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Larval razorback sucker and bonytail survival and growth in the presence of nonnative fish in the Baeser floodplain wetland of the middle Green River.

Ronald E. Brunson

and

Kevin D. Christopherson

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Utah Division of Wildlife Resources
152 E. 100 North
Vernal, UT 84078
James F. Karpowitz, Director

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Floodplain wetland, Green River, larval, razorback sucker, bonytail, nonnative fish, endangered species

EXECUTIVE SUMMARY

Floodplain restoration is an important element of the Upper Colorado River Endangered Fish Recovery Program. Floodplain restoration was initiated in 1996 by lowering natural and manmade levees that were preventing natural floodplain function by limiting the frequency and duration of river-floodplain connection.

Floodplain wetlands provide important rearing habitat for endangered razorback sucker *(Xyrauchen texanus)* and bonytail *(Gila elegans)* larvae. Nonnative fish species such as fathead minnow *(Pimephales promelas)*, black bullhead *(Ameiurus melas)*, green sunfish *(Lepomis cyanellus)*, and carp *(Cyprinus carpio)* flourish in this type of habitat and likely suppress survival of less abundant endangered fish species. Drought conditions eliminate, or reset, fish populations in wetlands that result in much lower initial fish densities during the next inundation period. Survival of larval razorback sucker and bonytail following reset of a floodplain wetland has been documented.

The goal of this study was to estimate the lower density threshold at which survival of larval razorback sucker and bonytail could be detected. Survival was evaluated at different levels of larval razorback sucker density and one level of bonytail density. Using twelve 1/8-acre experimental enclosures, equal numbers of nonnative fish species were introduced into ten of the twelve enclosures. The remaining two enclosures were established as controls (no nonnative fish). Growth of surviving razorback sucker and bonytail was also evaluated. Survival of razorback sucker larvae was detected in two enclosures stocked at the highest density of 40,000 larvae/acre (2 and 3%) and at the lowest density of 400 larvae/acre (6 – 23%). Bonytail stocked at a density of 8,000

larvae/acre along with razorback sucker at the same density showed a survival rate of 16 – 17%. Total number of surviving razorback sucker collected from the enclosures was 616 in 2003 and 1,095 in 2004. The total number of bonytail collected was 10 in 2003 and over 300 in 2004. Estimated larval razorback sucker survival in the experimental enclosures ranged from 0 – 58% and growth rates averaged 0.6 mm/day in 2003 and 0.6 mm/day in 2004 in the presence of nonnative predators. Larval razorback sucker survival was detected 88 days following introduction at a density as low as 400 larvae/acre. Bonytail larvae introduced sympatric with razorback sucker larvae at a density of 8,000 larvae/acre had an estimated survival of 16 – 17% in 2004 and a growth rate of 0.6 mm/day in 2003 and 0.4 mm/day in 2004. Larval bonytail survival was detected 106 days following introduction in 2003. Larval bonytail survival was detected 66 days following introduction sympatrically with razorback sucker larvae in 2004 at a density of 8,000 larvae/acre.

It is recommended that actions to identify, monitor, and manage variables and conditions necessary to achieve entrainment of at least 400 larvae/acre should be implemented. Floodplain wetlands of the middle Green River should continue to be managed based on the reset theory. Even with abundant nonnative fish predators, these habitats are important to recovery of endangered fish.

INTRODUCTION

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) initiated floodplain restoration on the Green River in 1996 (Birchell et al. 2002). Restoration was based on information that floodplain wetlands may provide critical rearing habitat for endangered fish, primarily razorback sucker (Wydoski and Wick 1998; Modde 1996 and Modde et al. 2001). The goal was to restore natural floodplain wetland habitats and functions that support the recovery of razorback sucker (Lentsch et al. 1996). Restoration to improve floodplain function includes mechanically lowering levees at selected wetlands to increase frequency of the river-floodplain connection to pre-Flaming Gorge Reservoir levels (Birchell et al. 2002).

Research questions following floodplain habitat restoration were the focus of other studies (Birchell and Christopherson 2004, Christopherson et al. 2004), Including:

1) Can razorback sucker larvae be entrained in floodplains by lowering levees to improve the river-floodplain connection?
2) Can larvae be entrained at high enough numbers to ensure survival from predation by nonnative fish and predacious insects?
3) Will razorback sucker survive, voluntarily migrate from the floodplain during high flows, and recruit into the river population?
4) What cues trigger migration from the floodplain?

To help answer the latter three questions, projects were proposed to evaluate survival and growth of larval razorback sucker and bonytail by experimentally introducing them into controlled enclosures. A study completed in 2002 at The Stirrup floodplain wetland (Christopherson et al. 2004), evaluated growth and survival of larval razorback sucker following “reset” (i.e. elimination) of the fish population due to an extended drought and subsequent drying of the floodplain depression. Two enclosures were used to control the experiment. Nonnative fish species obtained from the river and a nearby floodplain were introduced at densities present during the natural connection of the river with the floodplain wetland (Birchell et. al. 2002). Larval razorback sucker and bonytail were then stocked into the enclosures at very high densities. These razorback sucker and bonytail larvae along with introduced nonnative species were maintained in the enclosures for approximately three months. During this time, nonnative species reproduced and dramatically increased in numbers. Subsequent sampling to evaluate growth and survival revealed that several thousand larval razorback sucker and bonytail survived in the presence of abundant nonnative fishes.

This study evaluates survival of larval razorback sucker and bonytail at much lower densities following reset of the floodplain fish population than those described in Christopherson et. al. 2004. It provides the Recovery Program with an estimate of the density of larval razorback sucker and bonytail necessary for measurable survival in the presence of expected predator densities in a reset floodplain wetland.

Specific objectives were to:

1. Evaluate survival and growth of larval razorback sucker in the presence of nonnative predators by introducing larvae into experimental enclosures over a range of densities.

2. Evaluate survival and growth of larval razorback sucker and bonytail in the presence of nonnative predators by stocking together at equal densities into experimental enclosures.

STUDY AREA

The Baeser Bend floodplain, administered by the Bureau of Land Management is located near river-mile 273 on the east bank of the Green River. A lateral breech allows the floodplain to inundate 38 acres at 13,000 cfs (Valdez and Nelson 2004). The twelve 1/8-acre experimental enclosures used in this study were constructed on the east shore of the wetland and extended to the center.

METHODS

Enclosures and Fish Introduction - 2003

Enclosures were constructed at the Baeser floodplain site beginning in March and were completed in early May 2003. Twelve enclosures of approximately 1/8 acre were constructed using field fence and steel t-posts as the framework over which 7-mm hardware cloth was attached. Over the hardware cloth, a layer of 1-mm mesh screen was attached using lath and screws and then a final layer of poly-tarp to contain stocked larval razorback sucker and bonytail. The bottom 30 cm of the 1mm mesh screen was buried in a trench and the bottom of the poly-tarp was anchored into the substrate using iron rod (re-bar) of 1.2 cm diameter running the entire length of the tarp (See Photos Appendix B).

At the time bonytail were available, the Baeser wetland was dry. Water was pumped from the Green River through the lateral breech in the levee and into the floodplain site to allow introduction of bonytail larvae on 13 May 2003. A total of 2,000 bonytail larvae obtained from Dexter National Fish Hatchery were introduced into two enclosures prior to high flows and floodplain connection. The Baeser floodplain connected with the river on 20 May and was full by 22 May. Unpredicted high flows (~19,000 cfs) totally inundated the study enclosures, making it necessary to wait for flows to subside before razorback larvae could be stocked into the enclosures. After waiting for a week for the floodplain site to drain, water levels were still too high to stock larvae and maintain them in the enclosures. It became necessary to pump additional water out. Baeser was pumped with two 11-hp trash pumps for a week and then two more pumps were added for two additional days of pumping.

Originally the study was to have two enclosures used as controls. However, due to the over topping of the enclosures as a result of the high river flows and the resulting introduction of nonnative fishes, controls without nonnative species were not possible and control of nonnative fish density in treatment enclosures was compromised.   A total of 17,000 razorback sucker larvae obtained from Ouray National Fish Hatchery were introduced into the twelve enclosures at six different densities on 20 June 2003 (Table 1).

Table 1. Summary of razorback sucker and bonytail larvae introduced into each 1/8-acre enclosure at the Baeser floodplain wetland, Green River (RM 273): 2003

Enclosure	Density Larvae/Acre	Razorback sucker	Bonytail	Total
1A	800	100		100
1B	800	100		100
2A	1,200	150		150
2B	1,200	150		150
3A	4,000	500		500
3B	4,000	500		500
4A	8,000	1,000	1,000	2,000
4B	8,000	1,000	1,000	2,000
5A	18,000	2,250		2,250
5B	18,000	2,250		2,250
6A	36,000	4,500		4,500
6B	36,000	4,500		4,500
	Total	17,000	2,000	19,000

Water Quality Measurements

Water quality was monitored to ensure adequate conditions for survival and growth of larval fish. When water quality and/or depth degraded to point that it threatened fish survival, fresh water was pumped into the site from the river. Water temperature and depth was monitored at least bi-weekly throughout the experiment during both years (2003 and 2004). Dissolved oxygen was monitored for multiple 24-hour periods when conditions appeared to be marginal. Water quality data including depth, temperature, dissolved oxygen, pH and turbidity was monitored over a 24 hour period for multiple days at approximately one week intervals between June 25 and July 15, 2003 with a Hydrolab H2O multiprobe (Appendix). A staff gage was placed at the deepest site in a center enclosure and checked every few days to monitor maximum depth in the enclosures.

Zooplankton samples were taken in 2003 to monitor conditions within and outside the enclosures to detect potential problems affecting razorback sucker survival. Zooplankton densities were also monitored visually during bi-weekly visits and were determined to be very abundant both within and outside the enclosures.

Fish Introduction – 2004

Larval razorback sucker were introduced into twelve enclosures on 26 April 2004 at the following densities: 400, 800, 4,000, 8,000 and 40,000 larvae/acre (Table 2). Larval bonytail acquired from Dexter National Fish Hatchery were introduced on 4 May into two enclosures with razorback sucker larvae at the same density of 8,000 larvae/acre, for a combined total of 16,000 larvae/acre.

Nonnative fish species were collected from The Stirrup floodplain wetland on 27 and 28 April 2004. Nonnative fish introduced into each of the ten treatment enclosures included 38 fathead minnow, 21 red shiner, 8 black bullhead, 12 green sunfish, and 2 carp. Numbers and species composition of nonnative fish introduced was based on observations from earlier studies that documented initial relative abundance and species composition in a reset wetland (Birchell et. al. 2002). It should also be noted that in a natural situation, initial species composition and relative abundance could vary greatly from year to year depending on several factors and chance alone. The main factors that likely influence the number and species composition of nonnative fish initially entering a wetland during inundation include timing and duration of connection, water temperature during the connection period and location of wetland. The biggest factor in determining species composition in the fall is reproduction potential and success. Although the composition of nonnative fish introduced in 2004 was different than the composition that naturally invaded in 2003, this composition was introduced to remain consistent with earlier studies conducted at the Stirrup wetland by Christopherson et. al. 2004.

Field Data Collection

Sampling of the enclosures at Baeser began 5 August 2003 and was completed on 29 August 2003. In 2004, sampling began on 7 July and was completed on 23 July. Enclosures were netted repeatedly to allow abundance and survival estimation by depletion and linear regression. Three fyke nets (two 0.32 cm mesh and one 0.64 cm) were set for four nights in each enclosure. All fish were removed from the fyke nets and placed on a sorting table to quickly recover any surviving razorback sucker or bonytail. All fish captured were removed from the floodplain site. Bonytail and razorback sucker were transferred to The Stirrup wetland, approximately two miles upriver, where conditions were better for long-term survival during the prevailing drought.

Table 2. Summary of razorback sucker and bonytail larvae introduced in each 1/8-acre enclosure at the Baeser floodplain wetland, Green River (RM 273): 2004.

Enclosure	Density Larvae/Acre	Razorback sucker	Bonytail	Total
1A	400	50		50
1B	400	50		50
2A	400	50		50
2B	400	50		50
3A	800	100		100
3B	800	100		100
4A	4,000	500		500
4B	4,000	500		500
5A	8,000	1,000	1,000	2,000
5B	8,000	1,000	1,000	2,000
6A	40,000	5,000		5,000
6B	40,000	5,000		5,000
	Total	13,400	2,000	15,400

Analysis and calculations

Growth rates of razorback sucker and bonytail were calculated by subtracting the mean length at time of stocking from the mean length at capture divided by the mean number of days the razorback suckers and bonytail were in the enclosure. Abundance estimates including 95% confidence intervals for razorback sucker, bonytail and nonnative fish were calculated using depletion and linear regression.

RESULTS

2003

Water Quality Measurements

Water depth was maintained at approximately 0.6 m through the study. Water quality in the Baeser wetland was conductive to growth of YOY warm water fish with recorded temperatures ranging from 18 to 32 ^{o}C (Appendix).

Dissolved oxygen rarely dropped below 5.0 mg/l at any time of day during the study when data were collected.

Nonnative Fish Species Composition

In 2003 the enclosures were over-topped allowing all fish entrained in the wetland access to the enclosures. Two enclosures were sampled to determine initial relative abundance and composition of fish species present following initial inundation of the experimental enclosures. Two 0.32 cm mesh fyke nets were set in each enclosure for one night. These samples consisted primarily of young-of-the-year (YOY) carp (76.5% and 98.4%), followed by red shiner *(Cyprinella lutrensis*; 14.9% and 1.2%*)* and fathead minnow (8.2% and 0.37%). Green sunfish, black bullhead, juvenile white sucker *(Catostomus commersonii)* and sand shiner *(Notropis stramineus)* combined comprised less than 1% of the catch (Table 3).

Table 3. Initial relative abundance and percent composition of fish species captured in two experimental enclosures, June 2003.

Enclosure	YOY Black bullhead	Adult Black bullhead	YOY Carp	Fathead minnow	Green Sunfish	Red Shiner
Number						
3A	62	4	18,327	1966	76	3583
3B	0	0	13,508	51	11	159
Percent Composition						
3A	0.26%	0.02%	76.5%	8.2%	0.32%	14.9%
3B			98.4%	0.37%	0.08%	1.2%

Sampling in 2003, indicated the final nonnative species biomass composition was 75% common carp, 20% fathead minnow, 3% black bullhead, 2% green sunfish and less than 1% red shiners. Nonnative species composition was relatively consistent among enclosures, with the exception of significantly higher (Student's *t*, $P < 0.01$) composition of YOY black bullhead (16.9%) in and enclosure stocked at a density of 4,000 larvae/acre (Table 4). A total of 4,943 black bullhead, 113,907 carp, 23,178 fathead minnow, 2,557 green sunfish and a combined total of 1,380 for red shiner and sand shiner were collected from the enclosures over the four sample periods.

Table 4. Numbers and percent composition by biomass of nonnative fish species collected in each experimental enclosure in the Baeser floodplain wetland, Green River (RM 273), 2003.

Enclosure	Black bullhead		Carp (sub-adult)		Fathead minnow		Green sunfish		Shiners	
	#	%	#	%	#	%	#	%	#	%
1A	68	0.9	5,429	73.3	1,635	22.1	226	3.1	51	0.7
1B	24	0.4	2,863	52.8	2,417	44.5	90	1.7	33	0.6
2A	86	1.8	3,423	71.3	1,021	21.3	236	4.9	36	0.7
2B	56	1.2	2,836	63.0	1,505	33.4	69	1.5	36	0.8
3A	723	4.4	13,010	79.3	1,947	11.9	427	2.6	305	1.9
3B	3,043	16.9	13,431	74.5	1,291	7.2	32	0.2	234	1.3
4A	169	1.5	7,765	70.5	2,617	23.7	276	2.5	194	1.8
4B	245	1.5	12,246	76.1	2,766	17.2	606	3.8	237	1.5
5A	71	0.4	16,987	87.8	2,169	11.2	60	0.3	66	0.3
5B	202	1.5	11,899	87.5	1,237	9.1	97	0.7	159	1.2
6A	205	1.1	16,435	87.7	1,747	9.3	354	1.9	0	0
6B	51	0.5	7,583	71.7	2,826	26.7	84	0.8	29	0.3
Average		2.68		74.63		19.8		2		0.93
Total	4,943		113,907		23,178		2,557		1,380	

Razorback Sucker Survival and Growth

In 2003, depletion of razorback sucker in the enclosures was achieved by sampling each enclosure using three fyke nets set over four nights. All enclosures showed sufficient depletion to allow an abundance estimate with 95% confidence intervals using linear regression (Table 5 and Figure 1). Estimated survival of larval razorback sucker was quite variable ranging from no survival in enclosures stocked at 18,000, 1,200 and 800 larvae/acre to 11% survival in an enclosure stocked at 36,000 larvae/acre. Survival of razorback sucker larvae in the enclosure that had a significantly higher composition of black bullhead was 3.95%. This was the third highest estimated survival rate among the twelve enclosures.

These survival estimates are conservative, based on the likelihood of escapement from the enclosures of larval razorback sucker. Escapement was evaluated by setting nine fyke nets outside and on the perimeter of the enclosures for three nights in 2003. Nonnative species and one bonytail was all that was captured with this effort.

Larval razorback sucker stocked into the experimental enclosures on 20 June 2003 had grown to a mean length of 49 mm at the time of sampling. Growth rates averaged 0.6 mm/day for the average of 64 days they were in the enclosures. Growth rates ranged from 0.40mm/day in and enclosure stocked at 18,000 larvae/acre to 0.92mm/day in and enclosure stocked at 4,000 larvae/acre. Surviving razorback sucker were transferred to The Stirrup floodplain wetland.

Abundance estimates of nonnative species in each enclosure ranged from 3,993 to 15,216 in 2003. Enclosures with higher nonnative fish densities showed comparable survival of razorback sucker as the enclosures containing lower densities of nonnative fish (Table 6; Figure 1). The highest razorback sucker survival was detected in an enclosure with the third highest density of nonnative fish.

Table 5. Larval razorback sucker abundance estimates with 95% confidence limits and mean growth rates for each experimental enclosure at the Baeser floodplain wetland, Green River (RM 273): 2003.

Enclosure	Density Larvae/Acre	Date	Total RZ	Abund. Est.	Lower limit	Upper limit	% Survival	Growth rate (mm/day)
1A	800	8/29/2003	1	0.67		1.78	0.67	0.61
1B	800	8/29/2003	0	0	0		0	
2A	1,200	8/29/2003	0	0	0		0	
2B	1,200	8/29/2003	3	2.00	0	5.33	1.33	0.88
3A	4,000	8/21/2003	46	46.38	44.92	47.84	9.28	0.65
3B	4,000	8/21/2003	20	19.75	15.35	24.15	3.95	0.92
4A	8,000	8/21/2003	10	9.68	8.52	10.83	0.97	0.63
4B	8,000	8/21/2003	2	2.00			0.20	0.47
5A	18,000	8/7/2003	0	0	0		0	
5B	18,000	8/7/2003	34	35.47	34.08	36.85	1.58	0.40
6A	36,000	8/7/2003	481	488.63	483.80	493.46	10.86	0.50
6B	36,000	8/7/2003	10	9.68	8.52	10.83	0.22	0.46
		Total	607	614.26				

Table 6. Nonnative fish abundance estimate with 95% confidence limit in ascending order and percent survival of razorback sucker in each enclosure at the Baeser wetland, 2003 and 2004.

Year	Density larvae/acre	Abundance Estimate	95% CI Lower	95% CI Upper	Razorback sucker percent survival
2003	1,200	3,993	2,037	4,584	0.00
	1,200	4,291	925	5,515	1.33
	800	6,593	-1,686	10,366	0.67
	800	7,083	-5,065	12,774	0.00
	18,000	8,991	8,859	9,123	1.58
	8,000	11,088	9,885	12,290	0.97
	4,000	11,203	10,872	11,534	9.28
	36,000	11,568	10,904	12,232	0.22
	18,000	12,698	12,351	13,044	0.00
	36,000	13,348	12,775	13,922	10.86
	4,000	14,907	14,403	15,412	3.95
	8,000	15,216	14,264	16,167	0.20
2004	400	6,135	3,547	8,724	22.88
	400	6,754	4,321	9,187	6.00
	400	7,264	3,645	10,884	6.18
	2,000	8,212	5,231	11,194	19.49
	40,000	8,736	[a]N/A		3.20
	40,000	9,409	[a]N/A		2.34
	800	11,495	10,368	12,622	5.00
	2,000	11,758	2,308	18,659	13.51
	800	12,653	10,516	14,791	58.08
	400	13,042	9,418	16,666	13.50
	8,000	18,426	17,963	18,890	34.20
	8,000	26,001	-4,469	51,315	21.56

[a] Abundance estimate was not calculated due to lack of depletion attributed to increased sampling efficiency during removal sampling. The survival estimates are based on the total number of razorback suckers captured.

Bonytail Survival and Growth

Larval bonytail escaped from the two enclosures into the surrounding wetland and other enclosures due to water overtopping of the enclosures during unexpected high water in 2003. However, upon sampling the enclosures, survival of bonytail was confirmed. Ten bonytail were captured in eight of the twelve enclosures during evaluation sampling.

These bonytail ranged from 57 to 83 mm total length with a mean length of 70 mm and a mean growth rate of 0.6 mm/day. Surviving bonytail were transferred to The Stirrup floodplain wetland.

2004

Nonnative fish species composition

In 2004, overall nonnative species composition by biomass was 71% common carp, 17% fathead minnows, 12% green sunfish and less than 1% combined total black bullhead, red shiners and sand shiners. A total of 78,870 carp, 20,825 fathead minnow, 16,719 green sunfish and 351 red shiners were collected in fyke net samples (Table 7).

The high numbers of young carp captured following the initial introduction of only two age 1+ carp, indicated that the enclosures were not secure. It is presumed that YOY carp gained access to the enclosures as fry through seams in the enclosure panels or through a gap at the bottom of the enclosure tarp and adult carp entered the enclosures by jumping over the enclosure walls. Water levels were near the top of the enclosure walls for several weeks in 2004 during which time adult carp were observed jumping in and near the enclosures.

Table 7. Numbers and percent composition by biomass of nonnative fish species collected in each experimental enclosure in the Baeser floodplain wetland, Green River (RM 273): 2004.

Enclosure	Carp		Fathead minnows		Green sunfish		Shiners	
	#	%	#	%	#	%	#	%
1A	5392	96.4	14	0.3	184	3.3	4	0.1
1B	4712	67.9	156	2.3	2069	29.8	0	0
2A	6138	91.6	96	1.4	458	6.8	9	0.1
2B	7895	80.8	373	3.8	1494	15.3	6	0.1
3A	10348	90.3	1024	8.9	82	0.7	0	0
3B	8654	78.5	2345	21.3	10	0.1	8	0.1
4A	5922	71.0	2081	23.0	328	3.9	6	0.1
4B	3916	55.7	2599	36.9	285	4.1	202	2.9
5A	8575	48.1	1840	10.3	7410	41.5	15	0.1
5B	4255	30.5	5731	41.0	3894	27.9	92	0.7
6A	6672	70.9	2710	28.8	17	0.2	8	0.1
6B	6391	73.2	1856	21.3	488	5.6	1	0.01
Average		71.24		16.61		11.6		0.36
Total	78870		20825		16719		351	

Razorback Sucker Survival and Growth

In 2004, larval razorback sucker survival was confirmed in all twelve enclosures (Table 8 and Figure 1). Depletion of razorback sucker and bonytail was achieved through multiple sampling of each enclosure. All enclosures, with the exception of the two high density enclosures stocked at a density of 40,000 larvae/acre, showed sufficient depletion to allow an abundance estimate using linear regression (Table 8). Survival ranged from 58% in an enclosure where larvae were stocked at a density of 800 larvae/acre to 2% in the highest density enclosure where larvae were introduced at a density of 40,000 larvae/acre.

The survival estimate of 58% for the enclosure where larvae were introduced at a density of 800 larvae/acre is significantly higher (Student's t, $P < 0.01$) than the survival estimates of the other enclosures. There was no statistically significant difference in the nonnative species composition of this enclosure when compared to that observed in the other enclosures. Enclosures with significant differences in nonnative species composition included one in which larvae were introduced at a density of 4,000 larvae/acre. This enclosure had a significantly higher (Student's *t*, $P < 0.01$) composition of adult black bullhead and adult carp and the abundance estimate represents over 19% survival of larval razorback sucker while the replicate enclosure indicated survival at 14%. Survival of larval razorback sucker ranged from 6 to 23% in the four enclosures, including the two control enclosures, where larvae were introduced at a density of 400 larvae/acre. These enclosures also had a significantly lower (Student's *t*, $P < 0.01$) composition of fathead minnows than the other enclosures (Table 7).

Estimated final densities of nonnative species in each enclosure ranged from 48,705 fish/acre to 209,819 fish/acre in 2004. Estimated razorback sucker survival in each enclosure indicates that higher nonnative fish densities did not negatively affect survival in 2004 (Table 6 and Figure 2). The highest razorback sucker survival was detected in the enclosure with the fourth highest density of nonnative fish.

Table 8. Larval razorback sucker and bonytail abundance estimates with 95% confidence limits for each experimental enclosure at the Baeser floodplain wetland, Green River (RM 273), 2004.

Enclosure	Density Larvae/ Acre	Date	Total	Abund. Est.	Lower limit	Upper limit	% Survival	Growth rate (mm/day)
1A	400	7/23/2004	14	11.44	-0.544	23.42	22.88	0.59
1B	400	7/23/2004	6	3.00	0.650	5.35	6.00	0.73
2A	400	7/23/2004	3	3.09	2.795	3.39	6.18	0.65
2B	400	7/23/2004	8	6.75	0.791	12.71	13.50	0.77
3A	800	7/16/2004	6	5.00	2.853	7.15	5.00	0.56
3B	800	7/16/2004	55	58.08	45.303	70.85	58.08	0.74
4A	2,000	7/16/2004	66	67.53	33.771	101.30	13.51	0.60
4B	2,000	7/16/2004	89	97.43	84.386	110.48	19.49	0.75
5A	8,000	7/9/2004	230	215.63	126.311	304.95	21.56	0.63
5A bonytail	8,000	7/9/2004	177	156.28	91.78	220.78	15.63	0.40
5B	8,000	7/9/2004	323	341.95	318.137	365.75	34.20	0.52
5B bonytail	8,000	7/9/2004	111	165.49	145.81	185.17	16.55	0.34
6A	40,000	7/9/2004	117	[a] N/A			2.34	0.51
6B	40,000	7/9/2004	160	[a] N/A			3.20	0.54
		Total	1365	1117.6				

[a] Abundance estimate was not calculated due to lack of depletion attributed to increased sampling efficiency during removal sampling. The survival estimates are based on the total number of razorback suckers captured.

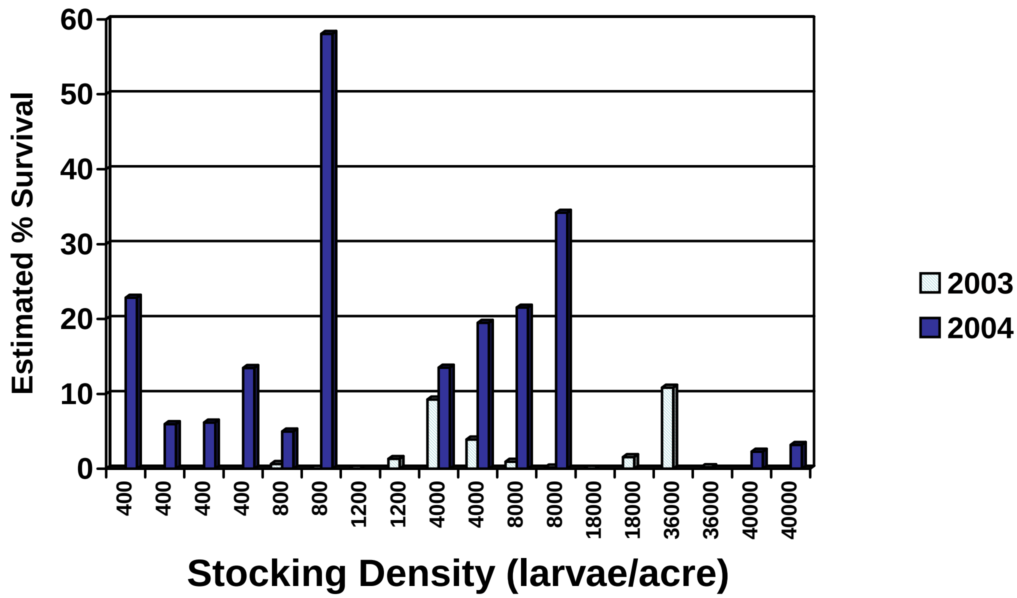

Figure 1. Estimated survival of larval razorback sucker introduced at different densities in the Baeser floodplain wetland, Green River (RM 273), 2003 and 2004.

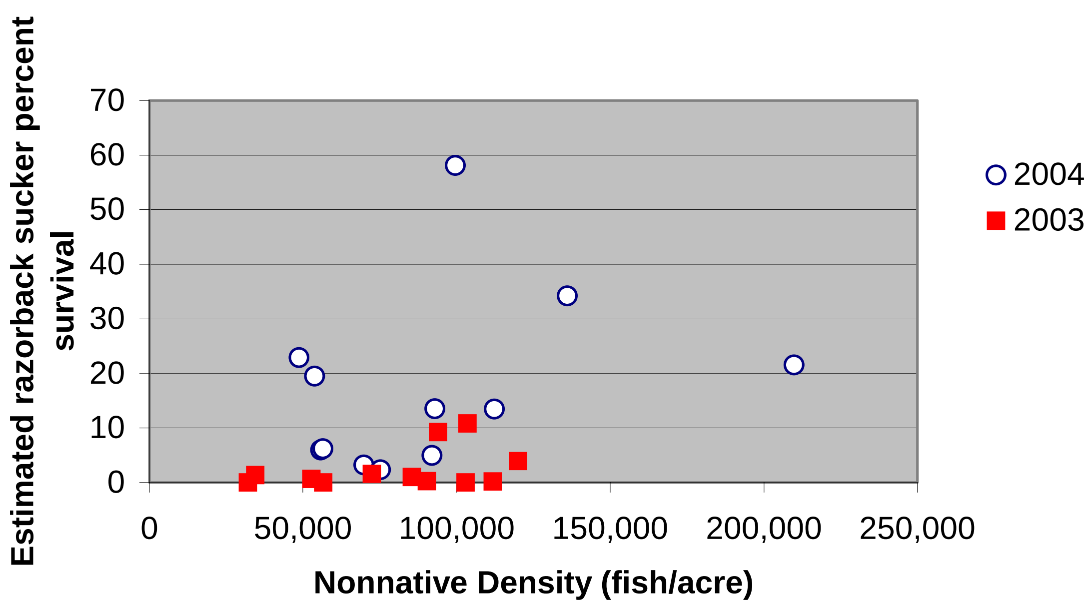

Figure 2. Estimated survival of larval razorback sucker relative to final nonnative fish densities in the Baeser floodplain wetland, Green River (RM 273), 2003 and 2004.

Razorback sucker larvae grew to a mean length of 54 mm from the time they were introduced into the enclosures on 26 April 2004 to the time they were removed from the wetland on 23 July 2004. Total length ranged from 25 to 92 mm and had an average growth rate of 0.6 mm/day. Growth rates ranged from 0.5mm/day in an enclosure stocked at 40,000 larvae/acre to 0.7mm/day in and enclosure stocked at 400 larvae/acre. Approximately 1,000 young-of-the-year razorback sucker were transferred to The Stirrup wetland.

These survival estimates are also conservative, based on the likelihood of escapement of larval razorback sucker and bonytail from the enclosures. Escapement of bonytail was detected by the capture of 31 bonytail in an enclosure adjacent to the enclosures where they were stocked. Bonytail were not captured in any other enclosure. Escapement was also evaluated by setting eight fyke nets (0.32mm mesh) outside and on the perimeter of the enclosures for two nights in 2004. Nonnative species were all that was captured with this effort.

Bonytail Survival and Growth

Bonytail larvae were introduced on 28 April into two enclosures sympatrically with larval razorback sucker at the same density of 8,000 larvae/acre. The estimated survival of bonytail in these two enclosures was 15.6 and 16.5 % (Table 8). Razorback sucker larvae in these two enclosures had an estimated survival of 34.2 and 21.6 %. Surviving bonytail ranged from 21 to 76 mm total length with a mean length of 32.4 mm and average growth rate of 0.4 mm/day. An additional 31 bonytail that had escaped from one or both of the two enclosures where they were stocked were collected in one of the high-density enclosures stocked at 40,000 larvae/acre. Approximately 200 surviving bonytail were transferred to The Stirrup floodplain wetland.

DISCUSSION

The essence of the reset theory is the timing of larvae entering the floodplain. Evidence from this study and the study conducted at The Stirrup in 2002 (Christopherson et al. 2004) indicates that endangered larval fish can withstand the predation from the relatively few adult nonnative fish that enter the floodplain at connection. The Stirrup study demonstrated that larval razorback sucker and bonytail survival could occur following a reset of nonnative fish populations. This study was designed to provide an estimate of the minimum density necessary to detect survival. This study demonstrated that fall YOY survival can be detected following spring larval fish density is as low as 400 larvae/acre in experimental enclosures and survival was detected in both years (2003 and 2004) at densities of 1,200 – 4,000 larvae/acre. Entrainment of larval razorback sucker at a density of 400 larvae/acre into a wetland should result in survival of razorback sucker in the fall. There are several variables and conditions necessary to achieve this density of naturally produced wild razorback sucker larvae in a floodplain wetland. These include:

1) An adequate number of spawning adults.
2) Proximity of the wetland to the area of spawning.
3) Survival of drifting larvae.
4) Dynamics of river flows and conditions required to entrain larvae into the floodplain wetland.

Once larvae have been entrained into a wetland in sufficient densities and survive, these juveniles or adults need to recruit back to the river. This requires the wetland to persist with sufficient water quality and depth to allow survival of remaining razorback sucker and bonytail until they can access the river during spring river-floodplain connection. These variables and habitat conditions should be investigated and synthesized to outline management actions necessary to aid recovery.

Survival estimates indicate that fall survival of larval razorback sucker is independent of nonnative fish densities. This is consistent with the reset theory. The adult fish, primarily fathead minnow, red shiner, green sunfish and black bullhead, entrained along with larval suckers during the initial flooding of the wetland are the primary fish predators on larval razorback sucker. Once larval razorback sucker are entrained in the productive wetland, they are able to grow fast enough to avoid predation by numerous YOY nonnative predators produced in the wetland.

The use of enclosures to maintain tighter control over the experiment presented some problems during this study. In 2004, many nonnative fish in excess of those stocked were collected in the control enclosures indicating that the enclosures were not completely secure. Escapement of bonytail was observed and therefore escapement of razorback sucker larvae was also very likely. However, razorback sucker were not captured during sampling outside of the enclosures. Presumably, escapement was minimal, with the exception of bonytail introduced in 2003 prior to water overtopping the enclosures. Escapement causes the survival estimates to be conservative. However, we feel it did not affect conclusions of this study.

CONCLUSIONS

- Estimated larval razorback sucker survival in the experimental enclosures ranged from 0 – 58% and growth rates averaged 0.6 mm/day in 2003 and 0.6 mm/day in 2004 in the presence of nonnative predators.
- Larval razorback sucker survival was detected 88 days following introduction at a density as low as 400 larvae/acre.
- Bonytail larvae introduced sympatric with razorback sucker larvae at a density of 8,000 larvae/acre had an estimated survival of 16 – 17% in 2004 and a growth rate of 0.6 mm/day in 2003 and 0.4 mm/day in 2004.
- Larval bonytail survival was detected 106 days following introduction in 2003.
- Larval bonytail survival was detected 66 days following introduction sympatrically with razorback sucker larvae in 2004 at a density of 8,000 larvae/acre.

RECOMMENDATIONS

- Actions to identify monitor and manage variables and conditions necessary to achieve entrainment of at least 400 larvae/acre should be implemented.
- Continue to manage floodplains based on the reset theory. Even with abundant nonnative fish predators, these habitats are important to endangered fish and should be used for recovery.
- During an average to high flow year, introduce larval razorback suckers into floodplain sites that have reset to test this theory under more natural conditions. This should include introducing larval razorback sucker at a density of at least 400 larvae/acre.

- Evaluate methods to improve larval razorback sucker entrainment including connection configuration, location, and river discharge. Entraining large numbers of larvae may be needed for recovery.
- Evaluate conditions necessary for razorback suckers and bonytail to recruit back to the river.

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APPENDIX A

Water Quality Data: Baeser 2003

Log File Name: BAESER 6-25-03
Setup Date (MMDDYY) : 062503
Setup Time (HHMMSS) : 142811
Starting Date (MMDDYY) : 062503
Starting Time (HHMMSS) : 150000
Stopping Date (MMDDYY) : 062603
Stopping Time (HHMMSS) : 120000
Interval (HHMMSS) : 010000
Warmup : Enable

==> Follow Variable and Calibration Change(s) <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Turb NTU
62503	150000	18.42	8.28	0.879	0.5	112.1	8.84	15.3
62503	160000	19.91	8.41	0.881	0.5	128	9.8	13.2
62503	170000	19.71	8.35	0.878	0.5	121	9.3	15.6
62503	180000	19.79	8.36	0.883	0.5	110.1	8.45	17.4
62503	190000	19.98	8.35	0.884	0.5	117.6	8.99	17.1
62503	200000	20.71	8.32	0.882	0.5	123.3	9.29	15.3
62503	210000	20.48	8.32	0.886	0.5	109.1	8.26	17.3
62503	220000	20.81	8.33	0.884	0.5	114.7	8.63	14.6
62503	230000	20.52	8.37	0.885	0.5	106.6	8.06	15.4
62603	0	20.8	8.31	0.878	0.5	113.3	8.52	13.4
62603	10000	20.52	8.36	0.885	0.5	113.8	8.61	12.9
62603	20000	20.09	8.35	0.885	0.5	111.1	8.48	12.7
62603	30000	19.69	8.34	0.886	0.5	107	8.22	12.7
62603	40000	19.35	8.29	0.886	0.5	99.7	7.72	13.3
62603	50000	19.01	8.27	0.886	0.5	93.8	7.31	13.7
62603	60000	18.67	8.18	0.886	0.5	83.2	6.53	17.2
62603	70000	18.41	8.2	0.886	0.5	84.2	6.65	14.8
62603	80000	18.39	8.2	0.886	0.5	91.2	7.2	12.9
62603	90000	18.65	8.26	0.885	0.5	100.8	7.91	12.2
62603	100000	19.07	8.31	0.887	0.5	104.6	8.15	12.1
62603	110000	19.14	8.29	0.885	0.5	96	7.46	13.5
62603	120000	19.56	8.28	0.888	0.5	99.1	7.64	13.4

Recovery finished at 062603 165129

Log File Name : BAESER 7-7-03
Setup Date (MMDDYY) : 070703
Setup Time (HHMMSS) : 134007

Starting Date (MMDDYY) : 070703
Starting Time (HHMMSS) : 140000
Stopping Date (MMDDYY) : 070903
Stopping Time (HHMMSS) : 140000
Interval (HHMMSS) : 010000
Warmup : Enable

==> Follow Variable and Calibration Change(s) <==

Date	Time	Temp	pH	SpCond	Salin	DO	DO	Turb
MMDDYY	HHMMSS	degC	units	mS/cm	ppt	%Sat	mg/l	NTU
70703	140000	25.23	8.48	1.153	0.6	114	7.8	16.4
70703	150000	25.45	8.55	1.158	0.6	108.1	7.37	0
70703	160000	25.71	8.54	1.164	0.6	104.3	7.08	0
70703	170000	26.53	8.66	1.158	0.6	131.2	8.77	17.6
70703	180000	26.46	8.55	1.165	0.6	114.2	7.65	21.3
70703	190000	26.85	8.6	1.162	0.6	121.7	8.09	20.2
70703	200000	26.65	8.47	1.174	0.6	92.6	6.18	27.7
70703	210000	26.99	8.49	1.167	0.6	102.4	6.79	25.2
70703	220000	27.23	8.49	1.156	0.6	116	7.66	22.8
70703	230000	26.89	8.44	1.149	0.6	121.4	8.06	31.5
70803	0	26.29	8.44	1.15	0.6	122.3	8.21	30.9
70803	10000	25.79	8.43	1.15	0.6	118.8	8.05	22.9
70803	20000	25.34	8.42	1.151	0.6	116.1	7.93	23.3
70803	30000	24.92	8.41	1.151	0.6	113	7.78	19.5
70803	40000	24.47	8.4	1.152	0.6	110.1	7.65	15.1
70803	50000	24.04	8.38	1.152	0.6	104.4	7.31	15.6
70803	60000	23.63	8.37	1.152	0.6	99.9	7.05	20.7
70803	70000	23.29	8.39	1.154	0.6	96.6	6.86	23.5
70803	80000	23.37	8.43	1.152	0.6	103.3	7.32	21.2
70803	90000	23.72	8.46	1.157	0.6	112.9	7.95	20.3
70803	100000	23.87	8.47	1.158	0.6	120.8	8.48	21.2
70803	110000	23.98	8.48	1.159	0.6	123.7	8.66	26.5
70803	120000	24.62	8.52	1.157	0.6	142.3	9.85	22.7
70803	130000	24.98	8.57	1.16	0.6	144.3	9.92	24.3
70803	140000	25.09	8.58	1.166	0.6	142.2	9.76	0
70803	150000	27.9	8.66	1.177	0.6	135	8.81	0
70803	160000	29.27	8.78	1.162	0.6	186.7	11.89	28
70803	170000	28.66	8.75	1.165	0.6	165.3	10.64	34.4
70803	180000	27.76	8.74	1.167	0.6	146.1	9.56	35.7
70803	190000	26.58	8.74	1.167	0.6	129.9	8.68	34.5
70803	200000	25.45	8.73	1.17	0.6	121.2	8.26	35.2
70803	210000	24.75	8.67	1.171	0.6	110.4	7.63	35.1
Date	Time	Temp	pH	SpCond	Salin	DO	DO	Turb
MMDDYY	HHMMSS	degC	units	mS/cm	ppt	%Sat	mg/l	NTU
70803	220000	24.26	8.65	1.172	0.6	100.6	7.01	40.3

70803	230000	23.83	8.61	1.174	0.6	96	6.75	37.7
70903	0	23.48	8.56	1.175	0.6	91.1	6.44	32.9
70903	10000	23.13	8.55	1.177	0.6	84.6	6.02	35.9
70903	20000	22.76	8.54	1.177	0.6	79.4	5.69	33.1
70903	30000	22.43	8.53	1.178	0.6	76.4	5.51	35.3
70903	40000	22.06	8.47	1.178	0.6	72.8	5.29	36.6
70903	50000	21.69	8.46	1.179	0.6	69.2	5.06	38
70903	60000	21.37	8.44	1.181	0.6	66.7	4.91	36.4
70903	70000	21.14	8.44	1.18	0.6	66.5	4.92	38.1
70903	80000	21.22	8.49	1.178	0.6	75.6	5.58	26.4
70903	90000	21.54	8.59	1.179	0.6	91.8	6.73	30.7
70903	100000							

Recovery finished at 071603 085412

Log File Name : BAESER 7-14-03
Setup Date (MMDDYY) : 071403
Setup Time (HHMMSS) : 143920
Starting Date (MMDDYY) : 071403
Starting Time (HHMMSS) : 150000
Stopping Date (MMDDYY) : 071603
Stopping Time (HHMMSS) : 150000
Interval (HHMMSS) : 010000
Warmup : Enable

==> Follow Variable and Calibration Change(s) <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Turb NTU
71403	150000	29.27	8.67	1.305	0.7	186.3	11.84	0
71403	160000	30.34	8.72	1.279	0.7	99999	99999	0
71403	170000	32	8.75	1.273	0.7	99999	99999	0
71403	180000	30.64	8.8	1.273	0.7	99999	99999	12.4
71403	190000	31	8.77	1.291	0.7	99999	99999	14.5
71403	200000	30.51	8.75	1.295	0.7	99999	99999	16.2
71403	210000	29.92	8.72	1.298	0.7	99999	99999	18.4
71403	220000	29.32	8.66	1.29	0.7	192.8	12.23	15.7
71403	230000	28.48	8.6	1.29	0.7	185.4	11.94	16.5
71503	0	27.95	8.54	1.29	0.7	177.2	11.52	17.1
71503	10000	27.57	8.47	1.294	0.7	164.3	10.75	17.2
71503	20000	27.02	8.41	1.297	0.7	152.5	10.08	18.6
71503	30000	26.6	8.34	1.303	0.7	137.8	9.17	20.3
71503	40000	26.29	8.29	1.308	0.7	119.1	7.98	20.7
71503	50000	25.95	8.2	1.315	0.7	101.4	6.83	21.1
71503	60000	25.65	8.1	1.324	0.7	82.7	5.6	23.8
71503	70000	25.35	8.11	1.331	0.7	74.9	5.1	26.6
71503	80000	25.12	8.14	1.331	0.7	75	5.13	28.3
71503	90000	25.21	8.2	1.33	0.7	83.6	5.71	23.5
71503	100000	25.83	8.35	1.329	0.7	101	6.82	15.7
71503	110000	26.45	8.46	1.326	0.7	126.9	8.47	0
71503	120000	27.38	8.59	1.329	0.7	155.3	10.19	0
71503	130000	28.12	8.69	1.328	0.7	191	12.38	12.8
71503	140000	28.66	8.78	1.339	0.7	99999	99999	0
71503	150000							

Recovery finished at 071603 085212

APPENDIX B