

A Case for Site Acclimation in the Reintroduction of the Endangered Razorback Sucker (*Xyrauchen texanus*).

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Open-File Report 99-110

Prepared in Cooperation with Northern Arizona University

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EXECUTIVE SUMMARY

Hatchery-reared razorback suckers were held 2 to 3 days prior to release to determine if site acclimation influenced short-term dispersal. Trials were conducted in Lake Powell and the Green River, a major tributary of the Colorado River in Utah. Thirty suckers were used in each trial. Fish were transported and acclimated (1 hr) to local water temperature following standard stocking protocol. Transmitters were externally attached, and fish were alternately subdivided into control and test groups. Suckers were released in calm water. Nonacclimated fish had immediate access to the reservoir or river while test fish were held 2 to 3 days in a backwater prior to actual release.

Initially dispersal was pronounced, however, the rate of dispersal significantly declined ($P=0.001$) with time for all fish. Average distance fish traveled was similar between trials (acclimated versus nonacclimated) but much greater (68.3 versus 11.6 km) for riverine versus reservoir fish. Also, there were marked differences in the dispersal distance (km) and dispersal rate (m/day) of acclimated and nonacclimated suckers.

Nonacclimated fish in both reservoir and riverine trials, continued to disperse during the course of the 60-day study. However, after the second week with the acclimated suckers, we either observed a change in dispersal rate or range. The average distance acclimated suckers moved away from the Lake Powell release site declined ($\bar{x}=3.1$ to 1.1 km) as several fish returned. Similarly, nonacclimated riverine suckers continued to disperse whereas the dispersal rate of acclimated fish significantly ($P=0.042$) declined (0.3 versus 3.5 km/d) after the second week. Acclimated fish either slowed, stopped, or reversed course while nonacclimated suckers continued to drift downstream.

Four weeks after release, the average dispersal distance for site-acclimated suckers was substantially lower than nonacclimated fish for both the reservoir (1.1 versus 3.7 km) and riverine (55 versus 81 km) trials. Eleven suckers were detected in the downstream reaches of Cataract Canyon and Lake Powell, of which only 2 (18%) were suckers that were site-acclimated. Data suggest site acclimation reduced the range and rate of short-term (2-month) dispersal.

Differences in dispersal was observed and when put in context with physiological concerns may indicate more serious stress and survival related issues. Two decades of poor stocking survival combined with the successful use of acclimation and conditioning by terrestrial programs suggests the need to reevaluate stocking procedures for the razorback suckers. Hatchery production and established stocking procedures that have served the recreational angler well, has failed the razorback sucker. Current methods of repatriating razorback sucker leads to unnecessary stress, diminished performance, causes wide dispersal or downstream drift, and exposes suckers to unnecessary predator exposure. Until we shift emphases from production quotas, to actual survival, razorback suckers will continue to disappear, resources squandered, and repatriation programs compromised.

INTRODUCTION

Two site-acclimation studies (Mueller and Marsh 1998, Foster and Mueller 1999) were conducted in 1997 and 1998. The primary emphasis was habitat use and dispersal but we also examined if the rapid dispersal, typically associated with hatchery-produced razorback suckers (suckers), could be mitigated by allowing fish a period of time to recover from stocking-induced stress. Findings of those studies and existing physiological literature suggest that current stocking protocols may subject stocked fish to unnecessary behavioral or physiological stress that could impact performance and ultimately survival. This report presents those findings and recommends an evaluation of existing stocking procedures for the sucker.

Background Once common, the razorback sucker (*Xyrauchen texanus*) has declined in both range and numbers and is presently represented by small, relic populations of old adults found in the Colorado River basin (Minckley et al. 1991, USFWS 1998). Even prior to being federally listed as endangered (USFWS 1990), suckers were massively stocked during the 1980's in efforts to reestablish populations (Minckley et al. 1991). Over 15 million razorback suckers were stocked in the lower Colorado River basin alone, with little reported success. Efforts to repopulate specific river reaches have been plagued by poor survival attributed to predation and downstream drift (Marsh and Langhorst 1988, Marsh and Brooks 1989, Burdick et al. 1995). Survival has been improved by stocking larger (>30 cm) individuals (Mueller 1995, Ryden 1997), however, downstream dispersal continues to be problematic (Marsh and Minckley 1995, Burdick and Bonar 1997, Day and Modde 1999). Several researchers have recommended site acclimation (Marsh and Brooks 1989, Minckley et al. 1991, Burdick et al. 1995, Ryden and Pfeifer 1996) and even physical conditioning (Wydoski 1994, Burdick and Bonar 1997), but these approaches have yet to be tested. Instead, fish are being stocked further upstream in anticipation of downstream drift or programs are being terminated (Hendrickson 1993, Burdick et al 1995, Ryden and Pfeifer 1996).

Stocking protocols, for both recreational and endangered fishes, have remained virtually unchanged for decades (Norris et al. 1960, Stickney 1983). Measures are taken to minimize fish stress, prevent physical injury, and avert diseases associated with handling and transport. However, once physically acclimated to local water conditions (often only temperature), fish are released (USFWS 1992 and 1994) and rarely allowed sufficient time to fully recover. For example, the time needed to repay oxygen debt caused from exercise or anoxia is 10 hrs for trout (Brett 1964) and 12 hours for goldfish (Van den Thillart and Verbeek 1991). Stocking losses and drift typically are accepted as unavoidable and are attributed to physical and behavioral stress, disorientation, starvation, and poor predator evasion skills of hatchery-produced fish (Legault and Lalancette 1987, Wedemeyer et al. 1990, Hansen and Margenau 1992). Ample research has shown that handling and transport stress can alter plasmic catecholamines and corticosteroids and affect fish behavior and performance for days and even weeks (Carmichael et al. 1984a and 1984b, Olla et al. 1995, Waring et al. 1996).

It is well documented that stress not only influences behavior and performance, but accumulative or chronic stress can actually lead to fatigue, total exhaustion and even death. Terrestrial biologists are at least a decade ahead at examining, not only site acclimation, but techniques to improve the conditioning of their animals (i.e., hunting, predator avoidance, converting to natural foods). Such approaches have been successful in reintroducing gray wolves, condors, blackfooted ferrets, and masked bobwhite quail to name a few (Ellis et al. 1978, Fritts et al. 1997, Biggins et al. 1998, Bangs et al. 1998). We feel similar approaches could improve repatriation efforts for the razorback sucker. Nevertheless, a period of convalescence, which has become common in terrestrial reintroductions has not been previously attempted with razorback suckers and seldom tried with any warm-water species. This paper describes the effect of site acclimation on the short-term dispersal of razorback sucker in reservoir and riverine environments and makes recommendations on how to mitigate those impacts.

METHODS

Two telemetry trials were conducted: one in the Colorado and Green rivers within Canyonlands National Park, Utah, and the other in the San Juan Arm of Lake Powell, Utah (Figure 1). Sixty subadult razorback suckers were provided by the U.S. Fish and Wildlife Service's Ouray National Fish Hatchery, Vernal, Utah; 30 fish were used for each trial. Lake Powell fish were transported to Castle Creek on 3 June 1997, and Green River fish were hauled to Millard Bottom (RK-54) within Canyonlands National Park, Utah, on 16 June 1998 (Figure 1). Handling, transport, and transmitter attachment were similar for both riverine and reservoir experiments. Upon arrival, fish were acclimated to local water conditions by gradual (1 h) water exchange, transmitters were tested, fish weighed and measured, and transmitters were externally attached.

Razorback suckers have a unique cartilaginous dorsal keel which is ideally suited for external attachment of small transmitters. Transmitters were externally attached to reduce stress and eliminate convalesce from abdominal surgery (Mellas and Haynes 1985, Begout Anras et al. 1998). Sonic (70 khz) transmitters were used in Lake Powell and radio transmitters (40 MHz) were used in the Green River. Sonic transmitter are not suited for high ambient noise typical of river environments and radio transmitters become ineffective at depths >3 to 4m. Transmitters were similar in shape, size, and weight, being 8 mm in diameter, 3 to 5 cm (sonic-radio) in length, weighed 4 to 7 g, and having a nominal transmission life of 60 to 90 days. Transmitters were attached to the side of the dorsal hump using two shallow (6 to 10 mm) sutures. Following transmitter attachment, suckers were alternately placed into two groups: one group had immediate access to the river or reservoir while the second group was placed behind a barrier net and denied access. Canyonland suckers were held in the flooded portion (10 m by 500 m) of Millard Canyon (RM-33.5) and the Lake Powell fish in a cove (10 m by 20 m) near Castle Creek. Reservoir fish were held 72 hrs, and riverine fish for 48 to 72 hours prior to net removal.

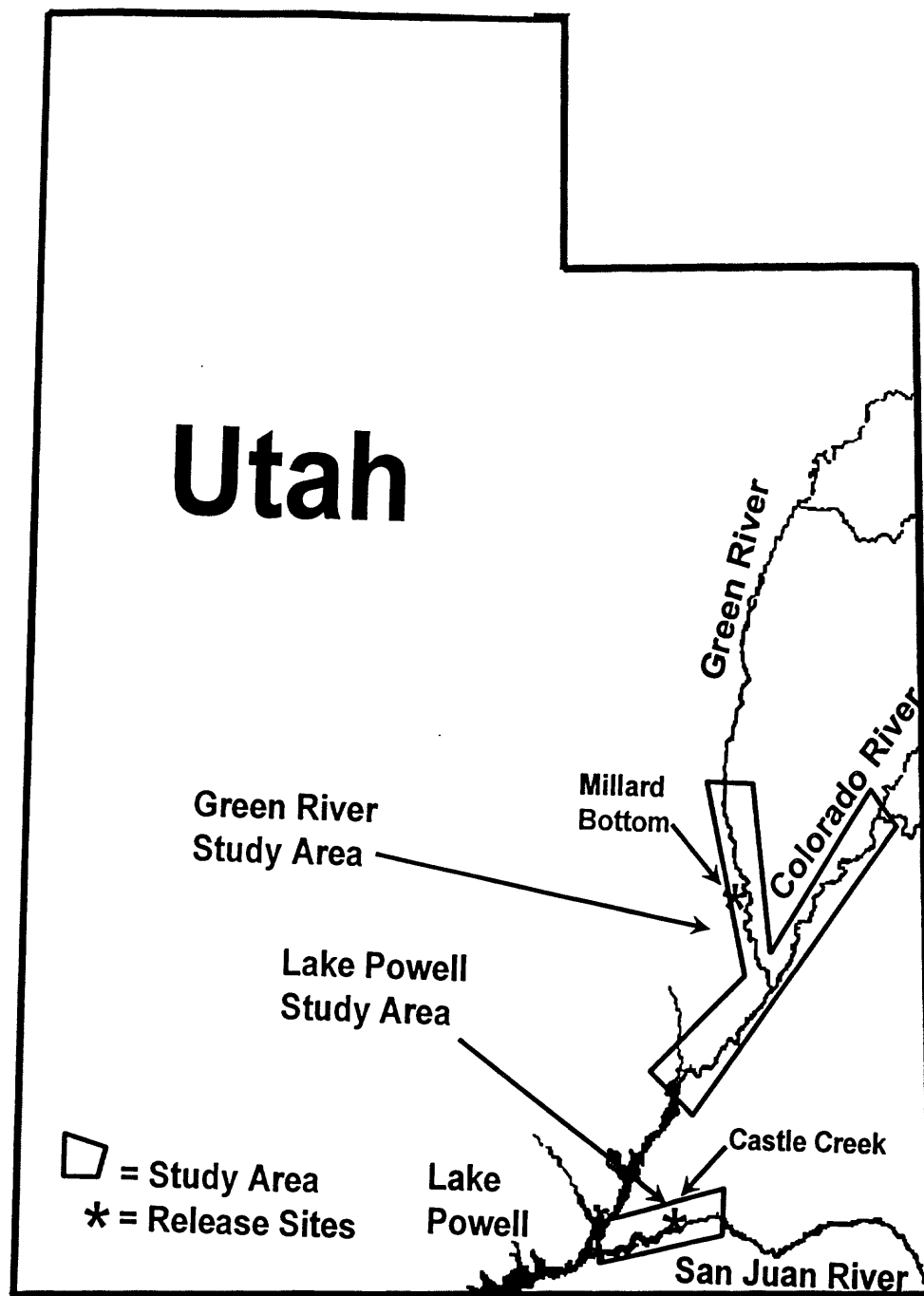


Figure 1. General map showing the study areas on the Green and Colorado Rivers, and the San Juan River and Lake Powell, Utah.

Lake Powell fish averaged 358 mm in length (335 to 402 mm) and 718 g (610 to 925 g). Fish released in the Green River were longer, but less robust, averaging 438 mm (394 to 483 mm) and 735 g (520 to 1018 g).

Monitoring was conducted weekly by boat for 2 months. Surveys began at each release site and expanded as fish dispersed. Fish locations were recorded on detailed maps along with supplemental information on relative distance from shore and habitat use. Reservoir surveys initially focused on a 20-km radius from the release site but expanded to 110 km of the lower 15 km of the San Juan River and the San Juan Arm of Lake Powell downstream to the Colorado River confluence (95 km). Riverine surveys initially focused on the lower Green River but expanded to nearly 455 km of the Green and Colorado rivers (Figure 1). Logistics and poor access made weekly surveys of the entire study area impossible.

Past Studies We examined the dispersal patterns of razorback sucker in previous riverine studies (Ryden and Pfeifer 1996, Day and Modde 1999, Foster and Mueller 1999, McAda and Wydoski 1980, Tyus 1987, Valdez and Masslich 1989, Modde and Wick 1997). We were particularly interested in comparing movement patterns of wild-captured and hatchery-reared suckers. Two factors that could not be independently assessed, was fish age and that wild-captured fish were not transported. Wild-captured razorback suckers are believed to be substantially older (10 to 50 yr) than hatchery-reared suckers (2 to 6 yr) used in these studies. Unfortunately, young, wild adults are rarely encountered (Minckley et al. 1991, USFWS 1998) and a comparison of similarly aged fish is impossible.

RESULTS

Lake Powell

All study fish vacated the release sites within 5 days. Twenty-three suckers were detected during the course of the study-14 acclimated and 9 nonacclimated fish. Numbers of fish being actively tracked gradually declined to 14 (9 acclimated and 5 nonacclimated) by day 29. The number of signal detections, average days tracked, and average distance traveled were similar for both acclimated and nonacclimated fish (Table 1).

Initial dispersal was pronounced and apparently indiscriminate. Suckers moved actively both day and night and used both shallow and deep open areas of the reservoir. Easy access allowed us to monitor reservoir fish movements more often and also after dark. After 3 to 5 days razorback suckers became more closely associated with shoreline habitats (Figure 2). Fish primarily moved at night and took up refuge during daylight in shallow cove habitats. Fish were quite individual, some wandered while others resided at specific locations within coves. Several fish moved between Castle Creek and Mike's Canyon, a distance of 5 km. These areas represent the two largest backwater complexes in the immediate area. All but two fish moved up reservoir toward the San Juan River inflow.

Lake Powell

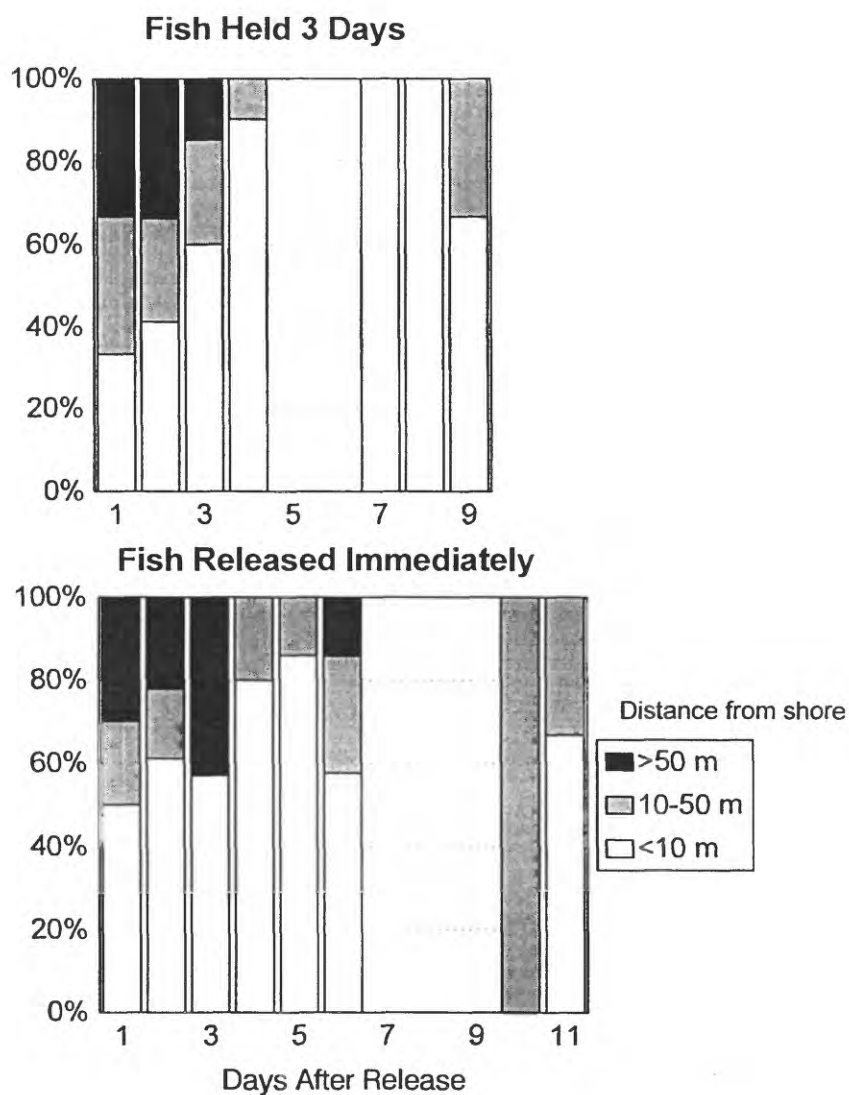


Figure 2. Comparison of the distance (<10, 10 to 50, >50 m) from shore that acclimated and nonacclimated razorback suckers were detected during the first 11 days following release in Lake Powell, Utah.

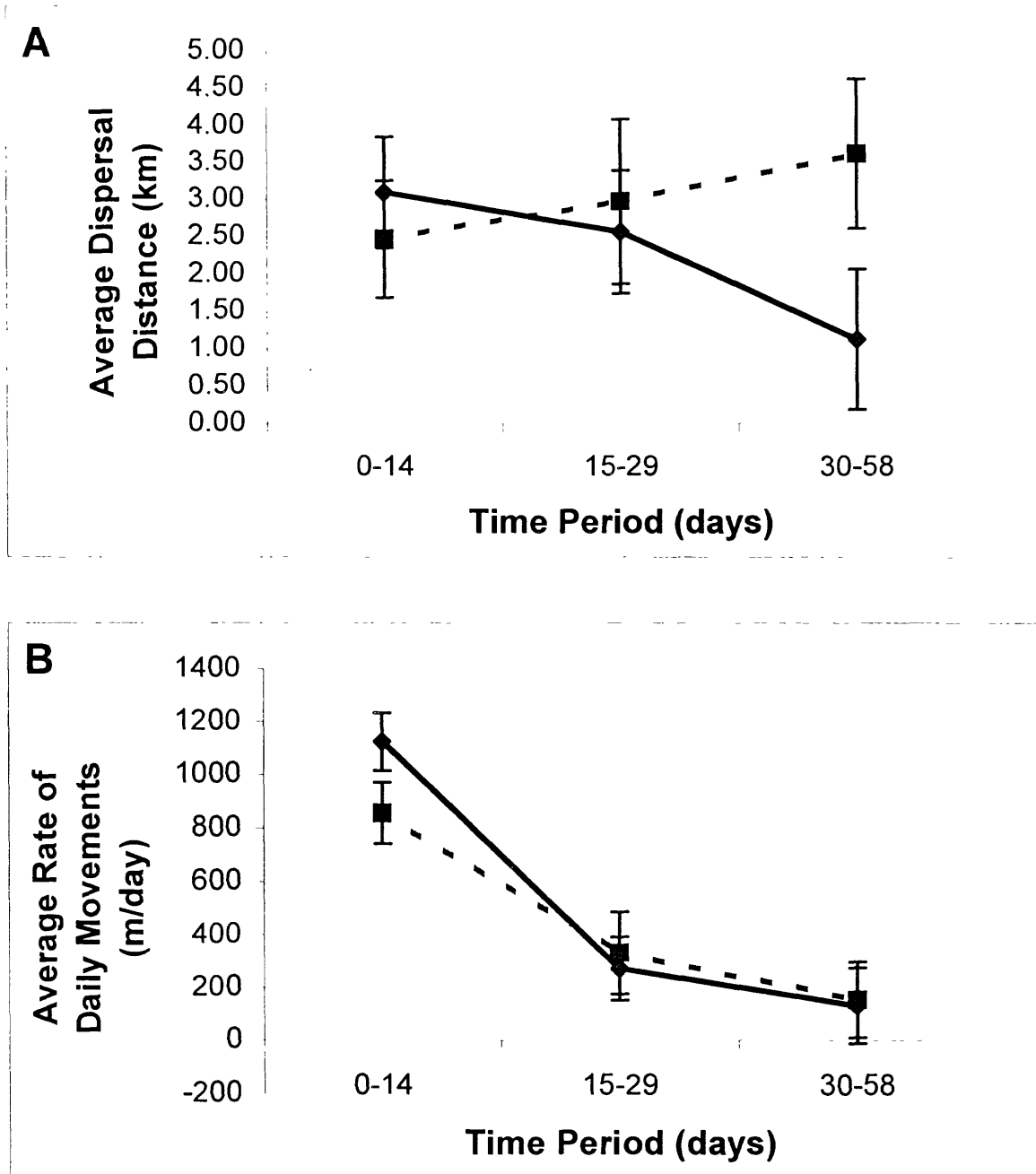
Table 1. Comparison of the number of transmitters detected, number of total signals detected, average distance traveled (m/d), maximum dispersal rate (km/month), and average dispersal distance by the 14, 30, and 58th day following release for razorback suckers either immediately released (nonacclimated) or acclimated for 3 days prior to release in Lake Powell and Canyonlands.

	Nonacclimated	Acclimated
Lake Powell		
# Fish detected	9	14
# Observations	71	74
Average days tracked	37	31
Average distance traveled (km)	12.1	11.1
Maximum dispersal range (km)	12.4	7.9
Average dispersal distance (km)		
(Day 14)	2.4	3.1
(Day 30)	3.1	2.6
(Day 58)	3.7	1.1
Canyonlands		
# Fish detected	14	9
# Observations	40	30
Average days tracked	32	40
Average distance traveled (km)	70.7	65.9
Average dispersal distance (km)		
(Day 14)	43	59
(Day 30)	71	72
(Day 58)	81	55

The average maximum distance traveled during the first week by Lake Powell fish was >2.1 km/d (range 400 to 5,000 m/d) compared to a monthly average of 383 m/d (range 3 to 763 m/d). Fish on average traveled 11.5 km (100 to 22,900 m) and dispersed a maximum distance of 8.1 km up and 4.3 km down reservoir during the 2-month study. No suckers were actually detected in the San Juan River, and maximum dispersal (12.4 km) over the 60-day study period was reached by day 24 (12.4 km).

Dispersal distances were lower for acclimated fish compared to nonacclimated suckers (7.9 versus 12.4 km), but were not statistically (*T*-test) different (Johnson 1999). There was a greater dissimilarity for average dispersal ranges after the second week. Dispersal continued to increase (from 2.4 to 3.1 to 3.7 km) for nonacclimated suckers while decreasing (from 3.1 to 2.6 to 1.1 km) for acclimated fish (Table 1, Figure 3A). Four of the nine detected-acclimated fish returned toward the release site. Only minimal (<0.1 km) movement was detected in either group after week 4.

Lake Powell



Figures 3A, B. Graphs A compares the average dispersal distance (km) away from the Lake Powell stocking site for site-acclimated (solid line) and nonacclimated suckers (dashed line). Graph B shows the average rate of movement (km/d) in time increments of 0-14 days, 15-29 days, and 30-58 days for suckers released in Lake Powell. Error bars represent on standard error of the mean.

Canyonlands

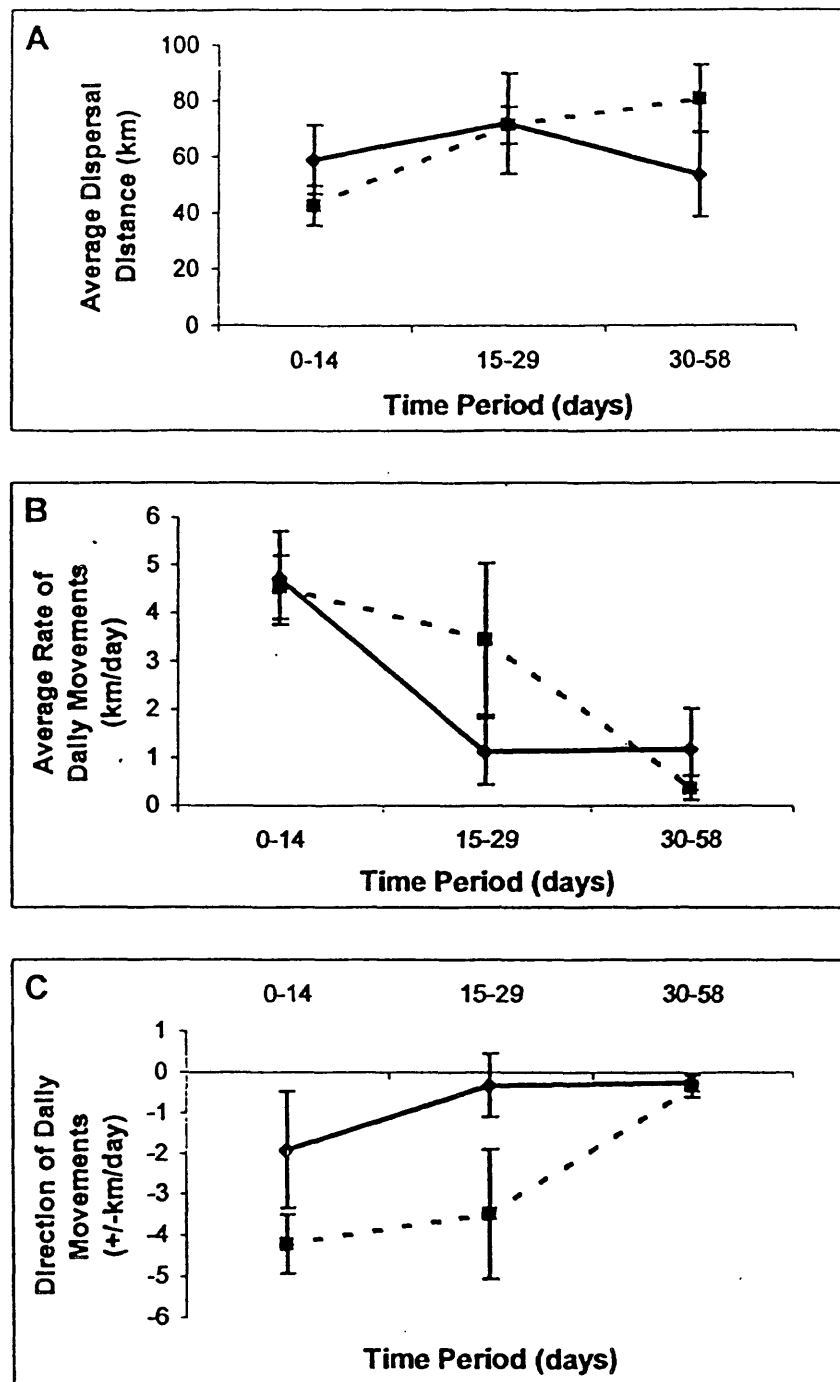
Twenty-three fish of the 30 study fish were detected, however, there were substantially fewer observations (70 versus 145) than the Lake Powell fish due to logistics and remoteness of the Canyonlands study area (Table 1). We collected sufficient contacts on only 17 of the 23 fish to estimate movement rates (km/d). Both acclimated and nonacclimated razorback suckers traveled downstream. Initially, fish movement averaged ~5 km/d but decreased with time to <1 km/d. Upon reaching the confluence of the Green and Colorado rivers (53.8 km) six fish (four acclimated, two nonacclimated) swam up the Colorado River. Five suckers (three acclimated, two nonacclimated) positioned themselves just upstream of Cataract Canyon while eight (all nonacclimated) continued to move downstream and entered Cataract Canyon.

No significant difference could be detected between the acclimated and nonacclimated fish in overall distance ($P=0.737$) or speed ($P=0.120$) traveled. Average dispersal distance from the release site continued to increase for nonacclimated suckers but decreased after the second week for acclimated fish (Figure 4A). Average daily movements (km/day) were initially similar (~5 km/d) for both acclimated and nonacclimated suckers, but after the second week, rates (0.3 versus 3.5 km/d) for acclimated suckers declined (Figure 4B). Acclimated suckers reduced downstream directional movements (+/- km/day) significantly sooner than nonacclimated fish ($P=0.042$, ANOVA)(Figure 4C). Nonacclimated suckers required an additional two to four weeks longer to attenuate downstream movements (Figure 4B, 4C). Of the 11 razorback suckers detected downstream in Cataract Canyon or Lake Powell, only 2 (18%) were fish that were acclimated.

Previous Studies

Movements of razorback suckers reported in previous riverine studies were plotted in Figure 5. Hatchery-reared suckers (Ryden and Pfeifer 1996, Day and Modde 1999, this study) appeared more prone to downstream movement than wild-captured suckers (McAda and Wydoski 1980, Tyus 1987, Valdez and Masslich 1989, Modde and Wick 1997, Burdick and Bonar 1997). A statistical (T-test) comparison indicated a significant ($P=0.001$) difference in dispersal patterns between these two groups. This result must be viewed with caution, since previous studies were dissimilar in terms of observations, locations, and frequency of monitoring. Also, as previously mentioned, it's believed there was a substantial age difference between the two groups which may have influenced dispersal.

Canyonlands



Figures 4A, B, C. Graph A compares the average dispersal distance (km) away from the Green River, stocking site of site-acclimated (solid line) and nonacclimated suckers (dashed line). Graph B shows the average rate of movement (km/d) in time increments of 0 to 14 days, 15 to 29 days, and 30 to 58 days of suckers released in the Green River. Graph C shows a significant ($P=0.042$) difference in the average direction (up/down-stream) razorback suckers traveled. (Error bars = one standard error of the mean).

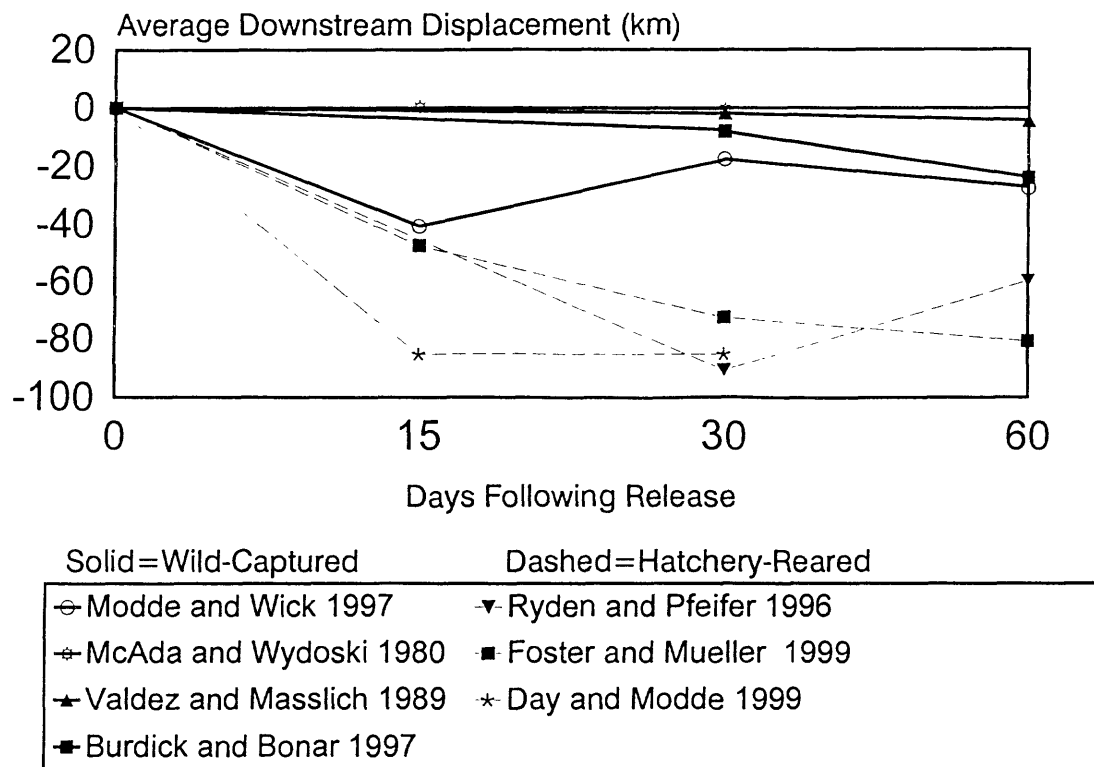


Figure 5. Comparison of downstream dispersal ranges of wild-captured and hatchery-reared razorback suckers used in previous telemetry studies.

DISCUSSION

Telemetric Data

Suckers exhibited a classic "fright and flight" response following stocking in Lake Powell (Funk 1957, Schreck 1981). Suckers released into Lake Powell were found swimming in open water at all hours of the day which mimicked behavior reported for similar releases in Lake Mohave (Mueller et al. 1998). Such behavior is abnormal and undoubtedly increases the chances of predation (Marsh and Brooks 1989, Mueller and Marsh 1998). After 4 to 5 days, suckers started to exhibit the same secretive behavior observed in rearing ponds (Mueller and Marsh 1993). Suckers became more nocturnal, were found along shore, and were utilizing vegetative or rocky cover.

Riverine dispersal was far more pronounced and was primarily downstream. The majority of nonacclimated fish moved downstream until they reached the inflow area of Lake Powell. Downstream movement of acclimated suckers slowed significantly after the second week. We believe the sustained drift of nonacclimated suckers reflected chronic fatigue. Hatchery reared suckers were simply over whelmed. We contend and the literature supports that the combined

stress of stocking *and* adapting to riverine conditions simply fatigues fish, which either could not physically resist, or relied on current as a means of movement or escape. It is well documented that multiple stressors have a cumulative effect on body physiology and performance (Mazeaud et al. 1977, Wedemeyer 1980, Carmichael 1984a, Wedemeyer et al. 1990) which can lead to physical exhaustion and, in some cases, death (Wydoski et al. 1976, Pickering 1981, Schreck 1981).

Stress associated with handling and environmental events can be effectively and economically mitigated by allowing fish to convalesce onsite before being released. Such steps may be sufficient to reduce downstream drift provided there is adequate backwater habitat to hold suckers. However, the issues of physical conditioning and predator recognition and avoidance (Johnson 1997) could be more difficult and costly to address.

Stocking Stress It is widely accepted that efforts to minimize handling and transport stress are worthwhile endeavors. Handling-induced stress can impact fish hormonal cortisol levels (Carmichael 1984a and 1984b, Pankhurst and Dedual 1994, Barton and Zitzow 1995), mobilize fat stores (Waring et al. 1996), decrease lymphocyte levels, impact osmoregulatory functions (Barton and Zitzow 1995, Bonga 1997), and cause resorption of eggs (Clearwater and Pankhurst 1997); all physiological changes that can influence performance and survival. Stocking large numbers can cause overcrowding or intra- and interspecific competition for limited resources that can result in submissive behavior, decrease fitness and access to preferred habitats (Pankhurst and Dedual 1994). This in turn can lead to higher mortality (Pottinger and Pickering 1992). Literature suggests that depending upon the level of stress, it may take a minimum of 2 weeks for fish blood chemistry to normalize (Schreck 1981, Carmichael 1984a, Pottinger and Pickering 1992).

Our findings suggest that site acclimation of 2- to 3-days for low densities of fish reduced average dispersal rates and ranges of razorback sucker in both reservoir and riverine environments. In retrospect, we believe a longer period (1 week) of acclimation should be tested especially for greater numbers of fish. Nevertheless, 2 to 3 day acclimated suckers tended to remain closer to the release site than nonacclimated fish. This trend is strikingly similar to dispersal patterns reported for mammal reintroductions based on similar release methods. Typically, mammals that have not been site acclimated tend to have wider dispersal ranges (Fritts et al. 1997, Bangs et al. 1998). Biggins et al. (1998) reported differences in performance between acclimated versus nonacclimated black-footed ferrets. Acclimated ferrets tended to remain closer to their release sites. Site acclimation also proved an important component in recent wolf reintroductions programs. Fritts et al. (1997) found that site acclimation (>60 days) substantially reduced dispersal and improved pack integrity compared to nonacclimated releases. Acclimated wolves also bred and produced young sooner.

Environmental Conditioning Telemetry data from previous studies suggest there was a significant behavioral difference between wild-captured and hatchery-reared suckers. Wild-captured fish surgically implanted with transmitters displayed virtually no downstream

movement while similarly handled hatchery-reared fish continued to drift downstream after release for nearly a month. We feel wild-captured fish are better conditioned, not only physically, but also behaviorally that allows them to recover more quickly from handling stress. Unlike wild-captive suckers, hatchery-reared suckers must also learn rudimentary survival skills in the process of adapting to a new environment that must tax their energy reserves. Hendrickson (1993) reported stocked suckers "demonstrated a tendency toward weight loss after stocking.."

Downstream drift is common for several hatchery species and has been attributed to poor physical condition and/or chronic stress (Barton et al. 1986, Sanger 1993, Burdick et al. 1995). It is interesting to note, that while raceway culturing is common for salmonids, it is rarely used for stream oriented, warm-water species.

Attempts have been made to precondition fish to flow, however, many tests have been made in terms of minutes or hours rather than days as suggested by the literature (Cresswell and Williams 1983, Beyers and Carlson 1993, Davison 1997). Minckley (et al. 1991) exposed juvenile razorback suckers to stream current for 24 to 36 hr in live-cars and observed no difference in dispersal behavior compared to suckers directly released. Cresswell and Williams (1983) described similar results from a 2-day flow experiment using brown trout. These failures probably reflect exposure periods and/or confinement-related issues (Carmichael 1984a, Barton et al. 1986, Love 1986). Exposure of pond-reared fish to even moderate velocities (0.1 m/s) for <2 days has been reported to lower muscle glycogen reserves and led to fatigue rather than conditioning (Poston et al. 1967, Love 1986). Experiments exposing fish to moderate flows (0.1 m/s) for periods longer than 2 weeks have proved more successful (Cresswell and Williams 1983, Beyers and Carlson 1993, Davison 1997). Physiologically, fish trained in moderate flows experienced benefits similar to exercise for mammals (Davison 1997). These benefits include increased growth rates, improved circulation, increased heart mass, and food conversion efficiencies improve.

Japanese researchers have identified other conditioning or behavioral traits that were directly linked with survival (Tsukamoto et al. 1990, Tsukamoto et al. 1997). Specific behavioral mannerisms are being used to determine the most appropriate age and time cultured fish should be stocked. For example, stocked ayu (*Plecoglossus altivelis*), a native salmonid, historically has been prone to downstream drift and poor survival. Stocking was delayed until ayu exhibited a unique schooling and jumping behavior mannerisms. Resulting survival increased. Tsukamoto et al. (1997) also discovered that red sea bream (*Pagrus major*) exhibited a unique tilting stance when they were properly conditioned that proved to be a defensive posture. When stressed, this posturing was not displayed and fish proved to be more vulnerable to predation. Researchers concluded that these, and other fish behavior traits, could be used as stocking indicators to optimize survival.

Terrestrial Applications Success rates for translocated, wild-captured animals are much higher (75% versus 38%) than programs using captive-bred individuals (Conant 1988, Griffith et al. 1989). Similar comparisons have been reported for wild versus hatchery produced trout

(Miller 1954). The only known reestablishing of a reproducing, Colorado River mainstem species has been the translocation of 611 flannelmouth suckers (*Catostomus latipinnis*) from the Paria River (Gordon Mueller unpublished data). When wild surplus animals were unavailable (the case with razorback sucker), researchers have developed methods of pre-conditioning or training captive-bred animals. These procedures are expensive and typically take weeks and even months, however, survival has been substantially improved for masked bobwhite quail (*Colinus virginianus ridgwayi*) and black-footed ferrets (*Mustela nigripes*) (Ellis et al. 1978, Biggins et al. 1998).

Terrestrial programs are focusing emphasis on the quality of animal rather than propagation numbers. Releases of neutered Siberian polecats (*Mustela eversmannii*) showed captive bred animals experienced substantially higher (81%) mortality than wild-captured animals (20%) even with site acclimation (Biggins et al. 1998). It became evident survival skills were extremely important in the black-footed ferret reintroduction program. Acclimation enclosures were enlarged to provide young ferrets a quasi natural setting to hunt and kill prairie dogs in burrows. The enclosures afforded them greater space, increased physiological conditioning, decreased stressful stimuli, and affected social skills and predatory efficiency, all considered important survival skills. Due to this, survival rates dramatically increased (Biggins et al. 1998). Similar approaches should be tested for razorback sucker.

RECOMMENDATIONS

The philosophy of the past two decades of numerically swamping habitats to reestablish the razorback sucker has failed. The sportfish culturing mentality that survival is linked to production numbers and that repatriation ends with an empty stocking truck must be reevaluated. Physiological literature by itself provides a compelling argument that site acclimation and conditioning should be incorporated into fish repatriation programs. Techniques to improve the quality and performance of these introductions, rather than the quantity of fish being introduced, merits closer examination.

We recommend razorback suckers for both reservoir and riverine repatriation programs be site acclimated to allow normalization of body physiology and behavior. Suckers should be acclimated on site for a minimum of 1 week prior to release and longer if sufficient space is available. Adults should be detained in calm water habitats which include: natural occurring backwaters, seasonally isolated flood plain ponds, and the inflow areas of mainstem reservoirs. Suckers should be held behind net barriers or on-site facilities that could be opened discreetly, allowing fish to leave on their own accord. Net cages should be avoided to reduce enclosure related stress (Carmichael 1984a).

Predation has been identified as a major problem of young suckers (Marsh and Brooks 1989, Hendrickson 1993, Mueller and Burke *In Press*, Marsh *In Press*). To reduce this threat the Upper Basin Recovery Program is currently treating a portion of an estimated 350 flood plain

ponds to remove unwanted fishes. Many of these, including many in the lower basin could be used to acclimate, partially condition (natural foods), and provide additional rearing time for juvenile suckers. Seasonal flooding or operational manipulation would reconnect these to the river, allowing sucker to seed the mainstem in a more natural manner. A good example is Old Charlie Wash, a large manipulated wetland described by Modde (1996). Ponds that are chemically renovated and reconnected less frequently (2 to 5 yrs) may allow natural recruitment of not only razorback sucker but also bonytail (Mueller 1995, Modde 1996, Marsh 1999).

There is substantial evidence that hatchery-reared suckers are less able to cope with river hydraulics than wild fish. Fish scheduled to be released in stream environments with limited backwater habitat should be conditioned to low and moderate velocities (<0.1 m/s) for a minimum of 2 weeks (Davison 1997). This could be accomplished by the construction of onsite screened flow channels or the use of existing hatchery raceways, large circular tanks or even irrigation canals.

Translocation of wild razorback suckers may not be possible, however, there may be other sources of physically conditioned fish. Reservoir repatriation programs have introduced literally tens of thousands of fish into Lake Mohave, Lake Havasu, and Lake Powell (Mueller 1995). Recent sampling suggests has shown that many razorbacks have, or eventually will, move upstream (in some instances >100 km) into contributing rivers. Recapture and translocation of these fish may improve introductions in further upstream habitats deemed more critical to recovery.

We recognize these recommendations may be viewed as "burdensome" to traditional culturing programs. However, if survival is the ultimate goal, then the release of 1,000 well-conditioned and acclimated suckers may actually result in more survival than stocking 100,000 highly stressed and naive suckers, a practice that has been repeated for over 2 decades.

LITERATURE CITED

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