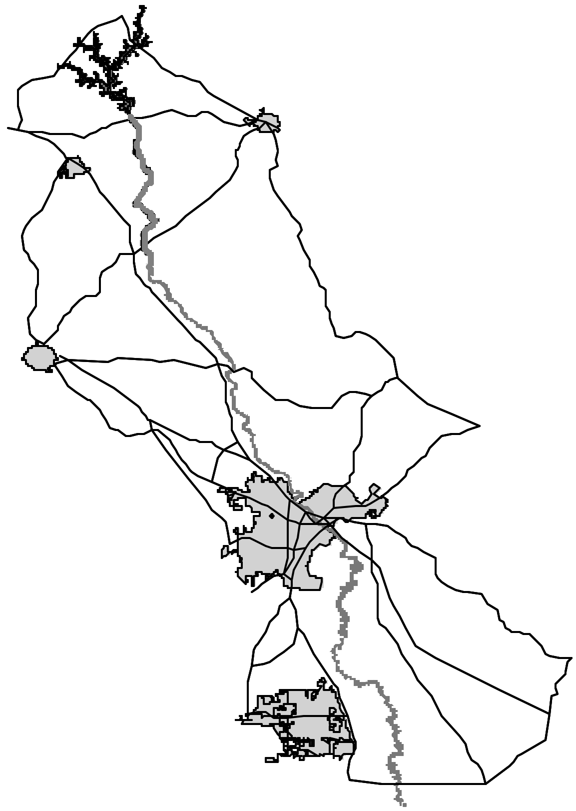
Movement and habitat use of hatchery-reared juvenile robust redhorse *Moxostoma robustum* released in the Ocmulgee River, GA



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Executive Summary

Robust redhorse are large catostomids that once were abundant in medium- to large rivers in the Atlantic slope. Currently, only three extant populations are known, and efforts to recover the species include the establishment of refugial populations. A Candidate Conservation Agreement with Assurances for the robust redhorse, *Moxostoma robustum* (CCAA), was developed as a collaborative effort between Georgia Power, Georgia Department of Natural Resources, and the US Fish and Wildlife Service to expedite the reintroduction of the robust redhorse into the Ocmulgee River, Georgia. This report documents the movement patterns and habitat use of 30 hatchery-reared, Phase II robust redhorse stocked in the Ocmulgee River and monitored via radio telemetry in support of Conservation Actions of the CCAA. The objectives for this work were to assess habitat used by the stocked fish, estimate the proportion of stocked fish that remained in study reach (i.e., between Lloyd Shoals Dam and Juliette Dam), and to determine how far downstream the stocked fish would migrate. During spring and summer 2002, the stocked fish were tracked for 104 days with a programmable scanning radio receiver. The tagged fish moved downstream gradually, with occasional upstream or lateral movements. Fifteen of the 30 tagged fish traveled less than 0.1 river kilometer (RKM) per day, nine fish traveled between 0.1 and 1.0 RKM per day, and six fish traveled between 1.0 and 2.0 RKM per day. Transmitter batteries began to fail on 82 days post-stocking. One fish died during the first 30 days of the study, and the remaining 29 ultimately were distributed throughout the study reach and beyond. As of 82 days post-stocking, 19 fish (66%) remained upstream of Juliette Dam, and 10 had moved downstream beyond Juliette Dam. The farthest signal was relocated near Warner Robbins, GA, which is about 115 RKM downstream of the release site. The tagged fish were associated most

frequently with woody debris cover (70%) and over gravel/cobble substrates (70%). The high survival of stocked fish and their propensity to stay within the study reach suggest that the use of hatchery-reared, Phase II robust redhorse to establish a refugial population in Ocumulgee River between Lloyd Shoals Dam and Juliette Dam has been effective short-term strategy.

Introduction

Much has been written about the imperilled robust redhorse *Moxostoma robustum* since its discovery in the Oconee River during the summer of 1991. Initially, nothing was known about this species, but research conducted in the intervening 12 years has answered many questions about the biology and ecology of these fish (Barrett 1997; Ruetz 1997; Walsh et al. 1998; Dilts 1999; Jennings et al. 2000; Ruetz and Jennings 2000; Weyers 2000; Freeman and Freeman 2001; Weyers et al. 2003). Unfortunately, many questions remain, and chief among them are 1) the fate of wild-spawned larvae and hatchery-produced juveniles and 2) their eventual contribution to the adult populations. Currently, questions about habitat use and movement patterns of juvenile robust redhorse hinder interpretations of the available size-class data. These questions also confound management decisions about when and where to release hatchery-reared fish and how best to monitor their fate.

Radio-telemetry has been used effectively to monitor natural behavioral processes (i.e., home range, movement patterns, and habitat use) for various free-ranging animal populations (White and Garrott 1990), including fishes (Winter 1996). Radio telemetry is especially useful for tracking fishes because fish movements can be quickly and continually monitored (Minor and Crossman 1978). For example, telemetry was used to estimate seasonal movement patterns of the endangered razorback sucker (*Xyrauchen texanus*) in the middle Green River, Colorado (Modde and Irving 1998). Also, telemetry methods were used to determine habitat use and movement patterns of hatchery-reared razorback suckers released in various parts of the Colorado River in Arizona, California, and Utah (Bradford and Gurtin 2000; Mueller et al. 2003).

Efforts to conserve robust redhorse within the species' historic range led to the establishment of the Robust Redhorse Conservation Committee (RRCC) in 1995. The RRCC exists by a memorandum of understanding signed by the Georgia Power Company (GPC), the Georgia Department of Natural Resources (GA DNR), the United States Geological Survey (USGS), and the United States Fish and Wildlife Service (USFWS), among others. The main objectives of the RRCC's recovery efforts are: 1) to establish refugial populations to serve as future broodstock, and 2) to eventually develop reproducing populations throughout the species' known historic range (RRCC 1995; 2000). In pursuing these objectives, the RRCC has coordinated the stocking of hatchery-reared juvenile robust redhorse into suitable rivers within the species' historic range.

As part of the recovery effort, GPC and the USFWS entered into a Conservation Agreement to establish a refugial population of robust redhorse in the Ocumulgee River, Georgia (Department of Interior 2001). The agreement also calls for an assessment of the fate of the stocked hatchery fish, whose success in the wild was thought to depend on the availability of suitable habitat and a refuge from the predation threat posed by the highly piscivorous flathead catfish *Pylodictis olivaris* that inhabits the Ocmulgee River.

In this report, we present results of a radio telemetry study of the movement patterns and habitat use of hatchery-reared juveniles released into the Ocmulgee River in Georgia. Our objectives for this study were to determine 1) general habitats used by the hatchery-reared robust redhorse released in the Ocmulgee River, 2) the proportion of stocked fish that remained in the study reach, and 3) how far downstream the stocked fish moved.

Material and Methods

Study site

Hatchery-reared robust redhorse were released into a 30-river kilometer (RKM) reach of the Ocmulgee River, GA (Figure 1). This reach was bordered by two dams and met the criteria (i.e., suitable habitat and without flathead catfish) established by the RRCC for the establishment of a refugial population. Lloyd Shoals Dam (which impounds Lake Jackson) served as the upstream boundary of the study reach, and the low-head Juliette Dam served as the downstream boundary (Figure 1). Woody debris, boulders, and a variety of substrates (gravel/cobble, sand, mud) were abundant and occurred throughout the site. Further, Juliette Dam blocks the upstream movement of flathead catfish, which are not present in the project site. Flathead catfish predation has been hypothesized as a contributing to the current status of the robust redhorse population in Oconee River (Evans 1994).

Transmitters

Behavior of fishes tagged with radio transmitters does not seem to be affected if the weight of the transmitter in air is # 2 % of the weigh to the fish (Winter 1996). Our estimate of the size of transmitter that would be suitable for use with the hatchery-reared robust redhorse to be released in the Ocmulgee was based on estimated weights provided by personnel from GA DNR. The radio transmitters (Advanced Telemetry Systems® model 1440) used in this study weighed - 2.1 g in air and were 19 mm long by 8.7 mm wide; the trailing whip antenna was 15 mm long (Figure 2). The transmitters broadcasted a radio signal (i.e., an intermittent beep at a rate of 35 pulses per minute and

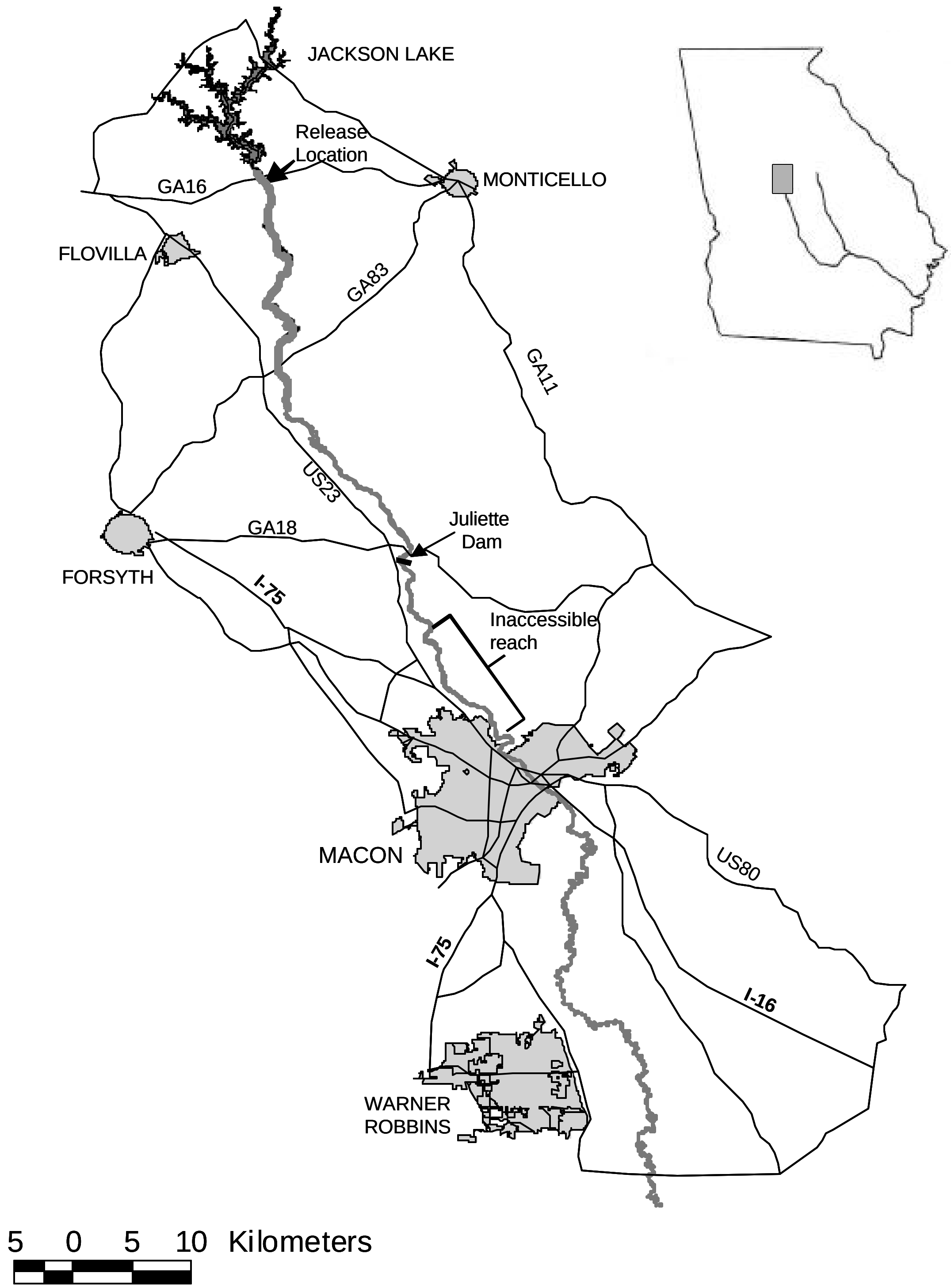

Figure 1. Map of Georgia that shows the location of the Ocmulgee River and a close-up of the reach of river where hatchery-reared Phase II robust redhorse were tracked with radio telemetry equipment during spring and summer 2002.

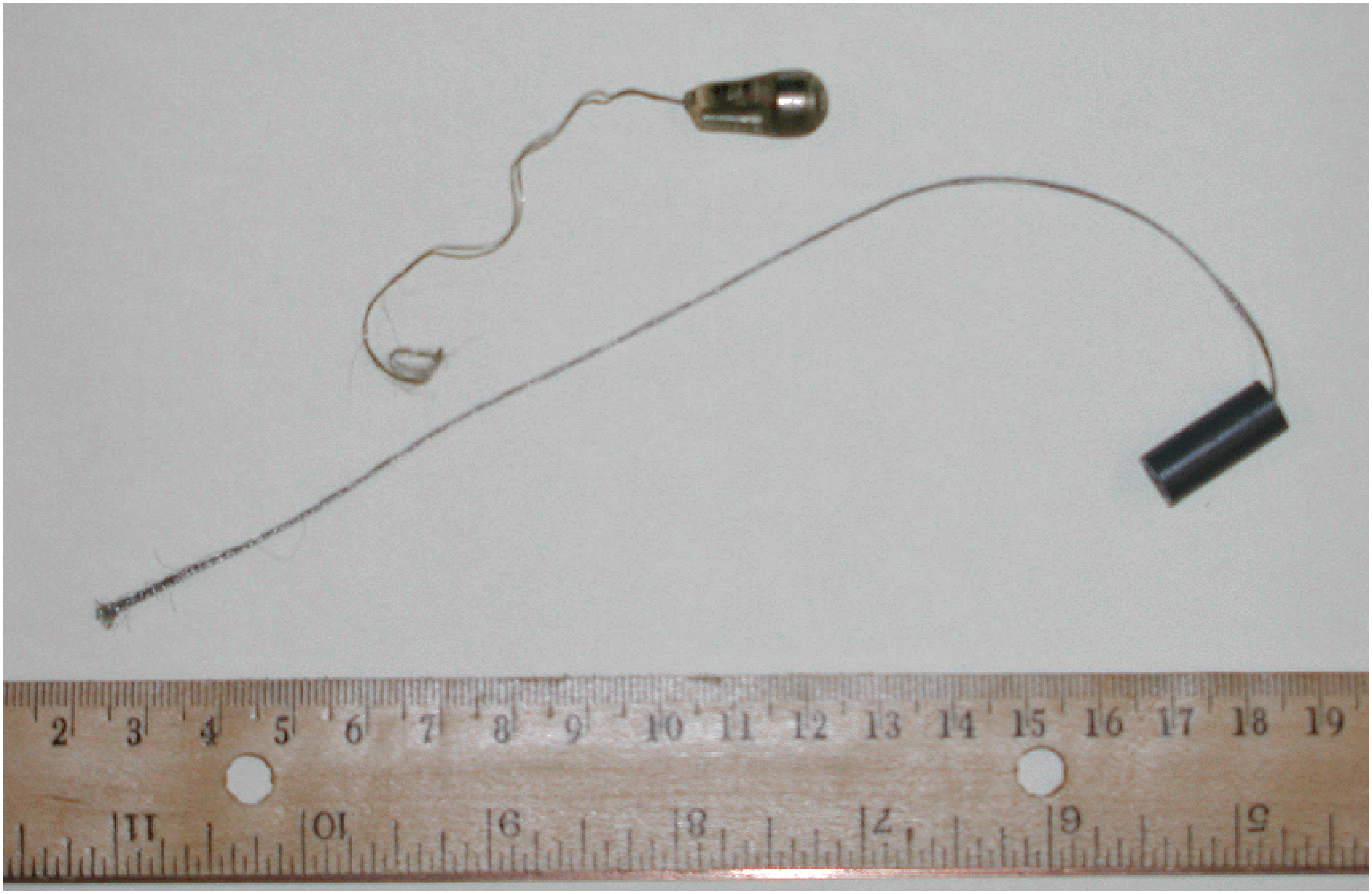

Figure 2. Photograph of real (left) and artificial (right) transmitters implanted in robust redhorse as part of the assessment of their habitat use and movement patterns in the Ocmulgee River, Georgia during spring and summer 2002.

pulse width of 15 m^{-s}) in the frequency range between 40-41 Mhz. The battery life on each transmitter was warrantied for 83 days. The small size of these transmitters did not permit the addition of circuitry for mortality switches or duty cycles that would have conserved battery power and extended the life of the transmitters.

Artificial transmitters that were similar in size, weight, and shape to the ATS model 1440 were used as surrogates to evaluate mortality associated with our implant procedure; the "control" fish were kept at the Whitehall Fisheries Laboratory at the University of Georgia in Athens, GA. The artificial transmitter had a polyvinylchloride (PVC) body and a cylindrical stainless steel core; a Teflon-coated wire was attached to simulate a trailing whip antenna (Figure 2).

Collection and transport of fish

On March 19, 2002, 70 phase II robust redhorse were harvested from GA DNR's McDuffie Fish Hatchery (McDuffie County, near Thompson, GA). These fish were placed into aerated hauling tanks and transported (about a 2.5 hour trip) to Lloyd Shoals boat ramp on the Ocmulgee River, about 300 m downstream of Lake Jackson. There, 30 fish were selected randomly, anaesthetized (see methods below), surgically implanted with radio transmitters, allowed to recover, and released into the Ocmulgee River. The remaining 40 fish were transported (about 1.5 hour trip) to the University of Georgia's Whitehall Fisheries Laboratory in Athens. There, 30 of the 40 fish were randomly selected and surgically implanted with artificial transmitters. The surgical procedures performed on the control fish was the same as that performed on the fish released in the Ocmulgee River.

Anesthesia methods

All fish were anesthetized similarly in preparation for receiving real or artificial transmitters. Each fish was anesthetized with a solution of 140 mg tricaine methyl-sulfonate (MS-222) per liter of water. The fish was considered to be anesthetized when it failed to maintain an upright orientation in the water column and did not respond to contact. The immobilized fish were transferred to a surgery cradle housed in a 53-L rectangular ice chest containing a water pump and about 10 L of water with a sedative dose (70 mg per liter) of MS-222 (See Courtois 1981). Once on the cradle, a small tube connected to the water pump was fitted into the fish's mouth, and aerated water containing the sedative dose of MS-222 was pumped over the fish's gills throughout surgery (Courtois 1981). After surgery, tagged fish were allow to recover from the anesthesia (i.e., they could maintain upright orientation in the water column and flee from attempted contact) in a second 53-L rectangular ice chest containing anesthesia-free water before they were released or placed in holding tanks for observation.

Transmitter implantation method

Transmitter implantation was conducted similarly for field and lab fish. Each anesthetized fish was positioned ventral side up on the surgery cradle (Figure 3). A No. 22 scalpel blade was held cutting side up and used to make about a 2.5 cm-long incision that began posterior to the pectoral fins. A groove director was used during this process to prevent the cutting of internal organs. Once the incision was made, a soluble, powdered formulation of the antibiotic oxytetracycline was sprinkled into the incision to prevent infection (Figure 4). Next, the shielded needle technique (Ross and Kleiner

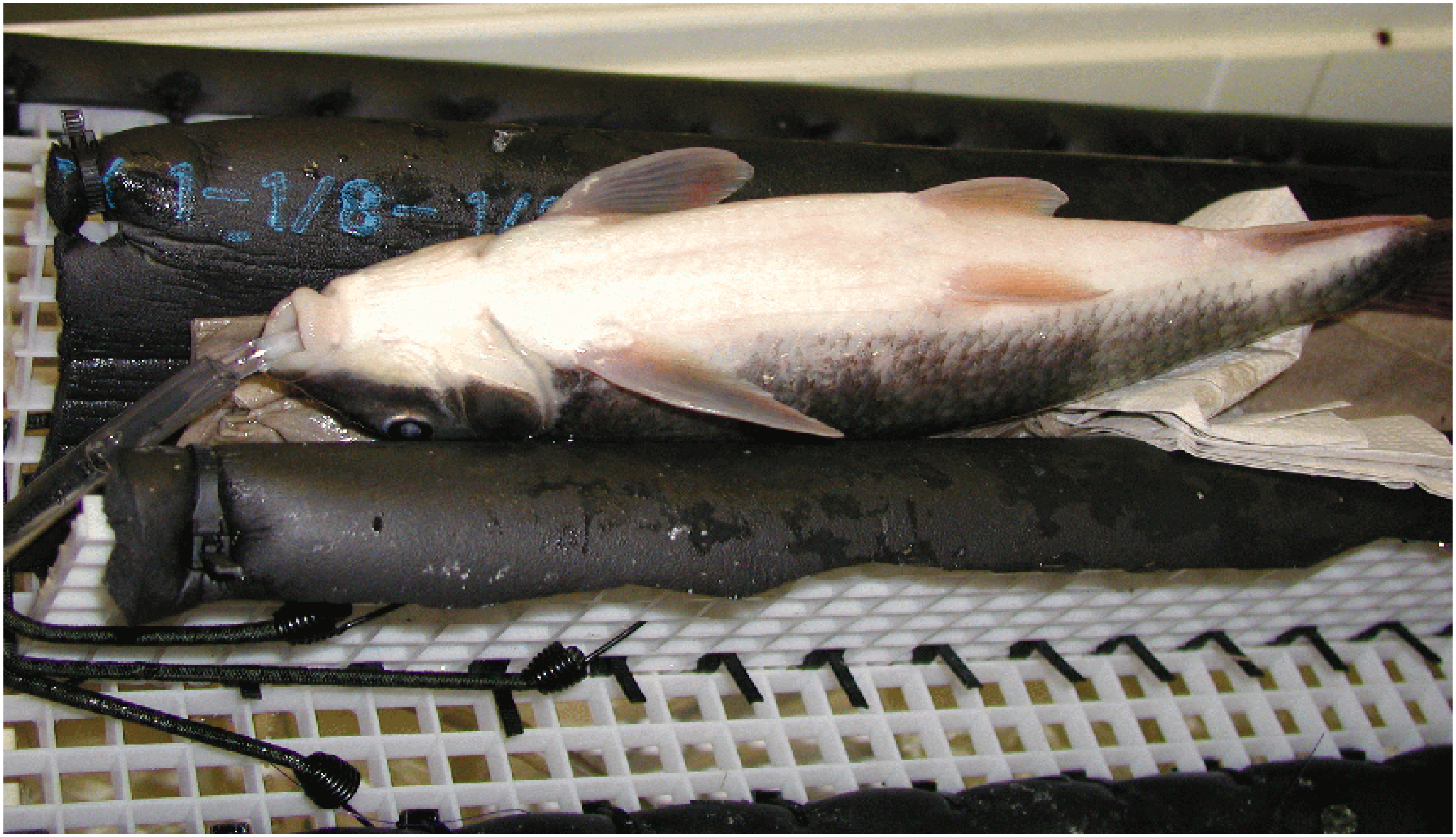

Figure 3. Photograph of hatchery-reared, Phase II robust redhorse positioned ventral side up on a surgery table and waiting to be implanted with a radio transmitter.

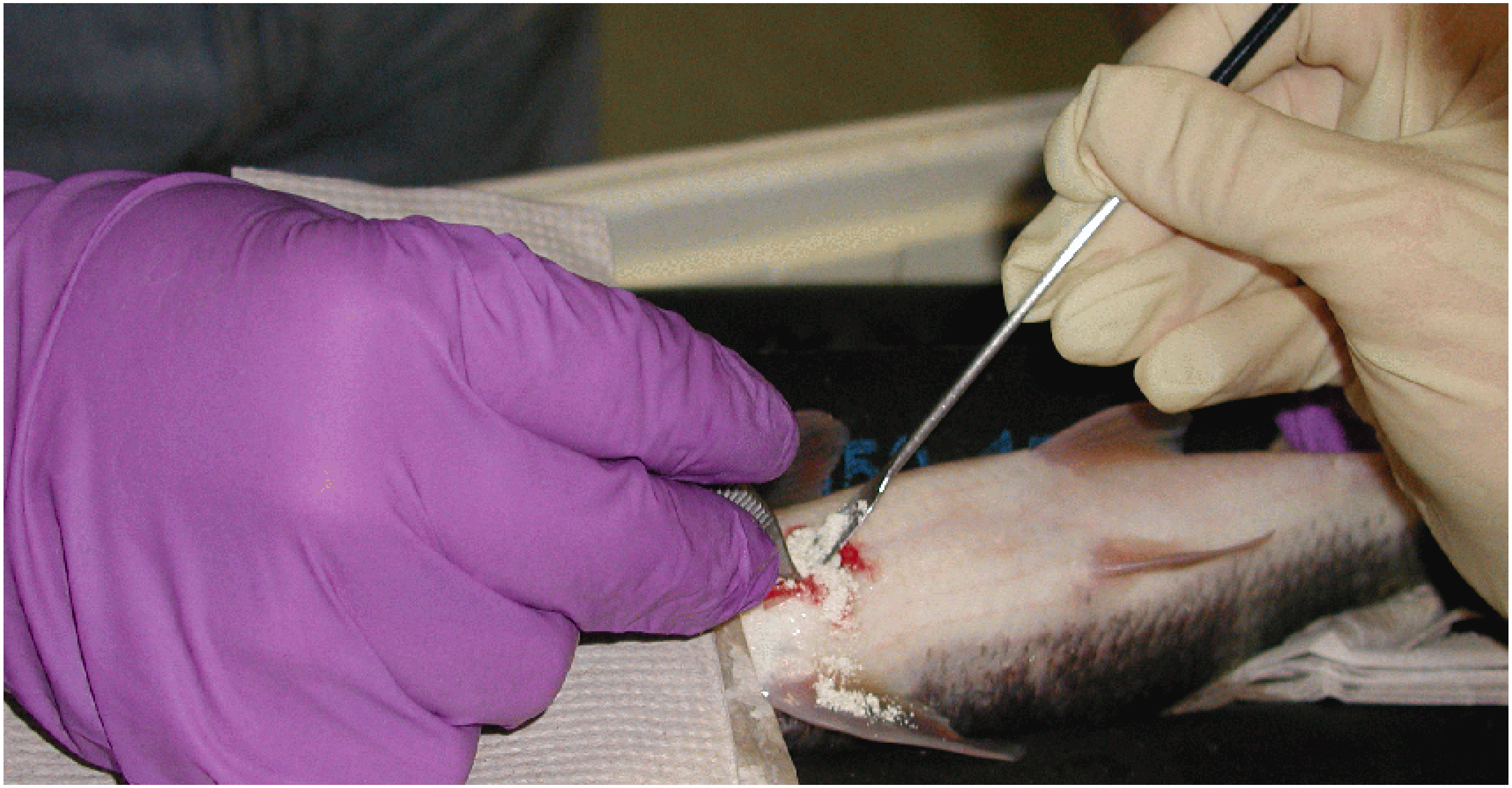

Figure 4. Photograph of hatchery-reared, Phase II robust redhorse with an incision in its ventral abdominal wall through which powdered tetracycline (antibiotic) is being added to reduce the risk of infection.

1982) was used to thread a whip antennae through the incision to exit point about 3.0 cm away from the posterior terminus of the incision. The transmitter was coated with a thin film of oxytetracycline powder and placed into the peritoneal cavity of the fish. Before the incisions was closed with sutures, a thin film of cyanoacrylate glue (i.e., crazy glue) was applied to the exterior of the incision to serve as a short-term water seal during the initial stages of wound healing (Dr. R. Borderson, UGA Veterinarian - personal communication). The incision was closed (usually with two or three sutures) with Olsen-Hegar needle holders and a FS-1 cutting needle equipped with Ethicon 2-0 Polydioxanone II absorbable suture material (Figure 5). A new sterile scalpel and package of suture material was used for each fish. All other surgical equipment was sterilized in 95% ethanol.

Post-implantation treatment of lab fish

Thirty juvenile robust redhorse were implanted with artificial transmitters with the procedures described above (i.e., same anesthesia, surgery, and recovery as the fish tagged and released into the Ocmulgee River). After surgery and recovery, these fish were randomly placed in one of three tanks (n=10 tagged fish in each tank) with a common recirculating system. The remaining 10 fish were not tagged, but they were randomly placed in the three tanks that held the tagged fish. All lab fish were fed trout chow and meal worms at a rate of about 3 percent of body weight per day. These fish were monitored daily for mortality throughout the duration of the study.

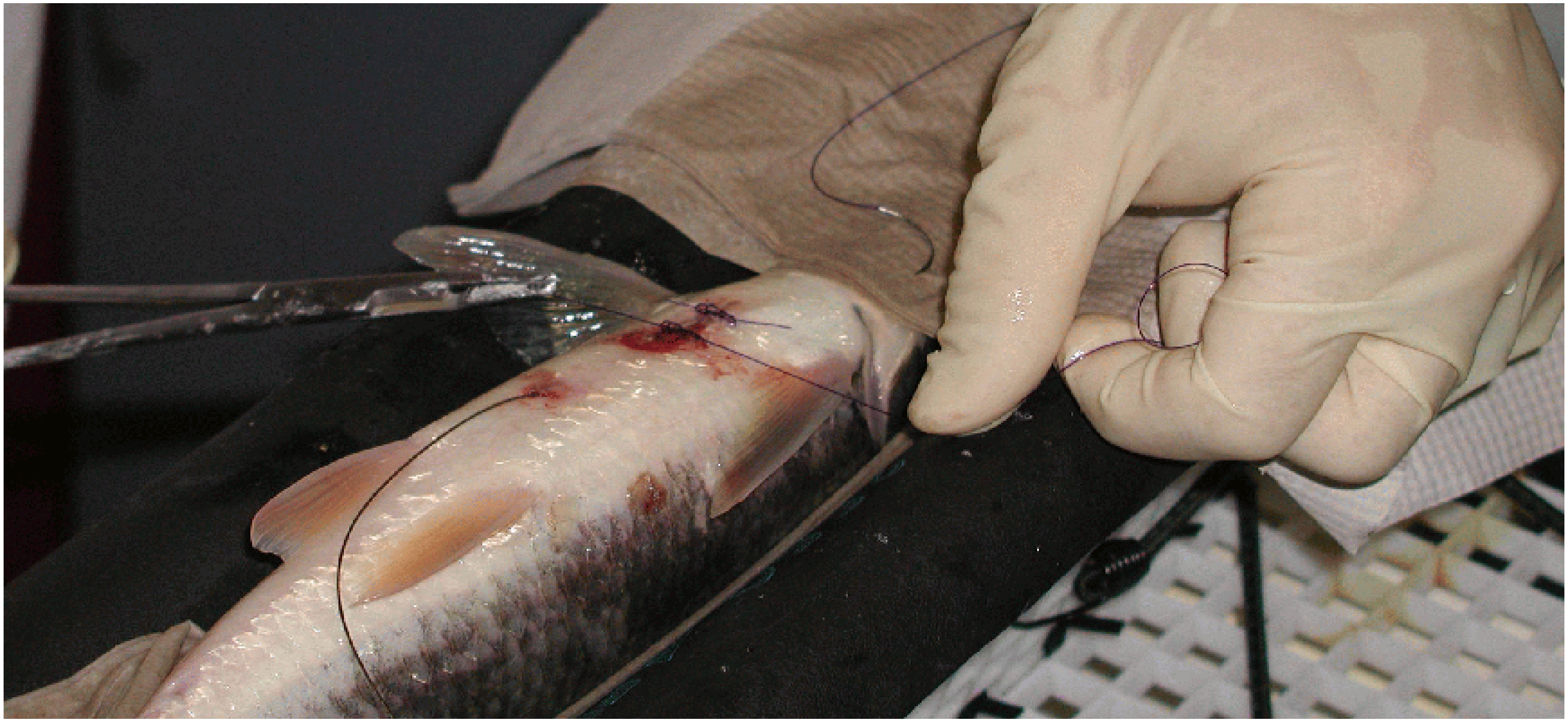

Figure 5. Photograph of hatchery-reared, Phase II robust redhorse that has two sutures used to close the incision through which a radio transmitter was implanted.

Fish tracking

The radio-tagged fish in the study were tracked with an Advanced Telemetry Systems (ATS) model R2100 programmable scanning radio receiver fitted with a hand-held loop antenna. The signal sensitivity of the loop antenna was from 400 meters to within four meters of the transmitter; within four meters of the transmitter, signal strength was equal in all directions. When this occurred, the antenna's coaxial cable was disconnected from the loop antenna and could be used effectively (i.e., signal strength was directional) to fix to the transmitter's (and the fish's) position. The coaxial cable as antenna could fix the transmitter's position to within one meter, at which time the associated fish was considered to have been located. Once each fish was located, latitude and longitude coordinates were taken with a Trimble® Scout global positioning unit, and habitat variables were measured.

Fish were tracked daily for the first 10 days post release; thereafter, they were tracked weekly (up to five days per week) as conditions permitted. Tracking was conducted mainly by boat, and occasionally on foot or by truck as necessitated by shallow river conditions. Finally, a remote monitoring station (i.e., Yagi antenna connected to an ATS R2100 programmable scanning receiver and an ATS Data Collection Computer) was placed behind a fenced enclosure (i.e., Georgia Power's Lake Juliette Water Intake Structure) adjacent to the Ocmulgee River. This remote monitoring station was about 4 RKM downstream of Juliette Dam and was used to continuously monitor for fish leaving the study site. A single radio transmitter was placed about 100 yards inland from the monitoring station, and it served as a reference signal to evaluate the performance of the telemetry equipment at the remote monitoring station. The expanding stretch of river between the release site and fish farthest downstream was considered the “target reach”. Water-level permitting, tagged fish were tracked weekly over the entire target reach.

Habitat and water quality measurement

Cover and substrate types were assessed and recorded for located fish; standard water quality variables also were measured and recorded for each located fish. The dominant substrate (e.g., gravel, sand, mud) associated with the fish’s location was estimated by probing a 1-meter radius of the substrate with a metal pole. The dominant cover (e.g., woody debris, boulders) associated within a three meter radius of the location was visually assessed. If visible cover was not apparent within the 3-meter radius of the location, the cover type was recorded as “none”. Depth (m) was measured with a graduated staff gauge. Water temperature (EC) and dissolved oxygen (mg/L) were measured with a YSI® (Yellow Springs Instrument Company) model 59 dissolved oxygen - temperature meter. Current velocity (m/s) was measured with a Marsh McBirney® current meter. Turbidity (ntu) was measured with a Hach® portable turbidity meter.

Data analysis

For each fish, distance traveled was estimated by plotting latitude and longitude locations on Delorme ® 3-D TopoQuads (Georgia) software. The rate of average daily travel was calculated by dividing the total RKM traveled by the number of days tracked for a given fish. Substrate and cover data were analyzed to ascertain frequency of occurrence of a specific cover type across all observations (i.e., all fish combined) and individually (for each fish).

Results

Sample population and transmitter implantation

All the robust redhorse sampled from McDuffie Fish Hatchery exceeded the minimum weight (210 g) necessary to comply with the # 2% transmitter-to-body weight guidelines recommended for radio telemetry studies. Mean weight of the tagged fish was 424 g (s.d.=49.5); mean total length (TL) was 300 mm (s.d.=11.6). Generally, the fish became immobile within two minutes of being placed in the anesthesia. The surgeries typically were completed in less than six minutes, and recovery from anesthesia occurred in about two minutes after the fish was placed in holding tank containing anesthesia-free water.

Fish survival

Almost all of the 70 (field-released and hatchery-held) radio-tagged robust redhorse used in this study were alive at the end of the 83 day field season. Twenty nine of the 30 (97%) tagged fish released in the wild were deemed to be alive when the transmitter batteries started failing on day 82 post-stocking. The single observed mortality among fish in the river was an individual that remained close to the release point and was relocated in the same location for two or three consecutive contacts over many days. An Aqua-Vu® underwater camera was used to confirm the fate of this fish 30 days after it was released. All the other fish displayed random (upstream, lateral, downstream) movement patterns that suggest independent locomotion. Of the 30 fish that received artificial transmitters and were held in the laboratory, 28 (93%) were alive and well at the end of the 82 day study. Survival was 100% among the 10 fish that were held in the lab but did not receive artificial transmitters. The 38 fish held in the lab remained alive and well until mid-October 2002 at which point they released into the Ocmulgee River just below Lloyd Shoals Dam.

Fish movement, habitat, use and associated water quality

Fish tracking was begun on March 19, 2003 and continued through June 30, 2003. There were 338 contacts with individual fish, the last of which was occurred on June 9th, 2003. This date coincides with the ATS's warranty for expected battery life for this model 1440 transmitter. On average, each fish was located 10 times (s.d.=5; n=30) after being released in the Ocmulgee River. Fish movement was generally downstream, with intermittent lateral or upstream movement. Typically, fish were found in the deepest, apparently-fastest water available. The average depth in such areas was 2.1 m (s.d. = 0.8; n=229) and average current velocity was 0.3 m^{-s} (s.d. = 0.3 m^{-s}; n= 183). Mean water temperature was 18.7 EC (s.d.=4.5; n=170), mean dissolved concentration was 0.9 mg/L (s.d.=4.4; n=169), and an average turbidity of 13.0 ntu (s.d.= 0.8; n=182).

The tagged fish remained at or near the release site for about two or three days post-stocking before beginning gradual downstream movement. All the tagged fish remained within a kilometer (i.e., above Georgia Highway 16) of the release site (Figure 6). During the next 20 days (i.e., day 4-24 post-stocking), most of the fish began to disperse downstream, sometimes in small groups of two or three individuals. This apparent "mini- schooling" behavior was observed throughout the study as some fish were found in groups of 2-3 individuals (within five meters of each other) far as 15 RKM downstream from the release site. Most downstream movement was in small (1-3 RKM per day) increments during the 2-3 days between radio contact, but there were a few individuals that traveled large distances downstream. Specifically, most of the tagged fish could be found within10 RKM (i.e., remained above GA Hwy 83) of the study site 30 days post-stocking; however, a few individuals had traveled much farther downstream. In fact, one individual had traveled the entire length of the study reach and was located just above the Juliette Dam (Figure 6).

The pattern of gradual downstream movement continued through the remainder of the study, and movement patterns seemed to be similar for individual fish and those in mini-schools. In addition to the general downstream movements, there were occasional lateral and upstream movements, and sometimes one mini-school would pass another mini-school (in either direction) without much apparent interaction. Both groups of fish seemed to move to an area, remain there for a few days, then move to the next area. The fish that moved the farthest distances downstream apparently did not remain in any one area for long. By 60 days post-stocking, most of the tagged fish were between Georgia Hwy 16 and Hwy 83. Three fish had traversed the entire study reach, and gone as far downstream as the Macon, GA (Figure 7).

The transmitters' batteries began failing about 82 days post-stocking and did so en masse. At this time, only a few fish could be contacted, despite many individual contacts the previous week. Further, extensive tracking downstream (as far as Warner Robin, GA) did not detect any of the fish that had been contacted upstream the previous week. By 82 days post stocking, most of the stocked fish remained within the study reach and were spread out between Hwy 16 and Juliette Dam (Figure 8). At this time, 10 fish had been detected below Juliette Dam, and six of these had traveled past Macon. The farthest downstream signal was found near Warner Robbins, GA, about 115 RKM downstream from the release site (Figure 8).

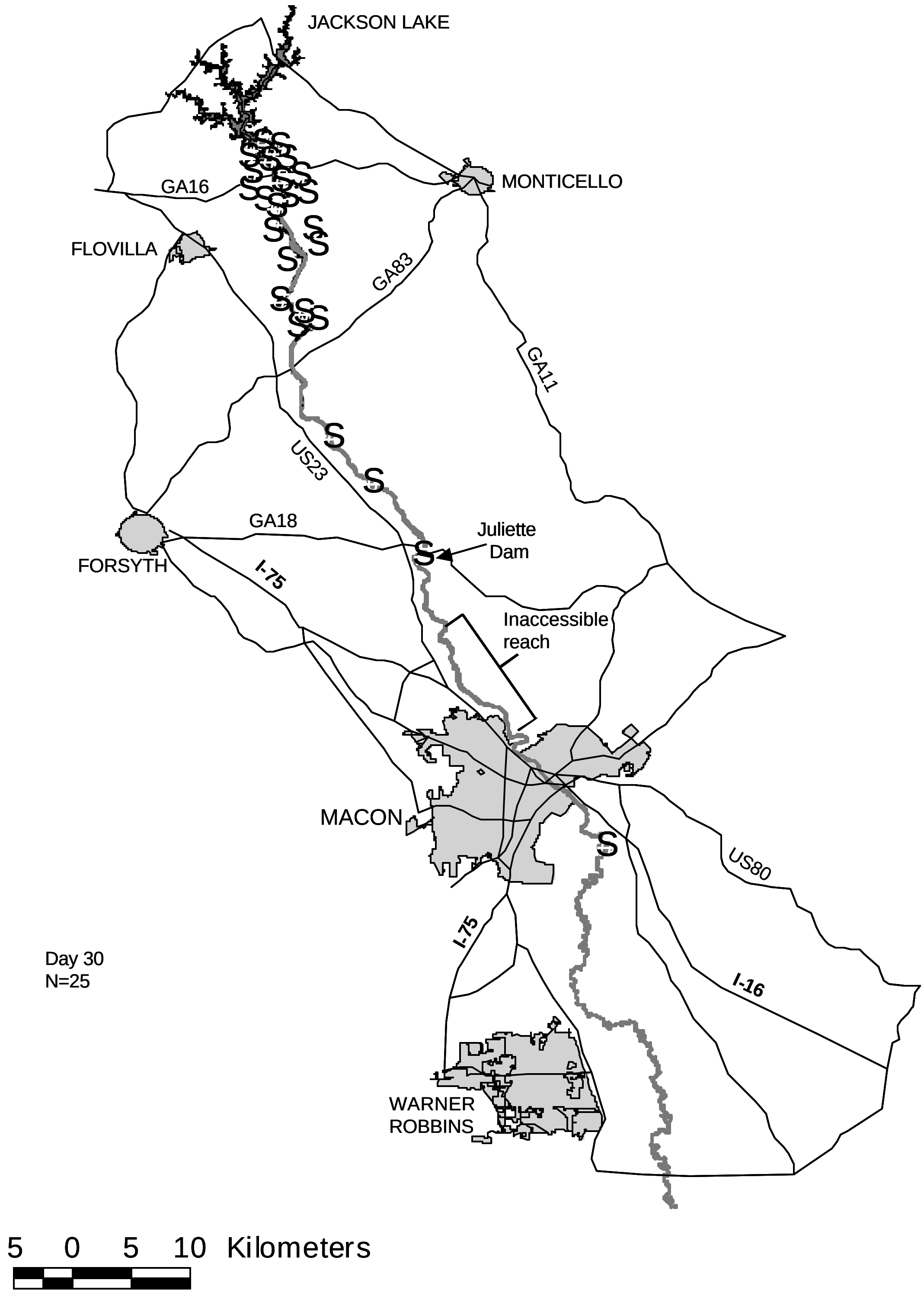

Figure 6. Map of the Georgia that shows the location of the Ocmulgee River and distribution of tagged, hatchery-reared, Phase II robust redhorse 30 days post-stocking. Individual fish are indicated with the symbol "•".

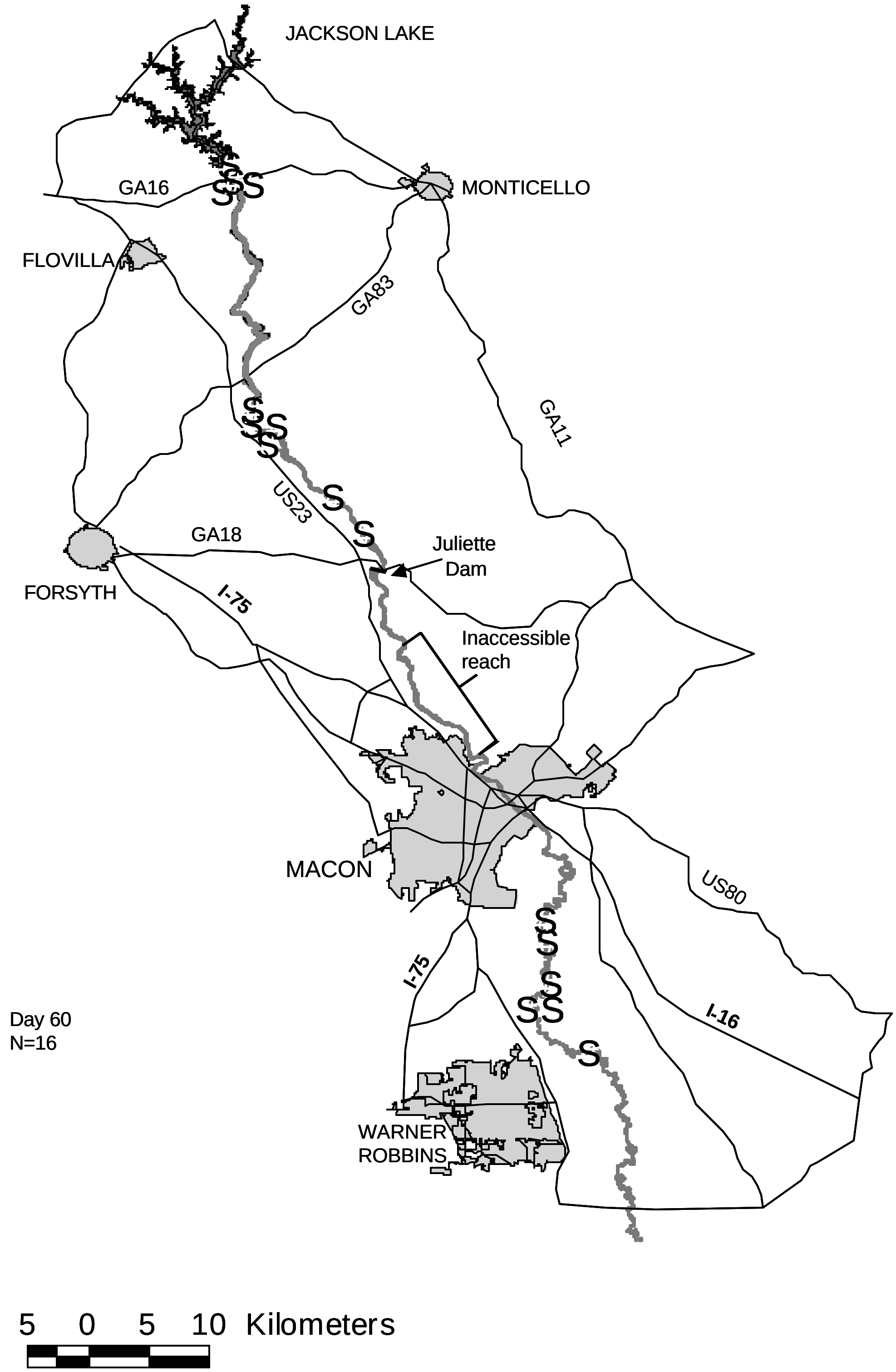

Figure 7. Map of the Georgia that shows the location of the Ocmulgee River and distribution of tagged, hatchery-reared, Phase II robust redhorse 60 days post-stocking. Individual fish are indicated with the symbol " • ".

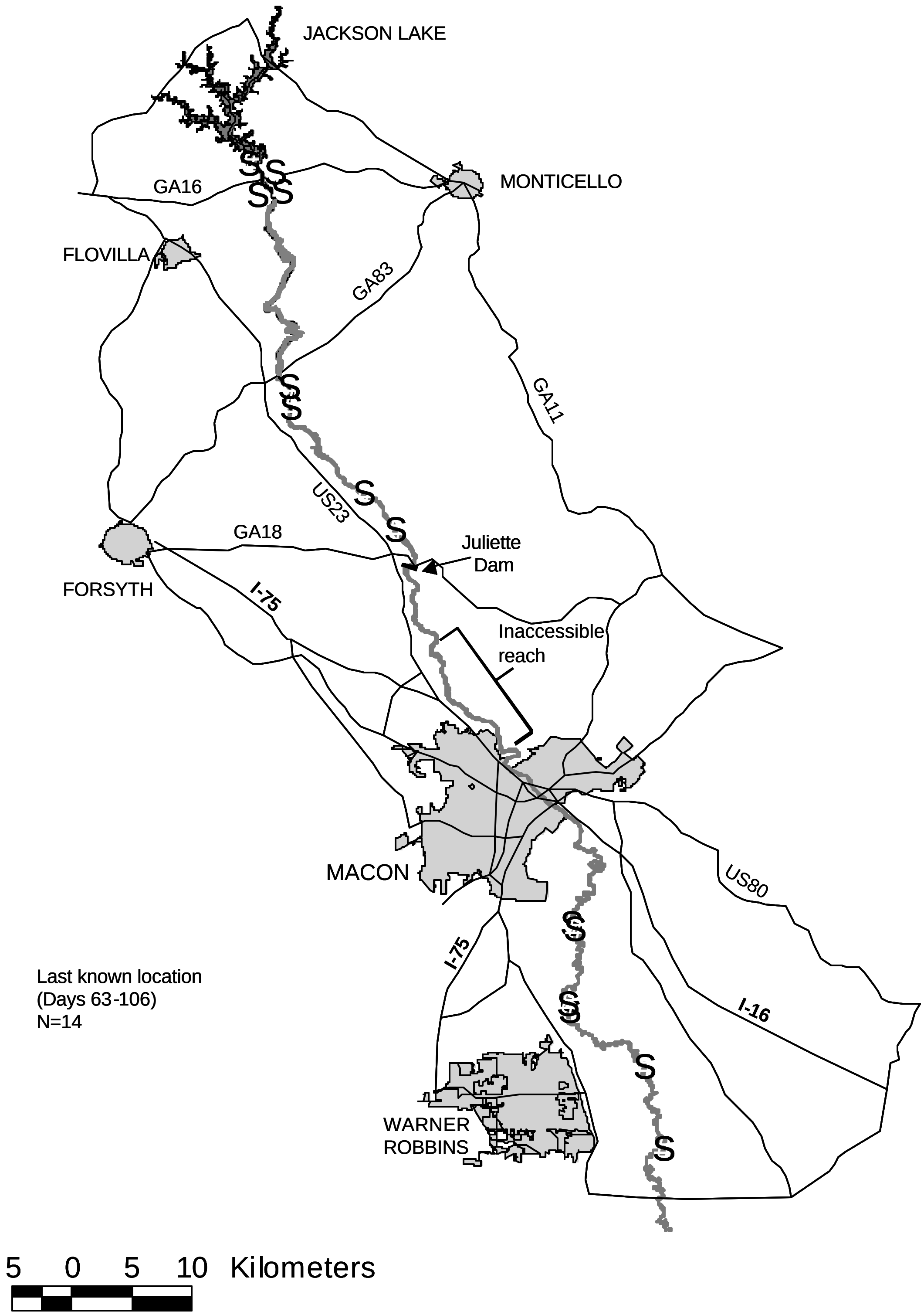

Figure 8. Map of the Georgia that shows the location of the Ocmulgee River and distribution of tagged, hatchery-reared, Phase II robust redhorse 82 days post-stocking. Individual fish are indicated with the symbol "• ".

During the study, half (n=15) of the tagged fish did not exhibited much daily movements (0.0 - 0.1 RKM); a third (n=10) of the tagged fish exhibited relatively short (0.1 - 1.0 RKM) daily movements. A small percentage (< 20%) of this tagged fish (n=5) made more extensive (1.0 - 2.0 RKM) daily movements compared with the others (Figure 9). Excluding the single confirmed mortality, most (65%) of the tagged fish (n=19) remained in the study site (i.e., upstream of Juliette Dam) through day 82 of the study.

The cover types with which the relocated tagged fish were associated varied, but a consistent pattern was evident. Generally, tagged fish were encountered most frequently (70%) near woody debris; the absence of cover (i.e., open water) was the second most-encountered (18%) cover type associated with relocated tagged fish (Figure10). This pattern also held among individuals, 86% (including those adjacent to and downstream of Macon) of whom were relocated most often near woody debris cover (Figure 11).

Patterns of associations between the relocated fish and the substrates with which they were associated also was predictable. Most often (70% of encounters), tagged fish were associated with gravel/cobble substrates (Figure 12); mud was the second-most (17%) substrate encountered with relocated fish. Among individual fish, 79% were located most often near gravel/cobble substrate. Half (3 of 6) of the tagged fish near or downstream of Macon were found most often near gravel/cobble substrates.

Discussion

During the spring and summer of 2002, we successfully documented the movements and habitat use patterns of hatchery-reared, radio-tagged robust redhorse released in the Ocmulgee River, Georgia

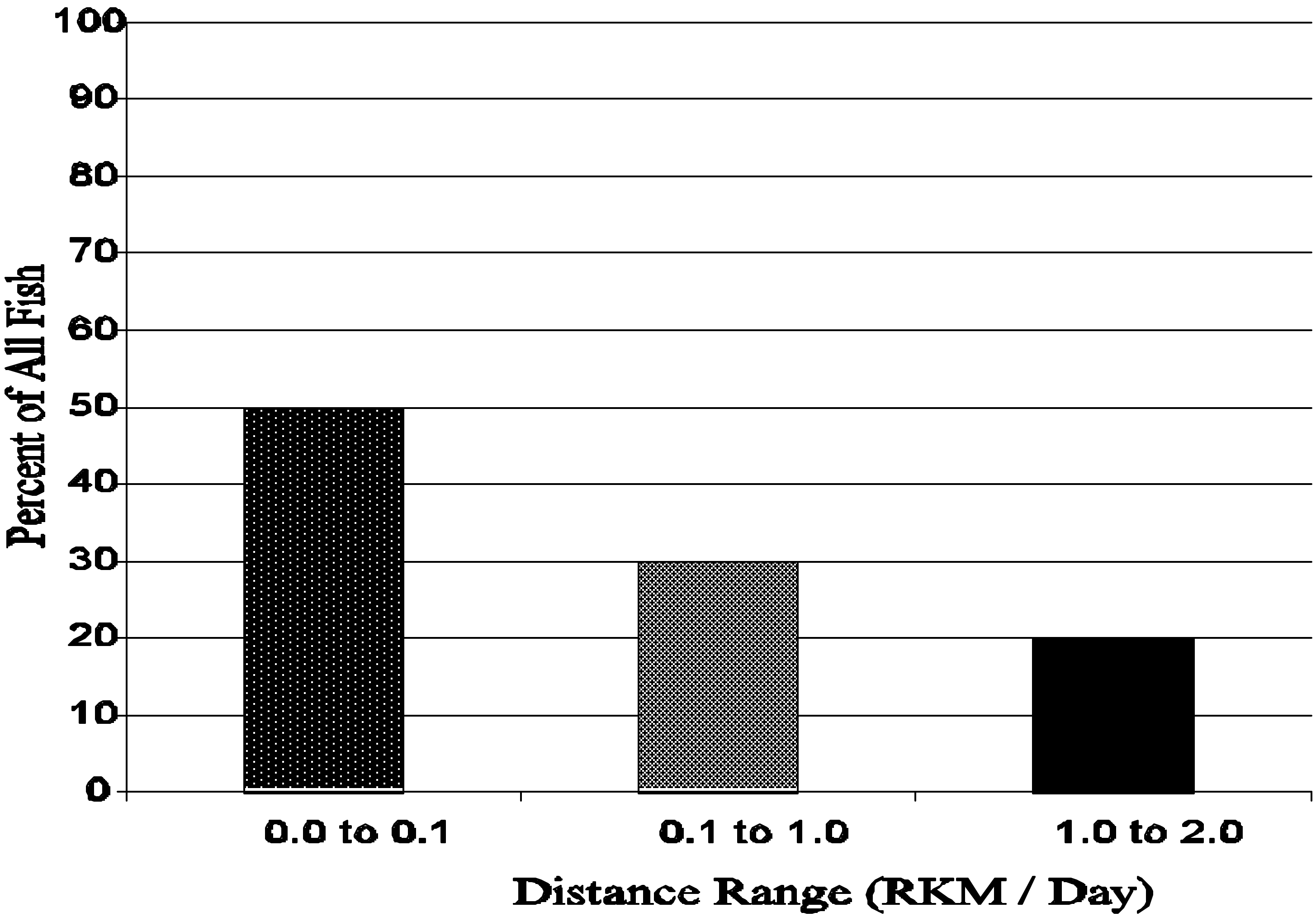

Figure 9. Mean daily movement rate (river kilometer per day) during spring and summer 2002 for tagged, Phase II robust redhorse stocked in the Ocmulgee River, Georgia.

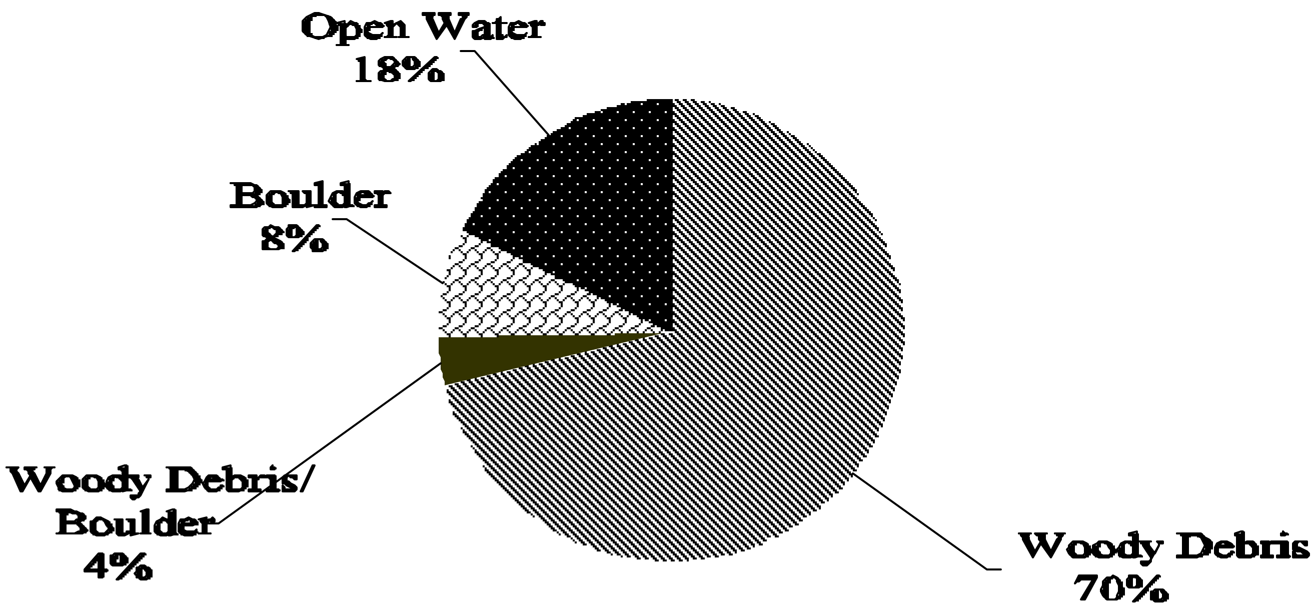

Figure 10. Graph representing the frequency of occurrence for the various cover types with which relocated hatchery-reared, Phase II robust redhorse were associated.

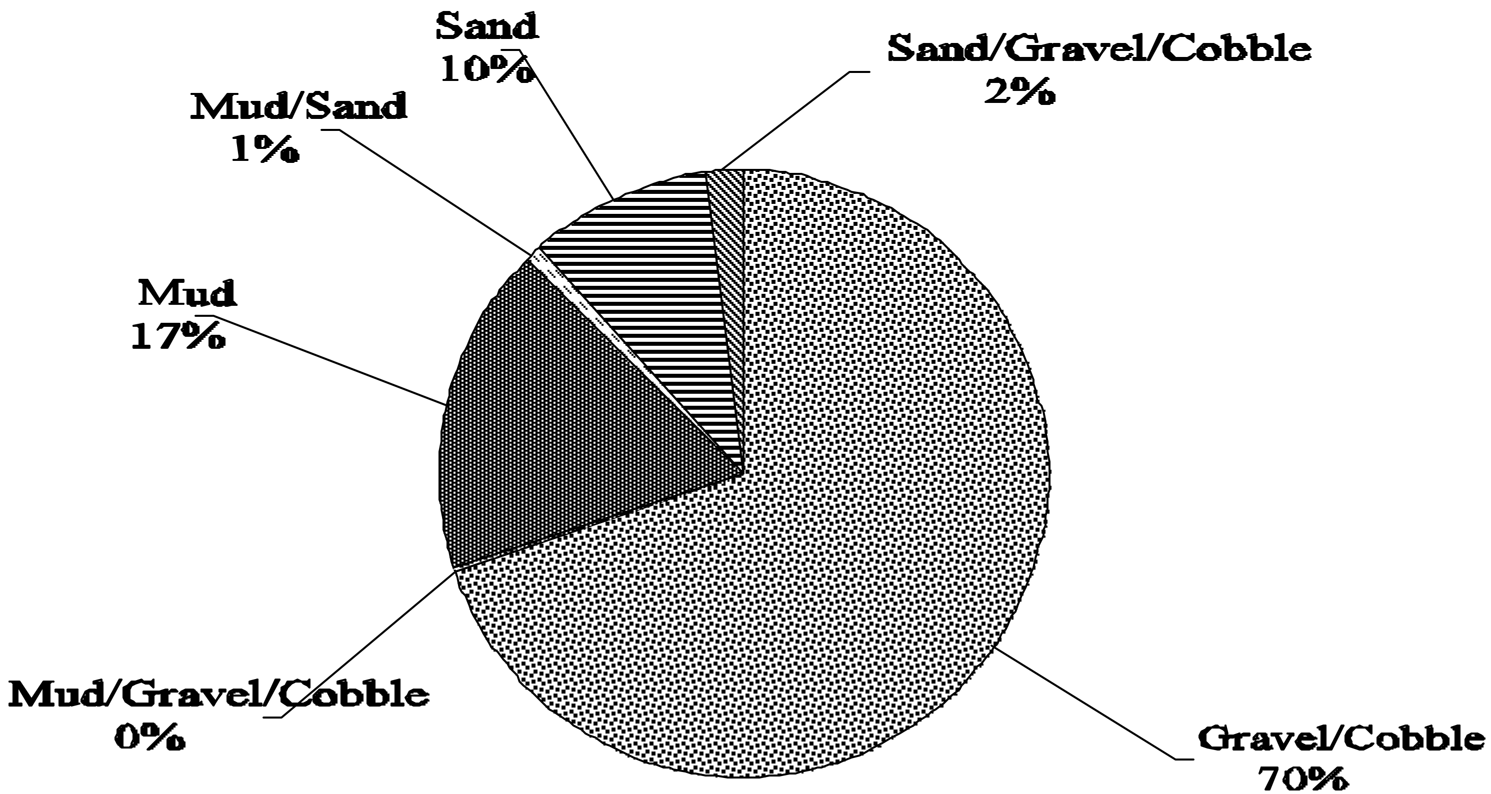

Figure 11. Graph representing the frequency of occurrence for the various substrate types with which relocated hatchery-reared, Phase II robust redhorse were associated.

Figure 12. Photograph of large, woody debris in the Ocmulgee River, Georgia with which the relocated hatchery-reared, Phase II robust redhorse was most (70% of the time) associated.

during spring 2002. Generally, the movement patterns and habit used estimated during this study were similar to those observed for other hatchery-reared robust redhorse released in the Oconee River during 1999 (Hess et al. in prep). Further, the habitat use of the hatchery-reared juveniles in the Ocmulgee and Oconee rivers is similar to that observed for wild adults in the Oconee River (Hess et al. in prep; Jennings et al. 2000).

Daily movement rates varied among individuals, about half of whom moved relatively short distances (i.e., #1 RKM); the remainder moved relatively longer distances (i.e., > 1 RKM) daily, including a few who averaged about 2 RKM daily. Why some fish disperse greater distances downstream than others is unknown, but other sucker species have shown movement patterns similar to those observed during the present study. Golden redhorse *M. erythrurum* and black redhorse *M. duquesnei* were "semi-mobile" in their movement patterns in warm-water streams in Missouri (Funk 1955). Fish-specific movement was common, but species movement was considered minor for both redhorse species (Funk 1955). Similarly, certain hatchery-reared razorback suckers moved throughout the study site while others were more sedentary and remained in the same general location (Bradford and Gurtin 2000). The more sedentary fish may be making generalized movement in response to local availability of cover or food (e.g., Mueller et al. 2003). In the case of hatchery-reared fish, those undertaking extreme downstream dispersal may be experiencing flow-related disorientation reported among pond-reared fish stocked in flowing environments without being preconditioned to flowing environments (e.g., Mueller et al. 2003). Whatever the reason, the movement patterns of hatchery-reared robust redhorse in this study seemed to be similar to the movement patterns of other redhorses and to that of the imperiled razorback sucker found in western rivers.

Tagged robust redhorse in this study were found associated with similar cover and substrate types as naturally-produced individuals in the Oconee River, GA (e.g., Jennings et al. 2000). Specifically, the fish in this study were found most often (83%) in association with large woody debris and most frequently (70%) associated with gravel/cobble substrates. Observations of substrate distribution in the river suggest that the reach of river between Lloyd Shoals Dam and Macon contained more long stretches of shoals and gravel/cobble substrates than was found in the reach of river below Macon. Despite the relatively limited distribution of gravel/cobble substrates downstream of Macon, three of the six fish in that area were found associated with gravel substrates. The association of robust redhorse with gravel/cobble substrates documented in this project has been reported for other redhorses (e.g., Yoder and Beaumier 1986; Bunt and Cook 2001) and other suckers (Jenkins and Burkhead 1994).

Open water (or the absence of any other obvious cover type) was the most abundant cover throughout the stretch of river from Llyod Shoals Dam to Warner Robbins, yet, only 18% of the contacts were for tagged fish in open water. These fish may have been in route from one habitat type (e.g., feeding) to another (e.g., resting). Many suckers and probably robust redhorse need clean substrates to be able to feed (Jenkins and Burkhead 1994). Perhaps the habitat use and movement patterns observed in this study (and others) suggest that robust redhorse inhabit fast water because the swift current keeps the substrates silt-free, which facilitates their feeding. When not feeding, robust redhorse may seek refuge from strong currents by positioning themselves downstream of fallen logs (Figure 12) or boulders (Figure 13) that are large enough to deflect the current (i.e., current break).

Figure 13. Photograph of large boulders in the Ocmulgee River, Georgia with which the relocated hatchery-reared, Phase II robust redhorse was most (70% of the time) associated.

These fallen current deflectors may provide robust redhorse a place to rest and conserve energy for more demanding tasks such as feeding in strong currents.

Only one confirmed mortality was recorded during the 82-day field portion of this study. The high survival of the tagged fish was confirmed by a similar survival rate among the control fish implanted with artificial transmitters. Though low, the observed mortality may have been related to stress associated with the harvest, transport, transmitter implantation, or being stocked. None-the-less, the estimated 97% survival recorded during this study can be used (assuming similar handling procedures throughout) to determine the number of individual needed to establish a target population size during other attempts to establish or augment refugial populations.

The results of this short-duration study suggests that hatchery-reared, juvenile robust redhorse could be used effectively to establish a refugial population that would remain within the study reach for at least 3-4 months. Our ability to track the radio-tagged ended about 82 days post stocking, when the transmitter batteries began failing. At this time, most (66%) of tagged fish were still in the study reach. Further, the slow downstream movement (i.e., < 0.1 RKM daily) undertaken by half of the tagged fish suggest that a sizeable portion of them would have remained in the study reach for at least another month. A small proportion of the tagged fish did disperse at a higher rate (i.e., 2 RKM daily) compared to the more sedentary group (i.e., < 1 RKM daily) of fish. Some of these fast dispersing fish eventually left the study site and were last contacted about 115 RMK downstream of the release site. Whether all of these movement patterns were seasonal (i.e., spring and summer) and may change during other seasons (i.e., fall and winter) are unknown. However, preconditioning pond-reared fish to flowing water prior to their release in riverine environments can reduce the rate and eventual distance of downstream dispersal. For example, the short-term (i.e., 23 days) downstream movement of razorback suckers pre-conditioned to flow for 2-3 days prior to being released was about 4X < fish that were not exposed to flow before being released into the river (Mueller et al. 2003).

Conclusions

Hatchery-reared, Phase II robust redhorse stocked in the Ocmulgee River Georgia just downstream of Lloyd Shoals Dam Fix remained near the stocking site for a few days post-stocking, then gradually dispersed downstream. The fish seemed able to find suitable habitat within the study reach, and most remained there through the end of the 82-day study. Why some of the robust redhorse in the present study left the designated reach is uncertain, but another study of hatchery-reared razorback suckers attributed long-range downstream dispersal to disorientation caused by inexperience with flowing water. Most fish in the present study were found near woody debris or over gravel substrates. This habitat associated may be related to the fish feeding over gravel substrates and resting behind woody debris or large boulders that deflect swift water currents. The high survival of stocked fish and their propensity to stay within the study reach suggest that the use of hatchery-reared, Phase II robust redhorse to establish a refugial population in Ocumulgee River between Lloyd Shoals Dam and Juliette Dam has been effective short-term strategy. How long the tagged fish will remain in the area or whether they establish a self-sustaining population are unknown, but the slow-dispersal rate of most of the fish is encouraging.

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