U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MOVEMENT PATTERNS, BEHAVIOR, AND HABITAT USE OF RAZORBACK SUCKER STOCKING INTO THE GREEN RIVER AT CANYONLANDS NATIONAL PARK, UTAH

By
[1]Dean K. Foster, University of Northern Arizona, Flagstaff
[2]Gordon Mueller, U.S. Geological Survey, Midcontinent Ecological Science Center

Open-File Report 99-107

Prepared in cooperation with the National Park Service, U.S. Fish and Wildlife Service, and Utah Department of Natural Resources.

[1] 311 ½ S. Lonetree Rd. Flagstaff, AZ 86001
[2] D-8220, P.O.Box 25007, Denver, CO 80225

TABLE OF CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

Background--This document represents the last of a series of reports for an NRPP study entitled: *Advancing Knowledge on Critical Early Life History and Survival of the Endangered Razorback Sucker.* Previous reports conducted under this study include: Nance, E. 1997. Planktonic and Benthic Invertebrate Densities in Three Backwater Habitats on the Lower Green River. Mueller, G. and E. Wick. 1998. Testing of Golf Course Ponds at Page, Arizona for Suitability as Grow-Out Facility for Razorback Sucker Using Surplus Fish from Ouray National Fish Hatchery. USGS Open-File Report 98-151. Mueller, G. and P.C. Marsh. 1998. Post-stocking dispersal, habitat use, and behavioral acclimation of juvenile razorback suckers (*Xyrauchen texanus*) in two Colorado River reservoirs. USGS Open-File report 98-301.

Thirty razorback suckers from Ouray National Fish Hatchery were fitted with external radio transmitters and released in the lower Green River at Millard Bottom. Half the fish were released immediately, while the remaining half were held in the canyon's backwater with a blocking net for 48 hours. Fish were tracked weekly for a 60-day period. Surveys extended from the city of Green River, Utah, and the confluence of the Deloris River downstream to Lake Powell.

All fish left the release site and generally headed downstream. Dispersal rates for both groups were similar for the first 15 days, averaging 4.6 km/day. Three acclimated (experimental) and two released (control) suckers moved upstream (one moves 72 km) once they entered the Colorado River. During the 15- to 30-day period, average daily movement rates of acclimated fish decreased to 1.1 km/day compared to 3.5 km/day for those simply released. Razorback sucker average "directed" movements per day (+/- km/day) decreased significantly over time ($p = 0.050$) and varied significantly between treatments ($p = 0.042$). Control fish required more than 30 days to reduce their downstream-directed movements, whereas experimental fish reduced their downstream directed movements after 15 days. Ten of 14 control fish entered either Cataract Rapids or Lake Powell by day 58, whereas only 2 of 9 experimental fish tracked were detected that far downstream. We feel this provides initial evidence that post-stocking acclimation may reduce dispersal and that additional research is needed to examine other aspects of site-acclimation.

INTRODUCTION

The razorback sucker (*Xyrauchen texanus*) is an endangered fish native to the Colorado River drainage of the Southwestern United States. Records of its capture in Canyonlands National Park have been extremely rare, undoubtedly due to the difficulty of sampling these remote reaches and possibly due to the rarity of the species. To our knowledge, no wild razorbacks have been captured in the past decade (Tom Chart, UDNR, personal communique) and only a few fish were taken prior to that period. Minckley et al. (1991) reported uncovering reports of only five razorback suckers being taken from Cataract Canyon and all were adults (Persons et al. 1982, Valdez et al. 1982, Valdez 1988). Holden conducted fish surveys within Canyonlands National Park between 1967- 1972 and reported razorback suckers were rare and juveniles absent (Holden 1973). Eight juveniles were reported captured between Moab and Dead Horse Point prior to Holden's effort in 1962-64 (Taba et al. 1965). By all accounts, it appears adults and especially juvenile razorback suckers have become extremely rare in the park during the past 4 decades.

Few extant populations of razorback sucker remain. Those remaining are scattered, comprised by very few fish (Tyus and Karp 1990) which experience low or no recruitment (Minckley 1983). The largest population occurs in Lake Mojave, Arizona/Nevada, with a small population in Lake Mead's Las Vegas Cove, and occasional collections downstream from Lake Mojave in the Lower Colorado River and its associated canal system (Minckley 1983, Marsh and Minckley 1989). The largest remaining population of riverine razorback sucker occurs on the Green River between the Yampa and Duchesne Rivers of Northeastern Utah (Tyus 1987, Tyus and Karp 1990). Very few naturally-spawned juvenile razorback suckers have been collected in the Colorado River drainage in recent history (but see Gutermuth et al. 1994, Marsh and Minckley 1989, Modde 1996, Modde et al. 1996), despite adult suckers being collected, albeit very rarely. Recently fisheries biologists in Utah, Colorado, Nevada, New Mexico, and Arizona have begun razorback sucker stocking programs to compensate for the razorback sucker's low rate of recruitment (Burdick and Bonar 1997, Langhorst 1989, Pfeifer and Burdick 1998, Ryden and Pfeifer 1995).

Historical efforts to enhance the dwindling populations of razorback suckers in the lower Colorado River (Langhorst 1989, Marsh and Minckley 1989) by stocking hatchery-reared larvae and small fish appeared to have failed (Minckley et al. 1991). In 1986, more than 1.4 million larvae were stocked into the Colorado River from Topock Gorge (just downstream from Davis Dam) to near Yuma. The U.S. Fish and Wildlife Service (USFWS) was able to capture only 41 juvenile razorback suckers from the original 1.4 million larvae (Marsh and Minckley 1989). Although the return seemed small, Minckley (1995) pointed out that between 1981 and 1989 ~15 million razorback sucker larvae were stocked in the lower Colorado River, and if only 0.1% survived, then we should have only expected to encounter slightly less than one fish per surface hectare of water.

Attempts to reestablish razorback sucker in the Verde and Salt Rivers of Arizona using hatchery-reared fish were unsuccessful. Between June 30, 1981, and December 1, 1989, 10,334,498 razorback suckers <100 mm in total length (TL) and 120,865 between 100 to 287 mm TL were stocked into the Verde and Salt Rivers and their associated tributaries (Hendrickson 1993). Recapture data showed that very few of these razorback suckers survived more than 1 year. Those that did survive were found to be in poor condition (lost weight) and harbored extremely dense infestations of the parasitic copepod *Lernaea cyprinacea* (Creef and Clarkson 1993). *Lernaea* is an exotic parasite first known to inhabit Arizona waters as early as the 1930s (James 1968). It imbeds itself on the dermal surface, predominantly fin bases, of fish and subsequently feeds upon them. *Lernaea* infected fish in the upper Verde River with the highest incidence rate (~54% of all catostomids) in Arizona (James 1968). Hendrickson (1993) found that razorback suckers infested with *Lernaea* were more likely to perish when caught in 3-hour trammel net sets than were other fish species (zero mortalities, with or without *Lernaea)* and alluded to parasitic loads, predation from exotic fishes, and stress related to transport as factors that may have contributed to the low survival rates of stocked razorback suckers.

Current efforts to artificially enhance razorback sucker numbers in Lake Mojave have been attempted by placing the larvae into predator-free enclosures and allowing them to grow to ~250 mm TL before release (Mueller and Burke 1999, Mueller 1995). Between 1993 and 1995, 640 razorback sucker had been stocked into Lake Mojave in this fashion and have yielded 15 recaptures. These 15 fish (28 to 53 cm) represented the largest assemblage of young adult razorback suckers collected from Lake Mojave in nearly 20 years. During the past 5 years, 20,000 additional razorback suckers have been stocked and have resulted in over 100 recaptures (Marsh and Pace 1999).

Stocking efforts to enhance razorback populations in the upper Colorado River Basin have just recently begun in earnest and have also resulted in low survivorship rates, except for perhaps stockings made into the San Juan River (Dale Ryden, FWS, personal communique). Twenty razorback suckers were released with 4.5-year radio tags in the upper Colorado River [river kilometer (RK) 339.0 to 367.0] during April of 1994 by U.S. Fish and Wildlife Service (USFWS) personnel (Burdick and Bonar 1997). These fish were all small adults (451 to 534 mm TL) and experienced relatively high post-release mortality for fish of this size during the first 150 days (7 of 10 confirmed or presumed dead, 10 missing). The same researchers also released 25 similarly sized razorback suckers (455 to 535 mm) into the Gunnison River during the same time period. Razorback sucker stocked into the Gunnison River also experienced high mortality rates during the first 150 days (19 of 22 confirmed or presumed dead, 3 missing).

In October 1994, 24 small adult razorback suckers (325 to 405 mm TL) outfitted with radio tags and 656 pit-tagged razorback suckers of similar size (~200 to 440 mm), were released into the San Juan River between RK 128 and 219 (Ryden and Pfeifer 1995). The authors report survival rates of radio-tagged razorback suckers between 40 and 53%. Twenty-five of the 656 pit-tagged razorback suckers were recaptured during the first 6 months. The recapture rate of pit-tagged fish is quite high when considering the large size of this study area and may indicate that the San Juan River is an excellent choice for future stocking of razorback suckers. However, since growth rates were low during the first 6 months following release (mean growth rate = .0105% of total length per ½ year), perhaps the aquatic food base available to the razorback sucker in the San Juan River is of poor quality or made partially unavailable due to competition with other fishes, the threat of predation, or some other factor. Or perhaps the low growth rates indicate that a substantial period of time is required for razorback sucker to make the transition from hatchery to turbid river.

The survivorship of stocked razorback sucker has been increased by releasing relatively large fish (>250 mm) instead of larvae (10 to 20 mm) (Mueller 1995), however, adult razorback suckers stocked into rivers undertake large movements during the first weeks of liberation and often suffer high mortality. For example, the releases of adult razorback sucker made by Ryden and Pfeifer (1995) in the San Juan River, Burdick and Bonar (1997) in the upper Colorado and Gunnison Rivers, and Day and Modde (1999) in the Green River have shown that stocked razorback sucker will undertake movements directed downstream (0 to 80 km) during the first few weeks following their release. This directed movement downstream accounted for a combined 46 out of 91 (50.5%) razorback suckers departing the two sites targeted for their introduction. Exceedingly few suckers (4 of 91) were observed to move upstream from their release points. Downstream emigration combined with fatalities (27 fish) have contributed in part to the difficulty in creating and maintaining viable, reproducing populations of razorback suckers in the habitats deemed to be suitable, as listed in the razorback sucker recovery plan (Tyus 1998). Researchers have suggested that stocked fish should be ". . .stocked as far upstream as possible" (Burdick and Bonar 1997, Ryden and Pfeifer 1996) . This suggestion does have merit considering the propensity of razorback suckers to initially move downstream from a stocking site, but this technique requires that a great many individuals be stocked at a far distant location due to the low probability that a particular fish will survive, move downstream a set distance, and become a resident in a targeted section of river.

This project assessed movements and habitat use of razorback sucker stocked in the Green River, Canyonlands National Park, and tested pre-stocking acclimation as an alternative method to "upstream stocking," as suggested by Burdick and Bonar (1997) and Day and Modde (1999). The study was directed at determining the practicality of reestablishing/augmenting a viable population of razorback sucker into the Green and Colorado Rivers within Canyonlands National Park.

Two groups of 15 razorback suckers were compared: an acclimated group held in a backwater for ~2 days, and a second group handled identically and placed immediately into the river adjacent to the backwater. The non-acclimated suckers served as a control. We examined if pre-release acclimation was able to affect the dispersal distance, dispersal rate, or behavioral patterns of razorback suckers following stocking, as well as examining the habitats that razorback suckers utilize within Canyonlands National Park.

MATERIALS AND METHODS

Sources and Transportation of Fish

Thirty razorback suckers were obtained from the USFWS Ouray fish hatchery located near Vernal, Utah. The 30 fish were the progeny of 1 female and 2 males collected from the Green River at the Jensen site (River Kilometer[RK] 490; RK 0.0 is the confluence of the Green and Colorado Rivers). The suckers were the control group for a canceled chemoreception experiment. (Tom Pruitt, USFWS, personal communique).

The razorback suckers were transported in a 2000-L tank with oxygen bubblers from the Ouray National Fish Hatchery to the Green River at Mineral Bottom (RK 84) on June 16, 1998. Fifteen fish were then transferred to 100-L Coleman coolers, lashed inside of a 5.5-m Achilles inflatable boat. Two transportation trips were made downstream to the release point at Millard Bottom backwater (RK 54). Two water changes were made during transport to maintain adequate oxygen levels during the 45 minute trip.

Transmitter Attachment

All suckers were measured (TLmm) and weight (g, Appendix 1), and had an Advanced Telemetry Systems (ATS©) 90-day radio transmitter attached. Each transmitter was verified to be functioning properly before being attached to a fish by removing the deactivation magnet and listening for a signal with the ATS receiver. Transmitters were 5.5 by 1.0 cm, outfitted with a beveled leading edge and a tapered rear cone, and attachment holes had been drilled through the epoxy. The holes were placed 1/3 up from the bottom on both ends of the transmitter. Transmitters were sewn with 9-kg test monofilament line onto the midline of the suckers' dorsal keels directly above the pectoral fins. Each suture was inserted ~10 mm below the dorsal keel surface and three square knots held each transmitter firmly against the keel. Each transmitter trailed a 25-cm whip antenna made of very fine stainless steel wire. The whip antennae terminated 1 to 10 cm anterior to the upper lobe of the caudal fin. None of the whip antennae needed to be trimmed in order to avoid contact with the caudal fin.

This external attachment method was modified from Mueller and Marsh (1998) and was designed to allow the fish to eventually "shed" the tag. Experiments in circular tanks showed that the monofilament sutures would be pushed to the dorsal keel surface and expelled by razorback suckers over time. A few fish shed their transmitter within the first month, but most fish retained their transmitters for two or more months. This method is in sharp contrast to the more widely used technique of surgically implanting radio transmitters. This method can lead to substantial fish mortality due to chronic infection of the abdominal dermis surrounding the exit hole created by the trailing whip antenna. However, some of the new transmitters employ an internal, coiled antenna that eliminates the exit hole but also decreases the detection distance. Implanted transmitters will remain inside fish for the remainder of their lives, while externally attached transmitters will likely be shed soon after the research project is complete.

Immediately following transmitter attachment, fish were alternately assigned to be either control or experimental treatment. A block net was placed at the mouth of Millard Bottom backwater, and experimental fish were released behind the blocking net and confined to the backwater while control fish were placed adjacent to the blocking net on the river side. Due to time and boat limitations, transmitters were only attached to 15 suckers (7 experimental, 8 control) and released on the evening (1815 to 2003 hrs) of June 16, while the remaining fish (8 experimental, 7 control) were released the next morning (0900 to1047 hrs). The block net was removed at 0640 hrs on June 19. Thus the period of time that the first seven experimental fish spent in the backwater (~ 2.5 days) was greater than the second group of eight fish (~1.9 days).

Tracking Design and Effort

Razorback sucker positions were recorded using a 40-MHZ ATS© receiver, a whip antenna, and a hand-held directional loop antenna. The previously mentioned National Park Service 5.5-m Achilles inflatable boat with a 60-hp jet outboard was used throughout the summer for surveys. For each fish located, the RK was recorded and habitat was described (see next section).

The study site was in Canyonlands National Park, Utah, and extended into the Colorado and Green Rivers outside of the park (Figures 1). Twenty-two field surveys were conducted between June 24 and August 13 (Table 1). Thirteen of the 22 surveys repeatedly surveyed 3 reaches of river that were observed to contain radio-tagged razorback sucker. The first of these reaches was Mineral Bottom (RK 81.7) to Spanish Bottom on the Green and Colorado Rivers. Spanish Bottom is located 6.4 km below the confluence of the Green and Colorado Rivers and lies 0.75 km upstream from the start of Cataract Canyon rapids. The Mineral Bottom to Spanish Bottom section was surveyed five times (June 24 and 30, July 9, and August 5 and 7). The second reach was Potash boat dock (RK 77.1) to Spanish Bottom on the Colorado River. Potash to Spanish Bottom was also surveyed five times (July 1, 8, 13, and 30, and August 13). The third reach was on Lake Powell from Hite Marina (RK 270.6) to the base of the Cataract Rapids at Imperial Canyon (RK 322). The river kilometer "zero point" below the confluence of the Green and Colorado Rivers is at Lee's Ferry; the confluence is considered to be RK zero if you are upstream in either the Green or Colorado Rivers, or

Colorado River RK 348.5 if you happen to be downstream of the confluence. This section of river/lake was surveyed three times (July 1 and 14, and August 12).

One 3-day survey was made in Cataract Canyon rapids on July 13-15. The remaining five surveys were made upstream of Mineral Bottom and Potash Boat dock. These surveys included the Green River from RK 81.9 to 218.4 and the Colorado River from RK 77.1 to 160.6.

A total of 452.9 km of river was surveyed for study razorback suckers. Throughout this section of river, an average sampling effort of one fish was located every two boat-hours. Alternatively, a radio-equipped fish was located every 53 km of river. Transmitters that were shed or otherwise immobile were not included in the effort estimation.

Habitat Use

Each time a razorback sucker was located, habitat type, surface water velocity, and water depth were estimated. Habitat was divided into four categories: channel, near shore, eddy pool, and backwater, and described below:

1. Channel - Defined as the deepest, and most often swiftest portion of the river. Both the Green and Colorado River channels were typically greater than 3 m in depth and surface currents greater than 5 km/hr.

2. Near shore - Defined as river habitat within 10 m from shore. If a fish was within 10 m of shore, but was also determined to be in the main channel or in a eddy, then the fish would be considered to be utilizing the alternative habitat type and not be considered near shore.

3. Eddy pools - Formed by water returning upstream, typically near shore, which then enters back into downward flowing currents. Eddy pools are typically oval in shape with the long side parallel to the main channel. Water flows quickly around the perimeter of the pool (referred to as an eddy fence), but never as swift as the main channel, with very slow moving water found in the middle of the eddy pool.

4. Backwaters - Most of the backwaters that exist in the study reach are naturally occurring areas of still water found in flooded canyon mouths. Backwaters are typically 15 cm to 1.25 m deep and can wind nearly 0.3 km up a canyon from the main river. These regions are devoid of current, are not as turbid as the main river, have heavily vegetated banks and margins (dominated by tamarisk, Russian olive, and willow), have slightly warmer water, and more productive plankton communities than found in their associated river (Mabey 1993). However, these regions are subjected to annual drying during the descending phase of the hydrograph, as well as being subjected to unpredictable flash floods during the summer monsoon season.

Discrete measurements of water velocity were not made; instead, visual assessments were made of the speed of water passing over the position of a located razorback sucker. Swift current was defined as being equal to the channel current. Slow current was defined as regions of no current or current that was visually estimated to be less than 2 km/hr. The category of moderate current was given to current other than swift or slow. The depth of the water where a razorback sucker was located was estimated by approaching as close to the fish as possible and lowering a 3-m-long, incremented oar into the water until it touched bottom or until the entire oar was beneath the surface. Water depth was placed into three categories: <1.2, 1.2 to 3, and >3 meters.

Equipment Performance

The ability of the ATS receiver to detect transmitter signals was affected by various factors. First, the effective range of the transmitter was more than doubled by efforts to eliminate static interference generated by the outboard engine. The receiver was placed into a large army-surplus rocket box. Next, the power supply was changed from running off of the boat's battery to a small motorcycle battery that was also placed inside of the rocket box. And finally, the whip antenna was mounted on the bow so as to maximize its distance from the outboard engine. After making these modifications, shallow water detections improved from 100 to 250 m to an average of 700 to 1000 m, with maximum detection ranges often approaching 1.7 km.

Even with the increase in receiver performance, deep signals >5 m remained difficult to detect due to signal attenuation. Razorbacks in the deepest portion of the channel were usually detected at less than 300 m. Since the boat was operated at a constant speed of ~ 350 m/minute, and the receiver was able to scan all of the tag frequencies in a single minute, it was unlikely that many tags were missed during the monitoring. Additionally, all surveys were "round-trip," so each portion of surveyed river was scanned for tagged razorbacks twice each trip. Very rarely were tagged razorbacks not detected on the initial leg and later detected on the return trip.

Data Analysis

The condition factor, a "plumpness" index, was calculated for each razorback sucker using the equation $K = [\text{weight(grams)}*100]/[\text{length(mm)}^3]$. A regression analysis was performed on the condition factors to determine if there was a significant positive or negative relationship between K and either length or weight. This analysis was performed on Excel '97. Next, a two-tailed t-test was utilized to determine if razorback suckers that utilized backwater habitat had significantly different condition factors than the suckers that were not observed to utilize backwaters. The t-test was performed on Excel '97. Finally, three separate 3-factor ANOVAs were performed to determine if the condition factor of a fish would influence its selection of a particular habitat type, current velocity, or water depth. The other two factors that were analyzed were time and treatment (acclimated vs. not-acclimated fish). The analyses were performed on SPSS (version 8.0) using the "General Linear Model - General Factorial" model. Type three, sums of squares were used and no data transformations were needed to meet the assumptions of normality and homogeneity of variances.

The movement patterns of the razorback suckers were analyzed with three 2-factor ANOVAs (SPSS version 8.0). The analyses were performed to determine the following questions:

1. Was the total distance that razorback suckers traveled since release dependent either upon the time since release or treatment?

2. Was the rate of razorback movements (km/day) dependent either upon the time since release or treatment?

3. Was the direction of a fish's travel (+/-km/day, + = upstream, - = downstream) dependent either upon the time since release or treatment?

Type three, sums of squares were used to compute the F-statistics for the ANOVAs. Data used for the total distance ANOVA was not transformed. Average daily movement data were log transformed. Data for the directed average daily movements were power 1.5 transformed. Data still did not meet the assumptions of homogeneity of variance or normality, but were modestly improved over non-transformed data (Appendix 3). In addition, the transformed data increased the power of the ANOVA models for both average daily movements (0.901 → 0.999) and directed movements (0.829 → 0.843).

RESULTS

Individual Movements – Distance From Release Point

All 15 razorback suckers that were placed into the backwater at Millard Bottom (Green River RK 54) actively swam within the flooded canyon mouth prior to their eventual release. The water in the backwater was turbid, so visual observations of the suckers' daily activities were impossible, however, each fish's position within the backwater was determined via telemetry on six separate occasions during the acclimation period. The backwater had four distinct regions: the inflow (4), the outflow (1), and two interior regions (3 and 4) delineated by bends in its channel. Razorback movements within the backwater are presented in Table 2. Initially, only 20% (9 of 45 contacts) of the fish were positioned next to the blocking net, but during the day before the net was removed 43% (16 of 37 contacts) were found near the blocking net.

Two fish escaped during this period of acclimation (Table 2). This occurred after heavy rains on June 17 caused the Green River to rise and create a ~2-m-wide passage around the western edge of the blocking net. This escape route was less than 50 cm deep and contained a dense stand of juvenile willows. The willows possibly aided in reducing the total number of fish that escaped.

The blocking net was removed at 0640 on June 19. The departure of the remaining 13 experimental treatment razorback suckers (acclimated fish – referred to as "E" for - experimental treatment) from the now river-accessible Millard backwater was monitored until 0912. The first razorback sucker to leave the backwater was 12E at 0805. This fish headed downstream, was out of the ~1/2-km receiver range in 7 minutes, and was never contacted again. Razorback sucker 14E exited next at 0841 and was followed by sucker 5E at 0846. Fish 14E headed downstream, was out of range in 18 minutes, and was never contacted again. Fish 5E departed downstream, moved out of range in 26 minutes, and would travel downstream to the Colorado River (54 km distance) and then swim at least 72 km up the Colorado River over the next 20 days.

The movements of razorback suckers during the first day following their release were only determined for the control group (non-acclimated fish – referred to as "C" for control treatment) due to logistical difficulties. On June 17, five control fish (1C, 2C, 4C, 6C, and 14C) were located in or near Andersen Bottom (Green River RM 48.9), and the search was terminated at Green River RK 47. Fish 1C, 2C, and 4C were all located within Anderson backwater. Fish 14C was located in the inside bend of the main channel of the Green River opposite Anderson Bottom, and sucker 6C was 1 km down river of Anderson Bottom in the river left portion of the main channel and moving downstream. Only fish 14C was released this same day (June 17, 7.8 hours earlier), whereas the remaining four fish were released the previous day (June 16, 23 hours earlier). It is inexplicable that the majority of the fish located within 7 km downstream from the release point were released the previous day and not fish released just 7.8 hours prior. Fish 1C, 2C, and 6C were located in different backwaters further downstream 7 days later. It would appear that control razorback suckers seek and enter backwaters as they move downstream following release.

Both the experimental and control razorback suckers initially moved downstream from the release point during the first 2 weeks. After this initial period of downstream movement, a few fish (1E, 5E, 8E, 15E, 2C, and 7C) that had reached the confluence of the Green and Colorado Rivers (53.8 km distant) began to swim up the Colorado River (Figures 2A, 2B, and 2C). By day 25, fish 8E was now located 8.8 km up the Colorado River from its confluence with the Green River and was not contacted again.

Razorback sucker 1E moved downstream to the Colorado River and swam 52 km upstream during the first 12 days. By day 54, razorback 1E had moved down the Colorado River, swam through Cataract Canyon rapids, and was now positioned in Lake

Powell adjacent to the mouth of Gypsum Canyon some 85 km downstream.

Fish 5E reached the confluence in no longer than 7.8 days and, as previously mentioned, swam up the Colorado River at least 72 km. Between 19 and 24 days after its release, 5E began to move downstream and was last contacted 4.8 km above the Green River confluence.

Razorback sucker 15E was the only fish observed to move upstream in the Green River during the course of the 58-day study. Initially, 15E moved downstream to Green River RK 29.1 by day 11.4. During the next 9 days, 15E moved 2.5 km upstream. During days 20 to 47, razorback 15E then moved upstream again and was last contacted day 49 at Green River RK 41.4—12 km below the release point.

Razorback 2C reached the confluence and traveled at least 24.9 km up the Colorado River during the initial 14 days. During the next 13 days, 2C moved 30.5 km downstream to 6 km below the Green River confluence. This position was ~0.9 km above the first Cataract Canyon rapid. Later this same day, at 1733 (day 27.9), 2C had moved into Cataract Canyon rapids and was in the large, swift, eddy pool circulating below rapid #2 (Colorado River km 340.2, confluence = RK ~348.5). By the following afternoon at 1622, fish 2C had completed its journey through Cataract Canyon rapids and was located ~0.5 km above Imperial Canyon (Colorado River RK 322.3). Fish 2C was able to move through the ~21 km of rapids in 1.05 days. By day 56, fish 2C's last known position was just inside the mouth of Clearwater Canyon in Lake Powell (Colorado River RK 308.2).

By day 14, razorback 7C had departed the Green River and swam 10.8 km up the Colorado River. During the next 7 days, 7C moved downstream and to the mixing zone of the Green and Colorado River confluence. From this time until day 58, razorback 7C positioned itself at Colorado River RK 345.2 and moved about within a 200-m section of river. This razorback sucker was observed to still be mobile by its periodically moving out from the deep channel (faint tag signal) and swimming along the shoreline (strong tag signal).

The remaining razorback suckers were either lost from contact early on, or moved downstream to the Colorado River and positioned themselves between the confluence and the head of Cataract Canyon Rapids (a reach of ~7 km), or they continued downstream and entered Lake Powell where contact was generally lost. Razorback suckers 3E, 10E, 1C, and 9C were all located only once or twice. These four fish were moving downstream and it is unknown whether they later entered Lake Powell, or remained in the Green or Colorado Rivers and avoided detection by seeking out the deepest portions of the river. The radio-tag signals may attenuate to below detection levels when ~9 or more meters deep. Fish 6E, 8E, 14E, 5C, and 11C rapidly moved downstream and out of the lower 52 km of the Green River and positioned themselves in the previously mentioned Colorado River reach above Cataract Canyon rapids and the Green River confluence.

The remaining fish (2E, 3C, 6C, 8C, 12C, 13C, 14C, and 15C) all moved continuously downstream and entered Lake Powell.

Individual Movements - Estimated Rates of Movements

Only 17 of the 23 razorback suckers that were located following their release were contacted a sufficient number of times to estimate their daily rates (km/day) of movement (Figures 3A and 3B). Six razorback suckers (10E, 1C, 3C, 4C, 11C, and 14C) were located just twice during the 58 days of tracking. The remaining 11 fish were contacted between 3 and 7 times. The general trend was for the initial movement of fish to be at a high rate of ~5 km/day and decrease over time to near 0 km/day.

However three razorback suckers increased their estimated daily rate of movement over time. Fish 10E and 1C increased their daily movements from ~3 km/day during the first few days following release to ~5 km/day by day 10. Contact was lost with both fish by day 12, so it will remain unknown if their rate of movement attenuated over time as occurred in the majority of the razorback suckers. Fish 2C, the third razorback sucker to have an increased daily movement rate over time, decreased its daily movements from ~5 km/day during days 1 to 8 to near 0 km/day during days 30 to 58. However, a burst of movement occurring during day 29 resulted in a positive slope (Figure 3B).

The direction of the estimated daily movement rates for the suckers can also be seen in Figures 3A and 3B. Positive data points designate upstream movements, whereas negative data points designate downstream movements. Only two suckers with greater than two contacts increased their rate of downstream movement over time. As previously mentioned, fish 2C moved down the Green River and then up the Colorado River 24.9 km. Fish 2C then began a fairly rapid movement downstream and entered Lake Powell. This rapid, mid-study, downstream movement resulted in a negative slope for 2C's average directed rate of movement over the course of the study period. Fish 5E also increased its rate of downstream movement over time. Fish 5E moved out of the Green River in approximately 8 days traveling at ~8 km/day (Appendix 1). Fish 5E then made a 55.8-km movement up the Colorado River between days 7 and 12 at ~12 km/day. Upstream movement continued at a reduced rate (~3 km/day) until day 19, at which point 5E moved downstream at ~-7 km/day and contact was lost 4.8 km above the Green River confluence. This trend in daily movements from large upstream, to small upstream, to large downstream resulted in the trend of 5E increasing downstream movements over time.

Individual Movements – Fish Condition Factor (K)

The movement patterns of razorback suckers did not appear to be dependent upon the condition factor [$K = (\text{weight}*100/\text{length}^3)$]. Condition factors (K) ranged between 0.734 and 1.057, and were not correlated with length ($p = 0.97$, regression analysis) but were positively correlated with weight (p = 0.02, regression analysis, Figure 4). Appendix 3 summarize aspects of the suckers' movements in conjunction with their condition factors. The condition factors of the experimental and control fish that were observed to either swim upstream or hold position in the river overlapped broadly with the condition factors of the fish that were observed to only move downstream. The 7 razorback suckers that were never contacted following release had similar condition factors to the 23 fish that were located via telemetry. In addition, the condition factors (average K = 0.845, n = 6) of the six razorback suckers that utilized backwater habitats were not significantly different from the condition factors (average K = 0.892, n = 14) of those fish not observed to utilize backwaters (p = 0.22, two-tailed t-test).

Individual Habitat Use and the Effects of Condition Factor

During the first 2 weeks since release, the razorback suckers distributed themselves throughout many of the available habitat types (Table 3). Many fish moved between multiple habitats during this time period. For example, fish 6C was positioned near shore and moving rapidly downstream at Green River RK 48 on day 1. Fish 6C then entered Horse Canyon backwater (Green River RK 23) by day 7, remained there until at least day 13 as the water level fell to an estimated <60 cm, and then re-entered the main channel sometime before day 22. Fish 2C, 7C, and 3E also moved between habitats during the first 14 days. Fish 2C utilized both near shore and main channel habitat, as well as venturing into Jasper Canyon backwater (Green River RK 15.3) on day 7. Both 7C and 3E were located in near shore, eddy pool, and channel habitats as they continued to move downstream.

During the 15 to 29 day period following release, the majority of fish now began to generally utilize a single type of habitat. Only two fish, 5E and 8E, were observed to be utilizing two or more habitat types. Fish 5E was located near shore at Colorado River km 71.9 on day 19 and then entered the channel and quickly moved downstream to Colorado River RK 4.8 by day 25. Fish 8E was located near shore in a deep run adjacent to the large cottonwood tree at Spanish Bottom (Colorado River RK 342, Green River confluence = RK~348.5). Later, 8E was moved upstream to the large eddy pool in the tailwater of "The Slide" at Colorado River RK 2.4.

During the last 4 weeks of the study (days 30 to 58), the majority of razorback suckers were no longer near shore, but rather were split between near shore (five fish) and channel habitat (five fish). At this point, the water level of the Green and Colorado Rivers is sufficiently low to have dried all of the backwaters that have formed at the mouth of ephemeral canyon inflows (Figure 5). Eddy pools were now the least utilized of the available habitats. Only fish 6E and 7C were now observed to be positioned in eddy pools. However, both 6E and 7C were now found in eddy pools only once during this period while being found near shore twice (6E) and in the main channel four times (7C).

Four different control fish and two experimental treatment fish were observed to occupy backwater habitat in the Green River below the release site. Fish 1C was observed in two separate backwaters (Anderson Bottom and at Green River RK 12) and fish 6C was located in Horse Canyon backwater (Green River RK 23.3) on three separate occasions. Backwaters were only utilized by the control fish during the first 2 weeks. Fish 15E was the only sucker observed to still utilize backwater habitat after 2 weeks (July 9, day 20). Fish15E was located in Dead Horse Canyon (Green River RK 31.5), which was rapidly becoming dry. This fish did not need rescued, however, because a flash flood carried 15E into the river shortly after day 20.

Between the 0 to 14 day period following release, razorback suckers utilized riverine habitats which experienced all available current intensities, but the majority of fish locations were in regions of slow or no current (Table 4). In spite of a high affinity for slow current, many razorback suckers (5E, 10E, 14E, 15E, 2C, 5C, 6C, and 7C) moved between regions of slow current (<~1.4 km/hr) and swift current (>~3.8 km/hr). Fish 6E, 8E, 1C, 14C, and 15C were observed to only utilize habitats with slow or no current. Fish 6E, 14C, and 15C were located in near shore regions; 1C was found in Anderson backwater (Green River RK 49.8) on day 1 and in a shallow backwater at Green River RK 12 on day 7; and 8E was in a slow moving eddy pool at Colorado River RK 342. Sucker 9C was the only fish that utilized solely regions of swift water. Fish 9C was located in different sections of swift water on three separate occasions during these first 15 days.

During the period of 15 to 29 days since release, 12 of 15 razorback suckers were found to be in habitats of slow or no current. Fish 11C, 15C, and 5E were positioned in slow current, as well as occupying moderate current (11C and 15C, ~1.4-4.6 km/hr) and swift current (5E).

During the final 4 weeks the suckers began to reoccupy habitats with swift current, as well as continuing to utilize slow current regions. Only 7C moved between habitats in different current categories. Fish 7C occupied the very deep, swiftly flowing water in the run adjacent to and upstream from the "Dangerous Rapids Ahead" sign at Colorado River RK 345. As previously mentioned, fish 7C was also observed on one occasion to move out of the channel and move upstream along the northwestern bank approximately 100 m.

Razorback suckers initially began to occupy habitats of seemingly every available depth (Table 5). During the first 14 days, the experimental fish were utilizing chiefly shallow (0-1.2 m) or deep water. Only one fish from the experimental treatment (15E) was located in a habitat of moderate depth (1.2 to 3.0 m). Fish 15E was also found in the shallowest backwater habitats and the deep main channel. The control treatment fish were found in similar proportions in shallow, moderate, and deep habitats. Three control fish (2C, 6C, and 7C) were observed to move between shallow and deep regions of the Green and Colorado Rivers.

During the 15 to 29 day period since release, razorback suckers were not observed to move between habitats of different depths as often as during the first 2 weeks. Only fish 5E and 8E were observed to utilize both shallow and deep habitats. Fish 5E utilized both near shore and eddy pool habitats while 8E utilized near shore and channel habitats.

During the final 4 weeks of the study (30 to 58 days), razorback suckers utilized predominantly deep-water habitats. Fish 6E was observed utilizing all three depth categories, 15E utilized moderate and deep water habitats, and the remaining fish (8E, 14E, 2C, 7C, and 11C) were utilizing habitats greater than 3 m deep. Fish 1E and 15C were found in >3-m-deep water in Lake Powell.

Tables 6, 7, and 8 summarize the condition factors of the fish that were located in each habitat, current, and depth category, respectively, over time. The average condition factors of the fish that frequented the four habitat types during the three time periods ranged from 0.81 to 0.93 and were not dependent upon habitat type ($p = 0.610$), treatment ($p = 0.766$), or time ($p = 0.404$). The average condition factors of the fish that occupied the three current intensities ranged from 0.771 to 0.966 and were not dependent upon current velocity ($p = 0.935$), treatment ($p = 0.072$), or time ($p = 0.070$). However, it appears that fish with large condition factors disproportionately utilized habitats of moderate depth (average $K = 0.922$) to a greater extent than either shallow habitats (average $K = 0.869$, $p < 0.001$ tukey's post-hoc) or deep habitats (average $K = 0.874$, $p = 0.018$ tukey's post hoc).

Comparison of Treatments: Movement Patterns and Habitat Use

The majority of razorback sucker dispersal away from Millard Canyon backwater occurred during the first 2 weeks for both treatment groups (Figure 6A). There was no significant affect of treatment ($p = 0.737$) or time ($p = 0.120$) upon the distance fish traveled from the point of release. However, there was a small but steady increase in the distance control fish traveled over time. Control fish dispersed 43, 71, and 81 km for the time periods 1 to 14 day, 15 to 29 days and 30 to 58 days following release. Experimental fish averaged 59 km distance traveled over the first 14 days, this increased to 71.6 km by days 15 to 29, and reduced to 53.6 km by the end of the study. Although differences in dispersal were very similar, a greater proportion of control razorback suckers traveled downstream upon reaching the Colorado River than did experimental suckers. Ten of 14 control fish entered either Cataract Rapids or Lake Powell by day 58, whereas only 2 of 9 experimental fish were found that far downstream (Appendix 3).

The average distance razorback suckers moved per day (as estimated from successive radio contacts) decreased significantly over time ($p <0.000$), and was not significantly affected by treatment ($p = 0.437$) (Figure 6B). The average daily movements (km/day) of both the experimental and control fish decreased incrementally over time, but at different rates. Experimental razorback suckers slowed their movements to 1.1 km/day after 15 days and remained similarly mobile (1.2 km) through day 58. Control fish were more than twice as mobile 15 to 29 days after release than the experimental fish, but reduced their overall movements to a much lower rate (0.37 km) than the experimental fish by the end of the study. The reason that the experimental suckers were more mobile during the 30 to 58 day period was in part due to fish 15E traveling upstream toward the release site.

The difference in the daily movement rates (km/day) between the experimental and control fish during the 15 to 29 day period becomes more profound when viewed in conjunction with the direction of travel of each fish (Figure 6C). For the purposes of addressing the direction of travel of a fish, the movement rates (km/day) have been defined as positive if fish are swimming upstream and negative if a fish is traveling downstream. Razorback sucker average "directed" movements per day (+/- km/day) became significantly less negative over time ($p = 0.05$) and varied significantly between treatments ($p = 0.042$). As seen in Figure 7C, control fish required more than 30 days to reduce their downstream-directed movements, whereas experimental fish reduced their downstream directed movements after 15 days.

DISCUSSION

Dispersal Patterns

Razorback sucker movements within the Millard Bottom acclimation backwater varied between individuals and changed in pattern over time. Three of the 15 fish were observed to roam nearly the entire length (~1/3 km) of the backwater within 10 minutes, while others appeared to roam within limited sections of the backwater or not move at all. Patterns in fish movement within this backwater were not correlated with condition factor, nor were these patterns able to predict post-release movement patterns. However, razorback suckers altered their movement patterns within the backwater over time. Fewer suckers (20%, n = 45 contacts) were observed to be positioned near the blocking net at the mouth of the backwater during the first day, but by the second day of confinement within the backwater the percentage rose to 43%(n = 37).

Only 3 of the 13 suckers (2 escaped) exited the cove within 2 hours of removing the blocking net. The three fish departed singly and moved downstream and out of the ~1/2-km directional receiver range within 7 to 26 minutes. Seven of the ten remaining razorback suckers were observed to approach the area where the blocking net had previously been only to turn around and swim back into the backwater. These fish either simply anticipated that the net would be in its previous location since the turbidity of the water prevented visual recognition of the net except at very close range, or they were not yet ready or willing to enter the river. The duration of time required for the last razorback sucker to depart the backwater remains unknown, but all the fish had departed the backwater within 5 days (the number of days until the next sampling occurred).

One short telemetry survey was made on June 17 to determine the locations of the 30 control (not-acclimated) fish that were released on June 16 and 17. Five razorback suckers were located approximately 5 km below the release site. Three of these fish had entered Anderson Bottom backwater, which is the first backwater downstream of the release point. Three of these five control fish were later located in backwaters further downstream 5 days later. Twenty-nine percent (4 of 14) of control razorback suckers were observed to utilize backwaters during the first 2 weeks, two fish at least twice. However, since sampling occurred on just 3 days during the first 2 weeks, the actual number of control suckers that utilized backwater habitats was probably larger. Stocked, non-acclimated razorback suckers seek and enter backwaters as they move downstream following release. This rate of backwater use by stocked razorback sucker is much higher than that observed by Ryden and Pfeifer (1995) in 1994 and 1995 on the San Juan River, but is similar to the rates of backwater use seen in wild razorback suckers in the Colorado (18% of contacts) and Gunnison (26% of contacts) Rivers (Burdick and Bonar 1997).

Fourteen of the 15 control razorback suckers were found following release and all had moved downstream. Only one control group razorback sucker was not located, and since no fish were found on June 19 in the 28 km of river above Millard Bottom, it is very likely that all 15 control razorback suckers moved downstream following release. The majority of dispersal occurred during the first 2 weeks for both the control and experimental treatment groups (Figure 6.) By day 14, the mean maximum dispersal of the experimental fish was actually further than the control fish (59 vs.43 km). The dispersal distance of the control fish is probably an underestimate because two control fish that were located ~5 km from the release point on day 1 were never located again, and if they behaved similarly to the other 12 control fish, they would have continued to move downstream. By day 29, the mean maximum dispersal distance increased to approximately 71 km. During the final period of the study, days 30 to 58, the control razorbacks continued to increase their dispersal distance to 81 km while the experimental razorbacks decreased their average dispersal distance to 53 km. Although differences in dispersal were similar, a greater proportion of control razorback suckers traveled downstream upon reaching the Colorado River than did experimental suckers. Ten of 14 control fish entered either Cataract Rapids or Lake Powell by day 58, whereas only 2 of 9 experimental fish were found that far downstream. However, due to large variability between individual fish and a low sample size, these modest treatment ($p = 0.74$) and time period ($p = 0.12$) effects were not statistically significant. Similar dispersal distances for both hatchery- and pond-reared razorback suckers stocked into rivers were observed in the San Juan River during 1994 (-62.3 km) and 1995 (-95.5 km) (Ryden and Pfeifer 1995) and in the Green River during 1995 (week-1 = -39.2km, week-3 = -87.1 km) (Day and Modde 1999).

The average rate of dispersal for both groups of razorback suckers was very similar during the first 14 days, but differed markedly over time. Initial movement rates were ~4.6 km/day for both treatments. During the 15 to 29 day period, average daily movement rates for experimental razorback suckers decreased to 1.1 km/day while control suckers decreased their movement rates much less (3.5 km/day). During the 30- to 58-day period since release, experimental suckers continued to move at approximately the same rate (1.2 km/day) while the control fish had decreased their movements to 0.37 km/day. Razorback sucker movement rates decreased significantly over time ($p < 0.001$), but due to high within-group variation the observed treatment affect was not significant ($p = 0.44$). This attenuation in the estimated rates of daily movement are very similar to those observed by Day and Modde (1999) in 1995 on the Green River. Their much smaller razorback suckers (average TL 197.9 mm vs. 437.6 mm) averaged 6.8 km/day ($n = 16$) during the first 13 days and decreased to 2.0 km/day ($n = 7$) between days 13 and 28.

Although the rates of dispersal of experimental and control suckers did not differ significantly over time, the average directed rates of movement (+/-km/day) were significantly different between treatments ($p = 0.042$). Directed rates of movement were calculated for a particular fish by defining upstream movement rates as +km/day and downstream movements rates as -km/day and then summing these within treatment and time periods. The effect of a 2-day acclimation was to significantly reduce the downstream directed movements rates of razorback suckers, as seen in Figure 6. Initial downstream directed movement rates of control fish were -4.2 km/day. This is more than double the rate (-1.9 km/day) for experimental razorbacks. During days 15 to 29, experimental razorback sucker directed movement rates had attenuated to just 0.3 km/day while control fish were still continuing to move downstream at a rate of 3.5 km/day. Control razorback suckers required at least 30 days from the time of release to reduce their downstream directed movements to a level that was reached by experimental razorbacks after 15 days.

The finding that the majority of dispersal of stocked razorback sucker occurs during the first few weeks following release has been observed in previous razorback sucker stockings (Brooks 1985, Day and Modde 1999, Marsh 1987, Mueller and Marsh 1998, Ryden and Pfeifer 1995), as well as in other species of fish. Chilton and Poarch (1997) observed that 50% of the total yearly movements of grass carp stocked into Texas reservoirs occurred during the first 2 weeks. Hanson and Margenau (1992) observed that the majority of young of the year muskellunge dispersal in lakes occurs during the first 2 weeks. Carlstein and Eriksson (1996) observed that 75% European grayling (*Thymallus thymallus*) stocked into an experimental stream dispersed greater than 400 m downstream during the initial 8 hours.

Habitat Use

Razorback suckers in both treatments utilized all available habitats, current intensities, and water depths during the first 2 weeks and altered their patterns of habitat use over time. However, the two treatments differed in their habitat utilization patterns. Initially, the majority of control suckers were located in shallow (<1.2 m) regions with slow current (<1.4 km/hr), while experimental fish were most often observed to utilize deep water (>3 m) that was either slow or swiftly flowing (>4.8 km/hr). Nine of 19 razorbacks were utilizing channel habitat during the first 14 days. During the 15 to 29 day period following release, both treatment groups were occupying slow, near-shore habitats and deep eddy pools. Only one razorback sucker was observed to utilize channel habitat during this period. This experimental treatment fish had moved 72 km up the Colorado River and was returning downstream towards the Green River confluence by way of the main channel. During the 30 to 58 day period since release, seven of the ten fish that could still be located were found in deep water (>3 m), and five fish were now utilizing channel habitat. Three of the razorbacks utilizing water greater than 3 m deep were located near flooded canyon mouths (2) or moving down lake (1) in Lake Powell.

The pattern of razorback sucker habitat use during the initial 14 days was similar to that observed by Burdick and Bonar (1997) in wild razorback sucker in the Gunnison River. The pattern of habitat utilization was proportionally 21% (60%) channel, 21% (19%) eddy pool, 21% (26%) backwater, and 37% (7%) near shore [parenthesis denote data taken from Burdick and Bonar (1997)]. The most obvious difference in the habitat utilization rates is that instead of utilizing mainly channel habitat, the razorback suckers in this study were found most often near shore as opposed to the channel.

However, this pattern changed during the 30 to 58 day period. During the last 4 weeks of the project, the majority of razorback sucker contacts (52%) were now in the main channel, 37% were still in near shore habitat, and 11% of contacts were in eddy pools. These results contrast with the 1994 and 1995 San Juan stockings in which razorback sucker utilized chiefly channel habitat (Ryden and Pfeifer 1996). However, Ryden and Pfeifer (1996) observed that razorback suckers show seasonal variability in habitat utilization patterns. Perhaps the razorback suckers in both this experiment, as well as those of Ryden and Pfeifer (1996), were utilizing deep channel habitat in August, not only because it was the most abundant habitat type (~75% of all habitats in the San Juan River), but perhaps in order to seek out a preferred temperature as well. Bulkey and Pimentel (1983) utilized electronic shuttle box experiments to deduce that razorback suckers' preferred temperature lies between 22.9 and 24.8 °C. The thermal profile of the Green River within Canyonlands National Park during August of 1998 is unfortunately unknown.

A surprising finding was a significant correlation between the condition factor of a fish and the depth of water that it utilized. Razorback suckers that utilized habitats of moderate depths (1.2 to 3 m) had on average larger condition factors than fish that utilized either shallow (<1.2 m) or deep (>3.0 m) habitats. The reason for this affect of condition factor upon depth selection is unclear, but there are at least three possibilities.

First, fish with large condition factors may be more "plump" than their kin because they are more efficient foragers. If this is the case, then it follows that Green River habitats of moderate depth should be more productive than either deep or shallow zones. It is not known if this true. However, this hypothesis is testable since the diet of razorback suckers is known to consist of benthic insects, such as Ephemeroptera and Chironomidae, algae, detritus, and other items such as Cladocerans in reservoirs (Banks 1964, Jonez and Sumner1954, and Vanicek 1967), and the availability of these items could easily be compared at these water depths.

A second explanation is that habitats of moderate depth may require fish to expend either greater or lesser quantities of energy to maintain position than either shallow or deep habitats. This does not seem to be a correct statement since there was no correlation between condition factor and current velocity. In addition, the condition factors of fish observed to utilize backwaters were not statistically different from the condition factors of fish found in eddy pools, near shore, or in the main channel.

A third explanation is that habitats of moderate depth are more competitive environments for razorback sucker than either shallow or deep habitats, and high condition factor fish have an advantage over low condition factor fish when involved in competitive interactions. This argument does have some merit in that Abbot et al. (1985) found that a weight advantage of only 5% was enough to ensure dominant status during paired intra-specific competition in steelhead trout, and that the razorback suckers used in this project had condition factors that were positively correlated with length. It then follows that a larger fish involved in inter-specific competition for a food item, current refuge, space, etc., would fair better than a smaller or thinner fish.

A Potential Explanation for the Large Initial Dispersal of Stocked Fish

Often fisheries biologists attribute the high initial dispersal rates of stocked fish to transport and handling stresses (Bonga 1997, Salonius and Iwama 1993, Waring et al. 1996). These stresses have been shown to cause fish to respond by secreting higher the resting levels of the hormone cortisol (Barton and Zitzow 1995, Clearwater and Pankhurst 1997, Pankhurst and Dedual 1994, Wallin and Van den Avyle), which can have major physiological consequences. Higher than normal circulating cortisol levels cause fat stores to be mobilized (Waring et al. 1996), circulating lymphocyte levels to decrease (Barton and Zitzow 1995, and Salonius and Iwama 1993), osmoregulatory imbalances (Bonga 1997, Barton and Zitzow 1995), and even lead to follicular atresia (Clearwater and Pankhurst 1997). Chronic stresses such as overcrowding or intra-specific competition for resources can result in submissive behavior and the loss of access to preferred habitats, as well as higher rates of mortality (Pottinger and Pickering 1992) and decreased fitness (Pankhurst and Dedual 1994).

Clearly, fisheries biologists agree that efforts to minimize handling and transport stresses generated during fish stocking is a worthwhile endeavor. The attachment of telemetry transmitters requires surgery or attachment with anchors or sutures and can be very stressful to the animal. Morton et al. (1995) determined that 17 of 18 species of African mammals captured by physical restraint increased plasma cortisol concentrations as compared to normal, whereas capture using chemical sedatives usually caused a decrease in cortisol levels. These findings illustrate the importance of employing MS-222 sedative when outfitting fish with telemetry transmitters.

However, stressors to stocked fish do not ameliorate following stocking. Naïve hatchery-reared fish will undoubtedly find that making the transition from hatchery pond or raceway to turbid, swift rivers is a very stressful event. Stocked fish must learn to feed upon natural food sources quickly, learn to identify and escape from predators, and navigate lotic environments. Razorback suckers typically move long distances downstream during the initial period following stocking, as well as experience reduction in growth rates and condition factors (Hendrickson 1993, Ryden and Pfeifer 1995). Based on our findings, it appears that this transition period is at least 2 weeks long.

This experiment has shown that pre-stocking acclimation is able to significantly alter the dispersal rates of liberated razorback suckers, however a longer period of acclimation appears to be needed for razorback suckers to remain near the release site. Perhaps a 2- to 4-week acclimation period is needed for razorback suckers to acclimate to their new surroundings. This is based on experiments by Pottinger and Pickering (1992) that showed that between 2 and 4 weeks is required for chronically confined (crowding and intra-specific competition stresses) rainbow trout cortisol levels to decrease to those of the controls.

CONCLUSIONS AND RECOMMENDATIONS

The collection of razorback sucker larvae from Middle Stillwater Canyon in 1993-1996 from the lower Green River (Muth et al. 1998) stimulated interest in this river section (USFWS 1999). Unfortunately, the backwaters where larvae are typically collected are ephemeral, flooding each spring for a few weeks before they drain with receding flood flows. It's doubtful larvae gain any appreciable growth before either being forced back to the main channel or stranded by receding flows. While nursery habitat is sparse, historically, these river reaches must have been important migration corridors. However, the apparent absence of both adults and juveniles may suggest these river reaches might be only marginally important to the species today.

Stocking within the boundaries of Canyonlands National Park is certainly a management or recovery option; however, we feel the likelihood of establishing local populations in themselves is probably unlikely. Cataract Canyon appears to represent a downstream conveyance vortex to newly stocked hatchery fish and possibly a hindrance for upstream migration. The reestablishment of razorback sucker within the park will probably be dependent upon reestablishing or expanding populations elsewhere.

It's well known that hatchery produced razorback suckers are extremely susceptible to downstream drift (Ryden and Pfeifer 1996, Burdick and Bonar 1996, Day and Modde 1999). As with this study, the majority of suckers stocked at Millard Bottom ended up in Lake Powell. Current methods to compensate for this drift involves stocking fish further upstream of targeted reintroduction sites or as this study suggested, fish should be site-acclimated to reduce post-stocking trauma and possibly subjected to flow prior to stocking in riverine environments.

Possible options for reintroducing razorback sucker to Canyonland National Park include:

In-Park.—Fish should be stocked during spring run-off and held in seasonally flooded backwaters for a minimum of 2 weeks. Backwaters could be effectively blocked with barrier nets. We also suggest tests be conducted with acclimating suckers to flow (0.1m/sec) for a minimum of 1 month prior to introduction.

Artificial backwater or holding facilities could be constructed in the upper reaches of the Green and Colorado River. These semi-permanent structures could be used to rear wild caught razorback sucker larvae for eventual reintroduction, or be used to rear and acclimate hatchery production to local conditions.

Out-of-Park.— As discussed in the report, razorback suckers could be stocked, held, and acclimated at upstream locations. Several possible locations exist. Another option would be to stock adults or large juveniles in the Colorado River inflow area of Lake Powell. It's been documented that razorback suckers stocked in the San Juan River inflow area have migrated as far as 80 km upstream (Dale Ryden, USFWS personal communique) and similar upstream migrations from reservoirs exceeding 100 km have been noted (Mueller unpublished data).

ACKNOWLEDGMENTS

Special appreciation goes to Ed Wick who developed the research theme and initiated the NRPP process; Bruce Rodgers and Craig Hauke (NPS) provided study guidance; the Canyonlands Park Ranger staff provided logistical support; Tom Czapla and Tom Pruitt (USFWS) provided study fish; Johnny Boutwell and David Mueller assisted in the field; and the manuscript was reviewed by Tim Modde. Work was conducted under permits issued by FWS, NPS, and Utah Division of Natural Resources and funded by USGS and NPS.

LITERATURE CITED

Abbott, C.C. 1861. Descriptions of four new species of North American Cyprinidae. Proceedings of the Philadelphia Academy of Natural Sciences 12(1860):473-474.

Banks, J. L. 1964. Fish species distribution in Dinosaur National Monument during 1961-1962. Master's thesis. Colorado State University, Fort Collins.

Barton, B. A. and R. E. Zitzow. 1995. Physiological responses of juvenile to handling stress with recovery in saline water. The Progressive Fish Culturist 57:267-76.

Bonga, S. E. W. 1997. The stress response in fish. Physiological Reviews 77(3):591-625.

Brooks, J. E. 1985. Annual reintroduction and monitoring report for razorback sucker Xyrauchen texanus in the Gila River Basin, Arizona, 1985. U. S. Fish and Wildlife Service, Albequerque, New Mexico.

Bulkey, R. V. and R. Pimentel. 1983. Temperature preference and avoidance by adult razorback suckers. Transactions of the American Fisheries Society 112:601-607.

Burdick, B. D. and R. B. Bonar. 1997. Experimental stocking of adult razorback sucker in the upper Colorado and Gunnison Rivers. Final Report. Colorado River Fishery Project, U. S. Fish and Wildlife Service, Grand Junction, CO. 28 pp.

Carlstein, M. and L.O. Eriksson 1996. Post-stocking dispersal of European grayling, *Thymallus thymallus* (L.), in a semi-natural experimental stream. Fisheries Management and Ecology 3:143-155.

Chilton II., E.W. and Steven M. Poarch. 1997. Distribution and movement behavior of radio-tagged grass carp in two Texas reservoirs. Transactions of the American Fisheries Society 126:467-476.

Clearwater, S. J. and N. W. Pankhurst. 1997. The Response to Capture and Confinement Stress of Plasma Cortisol, Plasma Sex Steroids and Vitellogenic Oocytes in the Marine Teleost, Red Gunard. Journal of Fish Biology 50:429-441.

Creef, E. D. and R. W. Clarkson. 1993. Razorback Sucker (*Xyrauchen texanus*) and Colorado Squawfish (*Ptychocheilus lucius*) monitoring, Verde and Salt Rivers, Arizona, 1991-1993. Special Report. Nongame and Endangered Wildlife Program. Arizona Game and Fish Department, Phoenix. 7pp.

Day, K. and T. Modde. 1999. Distribution and Recapture of Razorback Sucker Stocked in the Middle Green River in 1995. Final Report. Recovery Implementation Program, Project #29. 20pp.

Gutermuth, F.B., Leo D. Lentsch, and Kevin R. Bestgen. 1994. Collection of age-0 razorback suckers (*Xyrauchen texanus*) in the lower Green River, Utah. The Southwestern Naturalist 39(4):389-391.

Hanson, D.V. and Terry L. Margenau. 1992. Movement, habitat selection, behavior, and survival of stocked Muskellunge. North American Journal of Fisheries Management 12:474-483.

Hendrickson, D.A. 1993. Evaluation of the Razorback Sucker (*Xyrauchen texanus*) and Colorado Squawfish (*Ptychocheilus lucius*) Reintroduction Programs in Central Arizona Based on Surveys of Fish Populations in the Salt and Verde Rivers from 1986 to 1990. Final Report. Nongame and Endangered Wildlife Program. Arizona Game and Fish Department, Phoenix. 166pp.

Holden, P.B. 1973. Distribution, abundance, and life history of the fishes of the upper Colorado River Basin. Ph.D. diss., Utah State University, Logan.

James, A. E. 1968. Lernaea (Copepod) Infection of Three Native Fishes from the Salt River Basin, Arizona. Master's Thesis. Arizona State University, Tempe, AZ.

Jonez, A. and R. C. Sumner. 1954. Lakes Mead and Mojave investigations: A Comparative Study of an Established Reservoir as Related to a Newly Created Impoundment. Federal Aid to Fisheries Restoration Project Completion Report, F-1-R, Nevada Fish and Game Commision, Reno. 186pp.

Jorgensen, J. and S. Berg. 1991. Stocking experiments with 0+ and 1+ trout parr, *Salmo trutta* L., of Wild and Hatchery Origin: 2. Post-Stocking Movements.

Langhorst, D. R. 1989. A Monitoring Study of Razorback Sucker (*Xyrauchen texanus*) Reintroduced into the Lower Colorado River in 1988. Final Report. (Contract FC-9494). California Department of Fish and Game, Blythe.

Marsh, P.C. 1987. Digestive tract contents of adult razorback suckers in Lake Mojave, Arizona-Nevada. Transactions of the American Fisheries Society 116:117-119.

Marsh, P.C. and W.L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49(1):71-78.

Minckley, W.L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorago River Basin. The Southwestern Naturalist 28(2):165-187.

Minckley, W.L. 1995. Translocation as a tool for conserving imperiled fishes: experiences in Western United States. Biological Conservation 72:297-309.

Modde, T. 1996. Juvenile razorback sucker (Xyrauchen texanus) in a managed wetland adjacent to the Green River. Great Basin Naturalist 56(4):375-376.

Modde, T., K.P. Burnham, and E.J. Wick. 1996. Population status of the razorback sucker in the middle Green River (U.S.A.). Conservation Biology 10(1):110-119.

Morton, D. J., E. Anderson, C. M. Foggin, M. D. Kock, and E. P. Tiran. 1995. Plasma Cortisol as an Indicator of Stress Due to Capture and Translocation in Wildlife Species. The Veterinary Record January 1:60-63.

Mueller, G. 1995. A Program for Maintaining the Razorback Sucker in Lake Mojave. American Fisheries Society Symposium 15:127-135.

Mueller, G., and T. Burke. (In Press) Survival of young razorback sucker *(Xyrauchen texanus)* in relation to stocking rates (fish/ha) and in the presence or absence of predator communities in Lake Mohave, Arizona-Nevada. Proceedings of: Restoring Native Fish to the Lower Colorado River: Interactions of Native and Non-native Fishes, A Symposium and Workshop. July 13-14, 1999. Las Vegas, Nevada.

Mueller, G. and P.C. Marsh. 1998. Post-stocking dispersal, habitat use, and behavioral acclimation of juvenile razorback suckers (*Xyrauchen texanus*) in two Colorado River reservoirs. USGS open file report 98-301.

Muth, R.T., G.B. Haines, S.M. Meismer, E.J. Wick, T.E. Wick, D.E. Snyder and J.M. Bundy. 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado 1992-1996. Report 34, Recovery Implementation Program for the Endangered Fish Species in the Upper Colorado River Basin.

Pacey, C. and P.C. Marsh 1999. Resource use by native and non-native fishes of the Lower Colorado River: Literature review, summary, and assessment of relative roles of biotic and abiotic factors in management of imperiled indigenous ichthyofauna. Contract 7-MT-30-R0012, submitted to Bureau of Reclamation, Boulder City, Nevada.

Pankhurst, N. W. and M. Dedual. 1994. Effects of Capture and Recovery on Plasma Levels of Cortisol, Lactate and Gonadal Steroids in a Natural Population of Rainbow Trout.

Persons, W.R., R.V. Bulkley and W.R. Nonan. 1982. Movements and feeding of adult striped bass, Colorado River inlet, Lake Powell, 1980. Annual Report for U.S. Bureau of Reclamation. Contract 9-07-40-L-1060. Utah Cooperative Fisheries Unit, Utah Stage University, Logan.

Pfeifer, F. K. and B. D. Burdick. 1998. A Five-Year Experimental Stocking Plan to Evaluate Survival of Various Sizes of Razorback Sucker. 1998 Annual Project Report. Colorado River Recovery Program, U. S. Fish and Wildlife Service, Grand Junction, CO. 8pp.

Pottinger, T.G. and A.D. Pickering. 1992. The influence of social interaction on the acclimation of rainbow trout, *Onchorhynchus mykiss* (Walbaum) to chronic stress. Journal of Fish Biology 41:435-447.

Richards C. and Phillip J. Cernera. 1989. Dispersal and abundance of hatchery-reared and naturally spawned juvenile chinook salmon in an Idaho stream. North American Journal of Fisheries Management 9:345-351.

Ryden, D.W. and F.K. Pfeifer. 1995. Monitoring of experimental stocked razorback sucker in the San Juan River. 1994 Annual Report. USFWS, Colorado River Fishery Project, Grand Junction, Colorado.

Salonius, K. and G. K. Iwama. 1993. The Effects of Stress on the Immune Function of Wild and Hatchery Coho Salmon Juveniles. Bulletin of the Aquaculture Association of Canada 91(3):47-49.

Taba, S.S., J.R. Murphy, and H.H. Frost 1965. Notes on the fishes of the Colorado River near Moab, Utah. Proceedings of the Utah Academy of Science, Arts, and Letters 42, 280-283.

Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979-1986. Transactions of the American Fisheries Society 116:111-116.

Tyus, H.M. and Catherine A. Karp. 1990. Spawning and movements of razorback sucker, *Xyrauchen texanus*, in the Green River basin of Colorado and Utah. The Southwestern Naturalist. 35(4):427-433.

Tyus, H.M. 1998. Razorback Sucker (*Xyrauchen texanus*) Recovery Plan. U. S. Fish and Wildlife Service, Denver, CO. 76pp.

Valdez, R.A., P.G. Magnan, R. Smith, and B.Nilson. 1982. Upper Colorado River investigaions. In Part 2, Colorado River Fisheries Project, Final Report Field Investigations, ed. W.H. Miller, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L.R. Daeding, pp.101-279. Final Report for BOR Contract 9-007-40-L-1016, Salt Lake City, Utah.

Valdez, R.A., 1988. Annual summary report–1987, Fisheries biology and frafting. Annual Report for U.S. Bearu of Reclamation. Contract 6-CS-40-03980. Bio/West, Logan, Utah.

Vanicek, C. D. 1967. Ecological Studies of Native Green River Fishes Below Flaming Gorge Dam, 1964-1966. Ph.D. Dissertation, Utah State University, Logan. 125pp.

Wallin, J. E. and M. J. Van Den Avyle. 1995. Interactive Effects of Stocking Site Salinity and Handling Stress on Survival of Striped Bass Fingerlings. Transactions of the American Fisheries Society 124:736-745.

Waring, C. P., R. M. Stagg, and M. G. Poxton. 1996. Physiological Responses to Handling in the Turbot. Journal of Fish Biology 48:161-173.

TABLES

Table 1. A summary of telemetry sampling dates, locations, and total river kilometers scanned for tags. The information given below the table summarizes the surveying efforts.

Description	Date	begin river km	end km	tot km	hours
Short effort to locate control fish below release point	June 17	54.0	48.2	11.6	1.5
Millard Bottom to Mineral Bottom	June 19	54.0	81.9	27.9	2.5
Mineral Bottom to confluence	June 24	81.9	0.0	163.8	9.6
Mineral Bottom to Spanish Bottom	June 30	81.9	-6.4	176.7	9.3
Potash to Spanish Bottom	July 1	77.1	-6.4	167.0	9.03
Hite Marina to Imperial Canyon (base of Cataract Rapids)	July 2	270.6	321.4	*58.8	5.5
Potash to Spanish Bottom	July 8	77.1	-6.4	167.0	9.33
Mineral Bottom to Spanish Bottom	July 9	81.9	-6.4	176.7	8.8
Ranger's snout boat - Potash to river kilometer 29.9	July 13	77.1	29.9	47.2	4.5
Ranger's snout boat - river kilometer 29.9 to 336	July 14	29.9	336.5	41.9	7.5
Ranger's snout boat - river kilometer 336 to 302	July 15	336.5	301.9	34.5	5.5
Potash to Moab boat dock	July 21	77.1	118.0	81.9	4.5
Moab to top of Big Bend Rapids	July 23	118.0	130.1	24.1	2
Moab to confluence of the Delores and Colorado Rivers	July 25	118.0	160.6	85.1	8.1
Town of Green River upstream to diversion dam	July 26	192.7	218.4	51.4	3.5
Town of Green River to river mile 70	July 28	192.7	112.4	*138.1	9
Potash to Spanish Bottom	July 30	77.1	-6.4	167.0	9.95
Mineral Bottom to Spanish Bottom	August 5	81.9	-6.4	176.7	5.55
Near Spanish Bottom to Mineral Bottom	August 7	-3.2	81.9	170.2	5.28
Mineral Bottom up to Ten Mile Canyon	August 11	81.9	129.3	94.8	5.55
Hite Marina to Imperial Canyon (base of Cataract Rapids)	August 12	270.6	322.8	104.4	6.37
Potash to Spanish Bottom	August 13	77.1	-6.4	167.0	9.1

Total number of surveying trips	**22**
River km surveyed	**2136.9**
Hours spent surveying	**141.96**
Total fish contacts	**69**
Fish per hour of telemetry	**0.486**
Fish per river km surveyed	**0.032 or 1 fish per 33 river km surveyed**

*** = Telemetry effort shortened due to adverse weather**

Table 2. A summary of fish movements within Millard Bottom backwater during the acclimation period 6/16&17 – 6/19. Fish 1-7 placed into backwater 6/16 1615-2003, and fish 8-15 placed into backwater 6/17 @0900-1047.

Fish ID	6/17 1555	6/17 1605	6/17 1615	6/18 1030-1050	6/18 1241	6/18 2030-2130
1	2	3	3	4	4	4
2	4	4	4	2	1 or 2	2
3	2	2	2	escaped		
4	2	3	3	4	4	4
5	3	3	3	2	?	4
6	3	3	4	escaped		
7	1	1	1	2	1 or 2	4
8	1	2	2	4	2	1
9	3	1	2	4	3	4
10	4	4	4	1	3	3
11	1	3	1	2	?	1
12	3	2	2	4	4	2
13	4	2	4	4	3	?
14	1	3	3	4	3	3
15	3	3	3	4	3	4

Table 3. The following tables show razorback sucker utilization of 4 habitat categories during three time periods.

Days 0-14							
near shore		**eddy pool**		**backwater**		**channel**	
3E	2C	3E	3C	10E	1C	1E	2C
6E	2C	5E	5C	15E	1C	3E	5C
10E	4C	8E	7C		2C	5E	7C
14E	5C	8E	11C		4C	10E	9C
15E	6C	14E			6C	15E	
	7C				6C		
	7C				6C		
	7C						
	11C						
	14C						
	15C						

Days 15-29							
near shore		**eddy pool**		**backwater**		**channel**	
5E	6C	8E	2C	15E		5E	
6E	7C	14E	4C				
8E	8C		5C				
	11C		14C				
	11C						
	13C						
	15C						

Days 30-58							
near shore		**eddy pool**		**backwater**		**channel**	
6E	2C	6E	7C			1E	7C
6E	11C					14E	7C
8E	11C					14E	7C
	15C					15E	7C
						15E	15C

Table 4. The following tables show razorback sucker utilization of 3 current categories during three time periods.

Days 0-14					
slow (<1.4 km/hr)		moderate (1.4 - 4.8 km/hr)		swift (>4.8 km/hr)	
3E	1C	1E	2C	3E	2C
3E	1C	5E	2C	5E	5C
6E	2C		3C	10E	6C
8E	5C		4C	14E	7C
8E	5C		7C	15E	9C
10E	6C		11C		
14E	6C				
15E	6C				
15E	7C				
	7C				
	7C				
	11C				
	14C				
	15C				

Days 15-29					
slow (<1.4 km/hr)		moderate (1.4 - 4.8 km/hr)		swift (>4.8 km/hr)	
5E	6C		11C	5E	
6E	7C		15C		
8E	8C				
8E	11C				
14E	13C				
15E	14C				

Days 30-58					
slow (<1.4 km/hr)		moderate (1.4 - 4.8 km/hr)		swift (>4.8 km/hr)	
1E	2C	8E	11C	14E	7C
6E	7C		11C	14E	7C
6E	15C			15E	7C
6E	15C			15E	7C

Table 5. The following tables show razorback sucker utilization of 3 water depths categories during three time periods.

Days 0-14					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
3E	1C	15E	5C	1E	2C
3E	1C		6C	3E	3C
6E	2C		7C	5E	5C
10E	2C		7C	5E	6C
14E	2C		7C	8E	7C
15E	4C		11C	8E	9C
	5C		14C	10E	11C
	6C		15C	14E	
	6C			15E	
	6C				
	7C				

Days 15-29					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
5E	6C	6E	7C	5E	2C
8E			8C	8E	4C
15E			11C	14E	5C
			11C		
			13C		
			14C		
			15C		

Days 15-29					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
6E		6E	11C	1E	2C
		8E	11C	6E	7C
		15E	15C	14E	7C
				14E	7C
				15E	7C
					7C
					15C

Table 6. The condition factors of fish observed to use one of four habitat types are shown below as a function of both treatment and time period. Average condition factors are shown at the bottom of the columns.

Days 0-14							
near shore		eddy pool		backwater		channel	
exp.	control	exp.	control	exp.	control	exp.	control
0.827	0.8	0.768	0.882	0.93	0.734	0.743	0.8
0.913	0.8	0.799	0.896		0.734	0.768	0.896
0.908	0.831	0.891	0.906		0.8	0.799	0.906
0.912	0.896	0.891	0.966		0.864	0.908	1.057
0.93	0.864	0.912			0.864	0.93	
	0.906				0.864		
	0.906						
	0.906						
	0.966						
	0.932						
	0.904						
0.898	0.883	0.852	0.913	0.930	0.810	0.830	0.915

Days 15-29							
near shore		eddy pool		backwater		channel	
exp.	control	exp.	control	exp.	control	exp.	control
0.799	0.864	0.891	0.8	0.93		0.799	
0.913	0.906	0.912	0.831				
0.891	0.921		0.896				
	0.966		0.932				
	0.966						
	0.879						
	0.904						
0.868	0.915	0.902	0.865	0.930		0.799	

Days 30-58							
near shore		eddy pool		backwater		channel	
exp.	control	exp.	control	exp.	control	exp.	control
0.913	0.8	0.913	0.906			0.743	0.906
0.913	0.966					0.912	0.906
0.891	0.966					0.912	0.906
	0.904					0.93	0.906
						0.93	0.904
0.906	0.909	0.913	0.906			0.885	0.906

Table 7. The condition factors of fish observed to use habitats subjected to three different current intensities are shown below as a function of both treatment and time period. Average condition factors are shown at the bottom of the columns.

Days 0-14					
slow (<1.4 km/hr)		moderate (1.4-4.8 km/hr)		swift (>4.8 km/hr)	
exp.	control	exp.	control	exp.	control
0.768	0.734	0.743	0.8	0.768	0.8
0.768	0.734	0.799	0.8	0.799	0.896
0.913	0.8		0.882	0.908	0.864
0.891	0.896		0.831	0.912	0.906
0.891	0.896		0.906	0.93	1.057
0.908	0.864		0.966		
0.912	0.864				
0.93	0.864				
0.93	0.906				
	0.906				
	0.906				
	0.966				
	0.932				
	0.904				
0.879	0.869	0.771	0.864	0.863	0.905

Days 15-29					
slow (<1.4 km/hr)		moderate (1.4-4.8 km/hr)		swift (>4.8 km/hr)	
exp.	control	exp.	control	exp.	control
0.799	0.864		0.966	0.799	
0.913	0.906		0.904		
0.891	0.921				
0.891	0.966				
0.912	0.879				
0.93	0.932				
0.889	0.911		0.935	0.799	

Days 30-58					
slow (<1.4 km/hr)		moderate (1.4-4.8 km/hr)		swift (>4.8 km/hr)	
exp.	control	exp.	control	exp.	control
0.743	0.8	0.891	0.966	0.912	0.906
0.913	0.906		0.966	0.912	0.906
0.913	0.904			0.93	0.906
0.913	0.904			0.93	0.906
0.871	0.879	0.891	0.966	0.921	0.906

Table 8. The following tables summarize the condition factors of razorback suckers that utilized habitats ranging from <1.2, 1.2-3.0, and >3m deep during three time periods. Average condition factors are shown at the bottom of the columns. Razorback suckers inhabiting water 1.2-3.0 meters deep have higher condition factors than fish in either shallower or deeper water, irregardless of treatment or time since release.

Days 0-14					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
exp.	control	exp.	control	exp.	control
0.768	0.734	0.93	0.896	0.743	0.8
0.768	0.734		0.864	0.768	0.882
0.913	0.8		0.906	0.799	0.896
0.908	0.8		0.906	0.799	0.864
0.912	0.8		0.906	0.891	0.906
0.93	0.831		0.966	0.891	1.057
	0.896		0.932	0.908	0.966
	0.864		0.904	0.912	
	0.864			0.93	
	0.864				
	0.906				
0.867	0.827	0.930	0.910	0.849	0.910

Days 15-29					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
exp.	control	exp.	control	exp.	control
0.799	0.864	0.913	0.906	0.799	0.8
0.891			0.921	0.891	0.831
0.93			0.966	0.912	0.896
			0.966		
			0.879		
			0.932		
			0.904		
0.873	0.864	0.913	0.925	0.867	0.842

Days 30-58					
0 - 1.2 meters		1.2 - 3 meters		>3 meters	
exp.	control	exp.	control	exp.	control
0.913		0.913	0.966	0.743	0.8
		0.891	0.966	0.913	0.906
		0.93	0.904	0.912	0.906
				0.912	0.906
				0.93	0.906
					0.906
					0.904
0.913		0.911	0.945	0.882	0.891

FIGURES

Figure 1. A map of the study site. Multiple surveys were conducted on the boxed-in portions of both the Colorado and Green Rivers. The portions of both rivers below the transect lines and above the boxed areas, as well as Cataract Canyon rapids, were only surveyed once.

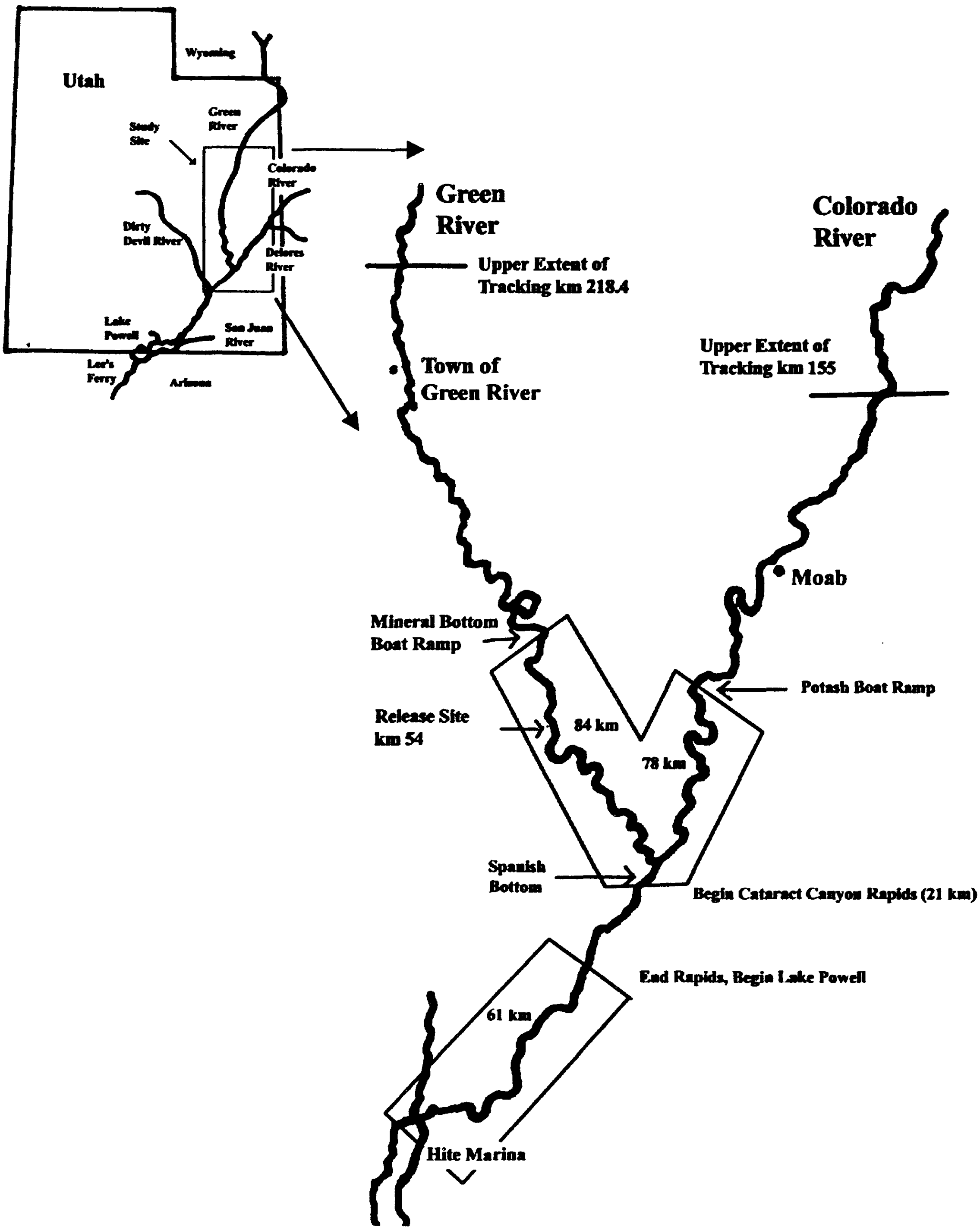


Figure 2A. The following 9 graphs show the dispersal distances (km) for razorback suckers in the experimental treatment. Fish 15E was the only sucker to still remain in the Green River by the end of the project.

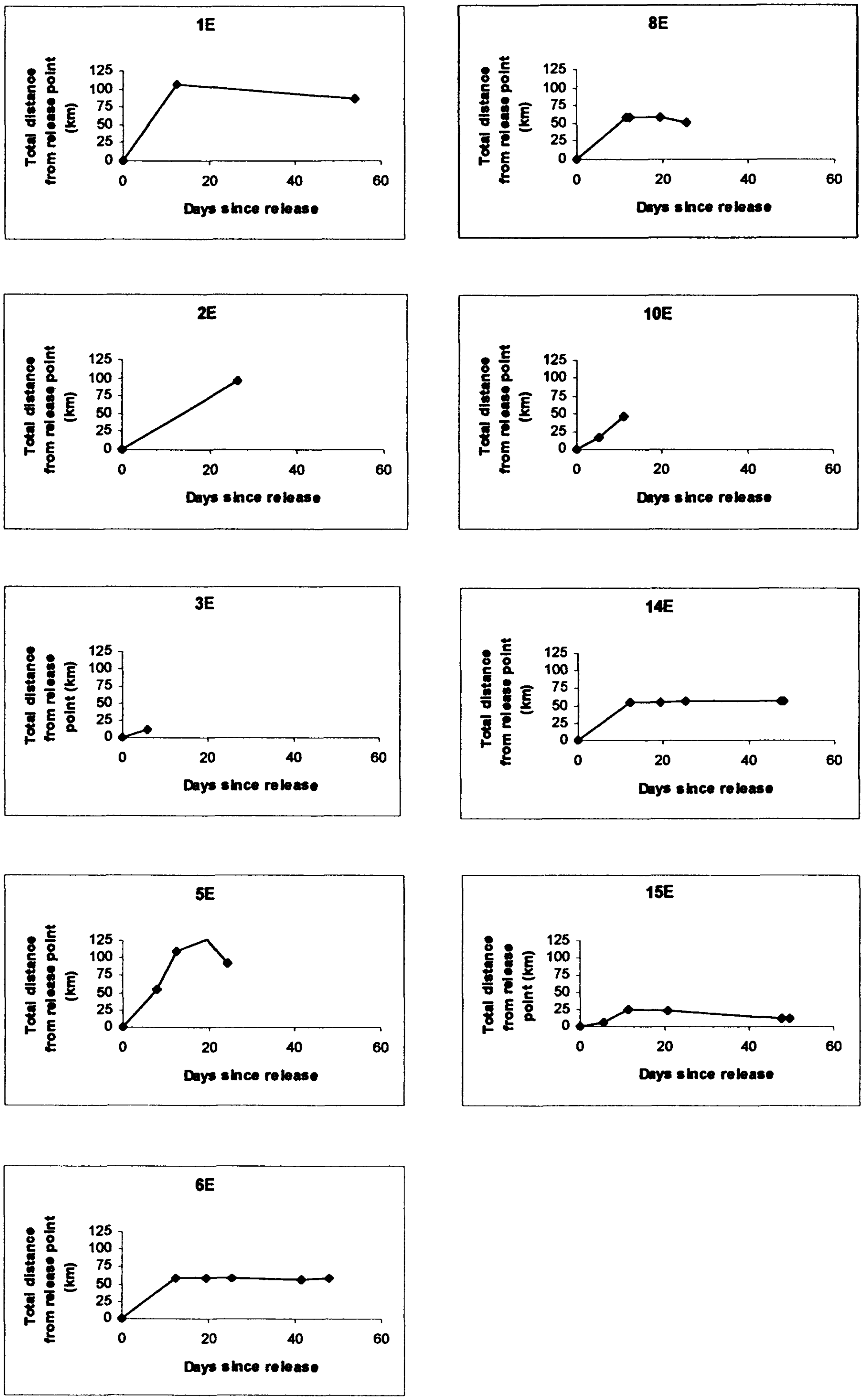


Figure 2B. The following 14 graphs show the dispersal distances (km) for razorback suckers in the control treatment. Four graphs could not fit on this page and are shown in the next Figure (3C).

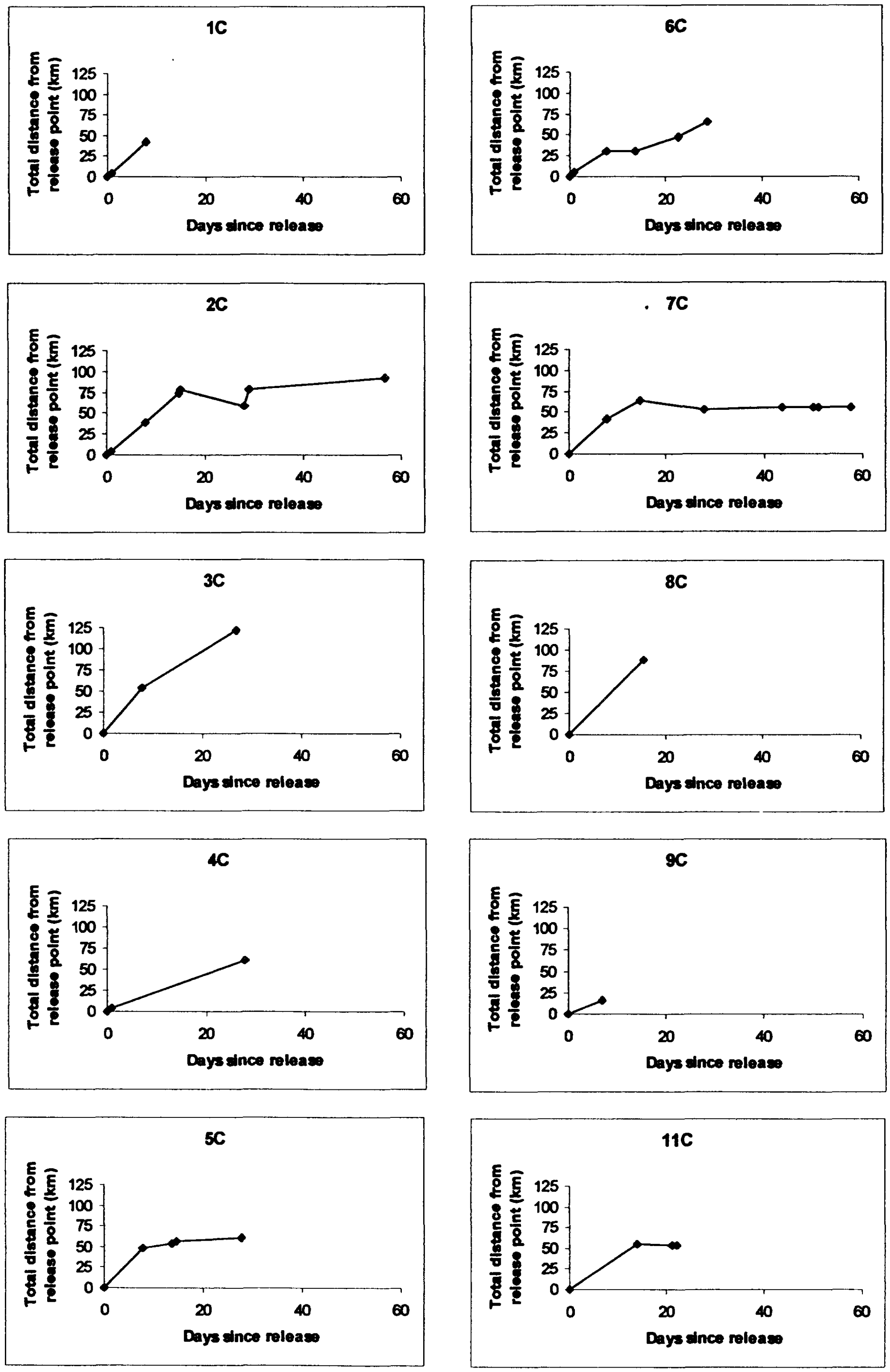


Figure 2C. These graphs are a continuation of Figure 3B.

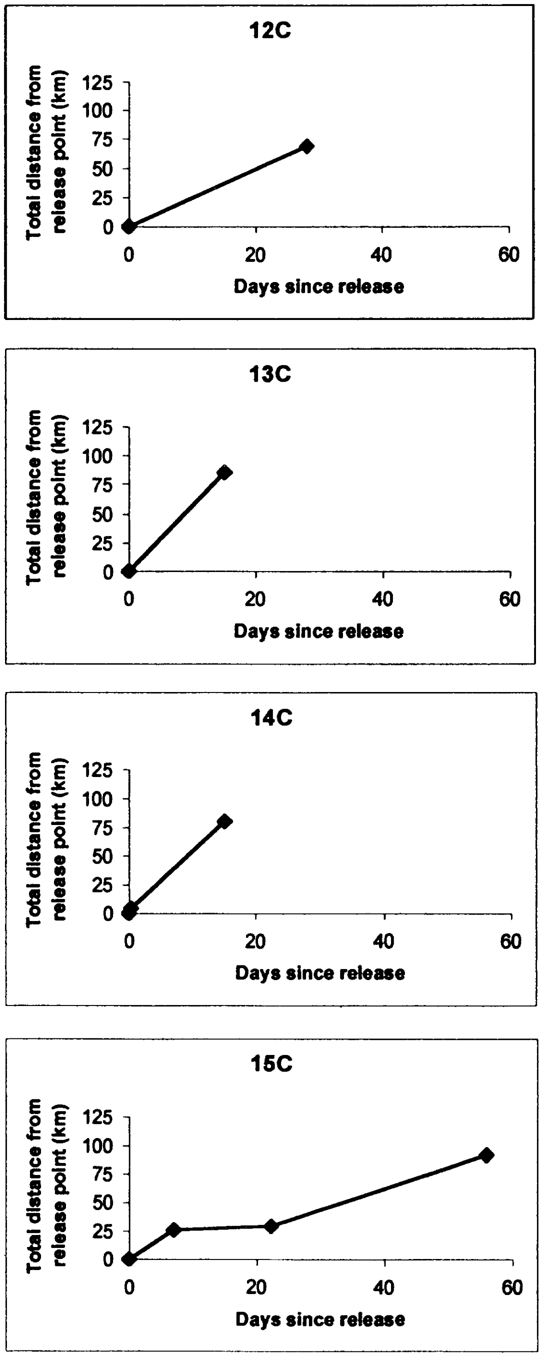


Figure 3A. The graphs show both the estimated average rates of daily movements (km/day) as well as the direction of the movements (+/-km/day) for experimental treatment fish. Solid lines show the trend in average daily movement rates, while dashed lines show the trend in the direction of travel.

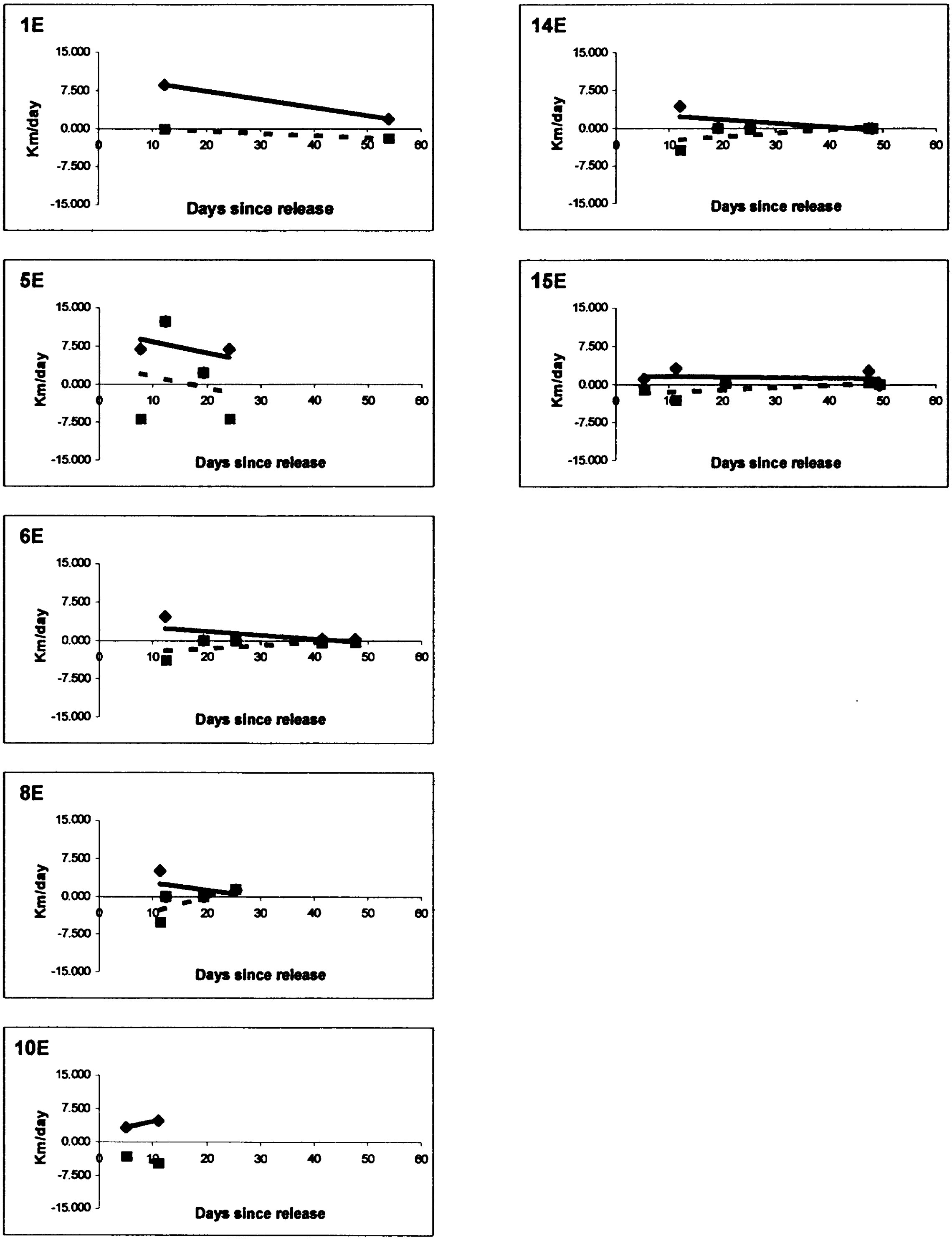


Figure 3B. The graphs show both the estimated average rates of daily movements (km/day) as well as the direction of the movements (+/-km/day) for control treatment fish. Solid lines show the trend in average daily movement rates, while dashed lines show the trend in the direction of travel.

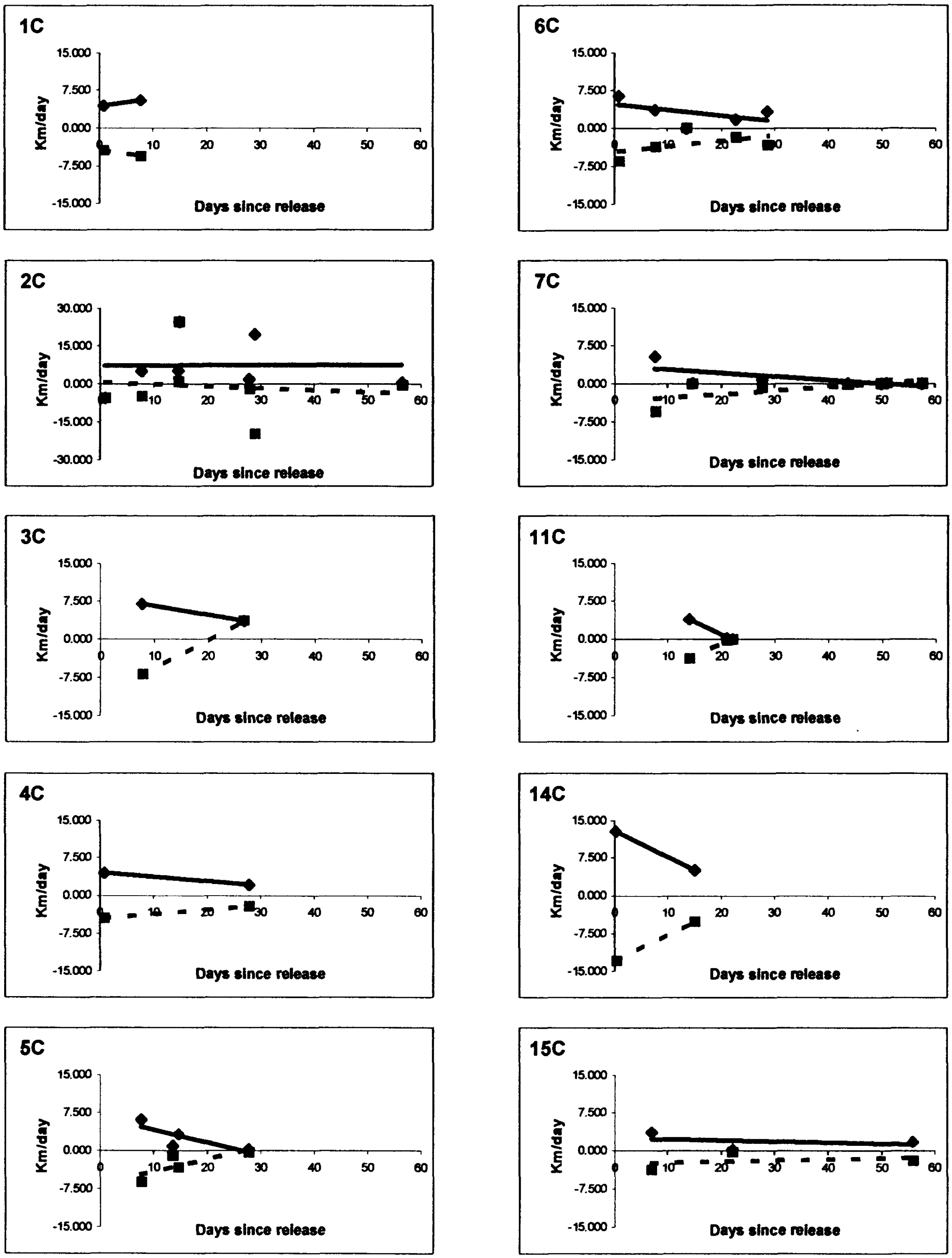
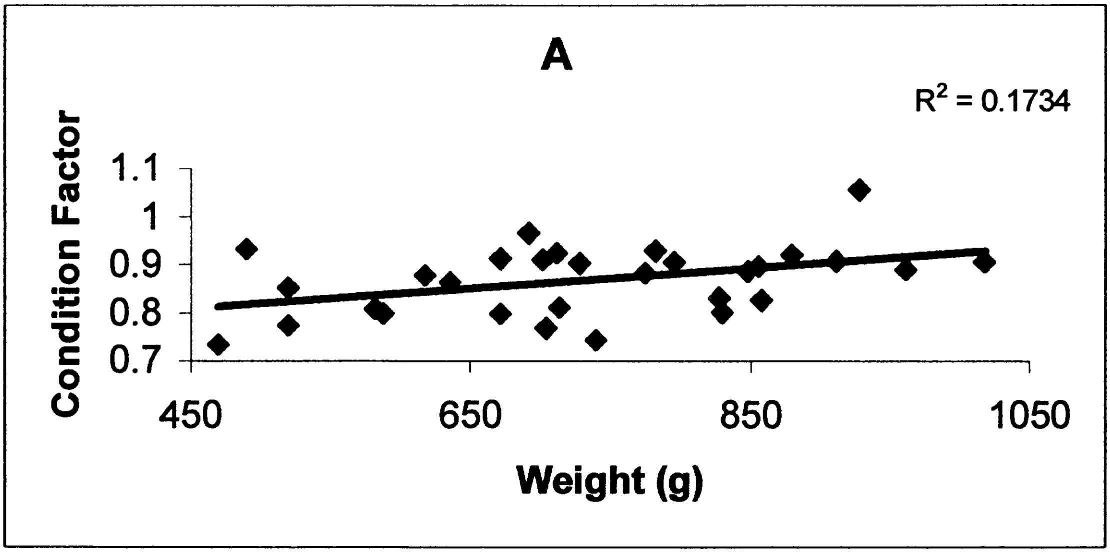


Figure 4. Plots of condition factor (K = [weight(grams)*100]/[length(mm)^3] vs. length(A) and weight(B). K is positively correlated with weight (p = 0.02), but not with length (p = 0.97, B).



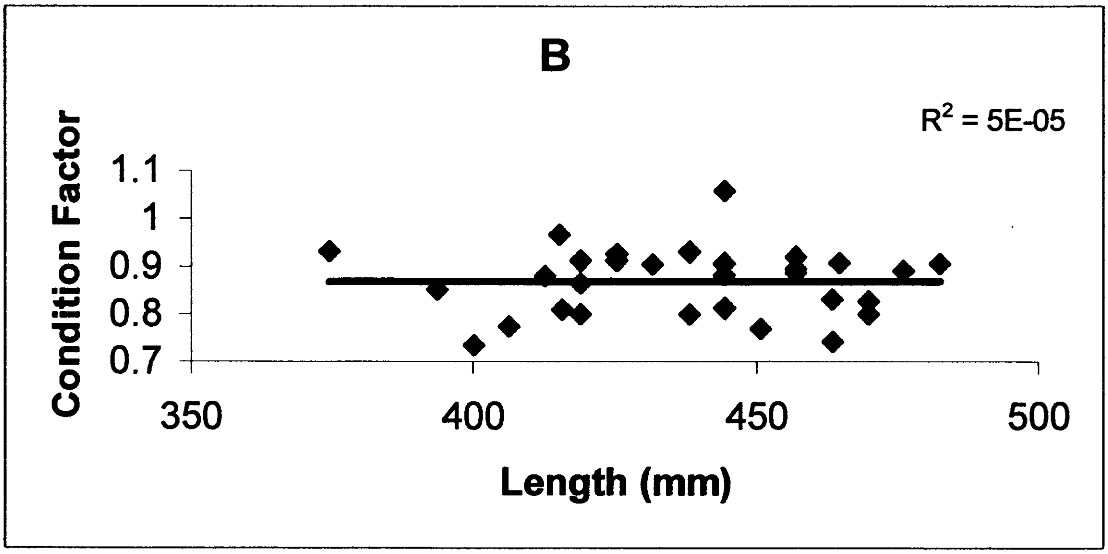
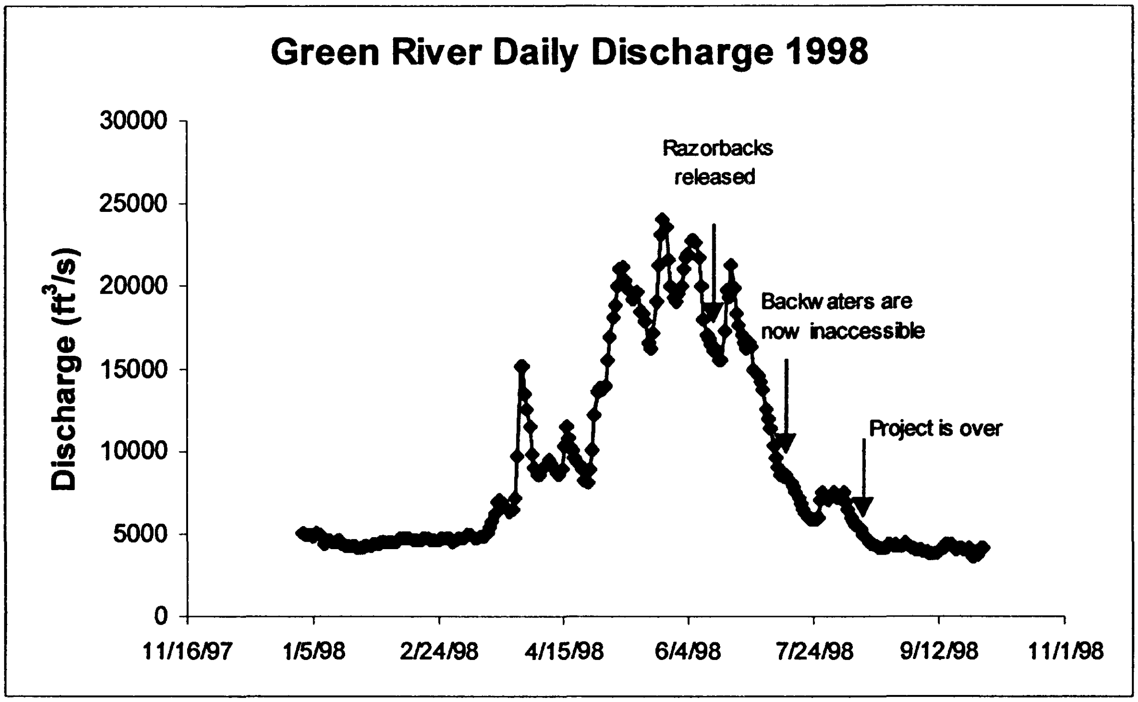


Figure 5. The following two graphs depict daily flow rates of the Colorado and Green Rivers within Canyonlands National Park and vicinity during the study period.



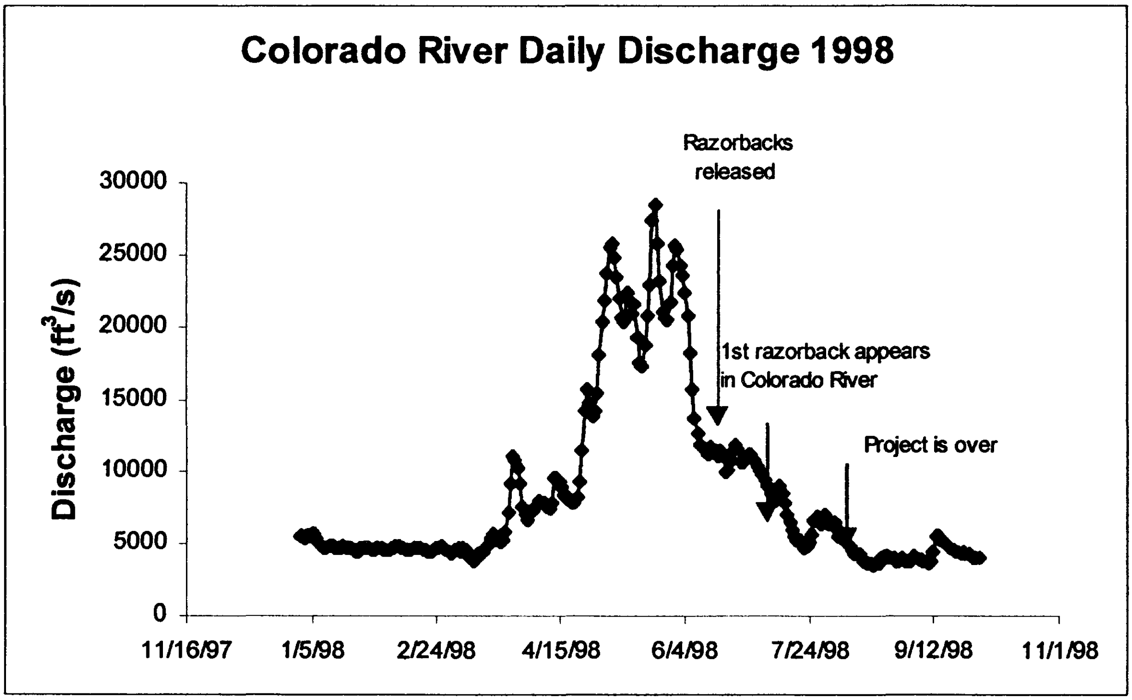
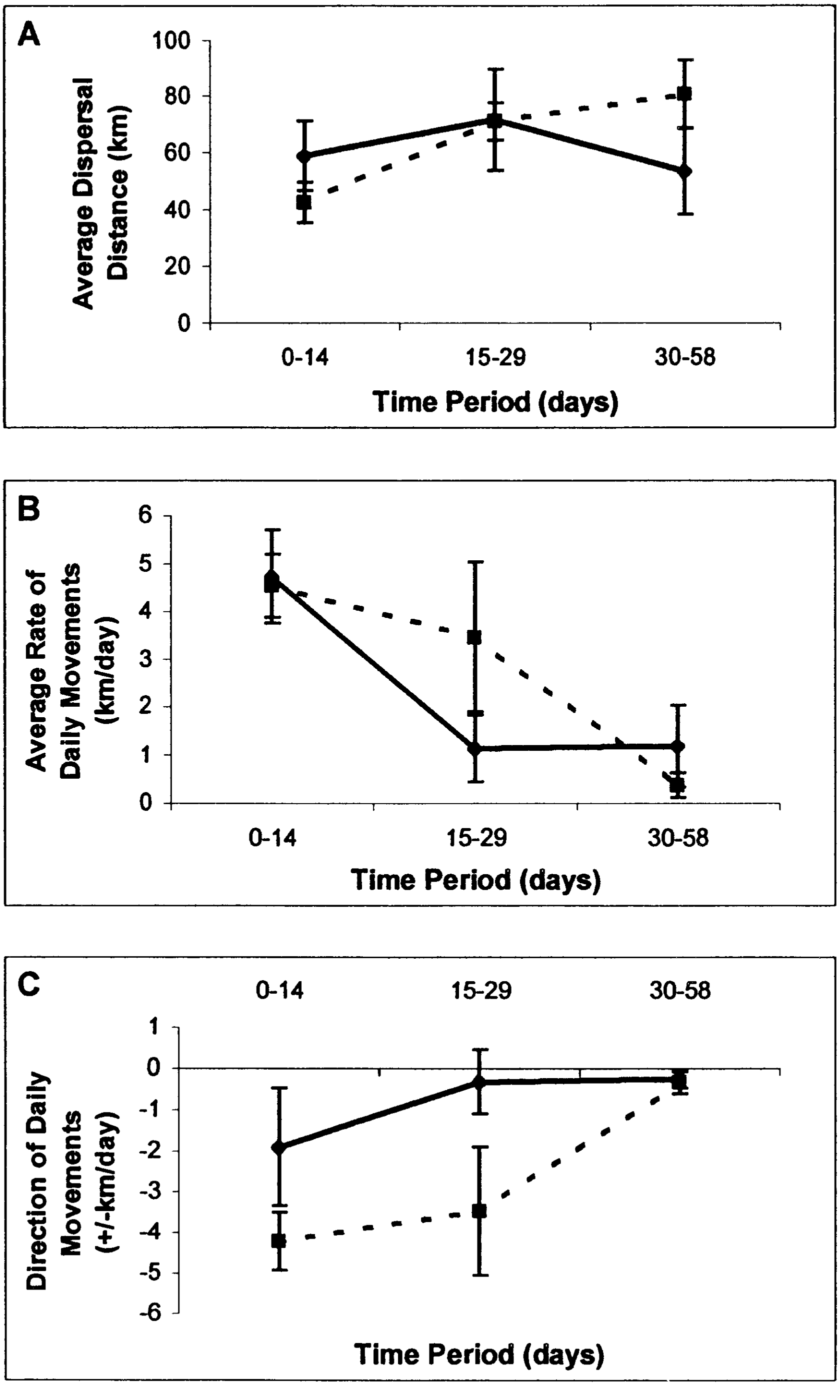


Figure 6. Graph A compares the average dispersal away from the stocking site between experimental fish (solid red lines) and control fish (dashed black lines). Graph B shows that the average rate of razorback sucker movement (km/day) decreases from an initially high rate following stocking. Graph C illustrates the average direction that razorback suckers traveled; there is a significant treatment affect ($p = 0.042$). The error bars used for the graphs are one standard error of the mean.



Appendix 1. Summarizes the rate (km/day) of razorback movements. Rates were calculated by dividing the distance traveled by the number of days between contacts. Only fish that were contacted at least twice during one of the three time periods are shown. The time periods are: 0 = 0-14, 15 = 15-29, 30 = 30-58 days.

tag ID	Days since release	trtmnt	time	distance	average km/day	directed km/day
11C	14.06	con	15	55.52	3.95	-3.74
11C	21.10	con	30	54.09	0.21	-0.21
11C	22.14	con	30	54.14	0.05	-0.05
12C	28.08	con	30	69.20	2.46	-2.46
13C	15.08	con	30	86.09	5.67	-5.67
14C	0.33	con	15	4.18	12.89	-12.89
14C	15.09	con	30	80.30	5.16	-5.16
15C	7.09	con	15	25.91	3.66	-3.66
15C	22.21	con	30	29.13	0.21	-0.21
15C	55.96	con	58	91.89	1.86	-1.86
15C	56.01	con	58	91.89	0.00	0.00
1C	0.95	con	15	4.18	4.42	-4.42
1C	7.79	con	15	42.00	5.53	-5.53
2C	0.96	con	15	4.18	5.54	-5.54
2C	7.79	con	15	38.78	5.06	-5.06
2C	14.68	con	15	74.83	5.24	0.80
2C	27.87	con	30	58.82	1.93	-1.93
2C	28.92	con	30	79.34	19.68	-19.68
2C	56.62	con	58	93.50	0.51	-0.51
3C	7.82	con	15	54.07	6.91	-6.91
4C	0.93	con	15	4.18	4.54	-4.54
5C	7.78	con	15	48.04	6.18	-6.18
5C	13.67	con	15	53.91	1.00	-1.00
5C	14.70	con	15	57.29	3.29	-3.29
5C	27.83	con	30	61.47	0.32	-0.32
6C	0.91	con	15	5.95	6.48	-6.48
6C	7.73	con	15	30.90	3.66	-3.66
6C	13.65	con	15	30.90	0.00	0.00
6C	22.74	con	30	47.23	1.80	-1.80
6C	28.63	con	30	66.62	3.32	-3.32
7C	7.79	con	15	42.64	5.47	-5.47
7C	14.70	con	15	64.85	0.09	-0.09
7C	27.71	con	30	54.07	0.83	-0.83
7C	43.75	con	58	56.32	0.14	-0.14
7C	49.98	con	58	56.48	0.03	-0.03
7C	51.00	con	58	56.40	0.08	0.08
7C	57.74	con	58	56.40	0.00	0.00

Appendix 1. Continued.

9C	7.13	con	15	16.50	2.32	-2.32
10E	5.16	exp	15	17.38	3.37	-3.37
10E	11.13	exp	15	46.35	4.86	-4.86
14E	12.16	exp	15	54.07	4.45	-4.45
14E	19.17	exp	30	54.88	0.12	-0.12
14E	25.25	exp	30	56.32	0.24	-0.24
14E	47.40	exp	58	56.48	0.01	-0.01
14E	48.12	exp	58	56.48	0.00	0.00
14E	48.42	exp	58	12.38	0.00	0.00
15E	5.13	exp	15	6.12	1.12	-1.12
15E	11.08	exp	15	24.94	3.16	-3.16
15E	20.30	exp	30	22.45	0.27	0.27
15E	47.16	exp	58	12.38	8.82	0.37
15E	49.11	exp	58	12.38	0.00	0.00
1E	12.35	exp	15	106.37	8.62	-0.14
1E	54.06	exp	58	85.77	2.10	-2.10
1E	54.09	exp	58	85.77	0.00	0.00
3E	6.30	exp	15	12.23	2.14	-2.14
5E	5.24	exp	15	54.07	6.91	-6.91
5E	12.36	exp	15	109.99	12.32	12.32
5E	19.41	exp	30	126.16	2.30	2.30
5E	24.23	exp	30	92.69	6.94	-6.94
6E	13.05	exp	15	58.66	4.70	-3.97
6E	20.08	exp	30	58.50	0.02	-0.02
6E	26.04	exp	30	58.42	0.01	-0.01
6E	41.56	exp	58	59.62	0.00	0.00
6E	42.09	exp	58	57.13	0.46	-0.46
6E	48.33	exp	58	59.62	0.40	-0.40
8E	11.16	exp	15	59.62	5.18	-5.18
8E	12.16	exp	15	59.62	0.00	0.00
8E	19.19	exp	30	59.62	0.00	0.00
8E	19.23	exp	30	59.62	0.00	0.00
8E	25.12	exp	30	94.95	1.39	1.39

Appendix 2. Summarizes the furthest distance each contacted fish had traveled during the three time periods. The time periods are: 0 = 0-14, 15 = 15-29, 30 = 30-58 days.

Tag ID	days since release	treatment	time	distance
11C	14.06	con	15	55.52
11C	21.10	con	30	54.14
12C	28.08	con	30	69.2
13C	15.08	con	30	86.09
14C	15.09	con	30	80.3
15C	7.09	con	15	25.91
15C	22.21	con	30	29.13
15C	55.96	con	58	91.89
1C	7.79	con	15	42.00
2C	14.68	con	15	74.83
2C	28.92	con	30	79.34
2C	56.62	con	58	93.5
3C	7.82	con	15	54.07
3C	26.74	con	30	121.74
4C	0.93	con	15	4.18
4C	27.85	con	30	61.47
5C	14.70	con	15	57.29
5C	27.83	con	30	61.47
6C	7.73	con	15	30.90
6C	28.63	con	30	66.62
7C	14.70	con	15	64.85
7C	27.71	con	30	54.07
7C	49.98	con	58	56.48
8C	15.63	con	30	88.51
9C	7.13	con	15	16.50
10E	11.13	exp	15	46.35
14E	12.16	exp	15	54.07
14E	25.25	exp	30	56.32
14E	47.40	exp	58	56.48
15E	11.08	exp	15	24.94
15E	20.30	exp	30	22.45
15E	47.16	exp	58	12.37
1E	12.35	exp	15	106.37
1E	54.06	exp	58	85.77
3E	6.30	exp	15	12.23
5E	12.36	exp	15	109.99
5E	19.41	exp	30	126.16
6E	13.05	exp	15	58.66
6E	26.04	exp	30	58.42
6E	48.33	exp	58	59.62
8E	11.16	exp	15	59.62
8E	19.19	exp	30	94.95

Appendix 3. Summary of fish lengths, weights, condition factors, and telemetry contacts. An * denotes fish that reached Lake Powell. An # indicates that fish were contacted in Cataract Canyon Rapids.

Fish ID	# days acclimation	Length (mm)	Weight(g)	Conditin factor	Contacted?	# of Contacts
1E	2.540	464	740	0.743	Y	2
2E	2.549	470	858	0.827	Y	1
3E	*.913 - 1.750	451	704	0.768	Y	1
4E	2.552	425	712	0.925	-	-
5E	2.545	438	672	0.799	Y	5
6E	*.913 - 1.750	419	672	0.913	Y	5
7E	2.536	394	520	0.852	-	-
8E	1.953	476	962	0.891	Y	4
9E	1.924	445	796	0.906	-	-
10E	1.917	465	912	0.908	Y	2
11E	1.960	419	588	0.799	-	-
12E	1.951	406	520	0.775	-	-
13E	1.930	445	714	0.813	-	-
14E	1.914	425	702	0.912	Y	5
15E	1.972	438	782	0.93	Y	5
1C	-	400	470	0.734	Y	2
2C	-	470	830	0.8	Y	6
3C	-	445	775	0.882	Y	2
4C	-	464	828	0.831	Y	2
5C	-	457	856	0.896	Y	4
6C	-	419	636	0.864	Y	5
7C	-	483	1018	0.906	Y	7
8C	-	457	880	0.921	Y	1
9C	-	445	928	1.057	Y	1
10C	-	416	582	0.809	-	-
11C	-	415	692	0.966	Y	3
12C	-	457	848	0.887	Y	1
13C	-	413	618	0.879	Y	1
14C	-	375	490	0.932	Y	2
15C	-	432	728	0.904	Y	3