Post-Stocking Dispersal, Habitat Use, and BehavioralAcclimation of Juvenile Razorback Suckers *(Xyrauchen texanus)* in Two Colorado River Reservoirs

Open File Report 98-301

Prepared in Cooperation with Arizona State University,
Bureau of Reclamation, National Park Service,
and U.S. Fish and Wildlife Service

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Post-Stocking Dispersal, Habitat Use, and Behavioral Acclimation of Juvenile Razorback Suckers (*Xyrauchen texanus*) in Two Colorado River Reservoirs.

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EXECUTIVE SUMMARY

Little information is available regarding the movements and habitat use of early life stages of razorback sucker (*Xyrauchen texanus*). Juveniles are rarely encountered in the wild (Minckley 1983, Minckley et al. 1991, Gutermuth et al. 1994, Modde 1996, Tyus 1997). Dispersal and habitat use of stocked, juvenile razorbacks was studied in lakes Mohave and Powell during the summer of 1997. Sonic transmitters (90 day) were externally attached to 55 fish, 27 were released into Lake Mohave and 28 into Lake Powell. Half of each lot was held three days in blocked coves to test if site acclimation influenced short-term dispersal rates.

Post stocking dispersal was rapid, widespread, and similar to earlier studies in Lake Mohave (Mueller et al. 1998). Movement was more pronounced immediately after release and declined with time. Maximum daily distance traveled by individuals released in Lake Powell averaged >2 km/d (0->7 km/d) and daily movements averaged 347 m/d (3-1,500 m/d) for Lake Mohave fish and 480 m/d (3-1,800 m/d) for Lake Powell. After the first week fish were typically found backwaters and coves and >50% of the fish detected were found in cover. Prevalent cover types in Lake Mohave and Powell included flooded tamarisk (48-86%), emergent vegetation (*Potamogeton & Najas spp.*) (40/0% absent in Lake Powell), and rock cavities (12-14%).

Preliminary data suggests behavioral acclimation may influence short-term dispersal rates. Of the 14 Lake Powell fish that remained in the study area for > 30 days, twice as many (64%) represented fish held for 3 day than those simply released. The sample size was small and might simply reflect normal variability, however, it's doubtful holding fish deter fish from remaining in the general area and might encourage it. To few contacts were made in Lake Mohave to draw any conclusions.

Sonic transmitters have been used successfully for tracking other fish species (Pelle and Paulson 1993, Marsh 1997, Mueller et al. 1998), however, they proved less effective on juvenile suckers that typically were found using shallow, vegetative backwaters. These habitats greatly reduced the effectiveness of sonic equipment. On the basis of our studies, we recommend that stocking programs consider the following:

- Expand monitoring programs to sample shallow, flooded habitats (i.e., <2 m depths).
- Stock only fish larger than 30 cm in length.
- Investigate seasonal (autumn-winter) rather than year-round stocking.
- Examine reservoir fluctuation zones and how changes in reservoir elevation influences predator population dynamics (i.e. densities, colonization rates).
- Use radio, rather than sonic transmitters for future juvenile telemetry studies.

INTRODUCTION

Information pertaining to post-stocking dispersal and habitat use of endangered razorback sucker (*Xyrauchen texanus*) is primarily limited to the adult life stage. Radio or sonic transmitters are normally surgically implanted in the fish's abdominal cavity (McAda and Wydoski 1980, Ulmer 1987, Tyus 1987, Tyus and Karp 1989, Marsh and Minckley 1989, Creef and Clarkson 1993, Ryden and Pfeifer 1995, Burdick and Bonar 1997). Due to transmitter size, this approach is not feasible with smaller life stages. Instead of surgery, we externally attached sonic transmitters on juvenile razorback suckers which reduced surgically related stress and mortality.

Wild populations consist of old individuals and young fish are rarely encountered (Minckley 1983, Minckley et al. 1991, Gutermuth et al. 1994, Mueller and Marsh 1995, Modde 1996 and 1997). Although juvenile or larval razorback suckers have been stocked in relatively large numbers (Johnson 1985), efforts to reestablish populations have generally failed (Minckley et al. 1991, Mueller 1997). Research attempts to determine habitat use and movements of juvenile suckers has been plagued by small numbers of wild fish, logistical problems associated with sampling remote riverine habitats, and fish disappearance due to dispersal and unknown survivorship. To our knowledge, reports of juvenile habitat use is limited to sparse information collected on pond-reared fish, stocking dispersal studies, and rare observations of wild fish (Brooks 1985, Marsh and Brooks 1989, Minckley et al. 1991, Mueller and Marsh 1993, Modde 1996, Mueller et al. 1998).

Similar information is lacking regarding the behavioral stress associated with repatriating endangered fish into historical or new habitats. Fundamental research has focussed primarily on the physiological response of fishes to physical, chemical and handling induced stress. Studies have examined the effect of stress on the body, with mortality the usual endpoint and not fixed on specific, short-term fish behavior. Factors such as anorexia, tendency toward to downstream movement, or abnormal behavior that may increase susceptibility to predation, are difficult, if not impossible to measure (Wedemeyer et al. 1990). Nevertheless, these factors undoubtedly influence the territorial behavior and repatriation of reintroduced fishes.

We intended to test if behavioral acclimation would influence short-term dispersal rates of young razorback suckers. If initial stocking behavior can be influenced, it could improve our ability to maintain fish in specific river reaches and improve survival by reducing predation exposure.

METHODS

Sources of Fish

Lake Powell Approximately 300 razorback suckers were transported from Ouray National Fish Hatchery, Utah, to golf course ponds in Page, Arizona, on May 16, 1996. Fish originated from "Green River" stock in 1993 and were designated "surplus" production from the upper basin stocking augmentation program. Fish were held in golf course ponds to determine the ponds suitability as grow-out facilities (Mueller and Wick 1997). Fish were scheduled to be released into critical habitat areas of Lake Powell (USDOI 1996a & 1996b).

Thirty fish averaging 358 mm in length (335-402 mm) were captured from the golf course ponds on May 3, 1997 (Appendix A). Fish were treated with stress reducing chemicals (salt, MS-222, stress coat, and furacin) and transported by boat to Castle Creek Canyon, River Kilometer (RK) 72 on the San Juan Arm of Lake Powell.

Lake Mohave Lake Mohave were supplied by the Willow Beach National Fish Hatchery. Fish were smaller, averaging 241 mm (201-290 mm, Appendix A). Fish were hauled in a tank treated with stress reducing chemicals. In addition to sonic transmitters, the fish were also PIT (passive integrated transponder) tagged.

Telemetry Equipment and Survey Techniques

Ultrasonic transmitters were chosen over radio transmitters for their ability to be detectable regardless of depth, which in Lake Powell could exceed 100 m. Transmitters have been successfully used on both small razorbacks suckers and bonytail (*Gila elegans*) in Lake Mohave (Marsh et al. 1996, Mueller et al. 1998). Transmitters (Sonotronics, model MT-95-2) used for this study measured 9x36 mm, weighed 3 g in water, and had an estimated battery life of 90 days. Normal detection range was 500 m.

Previous attempts to surgically implant sonic transmitters in juvenile razorback suckers led to high transmitter shedding and possibly mortality (Ryden 1997b, Mueller et al. 1998). We wanted to test external attachment techniques that might reduce stress, increase survival, and would eventually be shed. A literature review revealed various methods of attaching transmitters. Saddle-mounted transmitters were tested on several surrogate species (white suckers [*Catostomus commersoni*] and largemouth bass [*Micropterus salmoides*]) without much success (Winter et al. 1978) due to severe fungal and bacterial infections at the point of contact. Various combinations of metal wire harnesses were tested to determine if galvanistic corrosion could be used as a release mechanism. Combinations of steel, aluminum, and copper proved unreliable.

Razorbacks possess a dorsal keel, which is pronounced in adults and less developed in young. The keel of preserved speciemens loaned from the Arizona State University was examined as a potential attachment site. Dissection indicated the keel was composed of a cartilagineous ridge and a thin, poorly ossified bony plate. No major arteries, veins, or musculature were noted suggesting external attachment to the fish's keel might be an alternative that might prove less intrusive than surgical implants.

External sonic transmitters were attached to five razorback juveniles (32-35 cm TL) in Lake Mohave during 1994. The attachment technique is similar to those used for Carlin tags, where two sutures and a plastic backing plate held the transmitter in place (Stasko and Pincock 1977, Winter et al. 1978, Matthews et al. 1990). We remained in contact with 4 fish, all successfully carried the tags for the 45-day study.

The attachment technique was modified to a single suture and no backing plate to allow eventual transmitter shedding and speed healing. Prior to attachment, a monofilament line about 30 cm in length was positioned and glued to the center of each transmitter. The transmitter, line, and needles were sanitized in a solution of alcohol and 10% betadine prior to attachment. Each transmitter was activated and tested prior to attachment. Fish were weighed and measured and then wrapped in a wet towel and placed in shallow plastic tub filled with water. The needle was inserted about 6-8 mm below the fishes' dorsal keel. The ends of the lines were tightened over the keel and tied with three square knots, and the fish was placed in a holding tank for transport and release.

Twenty eight of the thirty Lake Powell transmitters functioned properly, one produced a weak signal, and another had no signal at all. Fish processing and transmitter attachment was rapid, typically taking less than a minute per fish. Groups of five fish were place within the blocked coves (held) and on the lake side (free) of the blocking nets. Fifteen fish were held three days and 13 were immediately released. The entire process took approximately 1.5 hours. Fish exhibited no obvious stress nor was their swimming skill impaired. Water visibility was less than 25 cm.

Blocking nets were removed 72 hours later and 5 suckers were found entangled in the net. Fish were securely held and the mesh was cut to minimize stressing the fish. Fish were examined and all sutures were still secure and wounds had not enlarged. One fish was released prior to checking its transmitter code, the remaining fish were # 238, 436, 446, and 447.

<u>Lake Mohave</u> Smaller meshed blocking nets were used to reduce the chance of entanglement. A group of 10 fish (5 held/5 released) was stocked at Owl Cove (RK45), 10 (5 held/5 released) at Tequila Cove (RK32), and 7 at Mesa Cove (RK 29). We only tagged 7 at Mesa Cove because we didn't want to use fish smaller than 21 cm. None of these fish were held for the acclimation test. On May 23, the holding nets were removed. Only one fish remained in the Owl Point holding cell and 2 in Tequila Cove, the other fish had already escaped.

Surveys were conducted each week by boat using a directional hydrophone. The San Juan Arm of Lake Powell is narrow and surveyors stopped at 500-800 m intervals along the channel and in every cove and side canyon to check for signals. Stream sections were monitored while floating downstream.

A GPS grid pattern was designed for Lake Mohave to accommodate its 5 km width. Waypoints or "listening stations" (71) were spaced 1,600 m apart to standardize monitoring locations and effort (Figure 1). After the second week we increased the number of stops to over 125 locations, and bimonthly, we visited each cove and intensified (100 m intervals) our monitoring of flooded, shoreline vegetation.

When a fish was located the following information was recorded: date, time of day, location determined using GPS and/or maps, relative depth, distance from the shoreline, vegetation, cover type, and hydraulic characteristics (flowing versus slack). Location was recorded in latitude and longitude, river mile, and marked on a map. Water depth was determined visually or by using a fathometer, shoreline distance was estimated (<10 m, 10-50 m, >50 m). Surveys continued for 100 days.

We attempted to recapture fish 80 days into the study to assess the attachment technique and to remove the transmitters. Trammel nets were set on fish found in shallow, calm habitats.

RESULTS

Tracking

Lake Powell Surveys at both study locations began the morning following release. Initially Lake Powell surveys were conducted between RK 51 to RK 85, a distance of roughly 34 km. At the time of release, fish access upstream of RK 85 was physically blocked by a 3 m high water fall.

It was impossible to discern individual signal codes when fish were first released due to garbled signals. No cove held fish were detected outside of the enclosures during their period of captivity. All fish had left their release sites after 5 days but many remained in the Castle Creek Canyon complex. Initial contact was made with 23 of the 28 fish (Figure 2). Fish gradually dispersed, with all but three moving upstream. By June 10, the reservoir had risen to a point where the falls was inundated and could be negotiated safely by boat. Rising waters also inundated hundreds of hectares of flooded tamarisk which was impossible to monitor effectively. Submerged vegetation absorbed the sonic signal significantly reducing the signal range in some cases <50 m. During this period the water falls was also inundated and surveys were extended upstream (20 km) to Slickhorn Rapids (RK106) and during the week of August 12, two boat crews searched the entire 106 km reach between the confluence of the San Juan and Colorado rivers (RK 0) to Slickhorn Rapids (RK 106). Although the search effort was extensive, no additional fish were found.

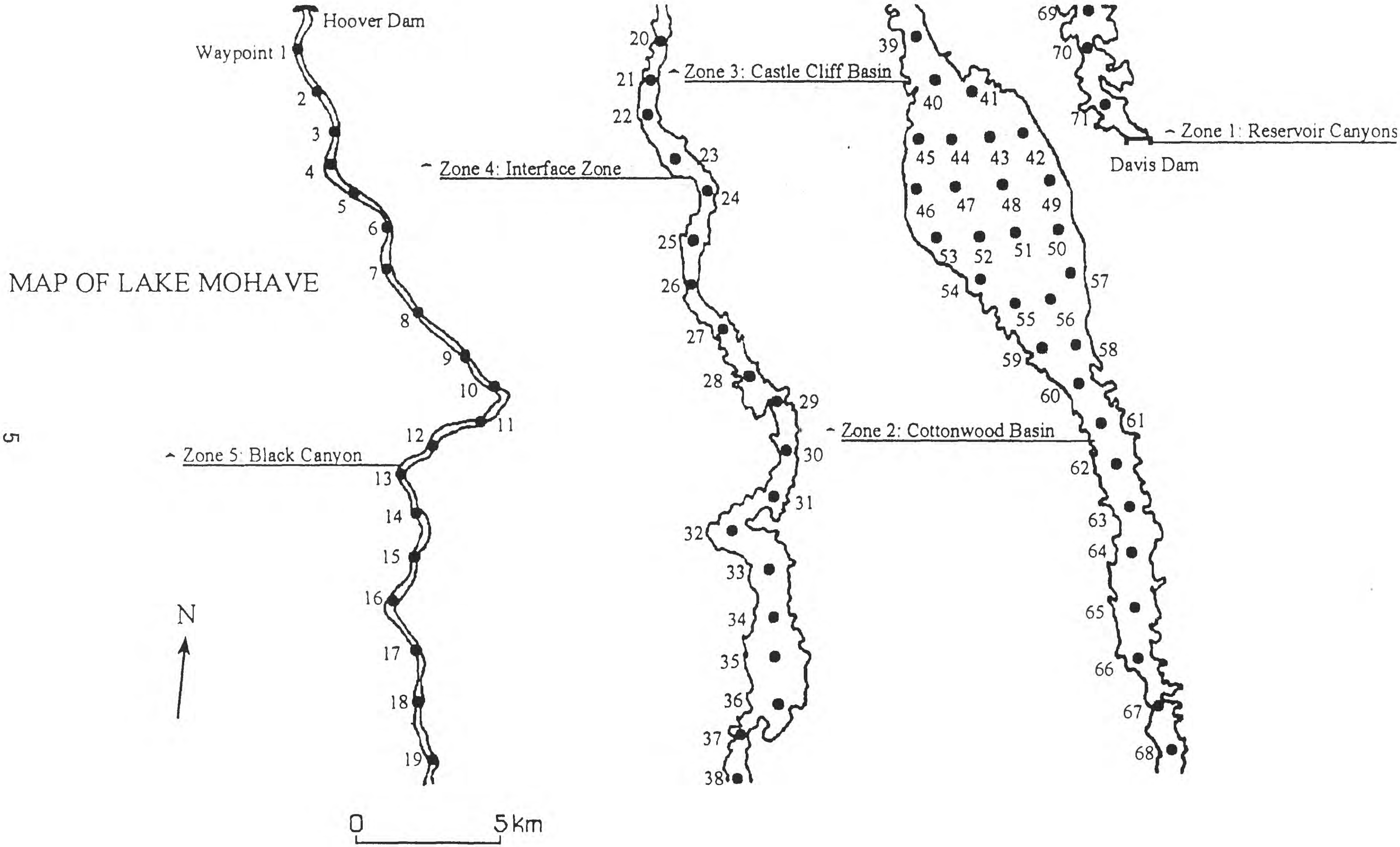

Figure 1. Map of Lake Mohave, Arizona and Nevada, showing numbered waypoints 1-71 and reservoir zones 1-5.

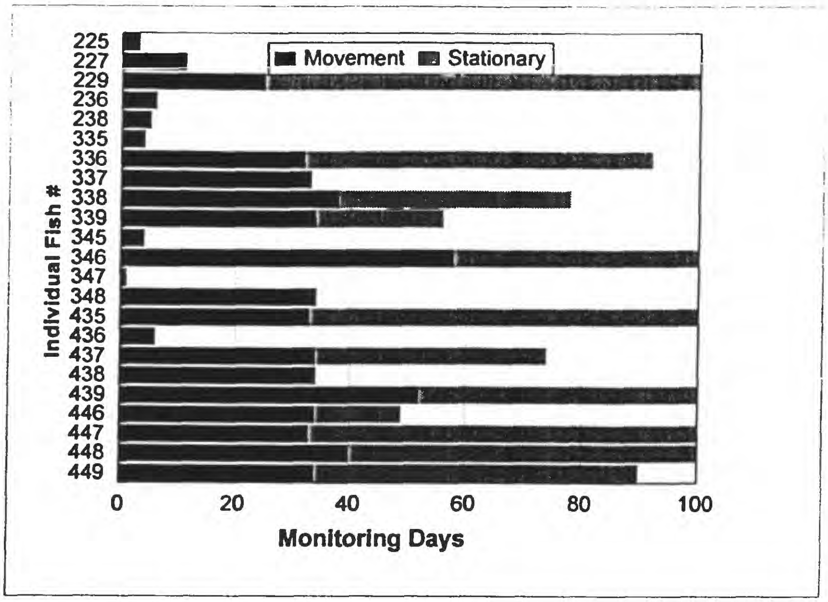

Figure 2. Time duration and movement for externally tagged juvenile razorback suckers released into the San Juan Arm of Lake Powell, Utah, May through July 1997.

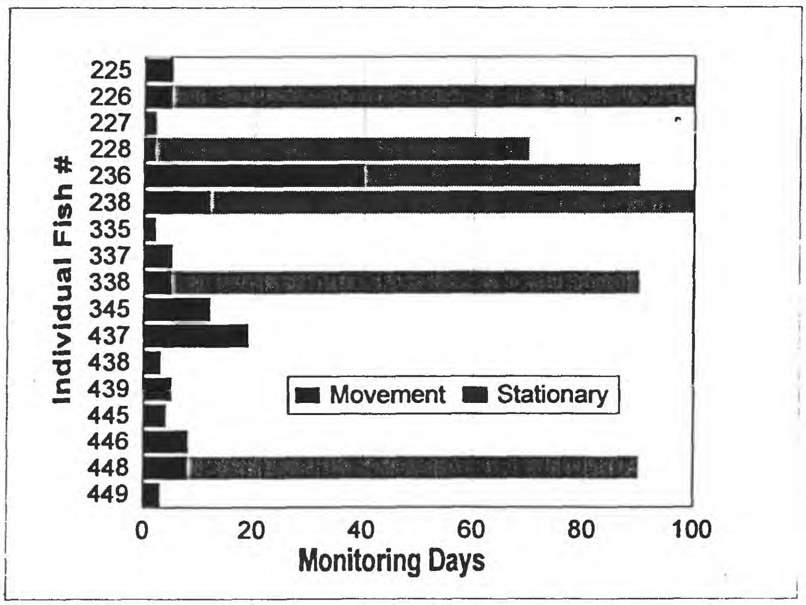

Figure 3. Time duration and movement for externally tagged juvenile razorback suckers released into Lake Mohave, Arizona-Nevada, May into August 1997.

Over time, the distance fish traveled declined and some fish appeared to take up residency in the shallow coves that typically had abundant cover. In several cases we were unable to detect any movement and suspected some fish had lost their tags. Into the fourth week of the study, we attempted to disturb several fish to determine if they would actually move and some moved distances greater than 100 m, only to return to their original location. Possibly juveniles had found cavities or "preferred" niches. During this period, reservoir elevations rose 10 m and it became increasingly difficult to detect fish movement. While it was quite possible that fish simply were not moving, we felt it equally likely that transmitters had been shed. For purposes of analysis, we only present location data that we are certain represents fish movement (Table 1).

Several transmitters were not detected in the search area, which prompted us to expand the weekly search area further downstream. During the week of August 12, two boat crews searched the entire 106 km reach between the confluence of the San Juan and Colorado rivers (RK 0) to Slickrock Rapids (RK 106). The search was not expanded any further upstream due to safety and power craft restrictions. Although the search effort was extensive, no additional fish were found.

Over time, the distance fish traveled declined and some fish appeared to take up residency in selected spots. These areas usually were at the back of coves or in areas that had abundant cover. In several cases we were unable to detect any movement and suspected some fish had lost their tags or had died. Into the fourth week of the study, we attempted to disturb and move several fish to determine their status. Some fish moved distances greater than 100 m, only to return to their original location. Possibly juveniles had found cavities or "preferred" niches. During this period, reservoir elevations rose 10 m and it became increasingly difficult to detect fish movement. While it was quite possible that fish simply were not moving, we felt it equally likely that transmitters had been shed. For purposes of analysis, we only present location data that we are certain represents fish movement (Table 1).

Lake Mohave The entire length (106 km) of Lake Mohave was surveyed, which normally took 2 days. We detected 17 of the initial 27 fish released but remained in contact with only 7 after the second week of the study. Of the 17, we detected 2 moving uplake, the rest moved down reservoir (Table 2, Figure 3).

Habitat Use

Habitat use was strikingly similar for both reservoirs. Fish were typically found within 10 m from 62% of the time in Lake Mohave compared to 65% in Lake Powell (Figure 4). Fish found at distances greater than 50 m from shore only represented 15 to 20% of the sightings.

Table 1. Range (River Kilometers) and movements of 23 of 28 juvenile razorback suckers released into the San Juan Arm of Lake Powell, Utah, May-August 1997.

Fish #	Days Tracked	# Contacts	Range (RK)	Tot. Dis. Travel(m)	Max.* m/day	Avg. m/day
225	3	5	73.2	1,800	900	600
227	11	8	73.2 - 78.8	8,700	2,100	791
229	25	9	68.9 - 78.4	18,700	2,400	748
236	6	6	73.2 - 74.8	5,400	2,600	900
238	5	2	72.7 - 74.0	2,600	1,000	520
335	4	1	73.2	100	-	25
336	32	7	73.2 - 80.1	14,800	2,700	462
337	33	13	73.2 - 78.8	17,000	3,800	515
338	38	10	73.2 - 78.8	7,600	2,900	200
339	34	6	73.4	100	-	3
345	4	5	73.2	1,200	700	300
346	58	15	73.2 - 81.3	6,700	2,000	115
347	1	2	73.2 - 73.5	1,800	1,800	1,800
348	34	9	73.2 - 76.7	4,750	400	140
435	33	7	73.2 - 77.6	14,700	4,800	445
436	6	8	73.2 - 74.8	6,100	2,500	1,016
437	34	11	73.2 - 75.1	9,300	1,200	274
438	34	13	73.2 - 78.8	22,900	5,000	674
439	52	14	73.2 - 79.0	10,090	1,200	194
446	34	11	73.2 - 73.4	4,400	1,000	129
447	33	6	73.2 - 78.8	16,700	2,000	506
448	40	7	72.7 - 75.5	8,250	1,600	206
449	34	7	73.2 - 80.6	16,150	1,200	475

*Within 24 hours (consecutive days).

Table 2. Range (River Kilometers) and movements of 17 of 27 juvenile razorback suckers released into Lake Mohave, Arizona-Nevada, May-August 1997.

Fish #	Days Tracked	# Contacts	Range (RK)	Tot. Dis. Travel(m)	Max.* m/day	Avg. m/day
225	5	3	33.8	15	15	3
226	5	4	33.0 - 33.8	700	300	140
227	2	1	33.0 - 33.8	1,200	-	600
228	2	1	33.0 - 33.8	2,100	-	1,050
236	40	15	28.2	200	-	5
238	12	10	32.2 - 65.2	84,700	20,500	7,050
335	2	1	23.7			
337	5	3	12.2 - 23.7	7,500	7,100	1,500
338	5	3	23.7	200	200	40
345	12	5	23.7	300	200	150
437	19	2	32.2 - 33.8	1100	-	60
438	3	2	33.8	20	-	10
439	5	2	33.0 - 33.8	1,150	-	230
445	2	2	45.4	300	300	150
446	8	2	43.4 - 45.4	3,300	-	410
448	8	3	44.2 - 45.4	1,800	-	225
449	3	2	44.2 - 45.4	1,900	-	635

***Within 24 hours (consecutive days).**

It was impossible to discern individual signal codes when fish were first released due to garbled signals. No cove held fish were detected outside of the enclosures during their period of captivity. All fish had left their release sites after 5 days but many remained in the Castle Creek Canyon complex. Initial contact was made with 23 of the 28 fish (Figure 2). Fish gradually dispersed, with all but three moving upstream. By June 10, the reservoir had risen to a point where the falls was inundated and could be negotiated safely by boat. Rising waters also

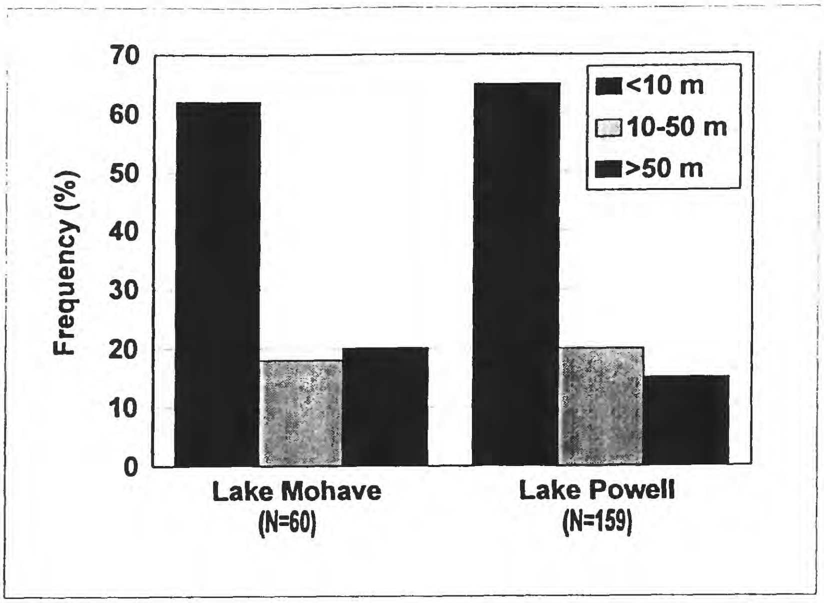

Figure 4. Percentage of razorback sucker detection less than 10, 10 to 50, and greater than 50 m from shore in lakes Mohave and Powell, May through July 1997.

inundated hundreds of hectares of flooded tamarisk which was impossible to monitor effectively. Submerged vegetation absorbed the sonic signal significantly reducing the signal range in some cases <50 m. During this period the water falls was also inundated and surveys were extended upstream (20 km) to Slickhorn Rapids (RK106) and during the week of August 12, two boat crews searched the entire 106 km reach between the confluence of the San Juan and Colorado rivers (RK 0) to Slickhorn Rapids (RK 106). Although the search effort was extensive, no additional fish were found.

Cover was an important habitat component and represented >50% of our observations. It appears cover was being used for concealment and the type used varied, dependent upon its availability. Fish utilized three types in Lake Mohave; submerged tamarisk (*Tamarix pentandra*), large rocks and ledges, and submergent vegetation (*Najas or Potamogeton spp.*). Fish were most often (48-86%) found in flooded tamarisk (Figure 5). The second most prevalent cover type where juvenile suckers were found in Lake Mohave was submergent vegetation (40%) and the last cover type used was rock ledges or rubble (12-14%). Similar cover types were found in Lake Powell with the exception of emergent vegetation.

Range

Lake Powell We detected 23 of the 28 fish released at Castle Creek Canyon (Table 1). The initial movement of some fish was pronounced, and generally uplake (RK >73) and only two ventured downstream. The maximum distance fish were detected from the release site was 4.6 km upstream and 2.7 km downstream.

The average maximum distance traveled by 21 fish was more than 2,080 m/d (range 400-5,000 m/day). One fish (#438) traveled a total distance of 5 km/d. Juvenile fish frequented and moved between Castle Creek Canyon and Mike's Canyon (RK 73-79). The average observed range was 2.2 km (0.1 to 7.4 km). We were unable to determine the actual dispersal range since we lost contact with 50% of the study fish.

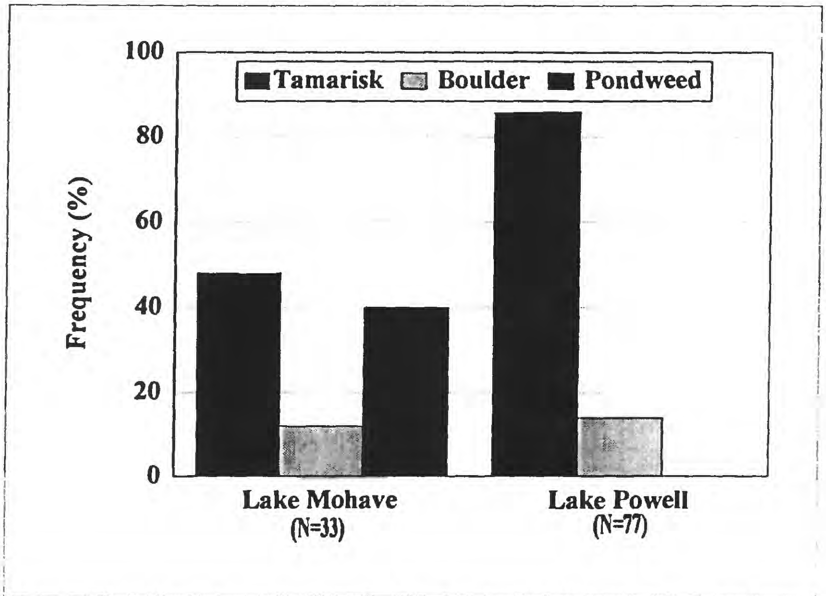

Figure 5. Cover used by juvenile razorback suckers released into lakes Mohave and Powell, May through July 1997.

Lake Mohave Fish rapidly dispersed and we only maintained contact with one fish (#437) past the third week. Fish #337 traveled 7.1 km in one day. On the fourth day we contacted and followed fish #238 moving at a rate more than 3 km/hour. It was traveling up the middle of the reservoir and by mid-day had moved an astonishing rate of 20.5 km/day. The transmitter traveled nearly 63 km, through the pelagic zones in Lake Mohave during the next four days, suggesting it might have been eaten by a striped bass.

Equipment Performance and Survey Design

Signal reception was best under calm conditions and when the transmitter was located in open water. At times signals could be heard at distances of 1-2 km. Wind, rain, wave action, and watercraft traffic interfered with listening and reduced detection range. The disappearance of nearly 80% of our transmitters in Lake Mohave caused us to examine if, and to what extent, aquatic vegetation might interfere with signal strength. We found if transmitters were placed inside sago pondweed beds or behind dense stands of submerged tamarisk, detection range was reduced to <40 m. Unfortunately, as spring run-off increased, rising reservoir elevations flooded broad (>200 m) bands of tamarisk. Tests proved submergent vegetation not only interfered with signal reception, but also proved impenetrable to watercraft. We were unable to effectively survey hundreds of hectares of flooded habitat near Owls Point and Wagon Wheel Cove (Lake Mohave) or at Piute Farms (Lake Powell).

Equipment failure is always a consideration when contact is lost with a fish. Initial failure rate was 2.5% (2 of 80). It is impossible to determine transmitter failure after fish were released, however, based on the longevity of the stationary transmitters, we believe failure was low. While we acknowledge that we could not be 100% effective on each survey, we feel that any fish that remained active, in either of the survey areas would have been eventually detected. The only other explanations for losses are: 1) equipment failure, 2) the removal of fish and transmitter from the system by terrestrial or avian predator, or 3) fish found, penetrated, and remained in the large, impenetrable flooded habitats where they were undetectable by telemetry equipment.

Tank Tests

We conducted tank tests on 2 groups of juvenile suckers to determine the shedding rate of externally attached transmitters and the healing process. Transmitters were attached with a single suture to the dorsal keel of a group of five fish ($\bar{x}$23 cm/21-27 cm). Fish were held in a holding tank (2 m diameter X 1 m deep) for 8 weeks. Fish were fed daily and examined weekly. The sutures gradually worked through the dorsal tissue. The wounds appeared clean, no bacterial or fungal infections were noticed. Average transmitter retention was 3.8 weeks (2->.8 weeks) and all fish recovered. Suture wounds healed within 2-4 weeks.

Similar tests were conducted with ten larger fish ($\bar{x}$=29 cm/27-32 cm) using two sutures. A control fish (no transmitter) was also placed in the tank. Five fish, including the control, died of unknown causes. Sutures of the study fish did not appear inflamed or infected. The first transmitter was lost on week 5 and the remaining 5 fish retained their tags through week 9.

DISCUSSION

Stocking Dispersal

Individual movements and ranges are quite variable. It appears roughly 50% of stocked suckers emigrate out of the 46 km study area during the first month. These movements are similar to those reported for juvenile flannelmouth suckers by Chart and Bergensen (1992). They reported that juvenile flannelmouths moved more, and had ranges larger than sexually active adults. Results were similar to comparisons made between the home ranges of adults and the movements of a single juvenile razorback sucker in Lake Mohave (Mueller et al. 1998).

Other than knowing that dispersal is wide spread, the actual range continues to be unknown.

Unfortunately, in Lake Powell, ambient noise generated by a water fall and then by high spring flows prevented us from effectively monitoring upstream sections of the study area. However, reservoir survey conditions were generally ideal. Efforts to locate fish downstream of the release site extended over 72 km. Only two fish moved 2.7 km downstream, the furthest 2.7 km. Twenty-one of 23 fish (92%) moved uplake whereas 84% moved down lake in Lake Mohave. It is unknown whether this might be a behavioral response triggered by handling, current, turbidity, or simply a factor of shoreline morphology.

Stocking Acclimation Methods of handling and stocking endangered or threatened fishes are generally the same as for trout, bass, catfish, or other game fish (USFWS 1992, 1994). They are transported by truck to the release site where they are acclimated to physical conditions, normally temperature and rarely pH (Stickney 1983, Wedemeyer et al. 1990). At that point they are simply released. The Upper Colorado River Basin Recovery Implementation Program (RIP) has establish stocking criteria and guidelines (USFWS 1992, USFWS 1994), however, behavioral acclimation is not included. Protocols have been established which mandate that stocked fish be "released in quiet-water areas (e.g., backwaters) that communicate with the river." Unfortunately, augmentation programs have met with mixed, if not poor results.

For instance, a ten-year reintroduction program in Arizona stocked nearly 12 million razorback suckers with no measurable results. The majority were stocked as fingerlings or fry and subsequent studies showed young fish moved en masse downstream and were rapidly eaten by channel and flathead catfish (Brooks 1985, Marsh and Brooks 1989, Minckley et al. 1991).

Since then, some success has been reported by stocking larger fish to reduce predation (Mueller 1995, Marsh 1997, Ryden 1997a). While survival can be improved with larger fish, managers often have been unable to stock and retain fish in desired locations. Often stocked fish travel great distances downstream. Several scientists speculated that fish reared in hatchery or rearing ponds might not have developed adequate muscle tone to cope with flowing habitats (Todd Crowl personal communique). Laboratory investigations that were conducted proved inconclusive.

Research on Lake Mohave (Mueller et al. 1998) suggests stocked juveniles travel substantial distances, even in lentic environments where hydraulics were not a factor. We believe this supports the contention that other factors, such as normal early life migratory behavior, handling and transport associated stress, or even habitat conditioning could also be factors.

Recent studies examining the movements and habitat use of bonytail in Lake Mohave found quite a difference in response between pond-reared and resident fish (Marsh et al. 1996, Foster et al. 1997). Researchers found that pond-reared bonytails roamed more widely and were more difficult to detect than resident fish that had distinct territorial ranges. When non-resident bonytail were found, they were detected in shallow, vegetated habitats, similar to habitats where they were taken from. Fish captured from the reservoir were more pelagic in nature and were quite territorial suggesting habitat conditioning might have occurred.

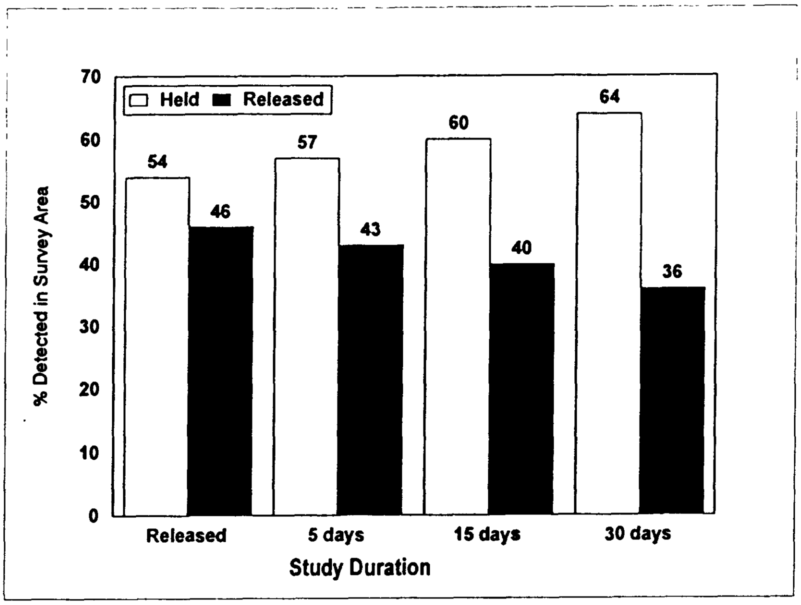

Figure 6. A comparison of the detection of cove held (3 days) versus juvenile razorback suckers released into the San Juan Arm of Lake Powell, Utah, May 3, 1997.

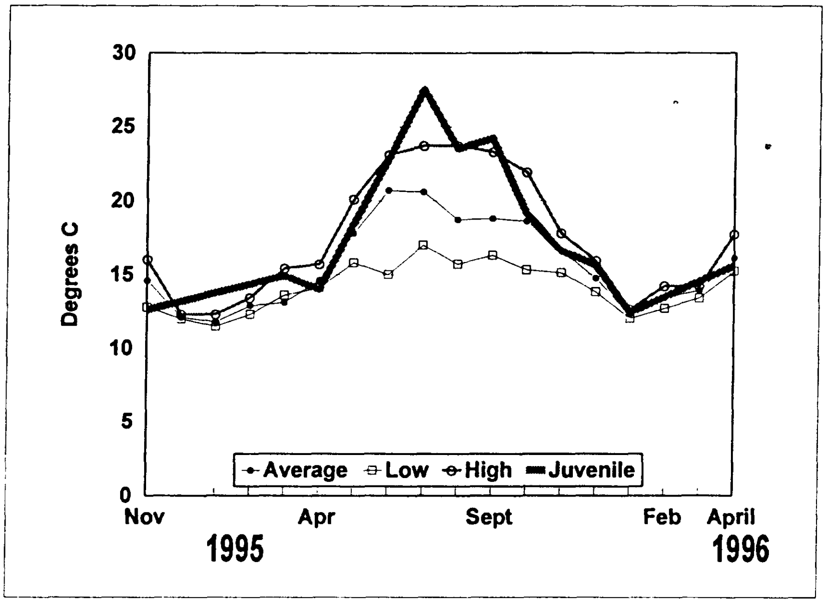

Figure 7. Comparison of the temperature regime used by one juvenile and 10 adult razorback suckers in Lake Mohave, Arizona-Nevada, during 1995-1996 (Mueller et al. 1998).

Behavioral acclimation may also be a factor. Of the 14 Lake Powell fish that remained in the study area for more than one month, we encountered twice as many cove held fish (64%) as those simply released and not held for 3 days (Figure 6). The sample size was small and might simply reflect normal variability, however, it appears that holding does not deter fish from remaining in the general area and might encourage it. The data collected from Lake Mohave were inadequate to draw any conclusions.

Habitat Use

Juvenile or subadult razorback suckers were found using the same broad, shallow, shoreline habitats as adults. They were seldom found in narrow, deep, canyon habitat. While adults are generally found in open areas along the shoreline (Mueller et al. 1998), juveniles are more secretive, being found in the back of coves or flooded washes hidden in vegetative or rocky cover. Fish were typically found within 10 m of shore and depths were less than 2 m.

Our findings support earlier observations in rearing ponds that young suckers were nocturnal and effectively concealed themselves in submergent vegetation during the daytime (Mueller and Marsh 1993). These shallower habitats naturally provide warmer temperatures and more food production; important factors in rapid growth. Surface water temperatures ranged 1-3 degrees C higher in these backwaters than the main lake. This mimics earlier information we collected in Lake Mohave (Mueller et al.1998). Body temperature data collected for 10 adults and one juvenile suggests the two-year old fish normally inhabited a thermal regime equal to, or greater, than the maximum temperature range used by adults (Figure 7).

Juveniles had a strong preference for flooded backwater complexes at Castle Creek Canyon and Mike's Canyon. These two sites afforded fish the largest, shallow, flooded habitats in the San Juan Arm, next to Piute Farms when lake elevations exceed 1,120 m (3,680 ft). These areas are similar to areas where juvenile razorbacks have been found in the Green River at Old Charley Wash (Modde 1996 and 1997). Dispersal appears to be strongly influenced by habitat/cover availability. The rapid dispersal observed in riverine systems suggests that habitat conditions did not attract and hold young fish. The physical changes brought about by channelization, loss of backwaters and oxbows, fluctuating hydroelectric releases, and the decline of large snags and other woody debris, have undoubtedly effected cover availability.

External Attachment Technique

Attachment of transmitters to the dorsal keel worked well as a short-term approach and is possibly the only practical method of studying the movements of juvenile suckers. We observed no initial mortality and all 55 fish left the release sites. We feel attaching transmitters to the dorsal keel is less intrusive than the common dart tag which is generally inserted into the dorsal musculature and is less stressful than surgery for short-term, behavioral studies.

Following the poor results of the Lake Mohave fish, we attached transmitters to five similar sized razorback suckers and held them at the Bureau of Reclamation fish holding facilities at Boulder City, NV. The fish ranged in size from 230 to 270 mm. The fish were inspected once a week to determine transmitter shedding and subsequent post-healing. When the transmitter was eventually lost, it left a small wound which healed in 2-3 weeks. The average transmitter retention was 3.8 weeks (2 to >8 weeks) and all experimental fish recovered.

Transmitter retention time for the smaller (TL $\bar{x}$ = 241 mm) Lake Mohave fish was shorter (<2 weeks) than of our tank fish or the larger Lake Powell fish (> 4 weeks). We believe there might be at least two reasons for this. First, we know that reservoir fish concealed themselves in aquatic macrophytes. We observed one study fish in Lake Mohave trailing a long strand of pondweed from its transmitter. Snagging undoubtedly could speed the shedding process. Vegetation was not a factor in the holding tank experiments nor are aquatic macrophytes common in Lake Powell. The second factor could be the ossification of the fishes dorsal keel. Younger fish have softer tissues which are less capable of supporting a transmitter. The use of a single, rather than multiple sutures undoubtedly is less intrusive, but may also be less permanent than double sutures.

Unfortunately, mortality is common with surgical procedures. Survival of adults reported by other researchers has also been highly variable (0-100%) with most studies achieving a 50-70% survival rate (Marsh and Minckley 1989, Creef and Clarkson 1993, Ryden and Pfeiffer 1995, Karp and Mueller 1996, Burdick and Bonar 1997, Holden et al. 1997, Ryden 1997b). While external attachment may be inappropriate for long-term studies, it does provide an alternative for short-term studies. The dorsal keel found on the razorback sucker and some other native Colorado River fish provides a unique attachment spot. This approach is non-lethal, less intrusive than abdominal surgery and allows a mechanism for transmitter shedding for all ages of fish.

Management and Research Implications

Augmentation and Recovery Efforts

Reservoir habitat will continue to play a role in augmentation and recovery of native Colorado River fishes. There is growing evidence that razorback suckers migrate between flowing and non-flowing habitats (Karp and Mueller 1996, Ryden 1997a, Mueller and Wydoski 1995, and unpublished data). High use of shallow, flooded backwaters by juvenile razorback suckers in both Mohave and Powell lends credence to the importance of these habitats during their early life stage. This dependency is somewhat disturbing since these habitats are also havens for known predators. In stable habitats, such as Lake Mohave, territorial predators like largemouth bass and channel catfish are not subjected to high fluctuation in reservoir elevation, which influences habitat availability. However, in larger reservoirs as lakes Powell and Mead, annual water elevation can fluctuate as much as 20 m which can cause inflow habitats to migrate as much as

15 km in only a few weeks. Changes this rapid undoubtedly influence the distribution and reproductive cycles of non-native predators, and might be manipulated to regulate predator densities.

If successful, present programs to augment spawning cohorts in either the San Juan, Green, or Colorado rivers will result in larval sucker transport into Lake Powell. With the general absence of nursery habitat in the lower 100 km reach of these rivers, natural recruitment associated with these portions of the river might be largely dependent upon nursery habitat found either further upstream, or downstream, in Lake Powell. Manipulation of reservoir elevations may provide the greatest chance for these, and other, young natives to survive. The concept certainly deserves more evaluation.

RECOMMENDATIONS

The behavioral acclimation test suggests that holding fish on site for 3 days may influence their dispersal rate. We recommend further testing be conducted to confirm this in both reservoir and riverine habitats.

We recommend that external attachment techniques be considered by other researchers when studying the short-term movements and behavior of the razorback sucker and other similarly keeled, Colorado River fishes. This approach is less intrusive than surgery, non-lethal, and possibly best suited for juveniles or wild fish.

Juveniles have a strong fidelity toward shoreline habitats which are also used by known predators such as largemouth bass and channel catfish (Harlan and Speaker 1951, Tyus 1997). This habitat attraction may help explain the virtual absence of young razorback suckers. We recommend that further research be directed at developing and evaluating methods of reducing or eliminating predation. Current efforts to augment existing population by stocking larger razorback suckers does not address the problems of early life stage survival. We also need to better understand non-native predator effectiveness, and explore methods that might reduce or minimize predator densities found in habitats used by early life stages of razorback sucker.

Until more information is available, we suggest that larger (>30-cm) fish be stocked and that stocking be delayed until winter when predators are dormant (Marsh and Brooks 1989). Predation concerns stemming from assessed survival rates has resulted in a recommended stocking size of 40-cm for augmenting San Juan River stocks (Ryden 1997a). We support this approach.

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APPENDIX A Specific Fish Data

Razorback Suckers released at Castle Creek Canyon, Lake Powell, Utah on May 3, 1997.

Transmitter Code	Length (TL mm)	Weight (Gr)	Held or Released
3-3-7	370	610	Held
3-3-5	351	680	Held
3-3-6	360	760	Held
3-3-8	384	925	Held
3-3-9	362	745	Held
2-2-5	335	*	Released
2-2-6	365	*	Released
2-2-7	368	*	Released
2-2-8	348	*	Released
2-2-9	340	*	Released
2-3-9	350	*	Held
2-3-8	375	*	Held
2-3-6	370	*	Held
4-3-5	342	*	Held
4-3-6	355	*	Held
4-3-7	352	*	Released
4-3-8	390	*	Released
4-3-9	342	*	Released
3-4-5	330	*	Released
3-4-6	344	*	Released
4-4-6	365	*	Held
4-4-7	350	*	Held
4-4-5	358	*	Held
4-4-8	358	*	Held
4-4-9	352	*	Held
3-4-7	351	665	Released
3-4-8	358	695	Released
3-4-9	362	660	Released
2-3-7/2-3-5	Malfunctioned		

* Electric scale malfunctioned
$\bar{x}$ = 357 mm, range 330-390 mm.

Razorback Suckers released In Lake Mohave, Arizona-Nevada on May 20, 1997.

Trans. Code	Length (TL mm)	Weight (g)	PIT Tag #	Site Location * (Held/Release)
2-3-7	236	152	41272B2729	1 (H)
2-3-5	238	156	41276E217E	1 (H)
2-3-8	285	264	41270E2C77	1 (H)
2-3-6	228	134	41272C4E49	1 (H)
2-3-9	222	126	41270A2D58	1 (H)
4-4-5	282	230	4127143D76	1 (R)
4-4-9	220	112	41270D4216	1 (R)
4-4-6	290	294	4127184933	1 (R)
4-4-7	276	254	412766023D	1 (R)
4-4-8	234	140	41272B6B0C	1 (R)
4-3-7	276	240	4127025E1C	2 (H)
4-3-8	218	116	41272F5436	2 (H)
4-3-5	256	172	4128066579	2 (H)
4-3-9	245	168	4127690336	2 (H)
4-3-6	262	198	41272A3660	2 (H)
2-2-6	254	190	41280B7D0E	2 (R)
2-2-5	245	160	4127107248	2 (R)
2-2-9	225	126	41277B7F65	2 (R)
2-2-7	235	138	4127741771	2 (R)
2-2-8	233	122	4127306C49	2 (R)
3-3-5	222	110	4127681665	3 (R)
3-3-9	224	122	41270F1B13	3 (R)
3-3-7	235	128	4127150905	3 (R)
3-3-8	210	94	41271F1D51	3 (R)
3-3-6	216	114	41277A6E2C	3 (R)
3-4-8	220	114	41271E5D3C	3 (R)
3-4-5	221	112	41277A287B	3 (R)

* 1 = Owl Cove (RK 45), 2 = Tequila Cove (RK 34), 3 = Mesa Cove (RK 24)

$\bar{x}$ = 241 mm, range 210-290 mm.