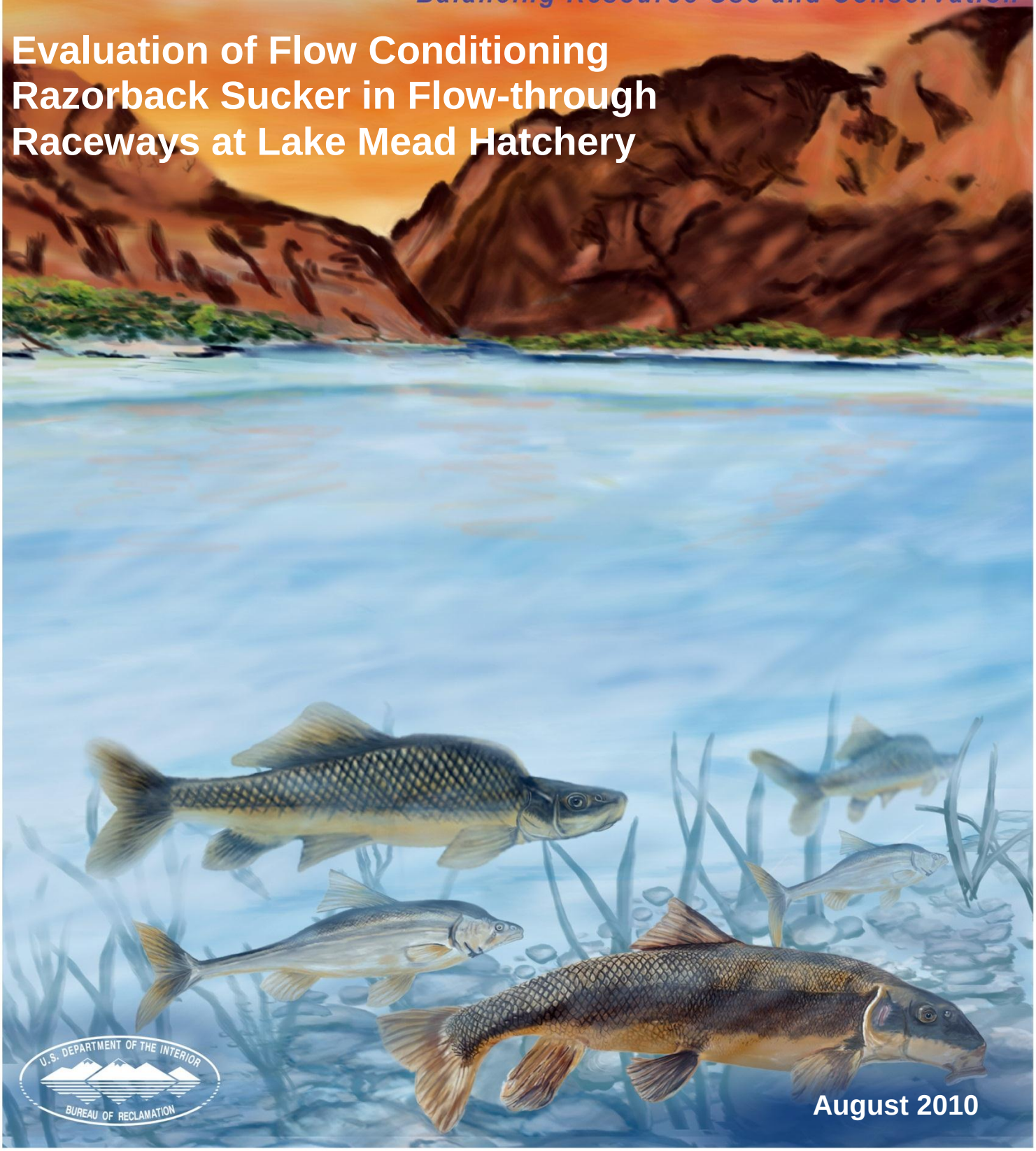
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Evaluation of Flow Conditioning Razorback Sucker in Flow-through Raceways at Lake Mead Hatchery



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

August 2010

Lower Colorado River Multi-Species Conservation Program Steering Committee Members

Federal Participant Group

Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit "B" Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users' Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState Local Governments Authority
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Wildlife
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
Chemehuevi Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
The Nature Conservancy

Lower Colorado River Multi-Species Conservation Program

Evaluation of Flow Conditioning Razorback Sucker in Flow-through Raceways at Lake Mead Hatchery

Prepared by:
Brandon Senger and Jon Sjöberg
Nevada Department of Wildlife
4747 Vegas Drive, Las Vegas, NV 89108

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
http://www.lcrmscp.gov

August 2010

ACRONYMS AND ABBREVIATIONS

cm	centimeter(s)
cm/s	centimeters per second
f/kg	fish per kilogram
kg	kilogram(s)
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
mm	millimeter(s)
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
T& E room	Threatened and Endangered Room
TL	total length
TR 1	treatment 1
TR 2	treatment 2

Symbols

°C	degrees Celsius
%	percent

CONTENTS

Page

Introduction 1
Methods 2
  Trial Raceways 2
  Trial Regime 3
  Swim Chamber Testing 5
Results 7
  Swim Chamber Tests 7
  Growth and Food Conversion Efficiency 11
Discussion 14
Acknowledgments 18
Literature Cited 19

Tables

Table Page

1 Failure velocities (cm/s) from swim chamber testing 8
2 Number of fish in each size class (TL) 11
3 TL (mm) of fish in each subsample per treatment 12
4 Summary of variables tested for each treatment group 14

Figures

Figure Page

1 TR 1 raceway design utilizing PVC returns. 4
2 Pumps in TR 2. Two pumps were placed in opposite corners of the raceway, which was split by cinder blocks. 5
3 Swim chamber used to measure failure velocities. 6
4 Mean failure velocities (cm/s) of treatment groups. 7
5 Relationship between TL and failure velocity for pre-trial unexercised fish. 9
6 Relationship between TL and failure velocity for TR 1 fish. 9
7 Relationship between TL and failure velocity for TR 2 fish. 10
8 Mean failure velocities (cm/s) of each size class per treatment. 10
9 Treatment size structures. 11
10 Mean TL (mm) of treatment groups.. 13
11 Sample weights (expressed as number of fish per kilogram) of treatment groups. 13

INTRODUCTION

Many hatcheries have long operated under a put-and-take methodology. These facilities have primarily been used to rear as many recreational fish as possible for as little cost as possible. These fish were then stocked for recreational anglers to immediately harvest; hence, post-stocking survivability was not a main objective of hatchery programs. As these programs have changed over the years, so have the species being reared and stocked. Programs aimed at conserving threatened and endangered species have turned to repatriation programs to augment populations of native species. The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) is one such program that is utilizing repatriation as a management tool in the ongoing conservation effort of endangered species (Kegerries and Albrecht 2009).

Razorback suckers (*Xyrauchen texanus*) are currently being raised in several hatcheries and are used for repatriation programs in the Lower Colorado River Basin. However, this species has shown poor post-stocking survivability (Mueller 2003; Schooley and Marsh 2007). Predation from nonnative fishes, alteration of habitat, and overall poor fitness of stocked fish are widely considered the main causes for such low survival rates (Marsh and Brooks 1989; Mueller 2003; Schooley and Marsh 2007). Addressing these elements has become an increasing interest of the LCR MSCP. Increasing the target size of stocked fish has been a popular method for decreasing their predation, as the larger target size makes it more difficult for gape-limited predators to consume repatriated fish. Recent research interest has also been geared toward investigating the condition and fitness of hatchery-reared fish.

Husbandry practices in hatchery environments do not replicate conditions in the wild (Wiley et al. 1993). Fish reared in hatcheries are provided ample food, are not exposed to variable seasonal flows, and are not exposed to predators. Poor physically and socially conditioned razorback suckers succumb more readily to predation by nonnative predators and are more prone to downstream dispersal soon after stocking (Avery, 2009; Mueller 2003; Ward and Hilwig 2004). Razorback suckers are generally reared in standing water systems or grow-out ponds (Ward et al. 2007). These fish are not exposed to flowing water conditions and do not acquire any exercise benefits gained by such conditions. Previous studies have shown that razorback suckers benefit from exposure to flowing water conditions (Avery, 2009; Mueller et al. 2007). Additional research focusing on various feeding methods, disease treatments, and increased flow rates for exercise conditioning could yield further benefits for captive-reared razorback suckers and may potentially boost post-stocking survival rates.

Kegerries and Albrecht (2009) conducted a literature review to map out areas of focus for flow conditioning trials. Additional research is needed to address those recommendations and to assess what role flow conditioning has on post-stocking survivability of razorback suckers, including objectives identified in LCR MSCP

Work Task C-26, "Evaluation of Raceway Rearing of Razorback Sucker at Lake Mead Fish Hatchery," for the LCR MSCP Fish Augmentation and Species Research Program (Bureau of Reclamation [Reclamation] 2006). Work Task C-26 calls for the design of experimental raceways to evaluate rearing protocols of razorback suckers in flowing conditions. The purpose of this study is to design and construct flowing raceways and evaluate how rearing razorback suckers in these raceways affect swimming stamina, growth, food conversion efficiency, foraging ability, and disease treatment.

METHODS

Trials were conducted at Lake Mead State Fish Hatchery. This facility is operated by the Nevada Department of Wildlife, but located within the National Park Service's Lake Mead National Recreation Area. Razorback suckers used in these trials were reared onsite from when they were larvae. These fish were captured from Lakes Mead and Mohave as larvae and also obtained as larvae from Reclamation's Fish Laboratory in Boulder City, Nevada. All 1,122 fish used were from the 2007 and 2008 year classes. The fish were previously passive integrated transponder (PIT) tagged while being reared in the Lake Mead Hatchery's Threatened and Endangered Room (T&E room) prior to translocation to the outdoor tanks/raceways. The T&E room was specifically designed for rearing razorback suckers at the hatchery, but does not have facilities suitable for testing raceway conditioning of subadult fish.

Trial Raceways

Trials were conducted in three rectangular fiberglass raceways (8.2 meters [m] long, by 1.2 m wide, by 0.89 m deep) located outside. Each raceway had fresh water flowing into the head of the raceway at a rate of 227 liters per minute. Screens were set at the end of each raceway in order to block fish from entering the overflow drain. An air compressor powered multiple aeration stones that were placed throughout each raceway. The outdoor raceway area was covered by an open canopy roof that was installed during construction of the hatchery. Mesh bird net (3.2 centimeter [cm] x 3.8 cm) was hung around the perimeter of the outdoor raceway area to deter a local blue heron (*Ardea herodias*) that arrived shortly after the fish were moved outdoors.

The two treatment raceways were customized in order to produce higher flows. Both raceways were divided down the middle by cinder blocks, but were left open at the front and end to allow water to circulate throughout the raceway and also to allow fish to move to either side of the cinder blocks. Flows in each treatment raceway were produced by in-tank propeller pumps (model PAB4, 1/2-horsepower propeller pump). These circulating pumps were needed to

achieve the high flows desired for this study. Each pump had a flow rate of 795 liters per minute. Typical culture facilities do not use in-tank pumps to produce flow; however, it would not be financially feasible to pump water from the lake at the rates needed to produce such velocities. Drainpipes in both treatment raceways were lowered to 0.4 m, which decreased the volume of water in the system, creating a higher velocity environment. Treatment 1 (TR 1) was the low/variable velocity treatment (figure 1). Two pumps were set upright at the end of the raceway in front of the screens and were connected to a polyvinyl chloride (PVC) manifold that ran the length of the raceway on each side. Water was returned through 12 PVC returns evenly spaced out the length of the raceway, producing variable flows. There were several small dead spots that had little to no flow; however, velocities where the water exited the 12 returns were much higher. This system allowed fish to access these small flow refuges, but in order to do so, they had to swim through the "jets" of water at each return. Treatment 2 (TR 2) represented the high velocity treatment. Four pumps generated the flows in TR 2. Two pumps were laid down horizontally in opposite corners of the raceway (figure 2), creating a counterclockwise flow pattern. The gaps at each end of the raceway allowed water to flow freely around the cinder blocks.

The fish were moved into two outdoor raceways in March and April 2010. They were then separated into the treatment raceways on May 21, 2010. The control raceway and both treatment raceways each held 374 razorback suckers. Random samples were taken of the 1,122 fish prior to the move to obtain an average total length (TL) in millimeters (mm) and an average number of fish per kilogram (f/kg).

Trial Regime

Pumps were plugged in and the trials initiated on May 25, 2010. The initial plan for the study was to expose the fish to current for 24 hours per day. On June 1, 2010, fish in TR 2 began showing signs of disease. TR 2 was treated with salt (NaCl-Sodium Chloride, 12.5 parts per thousand) for 5 days. The disease in TR 2 progressed, and fish in TR 1 suddenly began showing similar signs. Pumps in both treatment raceways were turned off on June 7, 2010. Oxytetracycline was administered for 4 days at a dosage of 20 milligrams per liter. The fish were immersed for 1 hour a day during the 4-day treatment. During immersions, water flowing into the raceways was turned off, and two pumps were turned on for water circulation. After the 4-day treatment, the pumps remained off to allow the fish to rest and properly regain their health. The pumps remained off until the fish showed no signs of disease and normal feeding behavior resumed. To lower the stress level on the treatment fish, it was decided to lower the time they were subjected to current. The pumps were on for 12 hours during the day and off for the other 12 hours, giving the fish time to rest at night. On June 21, 2010, the

Figure 1.—TR 1 raceway design utilizing PVC returns.

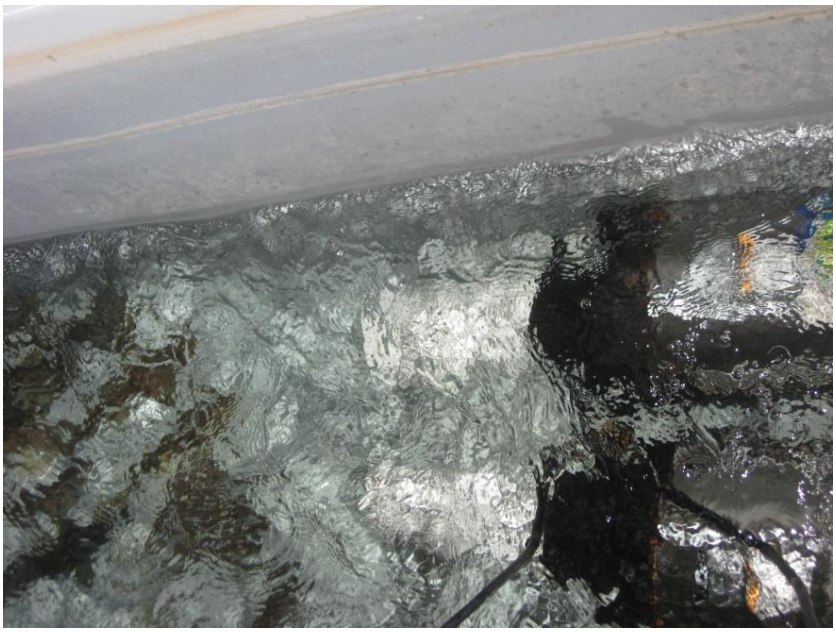


Figure 2.—Pumps in TR 2. Two pumps were placed in opposite corners of the raceway, which was split by cinder blocks.

trials resumed with the new flow regimen. Fish were fed by hand a commercially produced razorback sucker sinking pellet at approximately 2-percent (%) body weight. Feed events occurred in the morning, midday, and early evening. All the raceways were cleaned weekly. The 30-day trial concluded on July 20, 2010.

Flows were measured using a Swoffer Model 2100 series open stream current velocity meter. Current velocity was measured prior to fish inhabiting the tanks and then monitored weekly throughout the duration of the experiment. TR 1 had an average velocity of 23 centimeters per second (cm/s). The average velocity in TR 2 was 36 cm/s. The control raceway produced velocities too low to measure. The water temperature at the beginning of the experiment was 17 degrees Celsius (°C) and 27 °C at the end of the experiment.

Swim Chamber Testing

A swim chamber was used to test if there was a difference in swimming ability between unexercised (control) fish and exercised (treatment) fish (figure 3). Mueller (2003) and Avery (2009) both employed this same chamber for swimming performance testing. The chamber consisted of two Plexiglass tubes and a motor that powered a propeller. The tunnel where the fish swam was a smaller Plexiglass tube surrounded by a larger diameter Plexiglass tube. There was a removable cap at the head of the tunnel where fish entered or exited the swim chamber. A propeller that created the current within the chamber was

Figure 3.—Swim chamber used to measure failure velocities.

attached to an external motor at the other end. Water velocities were adjusted by a variable-speed motor controller. A screen was mounted in front of the propeller to protect fish from coming into contact with it. Aerated fresh water was continually pumped in through two nozzles at the motor end of the swim chamber, and excess water exited through a drain nozzle at the head of the chamber.

Pre- and post-trial testing was conducted on May 24 and June 21–22, 2010, respectively. One subsample of 19 fish was collected from the whole group (1,122 fish) prior to separation into treatment raceways for the pre-trial testing. One subsample (n = 19) from each treatment was collected for post-trial testing. Subsamples were randomly taken and then moved to a temporary holding tank inside the T&E room. Fish were individually drawn at random from the holding tank and placed in the swim chamber. Each fish was acclimated in the swim chamber, for 5 minutes, with no flow. The fish was then subjected to 12 cm/s, for 5 minutes, to acclimate to the flowing environment. Water velocities were then increased by 3 cm/s every 1 minute, and this increase continued until the fish was unable to maintain its position in the tunnel and was pinned against the screen. This was determined to be its failure velocity. Failure velocity and TL were recorded after each test, and the fish were then returned to their treatment raceway.

RESULTS

Swim Chamber Tests

The mean swim chamber failure velocities of the pre-trial and treatment groups ranged from 53.4 to 81.6 cm/s (figure 4). The mean failure velocity for pre-trial unexercised razorback suckers was 53.4 cm/s. Razorback suckers reared in TR 1 had a mean failure velocity of 61.1 cm/s. The mean failure velocity for fish in TR 1 was significantly higher than the pre-trial unexercised fish (two-sample *t*-test: $P < 0.05$). The mean failure velocity of fish in TR 2 (81.6 cm/s) was 28.2 cm/s higher than the pre-trial fish (two-sample *t*-test: $P < 0.05$) and 20.5 cm/s higher than TR 1 fish (two-sample *t*-test: $P < 0.05$). While some failure velocities of individual fish were common between treatments (table 1), mean failure velocities were significantly different among treatment groups (ANOVA: $F > F_{crit}$, $P < 0.05$).

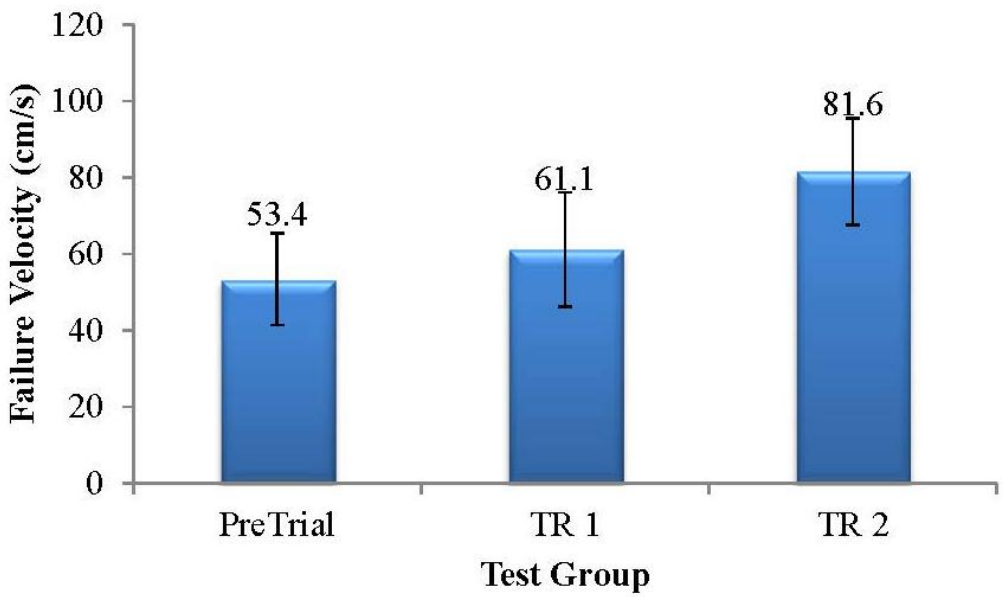


Figure 4.—Mean failure velocities (cm/s) of treatment groups.

The TL of subsampled fish was not found to have a strong correlation with failure velocity for pre-trial, TR 1, or TR 2 fish (figures 5, 6, and 7, respectively). However, when mean failure velocities for each size class of fish are compared between treatments, the highest failure velocities for all size classes resulted from TR 2 (figure 8).

Table 1.—Failure velocities (cm/s) from swim chamber testing

Test	Pre-trial	TR 1	TR 2
1	27	27	51
2	39	36	57
3	39	45	63
4	45	48	63
5	45	48	78
6	48	51	81
7	48	54	84
8	48	57	84
9	51	60	84
10	54	69	84
11	54	69	84
12	60	72	87
13	60	72	90
14	60	72	90
15	60	75	90
16	63	75	90
17	66	75	93
18	69	78	96
19	78	78	102
Maximum	78	78	102
Mean	53.4	61.1	81.6
Minimum	27	27	51

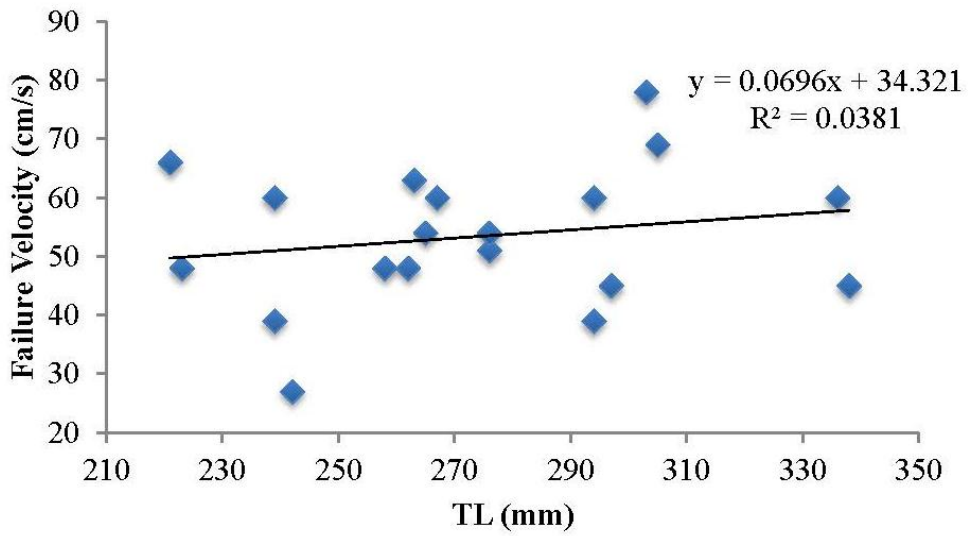


Figure 5.—Relationship between TL and failure velocity for pre-trial unexercised fish.

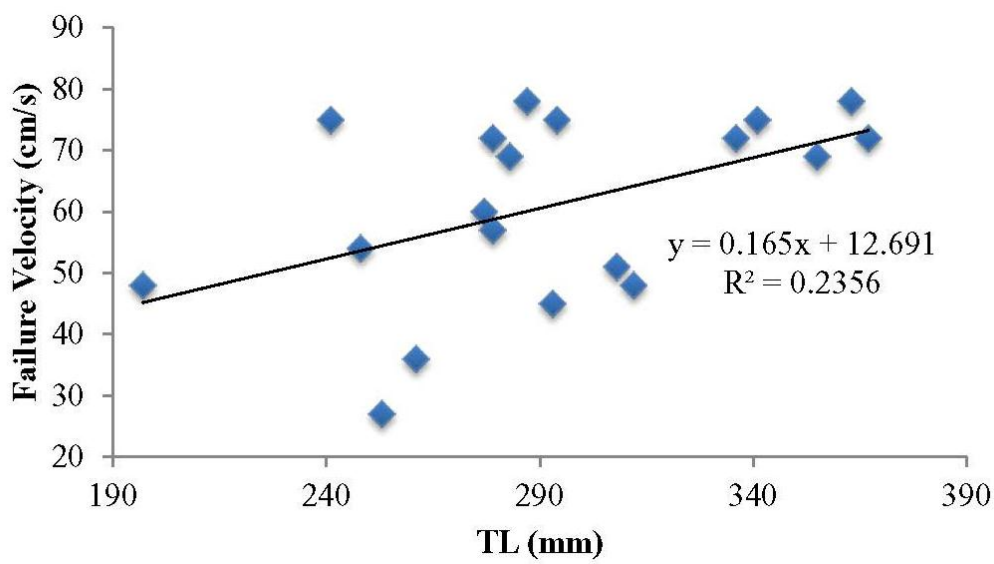


Figure 6.—Relationship between TL and failure velocity for TR 1 fish.

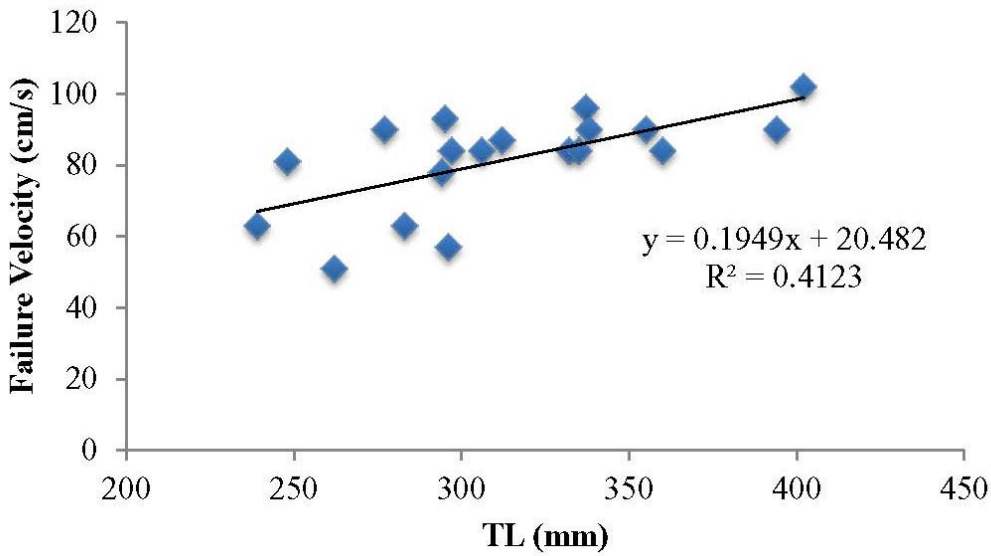


Figure 7.—Relationship between TL and failure velocity for TR 2 fish.

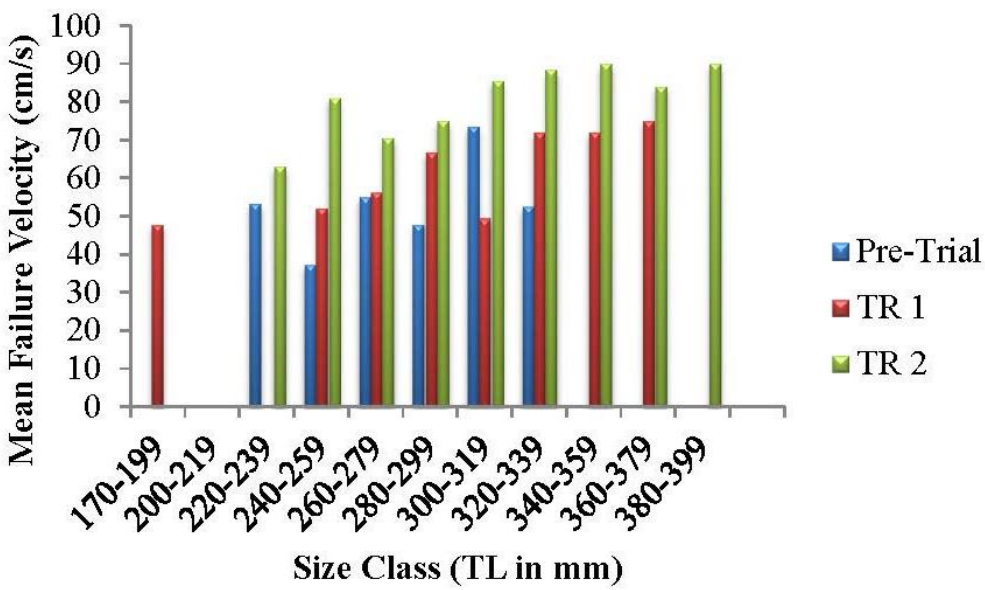


Figure 8.—Mean failure velocities (cm/s) of each size class per treatment.

Growth and Food Conversion Efficiency

Fish used in this study represented 12 different size classes defined to range from 170 to 419 mm (figure 9). These size classes were defined following measurements of treatment subsamples. The number of fish in each size class for each treatment subsample is summarized in table 2. The TL of individual fish subsampled from each treatment is summarized in table 3.

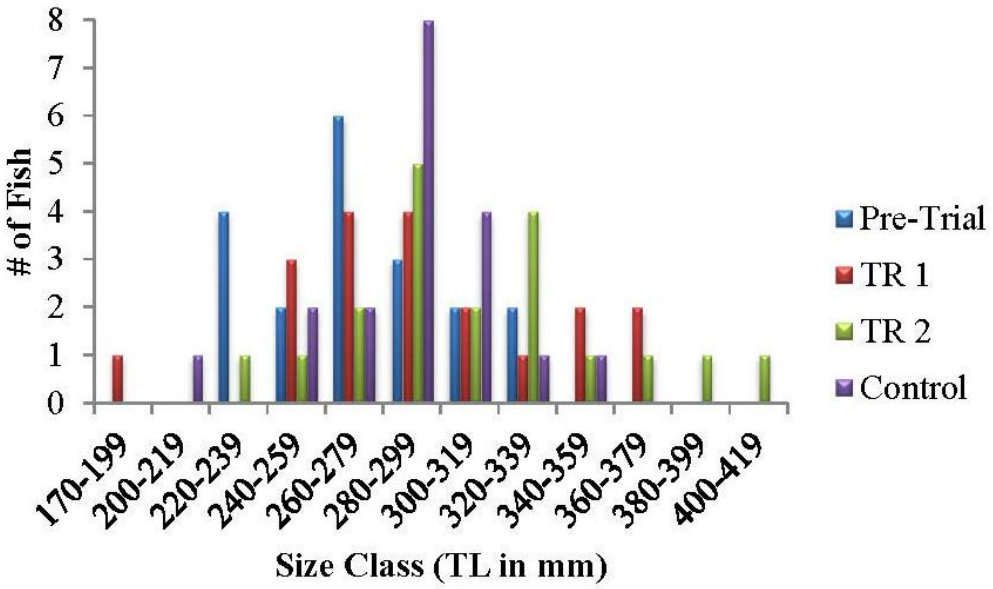


Figure 9.—Treatment size structures.

Table 2.—Number of fish in each size class (TL)

Size class	Pre-trial	Control	TR 1	TR 2
170–199	0	0	1	0
200–219	0	1	0	0
220–239	4	0	0	1
240–259	2	2	3	1
260–279	6	2	4	2
280–299	3	8	4	5
300–319	2	4	2	2
320–339	2	1	1	4
340–359	0	1	2	1
360–379	0	0	2	1
380–399	0	0	0	1
400–419	0	0	0	1

Table 3.—TL (mm) of fish in each subsample per treatment

	Pre-trial	Control	TR 1	TR 2
	221	216	197	239
	223	247	241	248
	239	253	248	262
	239	274	253	277
	242	274	261	283
	258	281	277	294
	262	285	279	295
	263	287	279	296
	265	292	283	297
	267	293	287	306
	276	294	293	312
	276	295	294	332
	294	298	308	335
	294	303	312	337
	297	308	336	338
	303	311	341	355
	305	315	355	360
	336	323	363	394
	338	356	367	402
Maximum	338	356	367	402
Mean	273.6	289.7	293.4	313.8
Minimum	221	216	197	239

The mean TL for unexercised fish (289.7 mm) was 16.1 mm longer than the pre-trial mean TL of 273.6 mm (two sample *t*-test: $P < 0.05$). Fish in TR 1 (mean TL of 293.4 mm) grew 3.7 mm longer than the unexercised fish (two sample *t*-test: $P > 0.05$). The highest growth occurred in TR 2, with a mean TL of 313.8 mm (figure 10). TR 2 fish were 24.1 mm longer than the unexercised fish and grew significantly more than the unexercised and TR 1 fish (two sample *t*-test: $P < 0.05$ for both). The mean TL was not significantly different among test groups (ANOVA: $F < F_{crit}$, $P > 0.05$).

Sample weights of razorback suckers averaged from 4.27 f/kg for the pre-trial group to 2.73 f/kg for TR 2 (figure 11). The unexercised fish gained 5.1 kg over

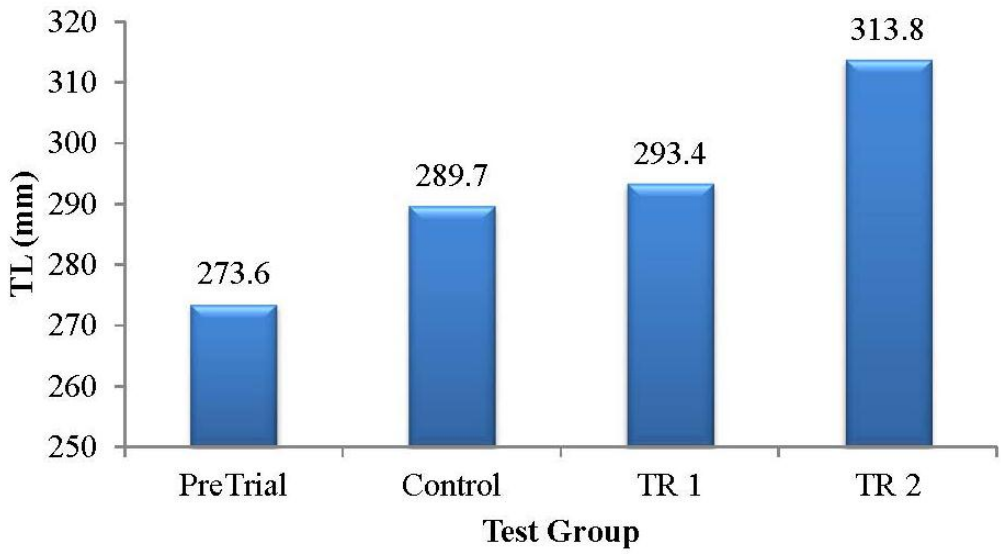


Figure 10.—Mean TL (mm) of treatment groups.

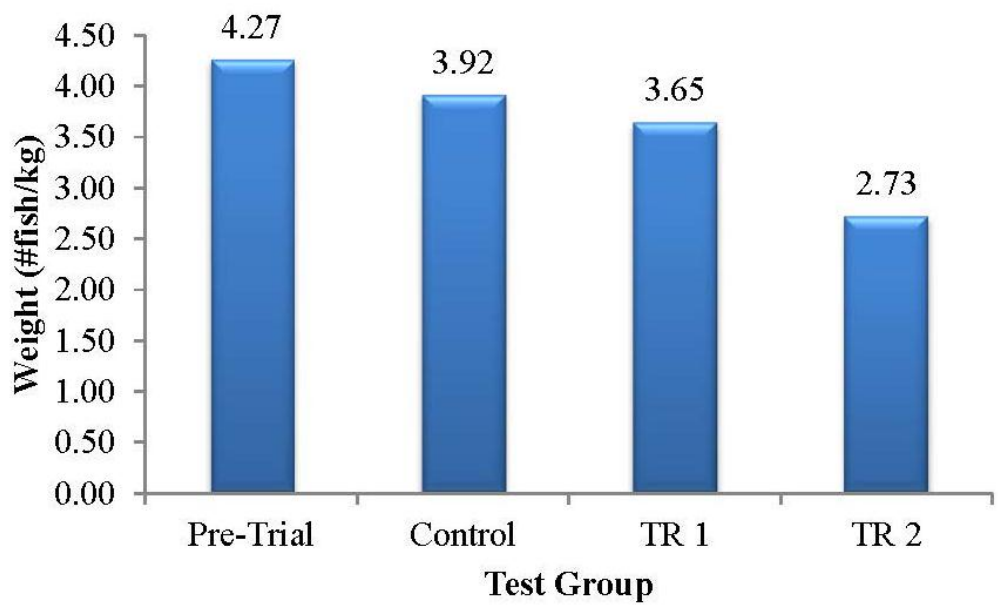


Figure 11.—Sample weights (expressed as number of fish per kilogram) of treatment groups.

the duration of the experiment (5% increase), and fish in TR 1 gained 10.2 kg (11% increase). The greatest weight increase was observed in TR 2, with fish gaining 47.8 kg (a 47% increase).

Food conversion rates are expressed as the pounds of feed fed for the fish to gain 1 pound. Fish culturists typically calculate and report these rates in pounds instead of the metric kilogram. The unexercised fish and TR 1 fish had food conversion rates of 16.1 and 8.0, respectively. TR 2 fish had a food conversion rate of 1.7, which was the most efficient among the three test groups.

DISCUSSION

Swimming performance, growth, and food conversion efficiency were highest among fish exposed to flowing water conditions (table 4). Furthermore, fish in the highest water velocity treatment (TR 2) performed better in each category tested, suggesting that the raceway design of TR 2 is more suitable for future pre-release flow conditioning. The unexercised control fish exhibited the worst exercise conditioning, food conversion efficiency, and growth among the treatment groups. These traits of unexercised fish have been reported among researchers and may, in part, be responsible for low post-stocking survivability in repatriation programs (Wiley et al. 1993; Brown and Laland 2001; Mueller et al. 2003; Ward and Hilwig 2004).

Table 4.—Summary of variables tested for each treatment group

Variable	Pre-trial	Control	TR 1	TR 2
Fish/kg	4.27	3.92	3.65	2.73
Group weight (kg)	89.3	94.2	96.8	129.7
Kg gained[1]		5.1 (5%)	10.2 (11%)	47.8 (47%)
Food conversion[2]		16.1	8.0	1.7
Mean failure velocity (cm/s)	53.4		61.1	81.6
Mean TL (mm)[1]	273.6	289.7 (5.8%)	293.4 (6.7%)	313.8 (12.8%)

[1] Parenthesis indicates percent increase from start of trial.
[2] Kg of food fed for fish to gain 1 kg.

One of the goals of this study was to construct and evaluate different flowing raceway designs. The practice of flow conditioning razorback suckers is relatively new, and there is little information available regarding design and rearing protocols. Using two different designs provided the opportunity to observe and assess how each system impacted razorback suckers.

As previously described, TR 1 was the low/variable flow treatment utilizing a PVC return apparatus. This design allowed fish to escape flows in certain areas, which may have contributed to the fish having a lower mean failure velocity than TR 2. The average velocity in this raceway was 23.6 cm/s. However, this

average velocity may be deceiving, as points where water exited the PVC returns had a much higher velocity than areas where there were no returns, and fish in this system generally faced in the upstream direction. Therefore, they were able to find dead spots where they could remain still, not exert any energy, and maintain their position in the water column.

While observing fish in TR 2, it was obvious that they constantly exerted energy. The water flow in this system was counterclockwise around the cinder blocks. There was an initial concern that the fish would just go with current and flow counterclockwise around the raceway. However, as soon as the pumps were turned on, the fish faced upstream on each side of the cinder blocks. When looking down at the raceway, the fish were faced in opposite directions of each other on each side of the cinder blocks. The current in this system was strong enough that the fish had to constantly swim to maintain their position. There were no dead spots in this system, and fish were forced to swim everywhere in the tank. It was noted that TR 1 and TR 2 stayed cleaner than the control raceway. The current in the raceway helped to keep debris from settling on the bottom.

The mean failure velocities in TR 2 indicate that these fish gained the most in terms of swimming performance. These fish were able to maintain body position at higher velocities than the unexercised control fish and TR 1 fish. Improved swimming abilities and stamina may improve their ability to escape predation in the wild. These exercised fish could have a higher "burst" swim speed when encountered by a predatory fish and could also have the stamina to endure a chase. It has been recorded that unexercised razorback suckers disperse further downstream upon stocking than exercised razorback suckers (Avery, 2009). An enhanced ability for stocked fish to escape initial predation upon stocking should lead to higher post-stocking survival rates and increase the opportunity for wild recruitment.

Growth is an important factor for hatchery programs rearing razorback suckers. Current hatchery practices are to grow fish as large as possible to avoid being consumed by predators. Fish in TR 2 grew 2.5 times more in TL than the unexercised control fish and had a 6.6 times more efficient food conversion rate. This tells us that not only do fish grow faster in flowing raceways, but they also have higher feed efficiencies. Other studies have shown similar results with exercised fish and improved feeding efficiency (Davison 1989, 1997). Davison (1997) reported that fish that are exercised consume more food. While exercised fish may consume more food, their bodies are essentially utilizing and metabolizing that food more efficiently and productively. It makes more sense from a cost-efficient and hatchery production point of view to raise fish that have a food conversion rate of 1.7 versus 16.1. We should note that these large differences in food conversion rates were unexpected. Our juvenile (150–200 mm TL) razorback suckers that we raise at the hatchery generally have a 0.7–1.5 food conversion rate. Future flow conditioning trials should continue to address this interaction between flow conditioning and food conversion rates.

Another focus of this study was to investigate alternative methods of food delivery and foraging behavior in flowing raceways. Fish were fed by hand, and food was weighed out at each feeding so that we could obtain accurate data for calculating food conversion rates. This method allowed us to observe the foraging behavior of razorback suckers in flowing raceways. In TR 2, feed was added directly in front of two pumps that were placed horizontally on the bottom of the raceway. The feed flowed downstream and continued to circle around the cinder blocks. Our initial concern about feeding the fish in strong currents was that the food would simply get flushed out through the drainpipe. However, this circular flow pattern actually kept the food in the raceway. As the food flowed around the raceway, the fish would have to actively capture the pellets. Fish in TR 1 had to actively capture their food as well; however, some food would settle in dead spots for a while before being swept further downstream. In the control raceway, the pellets immediately sank to the bottom, and fish would feed on the pellets at their leisure. While there was no attempt to feed live or natural food, observations from this study suggest that feeding razorback suckers in flowing raceways may improve their foraging ability, as they have to actively capture their food in captivity, which may increase their competitiveness and ability to find food in the wild.

Rearing fish in any captive environment puts added stress on fish. Hatcheries keep fish at higher densities than are found in any natural environment. High fish densities increase the bio-load of a system and, in turn, lower the water quality. Compounding that with increased water temperatures and handling, fish become stressed out very easily. As in humans, when fish become too stressed, their immune system weakens, and they become susceptible to illness. Disease treatment in flowing raceways is another area in which information is limited. Shortly after the trial began and fish were moved to their respective treatment raceways, they contracted a disease. Upon examination, it was determined that they were infected with columnaris disease. Columnaris disease is a bacterial infection caused by the bacteria *Flavobacterium columnare* (Pulkkinen et al. 2010). Columnaris disease is common among production facilities rearing channel catfish (*Ictalurus punctatus)* and salmonids. Columnaris is often identified by cotton-like growths on the fins and head. If left untreated, it could spread to the gills and ultimately the bloodstream (Rach et al. 2008). The two treatment raceways were affected, but not the control raceway, suggesting that this was a stress-induced disease caused from being exposed to current for 24 hours a day. After successful treatment of the disease, it was decided to lower the time exposed to current to 12 hours. We would recommend starting future flow conditioning trials at 12 hours and slowly acclimating to 18 hours of current exposure. Due to timing issues, it was not possible to acclimate the fish in such a manner. The columnaris outbreak resulted in 11 mortalities in TR 1 and 31 mortalities in TR 2 (this lowered our number of fish in TR 1 to 363 and 343 in TR 2 for the remainder of the experiment.) These fish were not replaced during the experiment, thus altering our treatment densities. The control population

remained at 374 fish for the duration of the experiment. This disease outbreak showed that disease treatment can be successfully applied during future flow conditioning. We expect that future disease outbreaks can be avoided by less handling during warmer temperatures and better acclimation procedures.

This study addressed the design and implications of rearing razorback suckers in flowing raceways. This first round of flow conditioning trials went very well. The design of TR 2 was the most efficient and beneficial for rearing razorback suckers. Thus, it is recommended that continued flow conditioning efforts be similar to the TR 2 design. Researchers are looking for ways to produce higher quality fish, which would lead to increased post-release survivability. Rearing strategies used in this study could achieve that goal. A stocking program for exercised razorbacks should be created and followed up with monitoring via tracking or netting. Research space is available at Lake Mead Hatchery for future flow conditioning experiments. We would recommend developing a predator avoidance/recognition study of flow conditioned razorback suckers using predators encountered in Lake Mead. Plans for tracking efforts should also be considered. Continued research should focus on flow conditioning and how it can aid in increasing the success of repatriation programs.

This study did not test what role flow conditioning has on predator avoidance and post-release dispersal. Previous studies have suggested that exercised fish have increased predator avoidance skills compared to unexercised fish (Mueller et al. 2007). Avery (2009) documented that unexercised fish dispersed further downstream than exercised fish. Brown and Laland (2001) and Mueller et al. (2007) suggest that predator naïve fish are unable to behave and respond appropriately when encountered by a predator in the wild. Predator avoidance and recognition is considered a learned social skill. Therefore, future studies need to be conducted to compare how exercised naïve fish, exercised predator experienced fish, and unexercised fish respond to predators. Striped bass (*Morone saxatilis*) is the largest predatory fish in Lakes Mead and Mohave. Future studies should consider incorporating striped bass in predator avoidance training. The data collected in this study imply that exercised fish are more physically fit, which should lead to an overall higher fitness than unexercised fish.

A thorough study should be conducted on post-stocking survival of exercised fish. This could be achieved by conducting a satellite tracking study in Lake Mead. While this study showed that exercised fish benefited from flow conditioning, no post-stocking tests were conducted. It remains unclear what the underlying factor is that leads to low survivability of repatriated fish. Multiple tracking studies of exercised fish could shed light on how flow conditioning affects post-release survival.

Based on the information gathered from this study, the following are recommendations for future flow conditioning research.

- Flow conditioning raceway designs should be similar to TR 2.
- Fish should be subjected to an acclimation period prior to start of flow conditioning. Researchers should then slowly increase time fish are exposed to current until trial duration is reached.
- Communicate with other facilities rearing razorback suckers and obtain growth and feed data from them, which would allow us to compare data we collected from our exercised fish with their data. This would further test how flow conditioning affects razorback suckers in comparison to fish being reared in standing water environments at other hatcheries.
- Run flow conditioning trials at different times of the year. It is currently unknown which time of year is best for flow conditioning and how the seasonal variations in temperature affect the results of such trials. Also, similar investigations should address the optimal duration for flow conditioning.
- Conduct a predator avoidance experiment using exercised and unexercised fish. We recommend using predators that razorback suckers will encounter in the wild. Striped bass is the largest predator in Lakes Mead and Mohave. Thus, we find it appropriate to utilize striped bass in future predator avoidance experiments.
- Develop a stocking plan for flow conditioned fish.
- A post-release followup study should be conducted to assess how flow conditioning impacts post-stocking survivability. This study can be achieved by conducting a thorough satellite/net tracking study of repatriated exercised fish. Other sampling protocols should also be considered when developing this recapture study.

ACKNOWLEDGMENTS

This project was funded by Reclamation. We would like to thank BIO-WEST and Reclamation for their assistance and recommendations. All input from the Lake Mead Work Group during this project was greatly appreciated. A special thanks goes out to David Ward (U.S. Geological Survey), Gordon Mueller (retired), and Luke Avery (Northern Arizona University) for sharing their experiences, equipment, and knowledge.

LITERATURE CITED

Avery, L. 2009. Exercise conditioning of pond-reared razorback suckers (*Xyrauchen texanus*) decreases rate of downstream movement upon release into a stream environment. (Unpublished Master's Thesis). Northern Arizona University, Flagstaff, Arizona.

Brown, C. and K. Laland. 2001. Social learning and life skills training for hatchery-reared fish: review paper. Journal of Fish Biology 59:471-493.

Bureau of Reclamation (Reclamation). 2006. Final fish augmentation plan. Lower Colorado River Multi-Species Conservation Program, Boulder City, Nevada.

Davison, W. 1989. Training and its effects on teleost fish. Comparative Biochemistry and Physiology 94:1–10.

_____. 1997. The effect of exercise training on teleost fish, a review of recent literature. Comparative Biochemistry and Physiology 117(A):67–75.

Kegerries, R. and B. Albrecht. 2009. Draft Literature and Data Review of Flow Conditioning and Exercise Pertinent to Hatchery-Reared Razorback Sucker (*Xyrauchen texanus*). 2009 Draft Report. Prepared for the Bureau of Reclamation by Bio-West, Inc., Logan, Utah. PR-1161-04.

Marsh, P.C. and J.L. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to reestablishment of introduced razorback sucker. The Southwestern Naturalist 34:189–195.

Mueller, G.A. 2003. The role of stocking in the reestablishment and augmentation of native fish in the Lower Colorado River mainstem (1998-2002). U.S. Geological Survey, Open-file Report 03-288, Denver, Colorado.

Mueller, G.A., J. Carpenter, R. Krapfel, and C. Figiel. 2007. Preliminary testing of the role of exercise and predator recognition for bonytail and razorback sucker: U.S. Geological Survey Open-File Report 2007–1423. 37 p.

Pulkkinen, K., L.R. Suomalainen, A.F. Read, D. Ebert, P. Rintamaki, and E.T. Valtonen. 2010. Intensive fish farming and the evolution of pathogen virulence: the case of columnaris disease in Finland. The Royal Society 277:593–600.

Rach, J.J., A. Johnson, J.B. Rudacille, and S.M. Schiles. 2008. Efficacy of oxytetracycline hydrochloride bath immersion to control external columnaris disease on walleye and channel catfish fingerlings. North American Journal of Aquaculture 70:459–465.

Schooley, J.D. and P.C. Marsh. 2007. Stocking of endangered razorback suckers in the Lower Colorado River basin over three decades: 1974–2004. North American Journal of Fisheries Management 27:43–51.

Ward, D.L. and K.D. Hilwig. 2004. Effects of holding environment and exercise conditioning on swimming performance of southwestern native fishes. North American Journal of Fisheries Management 24:1083–1087.

Ward, D. L., M. Childs, and W. Persons. 2007. Factors affecting growth of razorback sucker (*Xyrauchen texanus*) in captivity: Literature review and knowledge assessment. Report submitted to the Bureau of Reclamation. Contract number 06FG0039.

Wiley, R.W., R.A. Whaley, J.B. Satake, and M. Fowden. 1993. An evaluation of the potential for training trout in hatcheries to increase poststocking survival in streams. North American Journal of Fisheries Management 13:171–177.