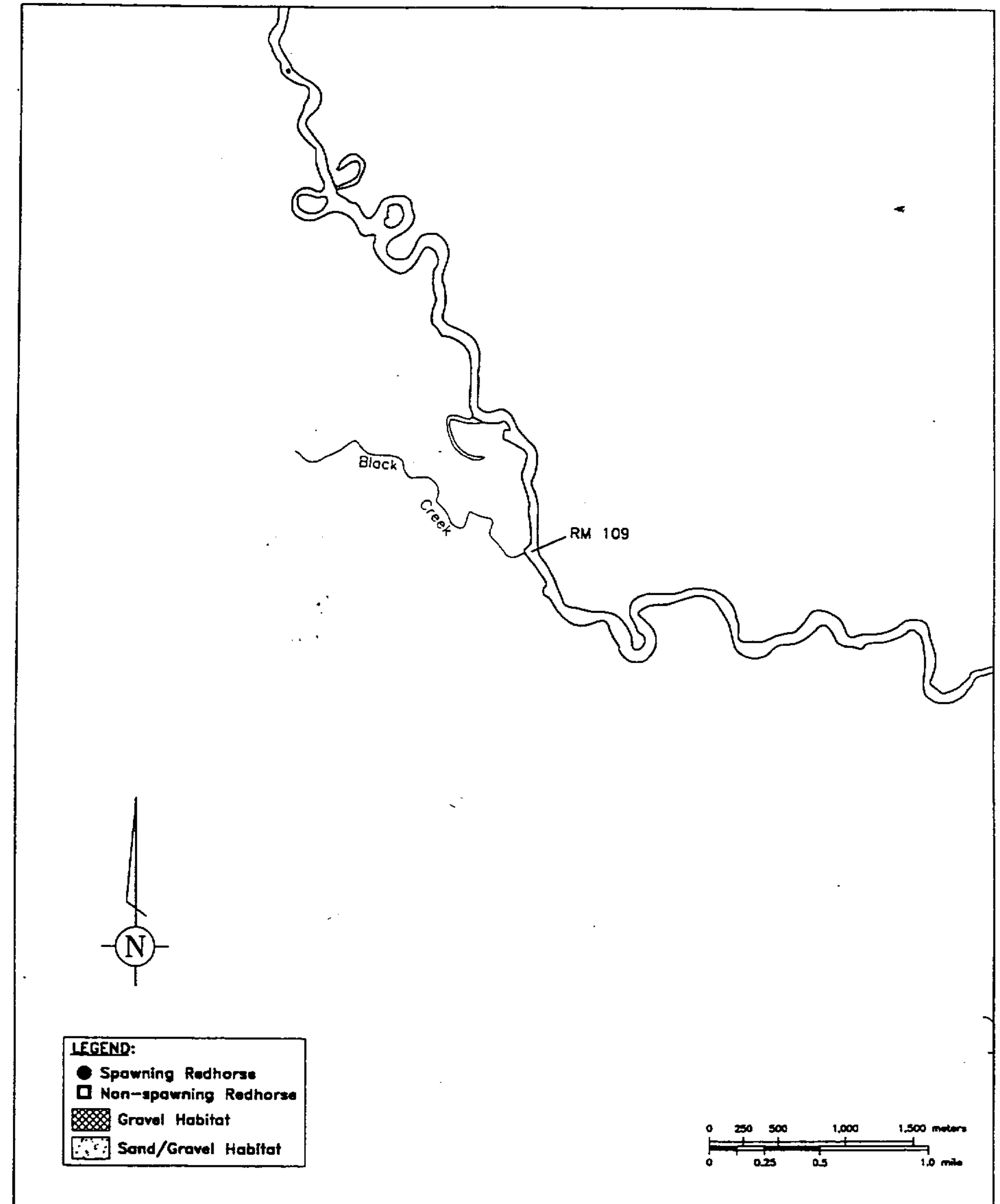
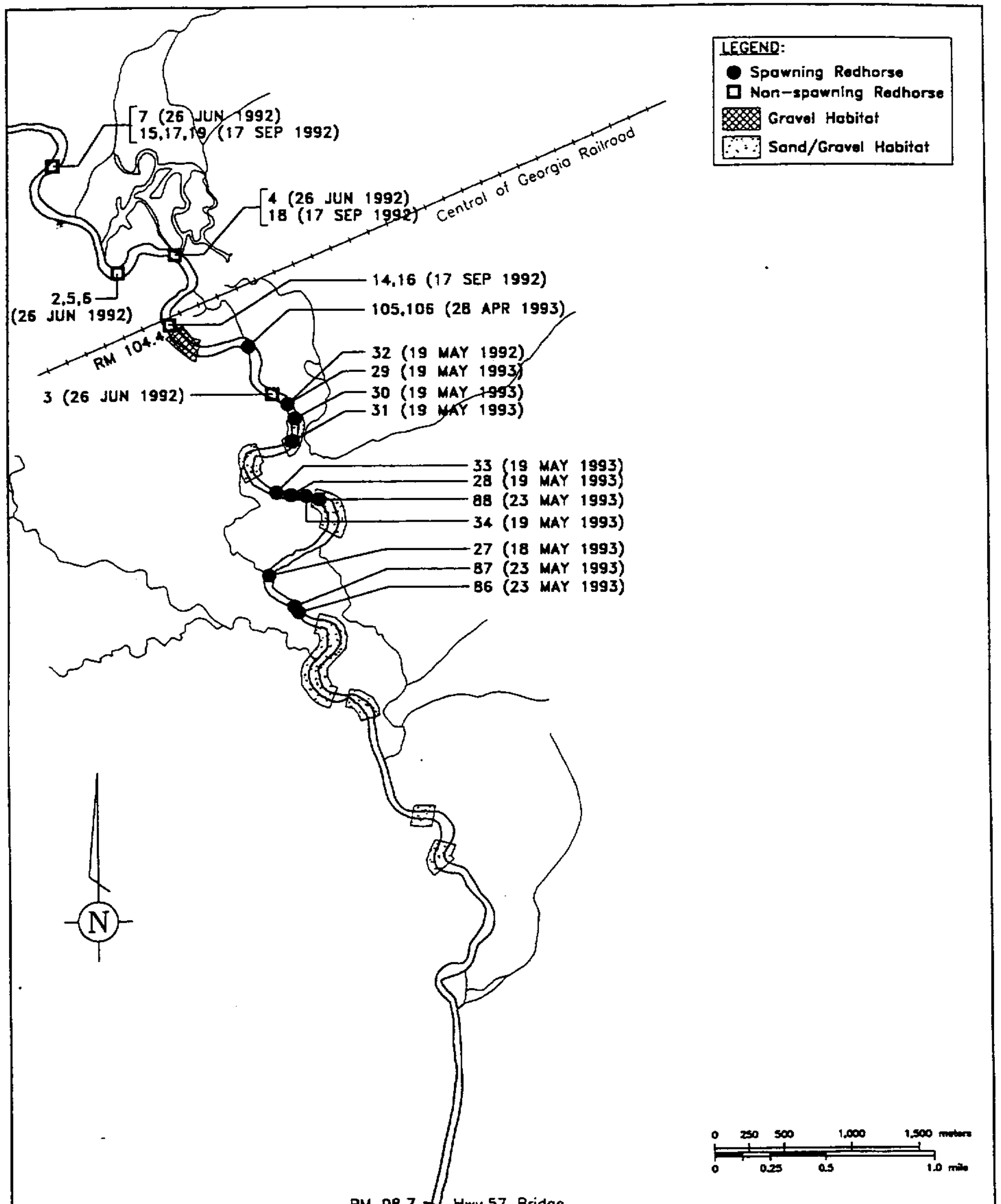


EA ENGINEERING, SCIENCE, AND TECHNOLOGY			OCONEE RIVER GEORGIA			**Figure 3-2 (cont).** LOCATIONS OF ROBUST REDHORSE	
PROJECT MGR. P. LEONARD	DESIGNED BY	DRAWN BY A. WOTTRICH	CHECKED BY T. DODD	SCALE AS NOTED	DATE 03/07/94	PROJECT NO. 11987.24	SHEET NO. 5 OF 9



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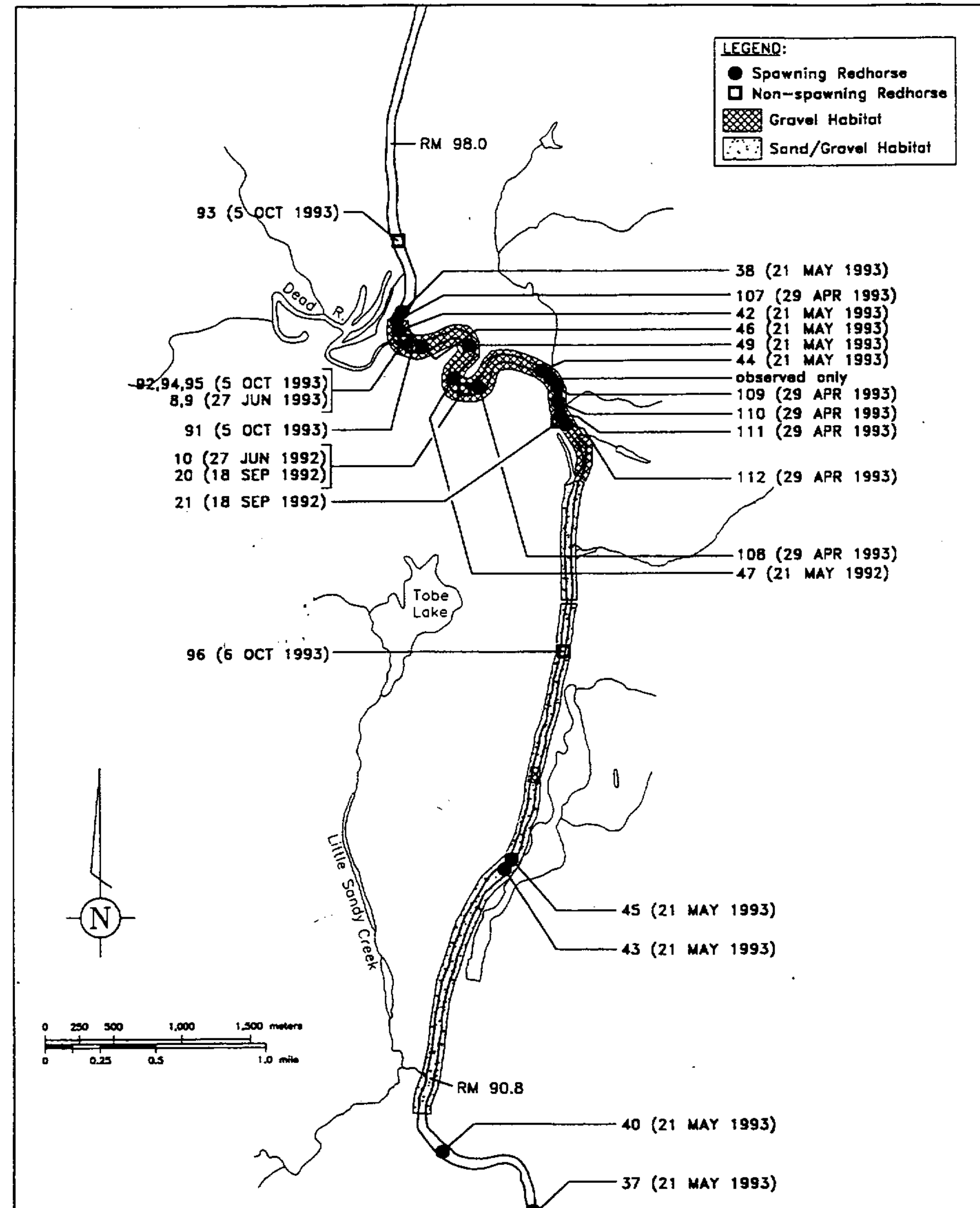
OCONEE RIVER GEORGIA						**Figure 3-2 (cont).** LOCATIONS OF ROBUST REDHORSE	
PROJECT MGR. P. LEONARD	DESIGNED BY	DRAWN BY A. WOTTRICH	CHECKED BY T. DODD	SCALE AS NOTED	DATE 03/07/94	PROJECT NO. 11987.24	SHEET NO. 6 OF 9



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OCONEE RIVER GEORGIA						**Figure 3-2 (cont).** LOCATIONS OF ROBUST REDHORSE	
PROJECT MGR. P. LEONARD	DESIGNED BY	DRAWN BY A. WOTTRICH	CHECKED BY T. DODD	SCALE AS NOTED	DATE 03/07/94	PROJECT NO. 11987.24	SHEET NO. 7 OF 9

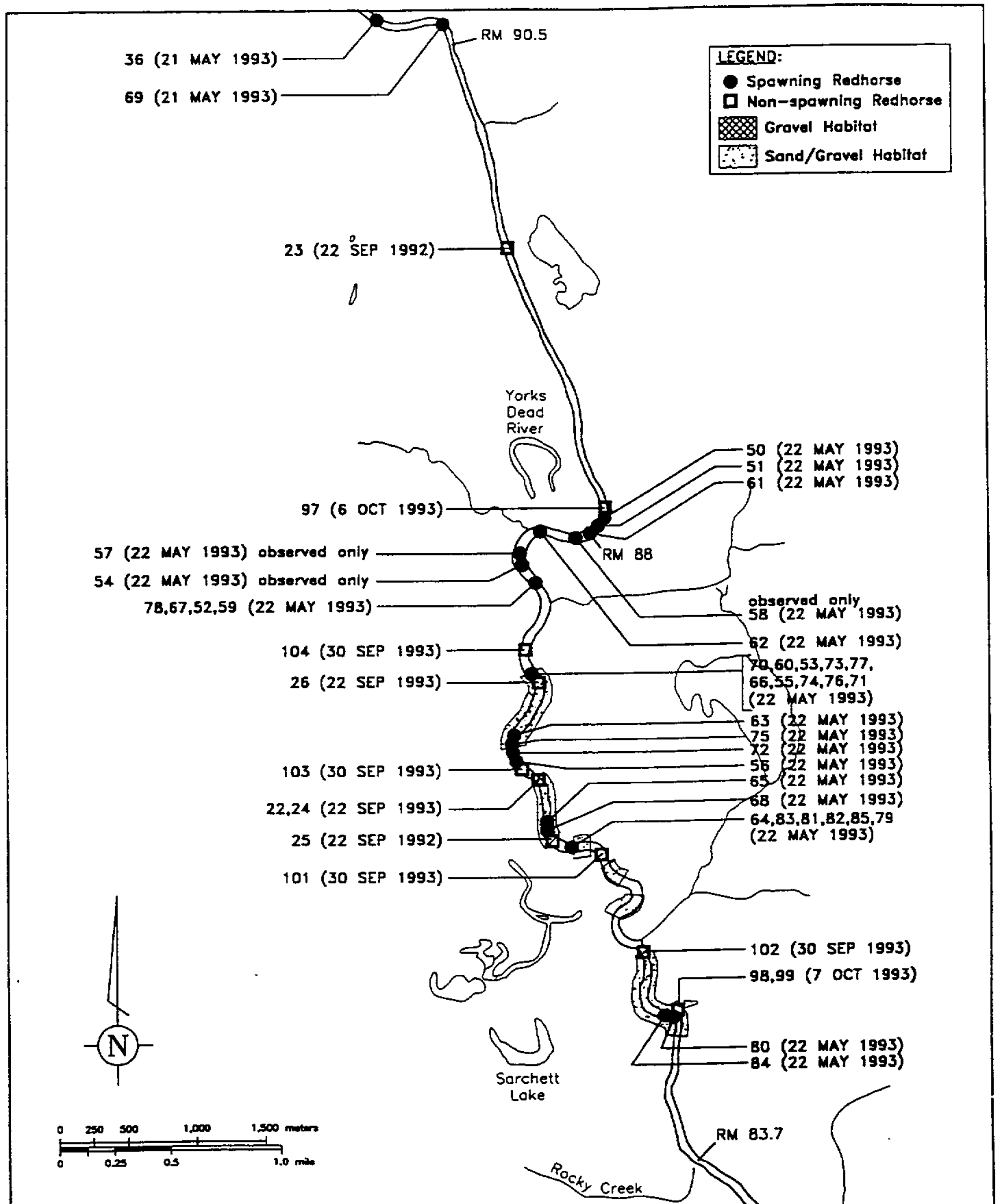

Figure 3-2 (cont). LOCATIONS OF ROBUST REDHORSE

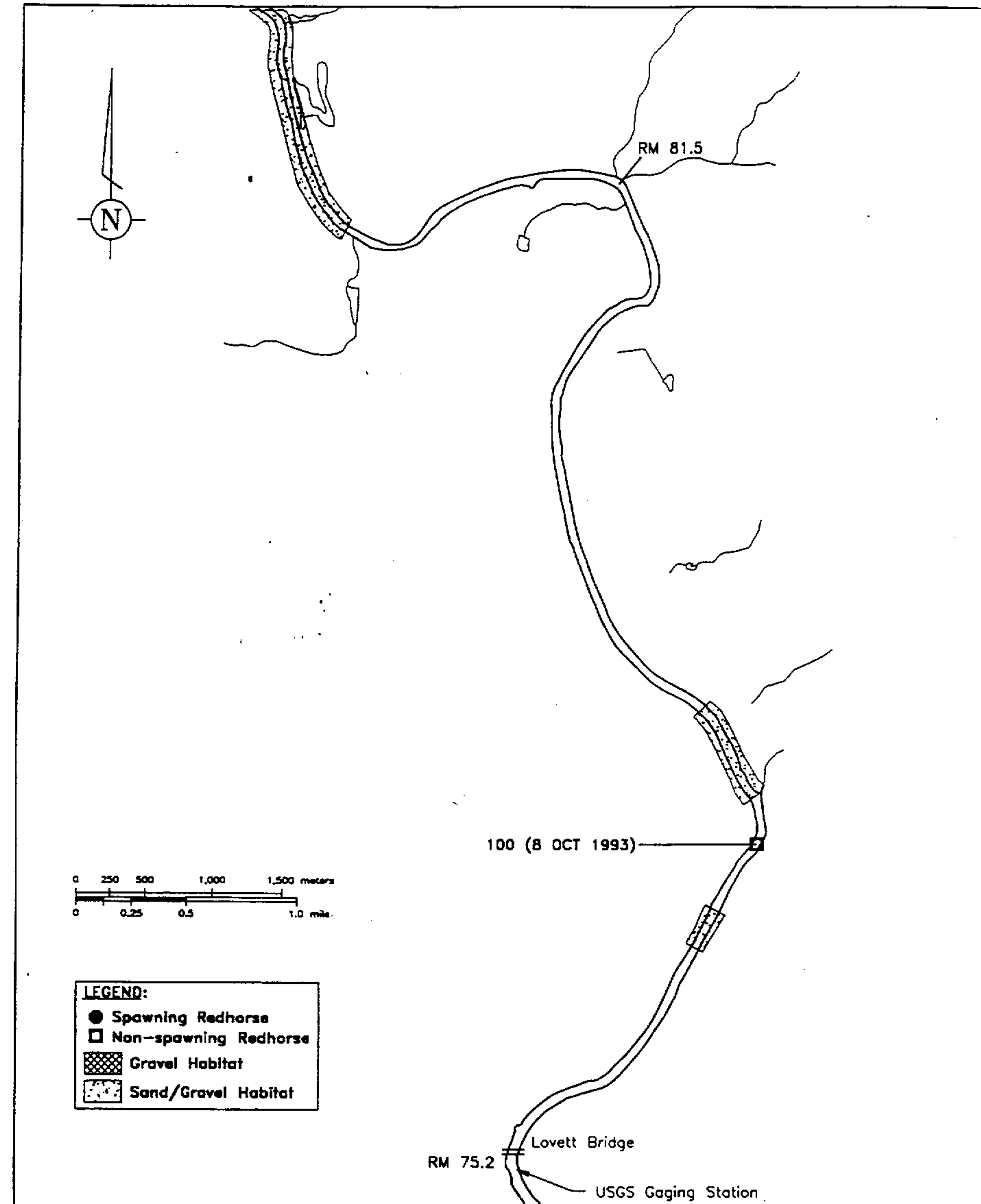

Figure 3-2 (cont). LOCATIONS OF ROBUST REDHORSE

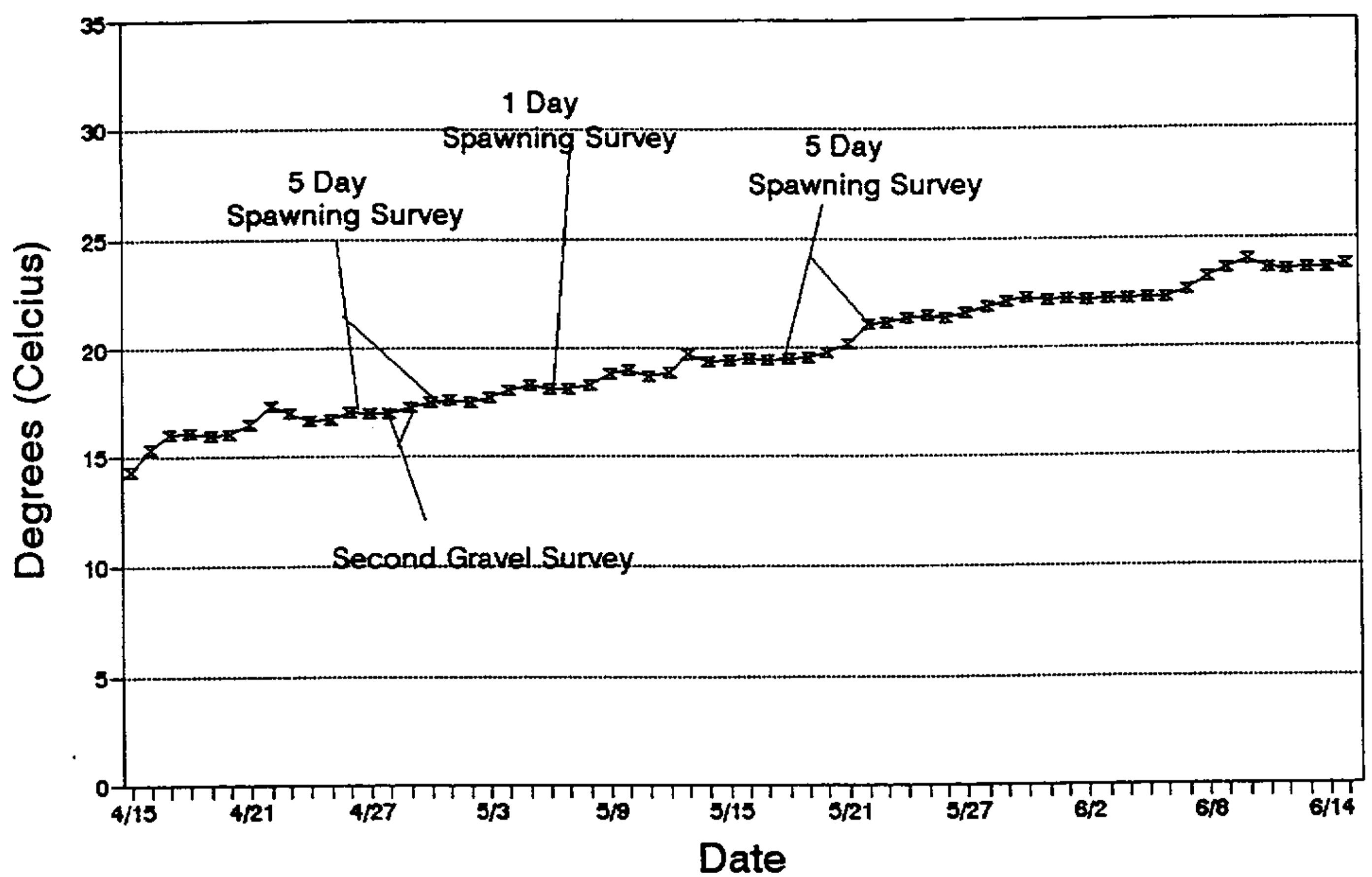

Figure 3-3. Daily water temperature measurements recorded downstream of Sinclair Dam from 15 April to 15 June 1993. Temperatures near 18 C were used to indicate spawning readiness of robust redhorse.

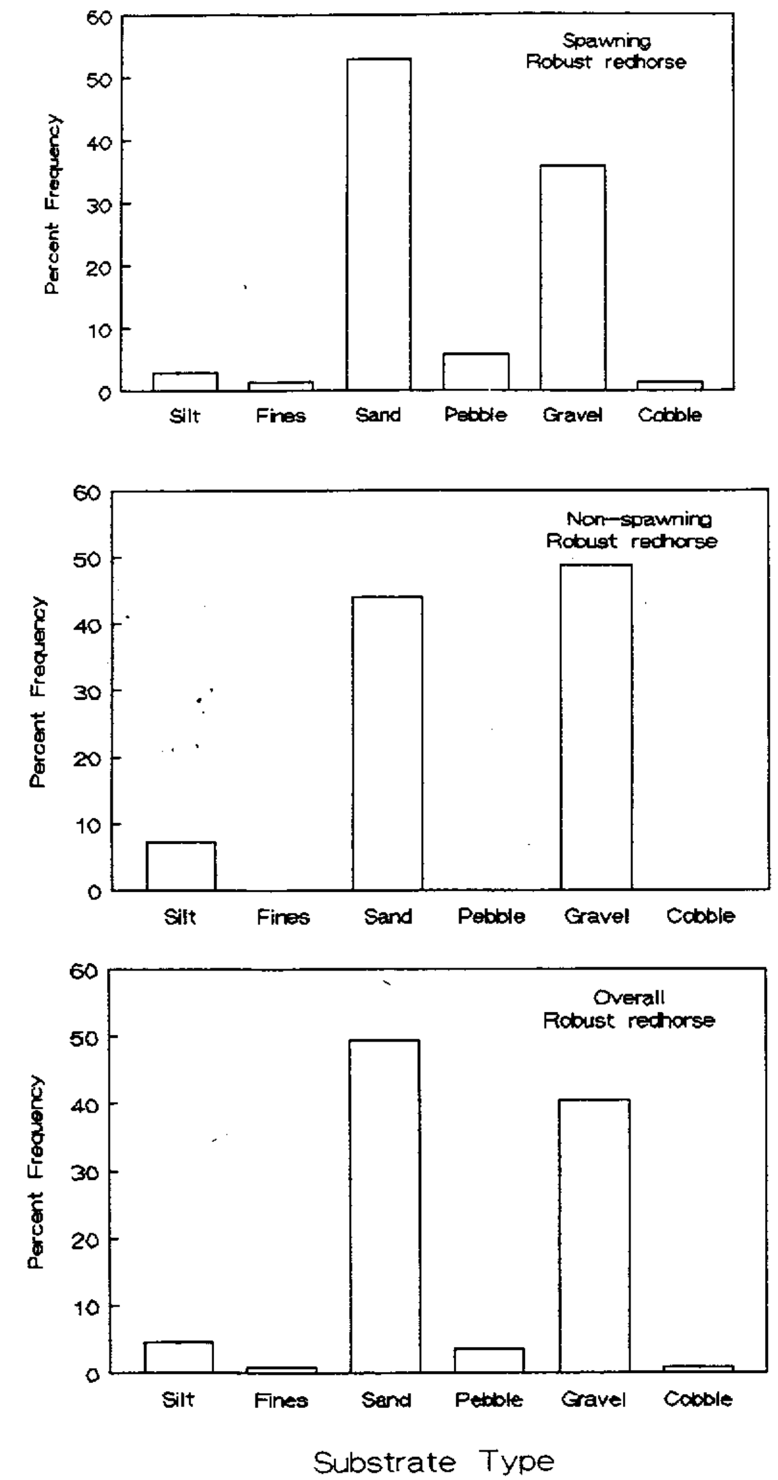

Figure 3-4. Percent frequency use of substrate types for spawning and non-spawning robust redhorse, and combined data sets from the Oconee River, Georgia, 1992 and 1993.

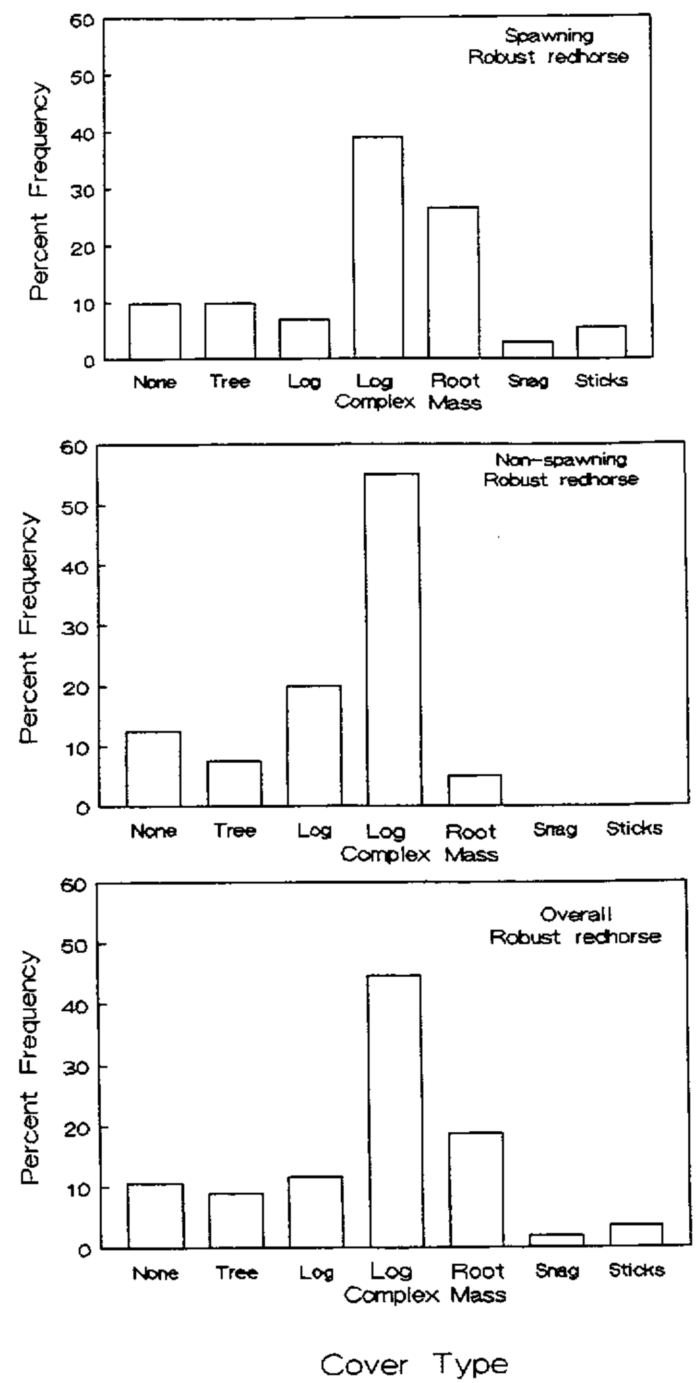

Figure 3-5. Percent frequency use of fish cover types for spawning and non-spawning robust redhorse, and combined data sets from the Oconee River, Georgia, 1992 and 1993.

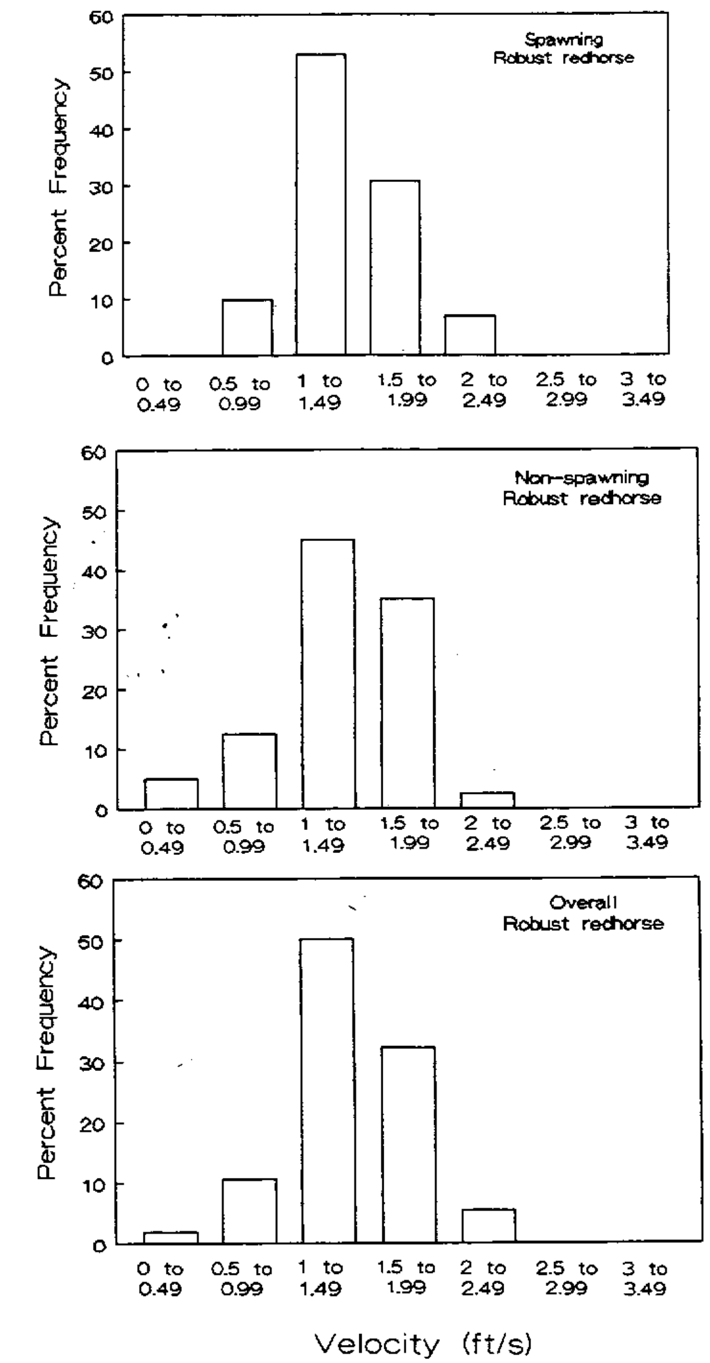

Figure 3-6. Percent frequency use of velocity intervals (ft/s) for spawning and non-spawning robust redhorse, and combined data sets from the Oconee River, Georgia, 1992 and 1993.

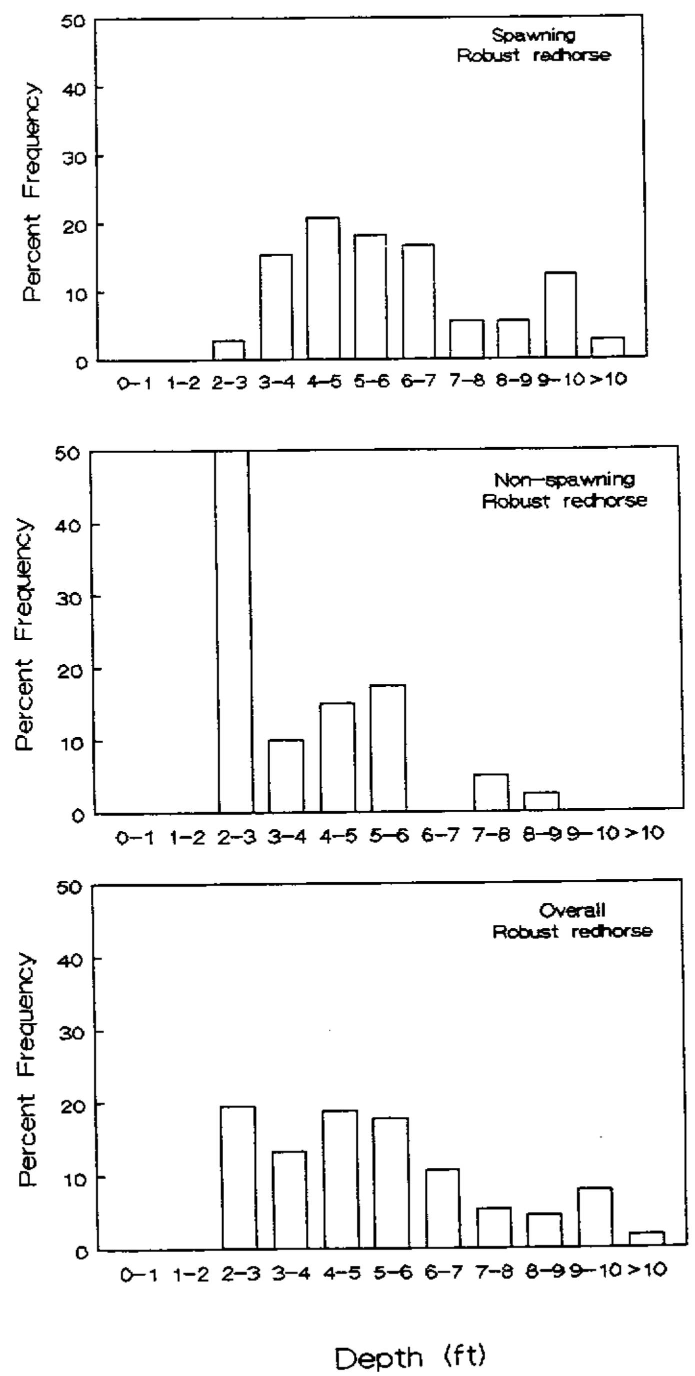

Figure 3-7. Percent frequency use of depth intervals (ft) for spawning and non-spawning robust redhorse, and combined data sets from the Oconee River, Georgia, 1992 and 1993.

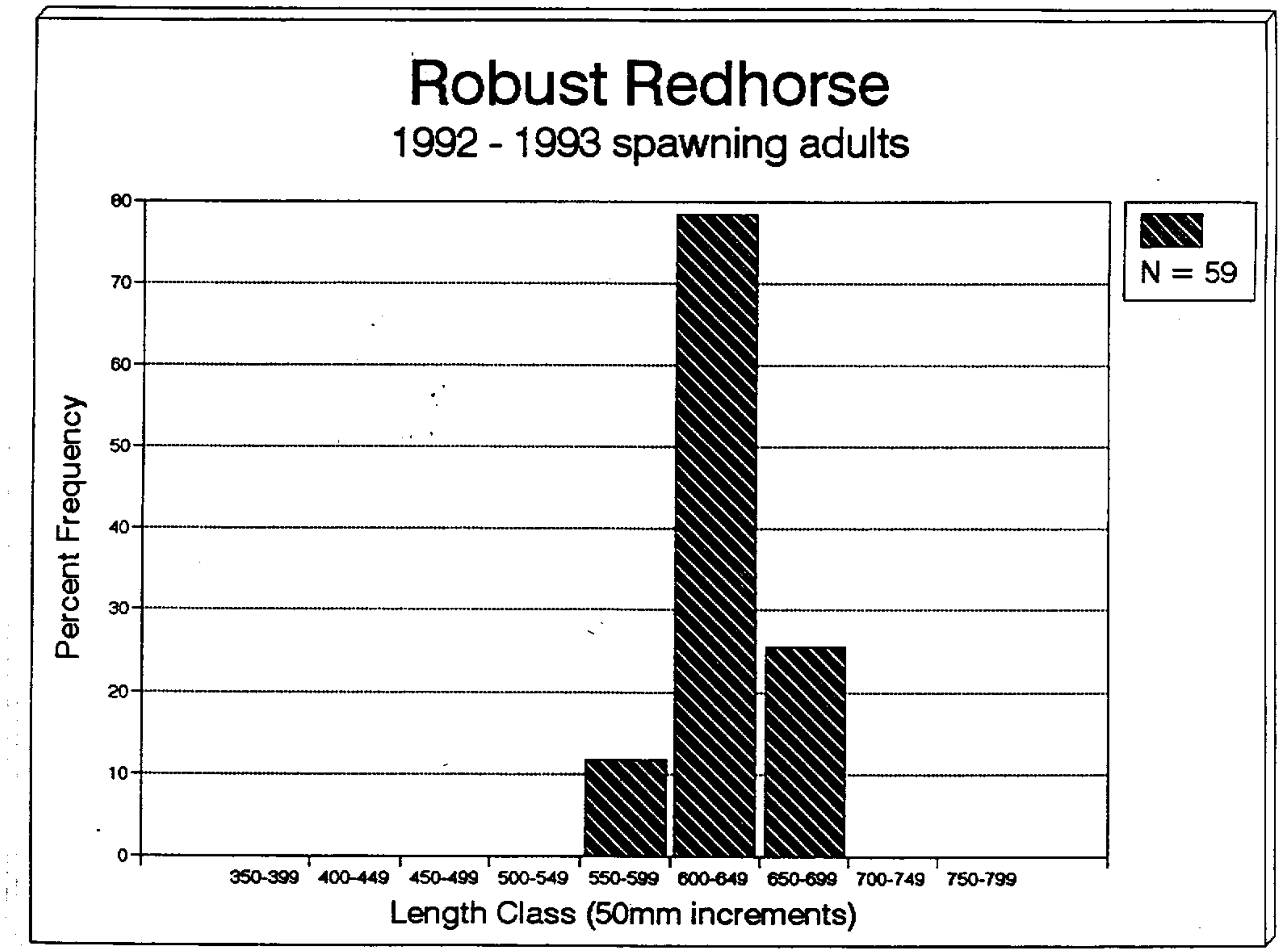

Figure 3-8. Length frequency (50 mm increments) of spawning robust redhorse collected from the Oconee River, Georgia, 1992 and 1993.

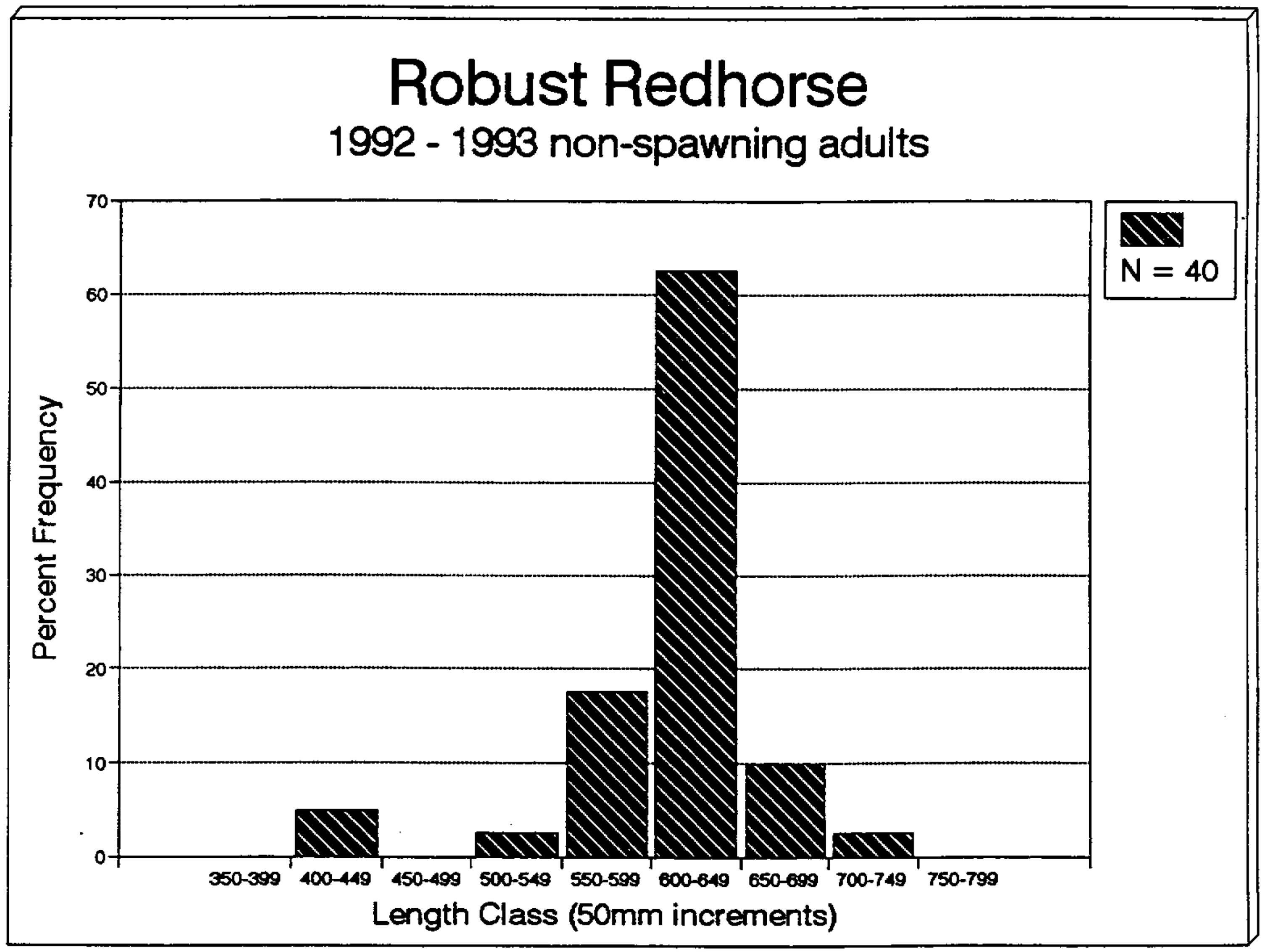

Figure 3-9. Length frequency (50 mm increments) of non-spawning robust redhorse collected from the Oconee River, Georgia, 1992 and 1993.

TABLE 3-1 WATER TEMPERATURE (C) MONITORING DATA FROM THE OCONEE RIVER AT HARDWICK PUBLIC BOAT RAMP, 4 MAY THROUGH 22 JUNE 1993

DATE	FLOW (CFS)*	TEMPERATURE (C)
4 MAY	6509	13
7 MAY	486	14
11 MAY	476	19
14 MAY	1452	20
18 MAY	481	20
21 MAY	504	20
25 MAY	4723	21
28 MAY	4651	22
1 JUNE	495	23
4 JUNE	593	23
9 JUNE	4640	24
15 JUNE	895	24
18 JUNE	4640	24
22 JUNE	3772	25

Note: Flow records from USGS Milledgeville gage as average flows from 0800 to 1800 hrs.

TBL3-1.RPT

TABLE 3-2 CHECKLIST OF FISHES COLLECTED FROM THE OCONEE RIVER DURING THE YOY ROBUST REDHORSE SURVEYS, 28 SEP-1 DEC AND 7-10 DEC, 1993

SPECIES	DAY TIME ADULT	DAY TIME JUV.	NIGHT TIME ADULT	NIGHT TIME JUV.
American eel		X		X
Longnose gar				X
Gizzard shad	X			
Threadfin shad		X		
Chain pickerel			X	
Grass carp			X	
Pugnose minnow			X	
Eastern silvery shiner	X		X	
Ocmulgee shiner	X		X	
Cyprinella sp.	X		X	
Spottail shiner	X	X	X	
Coastal shiner	X		X	
Highfin carpsucker		X	X	X
Carpiodes sp.		X		X
Spotted sucker	X		X	
Silver redhorse	X	X	X	X
Robust redhorse	X			
Channel catfish	X	X		X
Mosquito fish	X		X	
Brook silverside	X		X	X
Redbreast sunfish	X	X		X
Warmouth			X	
Bluegill	X	X	X	X
Redear sunfish				X
Hybrid sunfish				X
Largemouth bass	X			X
Black crappie				X
Christmas darter			X	
Tessellated darter		X	X	
Blackbanded darter			X	X

4. SUMMARY

The results of the gravel mapping surveys clearly indicated that gravel deposits are more widely distributed than was previously thought. Gravel deposits were most abundant in the lower half (segments 4, 5, and 6) of the study area, but did occur throughout the 70 mile study area. The shoreline gravel deposits were usually associated with point bars and extend part way into the main channel. Gravel deposits also occurred in the mid-channel areas of river segments 3, 4, 5, and 6. The gravel deposits located in mid-channel were where most of the robust redhorse spawning activity was documented.

The 1993 studies established the distribution of spawning and non-spawning adult robust redhorse and generally identified the extent of potential usable spawning habitat for robust redhorse in the main stem Oconee River between Milledgeville and Dublin, Georgia. The reported abundance and distribution of robust redhorse may be slightly biased by non-standardized sampling schedules, although, sample effort was fairly intense overall and the surveys were conducted in seven months of the year (April to December except July and November).

The 1993 surveys demonstrated that adult robust redhorse were present within most of the 70 mile Oconee River study area from spring through fall (Table A-1). Spawning and non-spawning robust redhorse were collected in the middle and lower study areas (RM 78 to RM 105) and were predominantly collected in meandering reaches of the Oconee River. Scattered deposits of large gravel substrates and woody debris were usually present in close proximity to where the robust redhorse were collected (Figure 3-2).

Robust redhorse catch data from the 1992 Oconee River Fishery Resource Surveys (GPC 1993) supported findings of the 1993 GPC surveys. Standardized surveys conducted in 1992 demonstrated that gravid specimens could be collected in the lower study areas (Segments 4, 5, and 6) during early June and adult robust redhorse were also present in the same areas during late September. Table 4-1 provides a summary of robust redhorse catch by month and study segment for spawning and non-spawning seasons.

A total of 112 adult robust redhorse suckers were captured in the months of April, May, June, September, and October 1992 and 1993 (Table 4-2). The May collections accounted for 57 percent of the total robust redhorse catch followed by 17 percent of the catch in September, 9 percent in June, 9 percent in October, and 7.1 percent in April. Many of the April, May, and June captures were readily identified by gender as described in Section 3.4. The April catch consisted of approximately 75 percent males, 12.5 percent females, and 12.5 percent undetermined. About 72 percent of the May catch consisted of sexually mature individuals with 48 percent males, 27 percent females (four individuals spent condition), and about 22 percent undetermined by gender. The June catch consisted of 60 percent males, 20 percent females, and 20 percent undetermined gender (Table 4-3).

Segment 6 (Table 4-3) yielded the highest number of robust redhorse during 1992 and 1993. Approximately 46 percent of the total catch was collected in Segment 6 followed by 33 percent of the catch in Segment 5, 18.8 percent in Segment 4, 1.8 percent in Segment 2, and no captures in Segments 1 and 3. Sexually mature robust redhorse were collected only in April, May, and June. During the spawning months, the number of males was higher than females in Segments 5 and 6, while females were equal or more numerous than males in Segments 2 and 4 (Table A-1). The ratio of males to females was 1:1 in Segment 2, 1:2 in Segment 4, 1:0.7 in Segment 5, and 1:0.27 in Segment 6. The higher number of males to females was particularly evident during May in Segment 6 between RM 84 and RM 89 (Figure 3-2). Overall, males were more numerous than females in the 1992 and 1993 collections.

As described throughout this report, adult robust redhorse were collected in the middle and lower study areas and were predominantly associated with meandering reaches of the Oconee River. A review of robust redhorse survey data (Table A-1) shows that both spawning and non-spawning robust redhorse were collected in the same meandering reaches of the Oconee

River. Figure 3-2 shows that relatively high numbers of non-spawning and spawning robust redhorse were collected between RM 89 and RM 98 in the months of April, May, June, September, 1992 and 1993. The same is true for the area between RM 101 to RM 105 during the same months; as well as for the area between RM 84 to RM 89 where both non-spawning and spawning robust redhorse were captured.

During the 18 to 23 May 1993 GPC surveys, adult robust redhorse were frequently collected. The 6 day sampling period in May 1993 yielded 50 observations of adult robust redhorse of which 49 individuals were actually captured. The average catch per unit effort (CPUE) for the six day period was 2.98 per hour of electrofishing while the daily CPUE varied from 0.66/hr on 18 May between RM 104 to RM 98 to 11/hr on 22 May 1993 in the vicinity of RM 84 to RM 88.5 (Table 4-3). The WRD calculated daily CPUE for robust redhorse in the month of May 1993 that varied from 3.6/hr in the area near RM 86 to 10/hr in the vicinity of RM 98 to 104 (Evans 1994). The WRD in collaboration with EA has calculated CPUE for daily robust redhorse collections as high as 18.7/hr on 3 June 1993.

4.1 SPAWNING AND NON-SPAWNING ADULT ROBUST REDHORSE HABITAT-USE

Comparison of use frequency for substrates showed that 49.5 percent of spawning robust redhorse were associated with coarse sand compared to 43.9 percent of the non-spawning robust redhorse. About 40 percent of spawning robust redhorse were associated with large-size gravel compared to 48.8 percent of the non-spawning robust redhorse. Substrate used was inconsistent with the 1993 observations of robust redhorse actively maintaining gravel redds and the tendency for other species of redhorse to seek out and utilize gravel as redd building material in other geographic areas (Pflieger 1975). The most likely explanation of why the majority of robust redhorse in spawning condition were collected over sand substrate is that there were large areas of sand around the gravel deposits and those individuals collected over the sand were not in the actual act of spawning at the time of capture.

Sampling gear also has been introduced as a possible explanation for the high incidence of robust redhorse over sandy substrates (Jenkins 1992). Additionally, it is possible that fish are frightened and flee to other areas as the electrofishing boat approaches their spawning or resting area. The fish would then potentially be captured in unrepresentative habitats.

Quantification of usable habitat was beyond the scope of the study; however, the cumulative area (river miles) from which spawning robust redhorse were collected was estimated. Areas of significant gravel deposits and relatively high frequency of occurrence of robust redhorse cumulatively accounted for approximately 15 river miles; although, the habitats associated with the high catch areas occur intermittently between RM 76 and RM 120 (about 44 river miles). The estimate of potential spawning area is preliminary and should be interpreted cautiously given that important factors such as mapping accuracy, flow, uneven sampling effort, and sampling at different periods of time or flows can introduce bias. It does appear, however, that there is sufficient useable spawning habitat to support a larger robust redhorse population than currently exists; therefore, spawning habitat does not appear to be a factor that is limiting the robust redhorse.

Comparison of velocities used by spawning and non-spawning redhorse showed some variation. A higher percentage of non-spawning robust redhorse were captured in velocities from 0 to 1 ft/s than spawning redhorse (17.5 vs. 9.7 percent, respectively). The opposite was true for velocities between 1 to 2 ft/s (80 vs. 83.4 percent, respectively), and a higher percentage of spawning robust redhorse (6.9 percent) used velocities between 2 to 3 ft/s compared to 2.5 percent for non-spawning redhorse. Overall, velocities between 1 to 2 ft/s were used by non-spawning and spawning robust redhorse suckers (Figure 3-6).

Comparison of spawn and non-spawning cover use by robust redhorse showed that non-spawning robust redhorse were slightly less dispersed demonstrating a stronger tendency for fewer cover types (Figure 3-5). Complex log cover was used by 55 percent of non-spawning robust redhorse and 38.9 percent of the spawning robust redhorse. Non-spawning robust redhorse used five cover types whereas spawning redhorse used seven different cover types.

Overall, heavy wood debris (complex log cover and root masses) were used by non-spawning and spawning robust redhorse (Figure 3-5).

Comparison of spawn and non-spawning depth use showed that spawning robust redhorse used a greater range of depth (2-14 ft) than non-spawning robust redhorse (2-9 ft) (Figure 4-6) and in terms of frequency, used waters deeper than that used by non-spawning robust redhorse. Sixty percent of non-spawning robust redhorse were captured from waters 4 ft deep or less, while approximately 82 percent of the spawning robust redhorse were captured in waters deeper than 4 ft. Figure 4-6 shows a modal tendency toward 4 to 7 ft depths for spawning fish compared to 2 to 3 ft for non-spawning fish. Overall, depth use by non-spawning and spawning robust redhorse was most frequent for depths of 2 to 6 ft (Figure 3-7).

River flows (source USGS gage at Milledgeville) from the May survey dates were compared to average depth use of robust redhorse on the respective dates. The average depth of use ranged from 2.7 (one fish on 18 May 1993) to 6.8 ft for individuals captured in river flows of approximately 600 cfs, while the average depth of use was 7.3 ft for individuals captured in river flows of approximately 4500 cfs. This information is summarized in Table 4-4 and further supports the finding that robust redhorse use depths of 4 to 7 ft during spawning.

4.2 JUVENILE ROBUST REDHORSE

No yoy or juvenile specimens have been collected from the Oconee River. Recently the USFWS recommended a series of critical studies necessary to fill the current information gaps on the life history of the robust redhorse (Walsh 1994). One of those recommendations is to provide habitat assessment and instream flow requirements for possible nursery areas and juvenile habitat during all seasons.

As discussed in Chapter 1, many reasons have been hypothesized why yoy or juvenile robust redhorse have not been collected. A very plausible reason that has not been given adequate attention is that juvenile robust redhorse may utilize microhabitats that can not be sampled effectively by conventional fish collection gears. It has been assumed that yoy robust redhorse utilize similar habitat to other redhorse species, but this may or may not be accurate.

TABLE 4-1 NUMBER OF SPAWNING AND NON-SPAWNING ROBUST REDHORSE OBSERVATIONS BY MONTH AND SEGMENT ON THE OCONEE RIVER DURING 1992 AND 1993.

SEASON	YEAR	MONTH	STUDY SEGMENT	NUMBER
SPAWNING	1992	JUNE	4	1
			5	6
			6	3
		SEPTEMBER	4	3
			5	6
			6	7
	1993	OCTOBER	5	7
			6	3
		SEPTEMBER	6	4
NON-SPAWNING	1993	APRIL	4	2
			5	6
		MAY	2	2
			4	15
			5	12
			6	35
TOTAL				112

TABLE 4-3 CATCH PER UNIT EFFORT (REDHORSE/HR) FOR ROBUST REDHORSE FROM THE OCONEE RIVER, GA 18-23, MAY 1993

Date	Location	Rate of flow (cfs)	Redhorse Observed	Redhorse Collected	Effort (hrs)	CPUE Observed	CPUE Collected	CPUE Total
18 May	RR-Bridge to Hwy 57 Bridge	600	1	0	1.5	0.66	--	0.66
19 May	RR-Bridge to Hwy 57 Bridge	600	4	3	4.0	1.0	0.75	1.75
20 May	Kaolin Mines	600	1	3	5.0	0.2	0.6	0.8
21 May	Below Hwy 57 Bridge	600	2	10	4.0	0.5	2.5	3.0
22 May	Above Dublin	600	3	32	3.0	1.0	10.7	11
23 May	RR-Bridge to Hwy 57 Bridge	4500	2	1	4.0	0.5	0.25	0.75
Average CPUE								2.98

Source: GPC, 1993.

TABLE 4-2 CATCH OF ROBUST REDHORSE BY MONTH AND STUDY SEGMENT FOR THE OCONEE RIVER, 1992-1993.

Month	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Total	Percent
April	--	--	--	2	6	--	8	7.1
May	--	2	--	15	12	35	64	57.0
June	--	--	--	1	6	3	10	9.0
September	--	--	--	3	6	11	20	17.9
October	--	--	--	--	7	3	10	9.0
Total	--	2	--	21	37	52	112	100
Percent	--	1.8	--	18.8	33	46.4		

Source: GPC, 1993.

TABLE 4-4. COMPARISON OF AVERAGE FLOW AND DEPTH USE FOR SPAWNING ROBUST REDHORSE

Date	Approximate Flow	Average Depth of Use
5 May	477.4	4.6
18 May	481	2.7
19 May	488	5.1
21 May	504	6.8
22 May	4718(a)	5.5
23 May	4731	7.3

Notes: * = USGS flow record at Milledgeville, Georgia.
(a) = The survey area was located upstream of Dublin, Georgia where higher from Milledgeville had not yet reached.

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APPENDIX A

Robust Redhorse Catch Data, 1992-1993

TABLE A-1 ROBUST REDHORSE SURVEY DATA FROM 1992 RESOURCE SURVEYS AND 1993 EVALUATION STUDIES, OCONEE RIVER, GEORGIA.

Serial No.	Season	Date	Year	Length (mm)	Weight (g)	Depth (ft)	Mean Col.Vel (ft/sec)	Dom. substrate	Dom. cover	Sex	Segment
1	non-spawn	Jun 25	1992	575	2750	2.10	1.75	3	4	U	3
2	non-spawn	Jun 26	1992	621	3170	2.80	1.25	3	4	M	4
3	non-spawn	Jun 26	1992	625	2730	2.80	1.25	3	4	M	4
4	non-spawn	Jun 26	1992	605	2825	2.80	1.25	3	4	F	4
5	non-spawn	Jun 26	1992	594	2725	2.80	1.25	3	4	M	4
6	non-spawn	Jun 26	1992	582	3075	2.80	1.25	3	4	F	4
7	non-spawn	Jun 26	1992	542	2260	2.80	1.25	3	4	U	4
8	non-spawn	Jun 27	1992	625	3250	2.30	1.95	3	4	M	5
9	non-spawn	Jun 27	1992	630	3475	2.30	1.95	3	4	M	5
10	non-spawn	Jun 27	1992	607	2550	2.30	1.95	3	4	M	5
11	non-spawn	Sep 16	1992	618	2750	2.30	1.25	3	4	U	3
12	non-spawn	Sep 16	1992	687	4250	2.30	1.25	3	4	U	3
13	non-spawn	Sep 16	1992	430	1700	2.30	1.25	3	4	U	3
14	non-spawn	Sep 17	1992	620	4000	5.70	1.00	3	4	U	4
15	non-spawn	Sep 17	1992	643	5500	5.70	1.00	3	4	U	4
16	non-spawn	Sep 17	1992	590	4000	5.70	1.00	3	4	U	4
17	non-spawn	Sep 17	1992	645	3500	5.70	1.00	3	4	U	4
18	non-spawn	Sep 17	1992	645	5250	5.70	1.00	3	4	U	4
19	non-spawn	Sep 17	1992	593	3500	5.70	1.00	3	4	U	4
20	non-spawn	Sep 18	1992	640	4000	2.40	2.30	3	4	U	5
21	non-spawn	Sep 18	1992	666	4000	2.40	2.30	3	4	U	3
22	non-spawn	Sep 22	1992	615	3750	2.90	1.85	3	4	U	6
23	non-spawn	Sep 22	1992	642	4250	2.90	1.85	3	4	U	5
24	non-spawn	Sep 22	1992	669	4500	2.90	1.85	3	4	U	6
25	non-spawn	Sep 22	1992	610	3500	2.90	1.85	3	4	U	6
26	non-spawn	Sep 22	1992	626	4250	2.90	1.85	3	4	U	6
27	spawn	May 18	1993	—	—	2.69	0.98	4	9	U	4
28	spawn	May 19	1993	621	4500	4.99	1.81	1	9	M,RIPE	4
29	spawn	May 19	1993	—	—	4.40	0.98	3	0	U	4
30	spawn	May 19	1993	—	—	6.10	1.35	3	2	U	4
31	spawn	May 19	1993	—	—	6.69	0.96	3	2	U	4
32	spawn	May 19	1993	—	—	4.99	1.11	5	5	U	4
33	spawn	May 19	1993	600	4750	4.00	1.07	5	2	F,RIPE	4
34	spawn	May 19	1993	628	4750	4.30	1.82	6	4	F,RIPE	4
35	spawn	May 21	1993	660	5250	5.51	1.81	1	9	F,SPENT	3
36	spawn	May 21	1993	612	4800	6.00	1.31	3	2	M,RIPE	5
37	spawn	May 21	1993	635	6250	6.99	0.82	3	5	F,RIPE	5
38	spawn	May 21	1993	615	5500	2.49	1.00	3	4	F,RIPE	5
39	spawn	May 21	1993	—	—	5.51	0.50	3	3	U	3
40	spawn	May 21	1993	672	6000	7.51	1.18	3	0	F,SPENT	5
41	spawn	May 21	1993	650	5250	3.60	1.04	4	5	F,SPENT	3
42	spawn	May 21	1993	607	5000	9.19	1.31	5	5	M,RIPE	5

TABLE A-1 (CONT).

Serial No.	Season	Date	Year	Length (mm)	Weight (g)	Depth (ft)	Mean Col.Vel (ft/sec)	Dom. substrate	Dom. cover	Sex	Segment
43	spawn	May 21	1993	—	—	3.61	1.15	5	0	U	5
44	spawn	May 21	1993	623	5250	9.19	1.31	5	5	M,RIPE	5
45	spawn	May 21	1993	610	5400	9.19	1.31	5	5	F,RIPE	5
46	spawn	May 21	1993	604	4500	9.19	1.31	5	5	M,RIPE	5
47	spawn	May 21	1993	675	6750	9.19	1.31	5	5	F,SPENT	5
48	spawn	May 21	1993	644	4300	8.01	1.60	5	0	M,RIPE	3
49	spawn	May 21	1993	—	—	3.61	1.15	5	5	U	5
50	spawn	May 22	1993	632	5750	13.12	2.13	—	0	M,RIPE	5
51	spawn	May 22	1993	665	5800	13.12	2.13	—	0	F,RIPE	5
52	spawn	May 22	1993	682	8000	6.12	1	3	7	F,RIPE	6
53	spawn	May 22	1993	614	5700	4.80	1.88	3	7	F,RIPE	6
54	spawn	May 22	1993	—	—	6.12	1	3	7	U	5
55	spawn	May 22	1993	598	5250	5.20	1.25	3	5	M,RIPE	6
56	spawn	May 22	1993	664	7300	6.12	1.25	3	7	F,RIPE	6
57	spawn	May 22	1993	—	—	6.12	1	3	7	U	5
58	spawn	May 22	1993	—	—	6.12	1	3	7	U	5
59	spawn	May 22	1993	659	6250	3.60	2.25	3	7	M,RIPE	6
60	spawn	May 22	1993	611	6000	4.80	2.25	3	7	F,RIPE	6
61	spawn	May 22	1993	632	5600	6.12	1	3	7	F,RIPE	5
62	spawn	May 22	1993	641	5600	3.60	1	3	7	M,RIPE	5
63	spawn	May 22	1993	612	4800	3.60	1.25	3	5	M,RIPE	6
64	spawn	May 22	1993	584	4200	3.60	1.95	3	7	M,RIPE	6
65	spawn	May 22	1993	640	4800	3.60	1.95	3	7	M,RIPE	6
66	spawn	May 22	1993	624	5400	5.20	1.25	3	5	M,RIPE	6
67	spawn	May 22	1993	640	5400	4.80	1.88	3	7	M,RIPE	6
68	spawn	May 22	1993	643	6500	3.60	1.95	3	7	M,RIPE	6
69	spawn	May 21	1993	600	5750	9.84	1.15	3	0	U	5
70	spawn	May 22	1993	606	4250	4.80	1.88	3	7	M,RIPE	6
71	spawn	May 22	1993	628	5100	5.20	1.25	3	5	M,RIPE	6
72	spawn	May 22	1993	607	5000	3.60	1.25	3	7	M,RIPE	6
73	spawn	May 22	1993	653	6000	4.80	1.88	3	7	M,RIPE	6
74	spawn	May 22	1993	637	4800	5.20	1.75	3	5	M,RIPE	6
75	spawn	May 22	1993	623	4900	3.60	1.25	3	7	M,RIPE	6
76	spawn	May 22	1993	642	5700	5.20	1.25	3	5	M,RIPE	6
77	spawn	May 22	1993	594	5600	5.20	1.25	3	5	F,RIPE	6
78	spawn	May 22	1993	655	5750	4.80	1.88	3	7	M,RIPE	6
79	spawn	May 22	1993	620	5300	5.58	1.97	5	5	M,RIPE	6
80	spawn	May 22	1993	662	6400	8.20	0.66	5	5	F,RIPE	6
81	spawn	May 22	1993	626	5100	5.58	1.97	5	5	M,RIPE	6
82	spawn	May 22	1993	561	4700	4.59	1.15	5	5	M,RIPE	6
83	spawn	May 22	1993	576	4200	5.58	1.97	5	5	M,RIPE	6
84	spawn	May 22	1993	649	6000	5.58	1.97	5	5	M,RIPE	6
85	spawn	May 22	1993	637	5600	5.58	1.97	5	5	M,RIPE	6

TABLE A-1 (CONT).

Serial No.	Season	Date	Year	Length (mm)	Weight (g)	Depth (ft)	Mean Col.Vel (ft/sec)	Dom. substrate	Dom. cover	Sex	Segment
86	spawn	May 23	1993	—	—	4.59	1.15	5	5	U	4
87	spawn	May 23	1993	647	4500	9.19	1.31	5	5	F,RIPE	4
88	spawn	May 23	1993	—	—	8.20	0.66	5	5	U	4
89	spawn	May 5	1993	641	5000	7.50	1.18	5	5	F,RIPE	2
90	spawn	May 5	1993	637	4250	1.30	0.82	5	5	M,RIPE	2
91	non-spawn	Oct 5	1993	619	—	4.40	1.10	3	5	U	5
92	non-spawn	Oct 5	1993	600	—	5.50	1.60	3	5	U	5
93	non-spawn	Oct 5	1993	652	—	8.00	1.00	3	0	U	5
94	non-spawn	Oct 5	1993	600	—	5.00	1.81	3	5	U	5
95	non-spawn	Oct 5	1993	632	—	5.00	1.81	5	5	U	5
96	non-spawn	Oct 6	1993	614	—	2.70	0.98	3	5	U	5
97	non-spawn	Oct 6	1993	400	—	4.00	0.98	3	4	U	5
98	non-spawn	Oct 7	1993	623	—	5.50	1.04	5	4	U	6
99	non-spawn	Oct 7	1993	640	—	4.30	0.50	5	2	U	6
100	non-spawn	Oct 8	1993	701	—	2.50	1.82	3	0	U	6
101	non-spawn	Sep 30	1993	645	—	6.10	0.96	3	5	U	6
102	non-spawn	Sep 30	1993	605	—	6.70	1.04	3	7	U	6
103	non-spawn	Sep 30	1993	595	—	6.00	1.35	5	5	U	6
104	non-spawn	Sep 30	1993	592	—	7.00	1.31	5	0	U	6
105	spawn	Apr 28	1993	597	3600	9	1.5	4	2	M	4
106	spawn	Apr 28	1993	645	5000	9	1.05	2	3	U	4
107	spawn	Apr 29	1993	600	3900	7.6	1.65	4	9	M	5
108	spawn	Apr 29	1993	635	4500	6.5	2.15	5	2	M,RIPE	5
109	spawn	Apr 29	1993	665	4600	8.3	1	3	4	M,RIPE	5
110	spawn	Apr 29	1993	635	4150	6.6	1	3	2	M,RIPE	5
111	spawn	Apr 29	1993	621	3650	7.7	1.80	5	4	M,RIPE	5
112	spawn	Apr 29	1993	677	>5000	7.7	1.80	5	4	F,RIPE	5

Notes:

1) Surveys yielded 112 total observations, 13 of which were only visual observations. Overall sample consisted of 22 females, 43 males, and 47 undetermined gender.

2) Mean Col. Vel. = mean column water velocity calculated by calculating the average of the top and bottom measured water velocity in a single water column.

3) Substrate and Cover Codes

Dominant substrate	Dominant cover
1 = clay or hardpack	0 = no cover
3 = coarse sand	2 = tree with branches
4 = small gravel	3 = snag
5 = large gravel	4 = log
	5 = log complex
	7 = detached root wads
	9 = sticks

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