ANNUAL REPORT
SMALL-BODIED FISHES MONITORING
SAN JUAN RIVER
Conducted September 2012

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San Juan River Basin Recovery Implementation Program

ANNUAL REPORT
SMALL-BODIED FISHES MONITORING
SAN JUAN RIVER

to

Bureau of Reclamation

From

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EXECUTIVE SUMMARY

Small-bodied fish autumn monitoring on the San Juan River resulted in the capture of 26 Colorado pikeminnow *Ptychocheilus lucius*. Most captures occurred in Reaches 6 and 5. The size range of fish collected was between 115-203 mm (total length). This was the second consecutive year since 1998-1999 that roundtail chub *Gila robusta* was collected. No razorback sucker *Xyrauchen texanus* was captured in 2012.

Although there is variation in the annual density of Colorado pikeminnow captured during small-bodied monitoring in the San Juan River, little difference in the distribution of this species was observed. The longitudinal distribution of Colorado pikeminnow, as defined by geomorphic reach and measured using catch per unit effort and frequency of capture, was not significantly different. The fish assemblages in the primary channel and secondary channels were different based upon results from a discriminant function analysis. Yet, the density of Colorado pikeminnow was not different between these two channel types or among backwaters.

Calculation of the potential to predict recruitment of channel catfish using time-lag analyses was continued from that conducted in 2011. The time-lag analysis suggests, the capture of age-0 channel catfish can successfully predict the maximum density of juveniles in subsequent years. Predictions of adult channel catfish recruitment, using age-0 and juvenile capture data and time-lag analyses, were not sucessful.

Additional sampling was conducted in 2012, in restored secondary channels and in upper portions of the San Juan River. Species richness and density of small-bodied fishes in naturally flowing and restored secondary channels were not different. Additional sampling in the San Juan River above its confluence with the Animas River did not result in the capture of Colorado pikeminnow or razorback sucker but potential Colorado pikeminnow prey was present.

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INTRODUCTION

The San Juan River Basin Recovery Implementation Program's (SJRIP) Long-Range Plan specifies that fish populations of the San Juan River will be monitored (Element 4; SJRIP 2012a). Task 4.1.2.2 of this plan specifies monitoring of juvenile and small-bodied fishes. The purpose of this monitoring is to provide information on fishes that occur in shallow-water habitats and the relation of these data to recovery of Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus*. Monitoring occurs in autumn to characterize the survival and/or recruitment of small-bodied and age-0 fishes. Recruitment of wild-spawned Colorado pikeminnow and razorback sucker has yet to be documented. Therefore, autumn small-bodied monitoring currently provides information on the survival and distribution of stocked age-0 and age-1+ Colorado pikeminnow and the native/nonnative fish assemblage, as well as the habitats used by these fishes.

Small-bodied and age-0 fishes numerically dominate the San Juan River fish assemblage and are an important component of the diet of piscivorous fishes in the San Juan River (Franssen et al. 2007, 2012). This is especially true for young Colorado pikeminnow whose ontogenic shift to piscivory may affect their recruitment probability as shown for other species of predatory fishes (Garvey and Stein 1998; Persson and Brönmark 2002). One goal of this research was to determine if Colorado pikeminnow encounter different prey or potential competitors in the primary channel as compared to secondary channels.

Element 3 of the SJRIP's Long-Range Plan is to control problematic nonnative fishes as needed (SJRIP 2012a). Currently, a large amount of effort is focused on the removal of channel catfish *Ictalurus punctatus*, a nonnative fish that may negatively affect Colorado pikeminnow and razorback sucker either as a predator or competitor (Marsh and Brooks 1989; Marsh and

Douglas 1997; Edds et. al 2002). The SJRIP designed larval fish monitoring to sample Colorado pikeminnow and razorback sucker and few larval channel catfish are detected (Brandenburg et al. 2012). It is believed that nursery habitat for channel catfish in the San Juan River is in fast flowing cobble nest habitats whereas Colorado pikeminnow and razorback sucker are more likely to be present in low water velocity habitat. Approximately one percent of the total catch of larval fishes has been channel catfish. Small-bodied monitoring has resulted in higher catches of channel catfish (approximately eight percent of total catch). Time-lag analyses conducted in 2011 showed a relationship existed between the capture of young-of-year channel catfish and the capture of juvenile channel catfish. Additional analyses were conducted in 2012 to strengthen the understanding of this relationship.

In 2011, The Nature Conservancy (TNC), through a grant from the New Mexico River Ecosystem Restoration Initiative (RERI) and in partnership with the Navajo Nation, US Fish and Wildlife Service, Bureau of Reclamation, and the SJRIP, restored channel complexity along portions of the San Juan River by increasing the amount of wetted secondary channel habitat. The project improved six sites, restoring 3.5 miles of secondary channels and 6.5 acres of riparian vegetation along six miles of river using channel sluicing, mechanical clearing and chemical treatment of invasive plant species, inlet re-establishment and cleaning, and excavation of secondary channels. In 2012, sampling was conducted in these secondary channels to determine whether the fish assemblage at these sites compared to naturally flowing secondary channels.

To expand the range of Colorado pikeminnow and razorback sucker, hatchery stocking of these species occurs in the San Juan River upstream of its confluence with the Animas River as well as in the Animas River (Furr 2011, 2012a, 2012b). In 2012, the SJRIP expanded adult and

small-bodied fish monitoring to reaches of the San Juan River upstream of Animas River confluence. This is the first time since the mid-1990s that adult and small-bodied fish sampling has been conducted in this portion of the San Juan River by the SJRIP. Sampling in these areas could determine if Colorado pikeminnow and razorback sucker augmentation can expand the range of these two species and if potential Colorado pikeminnow prey occurs in these areas.

Assessment of small-bodied fish sampling protocol and application of the overall monitoring program is a continual effort. In 2011, the SJRIP determined that an additional sampling method should be undertaken to sample a faster and deeper off-shore mesohabitat (Golden and Holden 2006). This additional method was paired with standardized sampling methods to assess its ability to capture additional species and size classes of fish. The SJRIP also requested a power analysis to determine whether small-bodied monitoring could be changed from sampling annually to biennially without losing the ability to detect changes in population trends. Analyses of this additional sampling method and the potential change in sampling regime are presented in the following report.

METHODS

Study-Site and Sampling Methods

Small-bodied fish sampling has occurred throughout the San Juan River every year since 1998 (Figure 1). In 2012, sampling effort was extended in the San Juan River upstream of the confluence with the Animas River, located at river mile (RM) 180.5, Reach 6 and occurred from Bloomfield (RM 194.4, Reach 6) to Sand Island (RM 76.4, Reach 3) (Figure 1). This is an upstream increase in sampling of 13.9 river miles. From 1998-2010, autumn monitoring occurred from the San Juan River and Animas River confluence downstream to Clay Hills Crossing (RM 3.0, Reach 1). As of 2011, autumn monitoring only occurs downstream from Sand Island to Clay Hills Crossing every fifth year; the next effort in this reach will be in 2015.

From 1998-1999, a secondary channel was sampled only if it occurred within the 1-mile reach to be sampled at every 3-mile interval (designated mile). This protocol excluded a large proportion of secondary channels (30 to 50%, depending upon the starting point of the designated mile). Beginning in 2000, attempts were made to sample all secondary channels >200 m in length which had surface water.

From 1998-1999, the primary channel was sampled at each sampled secondary channel or designated mile if no secondary channel was present in a 3-mile reach. Since 2000, fishes were collected from primary channel habitats at each designated mile whether or not a secondary channel was present. Small-bodied monitoring occurs in conjunction with sub-adult/adult monitoring and designated miles were coordinated to occur in miles that were skipped by the sub-adult/adult monitoring crews. All backwaters (>50 m^2), regardless of occurrence within a designated mile, were sampled.

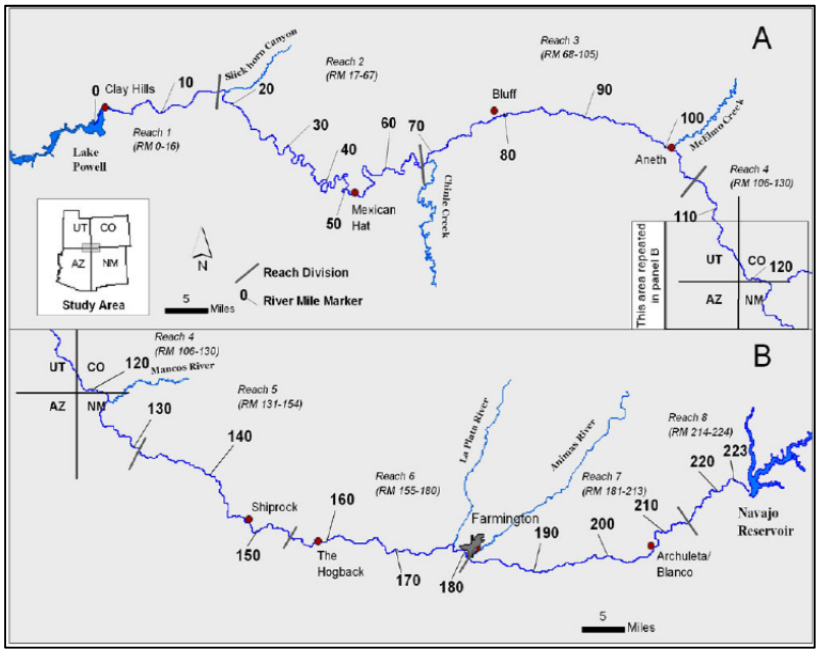

Figure 1. Map of the San Juan River including river miles and geomorphic reaches.

Primary channel sample sites were about 200 m long (measured along the shoreline). Lengths of secondary channel sample sites varied depending upon extent of surface water but were normally 100-200 m. River mile, geographic coordinates, and water quality (pH, dissolved oxygen, conductivity, and temperature) were recorded for each site. Within each site (primary and secondary channel), all mesohabitats (e.g. riffle, run, pool) were sampled in rough proportion to their surface area within a site (see Bliesner and Lamarra 2000 for full list of mesohabitats and definitions). Beginning in 2003, fish data from each mesohabitat within a site were recorded separately.

Most primary channel mesohabitats sampled were along stream margins, but offshore riffles and runs (<0.75 m deep) were also sampled. Secondary channel sampling was across the breadth of the wetted channel. All available wadeable mesohabitats within a site were sampled. Uncommon mesohabitats (e.g., debris pools and backwaters) were sampled in greater proportion to their availability than common mesohabitats (e.g., runs, riffles, shoals).

All mesohabitat types available at a site were sampled. At least five seine hauls (each seine haul samples a distinct mesohabitat) were made at each sample site. However, if habitat was homogeneous, as few as three seine hauls in secondary channels were made. Where there was high habitat diversity, as many as 22 seine hauls in the primary channel and 11 seine hauls in secondary channels were made. Typically, two seine hauls were made in each backwater, one across its mouth and the second parallel to the long axis of the backwater. In backwaters that were not large enough to make two seine hauls, one seine haul was made from the mouth, parallel to the long axis of the backwater to the point where water was no longer present.

Fishes were collected with a 2.2 m x 1.9 m x 3.0 mm mesh drag seine (Figure 2). Each catch was inspected to determine presence of protected species. Total length (TL) of each fish was measured, recorded, and the fish released. In some years, subsamples of >50 individuals of each native fish species, chosen to approximate the proportion of sizes present, were measured for each seine haul; the remainder were counted and released. If native fishes were too small to identify they were fixed in 10% formalin and returned to the laboratory. Nonnative fishes were removed from the river after measurements were taken and recorded. If nonnative fishes were found in such abundance that it was not feasible to measure them in the field, they were fixed in 10% formalin and returned to the laboratory.

In 2011 and 2012, additional collections were made using two 9.1 m x 1.9 m x 6.0 mm mesh seines. With these larger seines, a “block seining” technique was used (Golden and Holden 2006; Figure 2). One seine was held at the bottom of the mesohabitat and the second seine was used to seine downstream through the mesohabitat. A single sample was made in the primary channel at most designated miles.

Figure 2. Seining methods: two meter drag seine (top) and nine meter block seining (middle and bottom).

Following fish collection, the area (length x width) of each sampled mesohabitat was measured and recorded. For each mesohabitat, habitat type, depth in five generalized locations, and dominant substrate at each depth measurement were recorded. Any cover associated with the habitat was also recorded.

Retained specimens were identified, enumerated, and measured (total and standard length) in the laboratory. Personnel of the University of New Mexico Museum of Southwestern Biology (UNM-MSB), Division of Fishes and American Southwest Ichthyological Researchers, assisted in verification of fishes identified in the laboratory. All retained specimens were accessioned to the UNM-MSB, Division of Fishes.

Data Analysis

Catch per unit effort (CPUE) was calculated as the number of fish captured per square meter at a given sample site. In this report, density refers to CPUE and is the number of fish captured per square meter, unless otherwise indicated. Due to the natural variability seen with age-0 fish populations, probability values of <0.10 were considered significant (Brown and Guy 2007); although an alpha of 0.05 was used when assessing normality and homogeneity of variance. All statistical tests were run using SPSS® Software. Data for all years (1998-2012) are available from the U.S. Fish and Wildlife Service Program Office, Albuquerque, NM.

Colorado Pikeminnow Distribution

Differences in the CPUE of Colorado pikeminnow (captured between 2004-2012) among geomorphic Reaches 1 through 6 (as defined by Bliesner and Lamarra 2000) were tested. Since sampling in Reaches 1 and 2 last occurred in 2010, multiple tests were applied to different subsets of data collected. Only the data for Reaches 2 through 6 (years 2004-2010) and Reaches 3 through 6 (years 2004-2012) passed assumptions of normality and equal variance

(Kolmogorov-Smirnov, $p>0.05$ and Levene's test, $p>0.05$). Thus, an Analysis of Variance (ANOVA) was conducted to assess differences in mean density of Colorado pikeminnow among geomorphic reaches using these two data sets. To include data from Reach 1, a Friedmans's nonparametric test was used to determine if there was a difference in the median density of Colorado pikeminnow among Reaches 1 through 6 (years 2004-2010).

Since Colorado pikeminnow were caught consecutively from 2004-2012, these data were used to assess difference in the density of Colorado pikeminnow among channel types. The CPUE data for Colorado pikeminnow captured in the primary channel, secondary channels, and backwaters were not normally distributed (Kolmogorov-Smirnov, $p<0.05$) and were log+0.001 transformed. Log transformed CPUEs from the primary channel and secondary channel passed assumptions of normality and homogeneity (Kologorov-Smirnov $p>0.05$, Levene's test, $p>0.05$). Thus, a paired t-test was used to determine if there was a difference in Colorado pikeminnow mean CPUE between secondary channels and the primary channel. A Friedman's nonparametric test was used to determine if there was a difference in the median CPUE rank for backwaters, secondary channels and the primary channel. These tests were run including and excluding data from Reaches 1 and 2. When the Friedman's test indicated a significant difference, a Wilcoxon signed-rank test was used to determine which pairwise comparisons were significantly different.

Primary and Secondary Channel Fish Communities

A discriminant function analysis (DFA) was conducted to investigate whether differences existed between the fish community in the primary channel and secondary channels. CPUE of channel catfish, mosquitofish *Gambusia affinis*, red shiner *Cyprinella lutrensis*, bluehead sucker *Catostomus discobolus*, flannelmouth sucker *Catostomus latipinnis*, fathead minnow *Pimephales promelas*, speckled dace *Rhinichthys osculus*, and Colorado pikeminnow from 2003-2012 were

independent variables. With the exception of Colorado pikeminnow, each species was captured >10% of the time. To approximate normality and stabilize variances, all densities were log+0.001 transformed. Data from Reaches 1 and 2 were excluded as only three secondary channels in these reaches were sampled in the last ten years. The parameters of the DFA were set such that all independent variables were entered together, all groups were considered equal, and a within-group covariance matrix was used.

Channel Catfish Recruitment

Time-lag analyses were used to determine if the density of juvenile and adult channel catfish could be predicted by the capture of young-of-year channel catfish. Densities of channel catfish were log+0.001 transformed to stabilize variance. Data from 2002-2011, Reaches 1 through 5 were used in the analyses; few captures of channel catfish occur in Reach 6. Data for young-of-year channel catfish captures were obtained from the small-bodied monitoring and excluded captures of channel catfish >100 mm (TL). Data for juvenile and adult channel catfish captures were obtained from sub-adult/adult monitoring (Ryden 2002-2011).

Time lag analyses were conducted by plotting the density of young-of-year channel catfish at year x (Reach 1) against the density of juvenile channel catfish captured in year x+1 year, x+2 years, and x+3 years (Reach 1). This was repeated for Reaches 2 through 5. For example, one point on the plot was the density of young-of-year channel catfish captured in Reach 1 in 2002 plotted against the density of juvenile channel catfish captured in Reach 1 in 2003 (one year later). This same method was used to plot the relationship of the density of young-of-year channel catfish captured in year x against the density of adult channel catfish captured in year x+3 years, x+4 years and x+5 years. For comparisons of the relationship between juvenile captures of channel catfish and adult captures of channel catfish, capture of

juveniles in year x were plotted against capture of adults in year x+1 year, x+2 years, and x+3 years. Multi-year plots were conducted as an age class (for example juveniles range from 61-299mm TL) can be made up of multiple cohorts.

River Ecosystem Restoration Initiative Secondary Channels

In 2012, four RERI sites and four associated control sites were sampled to compare the species richness and density of fishes (Figure 3,

Table 1). Species richness comparisons were simply a tabulation of the average number of species captured at RERI and control sites. Since the samples sizes were small, a Shapiro-Wilks test was used to determine if the distributions of untransformed and log+0.001 transformed CPUE resulted in normal distributions for flannelmouth sucker, bluehead sucker, speckled dace, Colorado pikeminnow, fathead minnow, mosquitofish and channel catfish. Untransformed speckled dace, red shiner, and log+0.001 transformed mosquitofish CPUE passed assumptions of normality and equal variance (Shapiro-Wilks, $p>0.05$ and Levene's test, $p>0.05$). Thus, independent t-tests were used to compare the mean density between RERI sites and control sites for these species. A nonparametric, Mann-Whitney U test was used to compare the density of flannelmouth sucker, bluehead sucker, Colorado pikeminnow, channel catfish, fathead minnow, and mosquitofish between RERI sites and control sites.

Figure 3. River Ecosystem Restoration Initiative sites (circles) and control sample sites (triangles).

Table 1. Location of RERI and control sites with associated river miles sampled during small-bodied monitoring, Autumn 2012.

Site Type	River Mile
Control	134.3
Control	133.5
RERI	132
Control	130.1
RERI	130.7A
RERI	130.7B
RERI	127.2
Control	122.7

San Juan River Upstream of San Juan- Animas Confluence

To determine if there was a difference in the density of fishes upstream (13.9 river miles) of the San Juan River and Animas River confluence and downstream, the densities of fishes collected from the 13.9 river miles downstream of river mile 180.5 were used. The CPUE data for bluehead sucker and speckled dace passed assumptions of normality and equal variance (Kolmogorov-Smirnov, $p>0.05$ and Levene's test, $p>0.05$). Thus, independent t-tests were used to determine if there was a difference in the mean density of bluehead sucker and speckled dace between upstream and downstream sampling. Since the CPUE data for flannelmouth sucker, fathead minnow, mosquitofish, and plains killifish were not normally distributed (Kolmogorov-Smirnov, $p<0.05$) a Mann-Whitney U test was used to identify differences in the median density of these species between the upstream and downstream reaches.

Comparison of Two Meter Drag Seining and Nine Meter Block Net Seining

We compared captures of fishes collected using a two meter drag seine method and a nine meter block net seining method. All nine meter block seining occurred in the primary channel and most often in run habitats. To make paired comparisons between this method and the two meter drag seine method, all samples made in the primary channel in run type habitats using two meter drag seining were included in the analysis. Because only a single nine meter block seining sample was made at a single site, Colorado pikeminnow, bluehead sucker, flannelmouth sucker and channel catfish CPUE was calculated as the number of fish captured divided by the area seined (m^2). CPUE for the two meter drag seine hauls was calculated as the sum off fish captured divided by the sum of the area (m^2) of all seine hauls made in run type habitats at each site.

These data did not pass assumptions necessary to conduct paired t-tests. CPUEs were not normally distributed and a log+0.001 transformation did not result in a normal distribution (Kolmogorov-Smirnov, $p<0.05$). Thus, a Wilcoxon signed-rank test was used to make paired comparisons of the CPUEs for species captured using the two different seining techniques.

Power Analysis of Annual and Biennial Monitoring

The statistical power to detect a 20% annual change in the density of small-bodied fishes, either through annual or biennial sampling, over the next 10 years was conducted using the software MONITOR (Gibbs and Ene 2010). MONITOR uses a Monte Carlo simulation approach and user defined sampling design. To create the statistical power curves for each species, an estimate of the magnitude and variation in the densities of Colorado pikeminnow, bluehead sucker, flannelmouth sucker, speckled dace, channel catfish, and red shiner were calculated. The magnitude, which is the initial value from which trends are projected, was the average of annual means (2003-2012). Total variation was the standard deviation of annual means. To normalize the data, density (in this instance number of individuals/km^2) was log+1 transformed. Power estimates were based on 1000 iterations and simulations were run using exponential trend projection, constant standard deviation over time, and simple regression. At each survey occasion (N=10 for annual monitoring and N=5 for biennial monitoring), densities were generated randomly from a distribution with the mean equal to the initial magnitude and a variance approximated by the standard deviation. Power was calculated based on the proportion of iterations where the slope of a least-squares regression of the plot of densities versus survey occasion differed significantly from zero ($p>0.05$).

RESULTS

River-wide Summary

Slightly more than 50% of the fishes captured during autumn small-bodied monitoring in 2012 were native (Table 2). The total number of fishes captured in 2012 was low compared to the prior 10 years (2002-2011) and was about half that of the prior 10-year mean. Although Reaches 1 and 2 were not sampled in 2012, the mean density of all species captured in the primary channel, secondary channels and backwaters was within the range observed in prior years (Appendix II-Appendix IV). More Colorado pikeminnow were captured in 2012 (N=26) compared to the 10-year mean, but razorback suckers were not collected during the 2012 small-bodied fish monitoring. Two roundtail chub *Gila robusta* (131 mm TL and 119 mm TL) were captured in the San Juan River near its confluence with the Mancos River (RM 123.9 and 134.3).

Table 2. Summary of fish captures in the San Juan River 2012 small-bodied fish monitoring effort. *Razorback sucker captured in 2005 was 405 mm TL.

	2012	2002- 2011 Mean	2002 – 2011 Range
Total Fishes	4,673	9,783	3,795 - 29,785
Native Fishes	2,436	3,079	1,130 – 6,845
Non-native Fishes	2,237	6,699	787 – 22,939
Colorado Pikeminnow	26	20	0-62
Razorback sucker	0	0	0-1*
Roundtail chub	2	0	0-2

Colorado Pikeminnow Distribution

Since 1998, Colorado pikeminnow was captured during small-bodied monitoring each year, with the exception 2001-2003 (Appendix I). In 2012, a total of 26 individual Colorado pikeminnow were captured (Table 3). The length of fish captured ranged in size from 115 to 203 mm TL (Table 3). Although Colorado pikeminnow has been captured throughout the San Juan River each year since between 2004, the locations of these captures do not appear to be consistent (Figure 4). Among years, the catch per unit effort at river miles in which capture occurred also varied (Figure 4).

Table 3. Summary of 2012 Colorado pikeminnow captures in the San Juan River. Reaches 1 and 2 not sampled.

Length Category (total length in mm)	Number of Captures in each Reach				
	6	5	4	3	Total
100					26
110	1				
120	3	1			
130					
140	1	3	1	1	
150	3				
160	2	1		1	
170	1			1	
180					
190	2	1	1		
200	1		1		
Total	14	6	3	3	

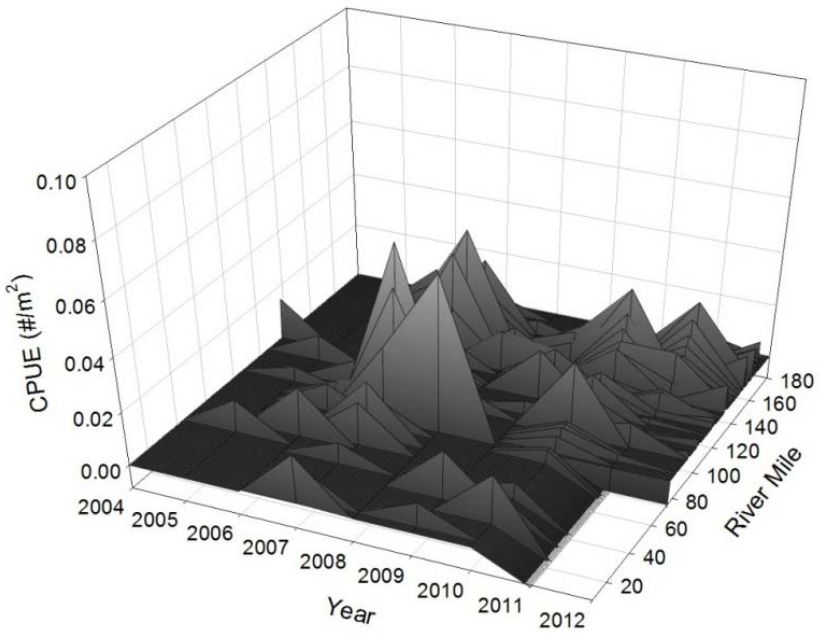

Figure 4. Annual and longitudinal distribution of Colorado pikeminnow (CPUE): 2004-2012.

The mean CPUE of Colorado pikeminnow in the San Juan captured from 2004-2012 was 0.002 fish/m^2 (SD = 0.001). The mean CPUE for Colorado pikeminnow, specifically for 2012, was 0.001 fish/m^2. The highest CPUE values occurred upstream of the canyon bound portion of the San Juan River (upstream of Reaches 1 and 2) (

Figure 6; Table 4). The frequency of capture of Colorado pikeminnow (percent of captures which occurred within each geomorphic reach), was also the highest in upstream reaches, with Reach 5 having the highest frequency of capture (34%) followed by Reach 3 (23%) and Reach 4 (20%). Reaches 1 and 2 had the lowest frequency of Colorado pikeminnow capture, 2% and 6%, respectively.

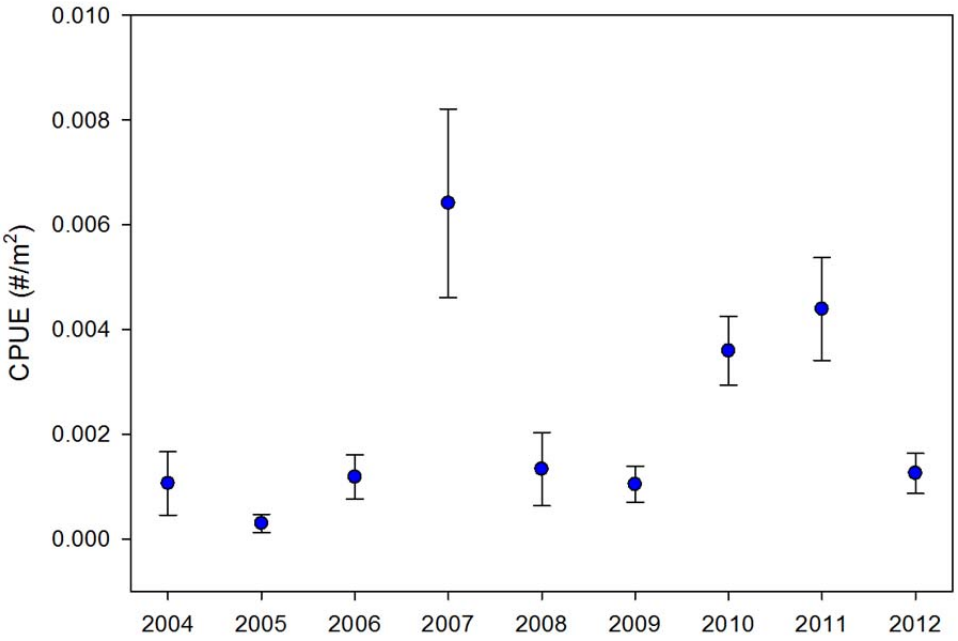

Figure 5. Mean annual CPUE of Colorado pikeminnow (2004-2012), ±1 standard error.

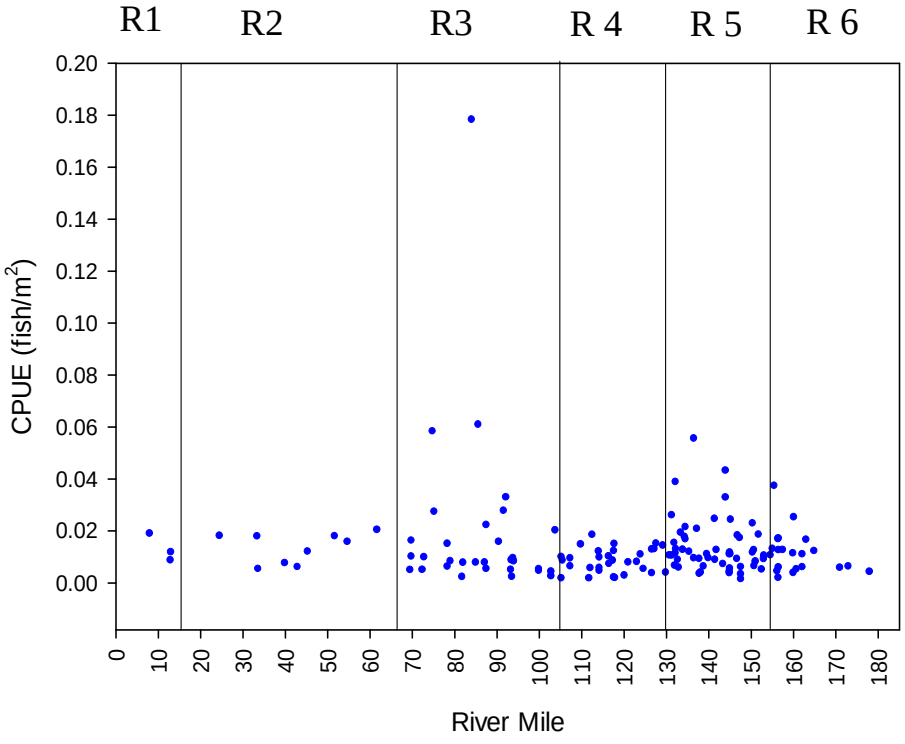

Figure 6. Colorado pikeminnow CPUE among river miles: 2004-2012. Reaches (R) 1 through 6 depicted by vertical lines.

There were no differences in the density of Colorado pikeminnow among geomorphic reaches 2 through 6 (years 2004-2010) (ANOVA, p=0.343) or among Reaches 3 through 6 (years 2004-2012) (ANOVA, p=0.423) (Table 4). In addition, there were no significant differences in the median CPUE for Colorado pikeminnow among Reaches 1 through 6 (years 2004-2010) (Friedman's test, p=0.223) (Table 4).

Table 4. Mean, median, and standard deviation Colorado pikeminnow catch per unit effort among geomorphic reaches:2004-2012 (Reach 1 and 2 data from 2004-2010).

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Mean CPUE (#/m^2)	0.001	0.001	0.003	0.002	0.004	0.002
Median CPUE (#/m^2)	0.000	0.001	0.000	0.002	0.002	0.002
Standard deviation	0.002	0.000	0.005	0.001	0.001	0.002

The density of Colorado pikeminnow, captured between 2004 and 2012, was similar among channel types between (Figure 7). There were no differences in Colorado pikeminnow mean CPUE between the primary channel and secondary channel for reaches 1-6 (years 2004-2012, (paired t-test, p=0.297). There were also no differences between the CPUE in backwaters compared to the primary or to secondary channels when reaches 1 and 2 were excluded (Friedman’s test, p=0.121). But there were significant differences when Reaches 1 and 2 were included in the data set (Friedman’s test, p=0.097). Despite overall significant differences as determined by the Friedman’s test, a Wilcoxon signed-rank test did not indicate differences existed in the density of Colorado pikeminnow between backwaters and secondary channels (p=0.110) or between backwaters and the primary channel (p=0.260).

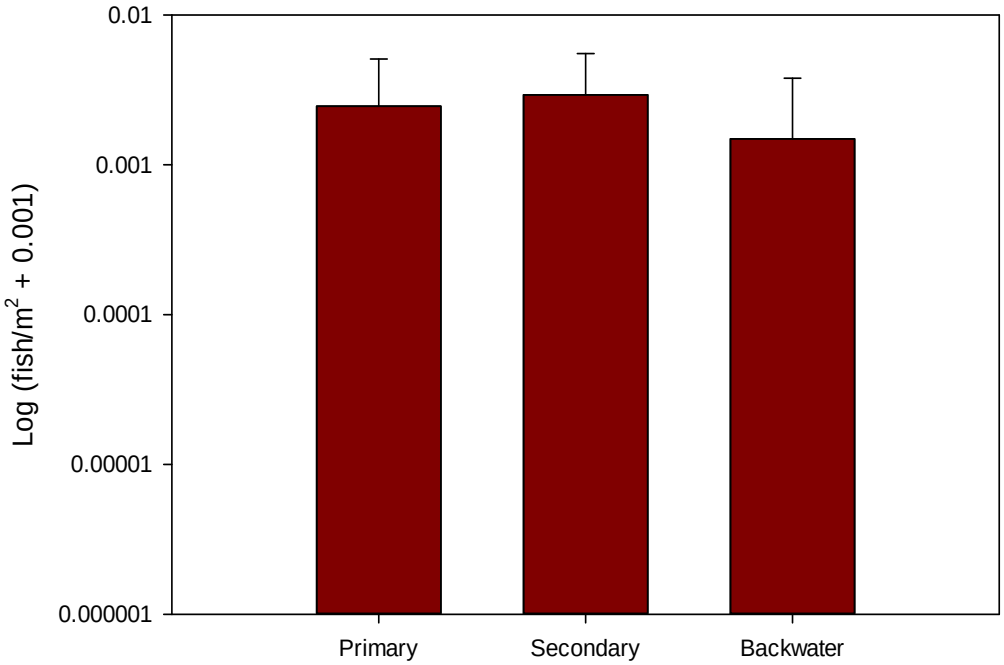

Figure 7. Log transformed mean catch per unit effort of Colorado pikeminnow among sampled channels, +1 standard error.

Primary and Secondary Channel Fish Communities

The fish communities present in secondary channels and the primary channel are significantly different (Wilks' lambda, $p<0.05$) such that discriminant function analysis correctly predicts membership within a given channel type 55% of the time. Membership within the primary channel, specifically, was correctly predicted 70% of the time and the secondary channel was predicted correctly 40% of the time. Densities of speckled dace, bluehead sucker, and channel catfish were the best predictors of primary channel samples whereas mosquitofish, flannelmouth sucker, red shiner, and fathead minnow were good predictors of sample collected in secondary channels (Table 5)

Table 5. Standardized canonical discriminant function coefficients

Species	Coefficient	Associated Channel Type
Speckled dace	-0.366	Primary
Bluehead sucker	-0.292	Primary
Channel catfish	-0.109	Primary
Colorado pikeminnow	0.080	Neutral
Mosquitofish	0.586	Secondary
Flannelmouth sucker	0.391	Secondary
Red shiner	0.363	Secondary
Fathead minnow	0.207	Secondary

Channel Catfish Recruitment

The time-lag analyses, plotting the log transformed densities of young-of-year channel catfish against juvenile channel catfish (size range: 61-299mm TL), indicated that the capture of juvenile channel catfish is constrained by the captures of young-of-year channel catfish (Figure 8). Thus, the maximum density of channel catfish in the juvenile size class can be predicted by the capture of young-of-year channel catfish. Such a relationship was not observed for adult captures (size range: >299 mm TL) (Figure 9) or between juvenile and adult channel catfish captures (Figure 10).

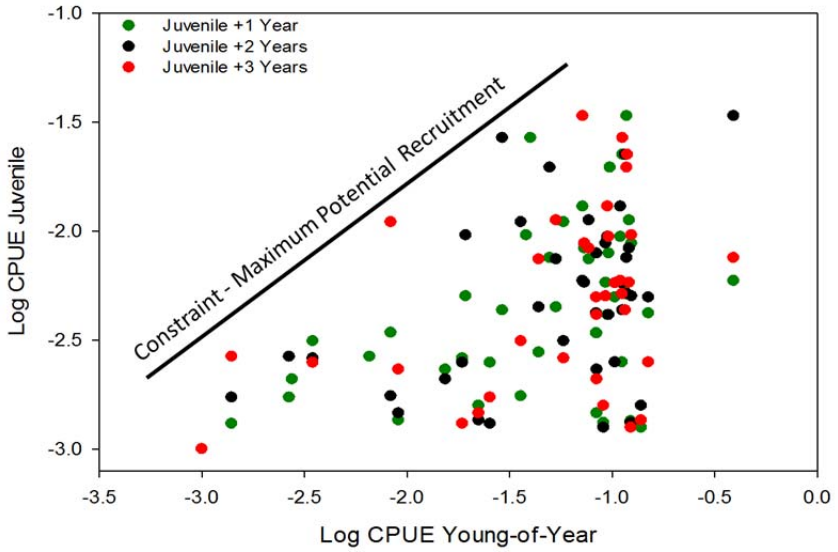

Figure 8. Time-lag analysis: young-of-year (from small-bodied monitoring) and juvenile catfish (from sub-adult/adult monitoring). Data are log transformed catch per unit effort.

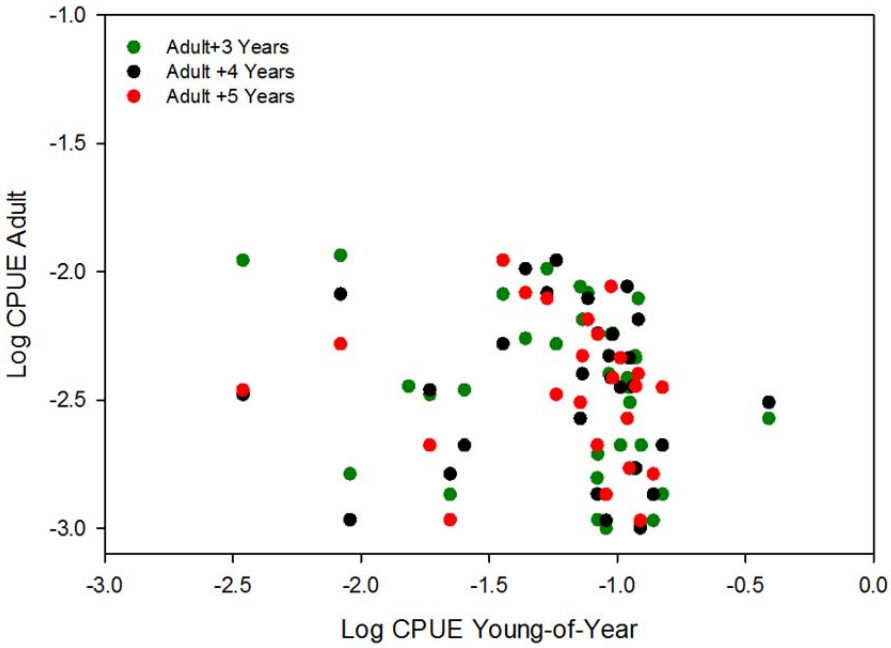

Figure 9. Time-lag analysis: young-of-year (from small-bodied monitoring) and adult catfish (from sub-adult/adult monitoring). Data are log transformed catch per unit effort.

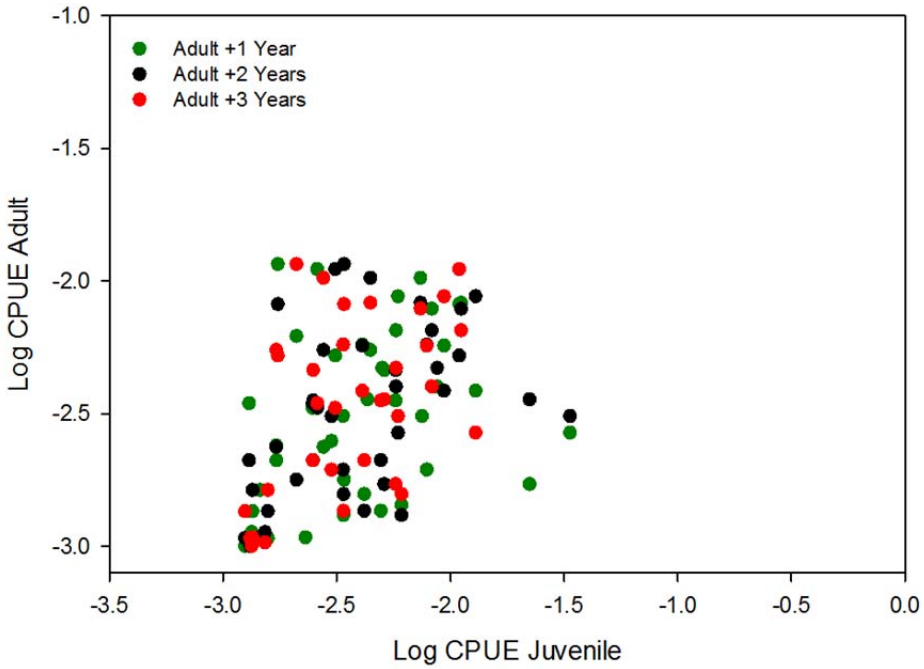

Figure 10. Time-lag analysis: juvenile and adult catfish (from sub-adult/adult monitoring). Data are log transformed catch per unit effort.

River Ecosystem Restoration Initiative Secondary Channels

Only four of six RERI sites were sampled in 2012 because the secondary channel at RM 132.2 was dry and the secondary channel at RM 127.2 was not located. Daily flows, one week prior to sampling, were between 600-700 cubic feet per second (Figure 11). Fishes were captured in all four RERI sites sampled and a single Colorado pikeminnow was collected in two of the four sites. The average number of species captured at the RERI sites compared to the control sites was similar (Table 6). There were no significant differences in the mean density of speckled dace, red shiner, and mosquito fish between treatment and control sites (t-test, $p>0.10$)

(

Table 6;Appendix VI). Likewise, the median density of bluehead sucker, flannelmouth sucker, Colorado pikeminnow, channel catfish, fathead minnow and mosquitofish did not differ between RERI and control sites (Mann-Whitney U, $p>0.10$) (

Table 6; Appendix VI).

Table 6. CPUE (fish/m^2), mean, median, and standard error and species richness of fishes captured at RERI and Control sites.

Density	RERI Mean	RERI Median	RERI ±1SE	Control Mean	Control Median	Control ±1SE
Bluehead sucker	0.031	0.015	0.016	0.013	0.017	0.000
Flannelmouth sucker	0.063	0.008	0.047	0.039	0.039	0.010
Speckled Dace	0.054	0.046	0.021	0.020	0.020	0.000
Colorado pikeminnow	0.008	0.004	0.000	0.016	0.000	9.000
Red shiner	0.037	0.035	0.015	0.113	0.077	0.047
Channel catfish	0.024	0.000	0.024	0.002	0.000	0.002
Fathead minnow	0.024	0.000	0.024	0.077	0.010	0.071
Mosquito fish	0.019	0.008	0.004	0.193	0.016	0.182
Green sunfish	Not collected			0.008	0.008	0.008
Roundtail chub	Not collected			0.001	0.001	0.001
Yellow bullhead	0.008	0.010	0.024	Not Collected		
Species Richness						
Native Species Average	3			3		
Nonnative Species Mean	2			3		
Total Average	5			6		

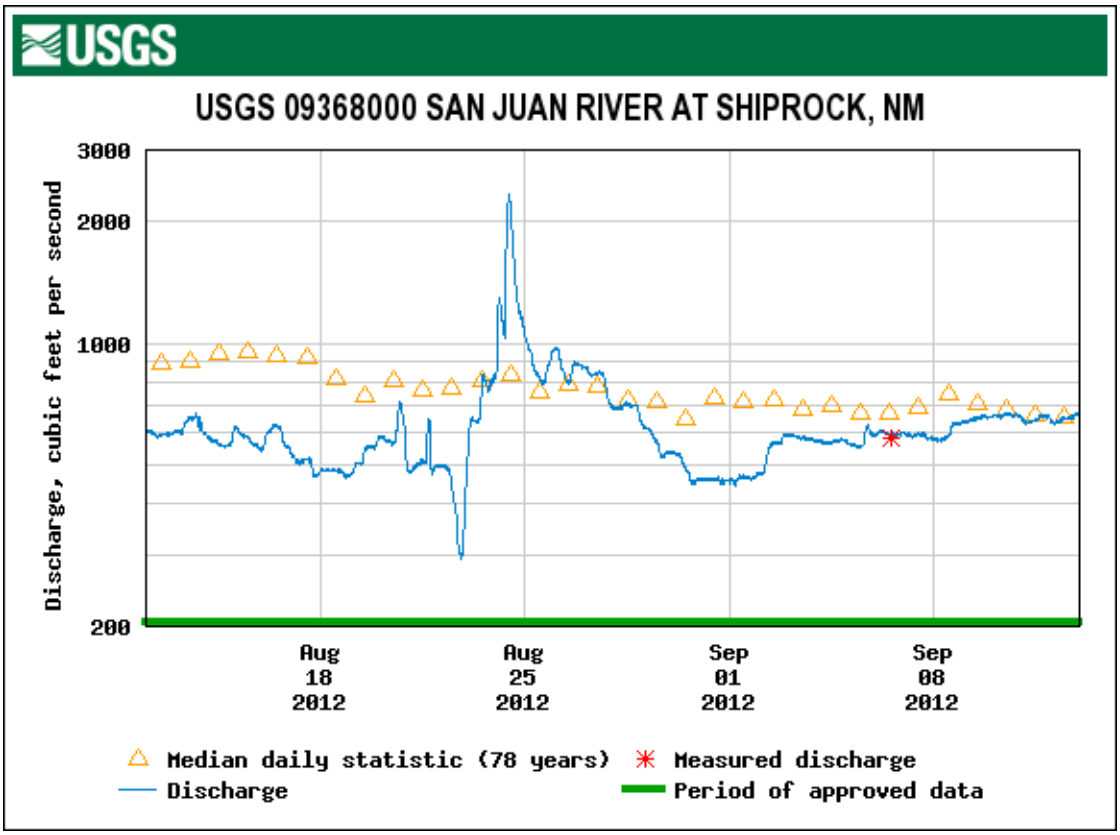

Figure 11. Mean daily discharge at USGS Shiprock gage prior to monitoring RERI sites

San Juan River Upstream of San Juan- Animas Confluence

Sampling effort 13.9 river miles upstream and downstream of the San Juan River and its confluence with the Animas River was comparable. Eight sites were sampled upstream compared to nine sites sampled downstream. A total of 56 seine hauls were made upstream and 72 seine hauls were made downstream. The percent of seine hauls without fish upstream was 30% compared to 22% downstream.

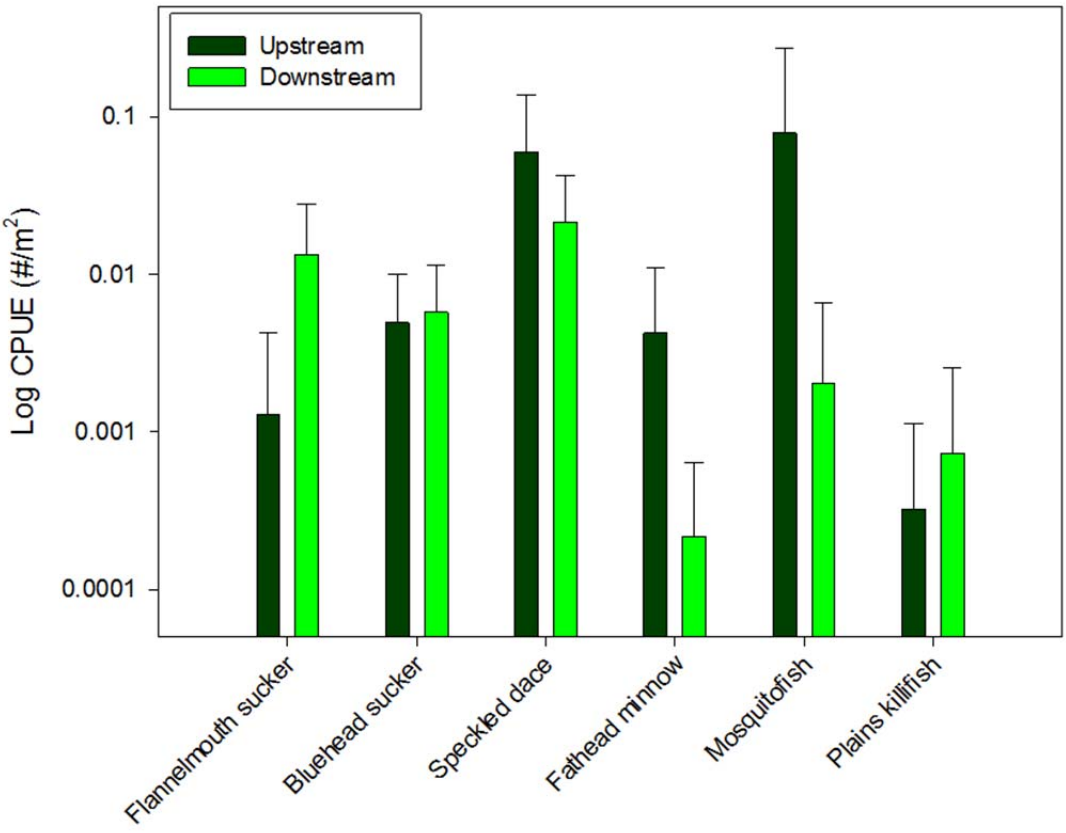

Figure 12. Log transformed mean CPUE for common species captured 13.9 river miles upstream and downstream of the San Juan River and Animas River Confluence, +1 SE.

Potential prey of Colorado pikeminnow were present upstream of the San Juan and Animas Rivers' confluence in 2012, although native species showed longitudinal variation in relative abundance (Figure 12). Flannelmouth sucker was not captured until the seventh and eight sites sampled in upstream section (Figure 13). Speckled dace was captured at all sites with the exception of one downstream site. Colorado pikeminnow and razorback sucker were not captured in either the upstream or downstream reaches. Mottled sculpin, *Cottus bairdii*, rainbow trout, *Oncorhynchus mykiss*, and green sunfish, *Lepomis cyanellus* were species unique to captures upstream of the confluence and largemouth bass, *Micropterus salmoides* was unique to the 13.9 river miles sampled downstream of the confluence.

Catch per unit effort of bluehead sucker was not different between upstream and downstream reaches (t-test, $p>0.10$). Similarly, speckled dace CPUE, upstream of the confluence, did not significantly differ from the CPUE of speckled dace captured downstream (t-test, $p>0.10$). Of all the remaining species captured (flannelmouth sucker, fathead minnow, mosquitofish, and plains killifish) both in upstream and downstream sites, only flannelmouth sucker CPUE was different between reaches, with greater abundance downstream (Mann-Whitney U, $p=0.007$).

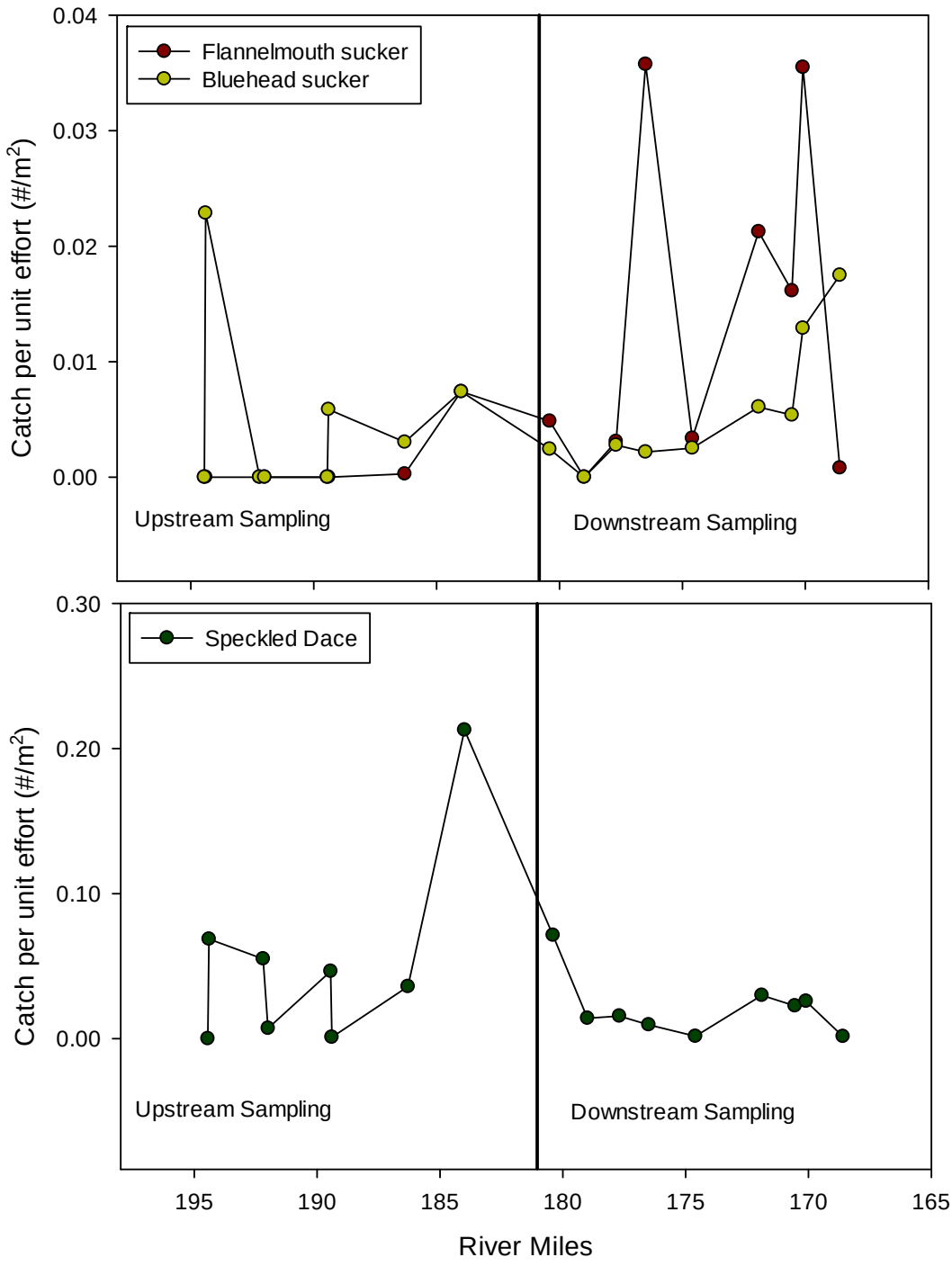

Figure 13. Longitudinal distribution of mean CPUE for native fishes sampled at different locations on the San Juan River: 13.9 river miles upstream and downstream of the San Juan River and Animas River confluence (RM 180.5). Note difference in y-axes.

Comparison of Two Meter Drag Seining and Nine Meter Block Seining

In 2011, a total of 13 primary channel sites were sampled using both the nine meter block seining technique and two meter drag seining; this was increased to 31 paired samples in 2012. In both years, the mean CPUE for all species was higher for samples made using the two meter drag seine as compared to the nine meter block net seine (Figure 14). For samples made in 2012, significant differences between capture techniques were observed for the capture of bluehead sucker, flannelmouth suckers, and channel catfish (Wilcoxon signed-rank test, $p<0.10$) (Figure 14 and Table 7).

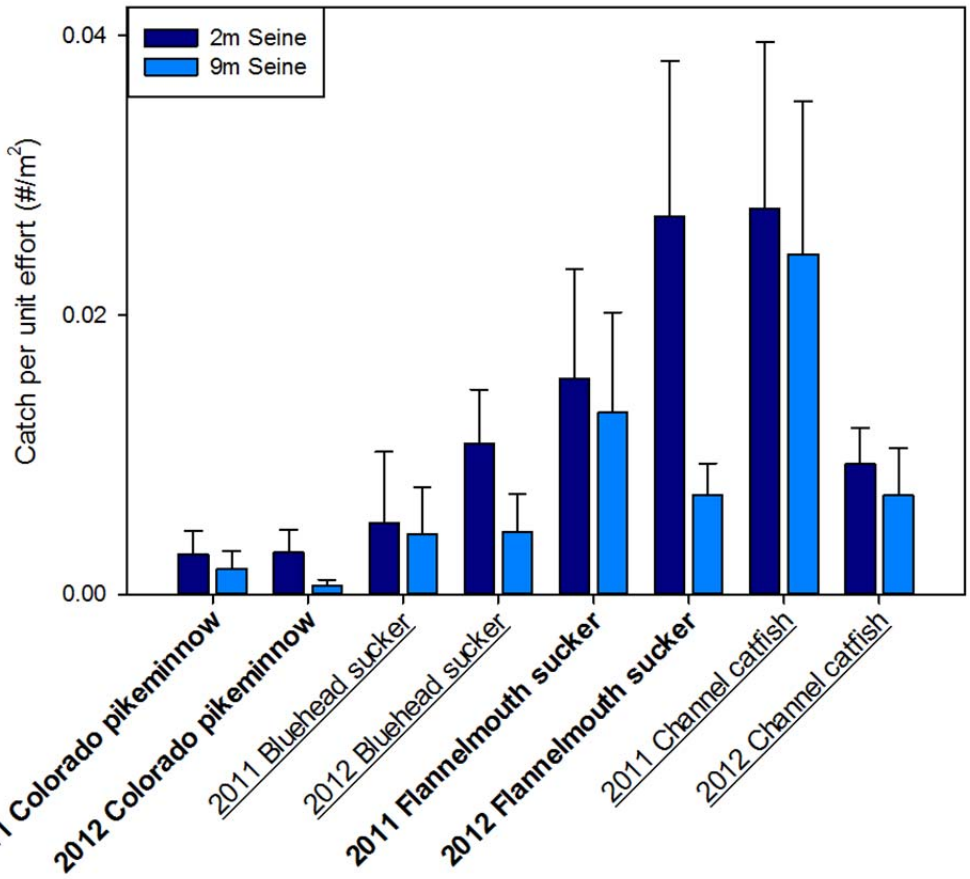

Figure 14. Mean CPUE and SE (+1) of fishes captured using two meter seine hauls and nine meter block seining: 2011- 2012

Table 7. Comparisons of fish capture success of two meter seine hauls versus nine meter block net seines for commonly captured large-bodied fishes (Wilcoxon Signed-rank Tests): 2011- 2012

2011	Colorado pikeminnow 2m vs. 9m	Bluehead sucker 2m vs. 9m	Flannelmouth sucker 2m vs. 9m	Channel catfish 2 vs. 9m
Z	-0.535	0.000	-0.420	-0.314
Significance (2-tailed)	0.593	1.000	0.674	0.753
2012				
Median 2m vs. 9m	0.000 vs. 0.000	0.004 vs. 0.000	0.011 vs. 0.004	0.000 vs. 0.000
Z	-1.540	-2.897	-2.739	-1.810
Significance (2-tailed)	0.123	0.004	0.006	0.070

Power Analysis of Annual and Biennial Monitoring

Annual surveys conducted over the next 10 years have the capacity to detect a 20% annual population increase with a power >0.80 for all fish species for which a power analysis was conducted (Figure 15). A 20% annual decrease, using annual surveys, could only be detected with a power >0.80 for speckled dace. A 20% annual decrease for flannelmouth sucker, channel catfish and red shiner could be detected with a power of ~ 0.60. The power to detect a 20% annual decrease for bluehead sucker and Colorado pikeminnow was < 0.20.

If changed to biennial surveys, a 20% annual population increase for Colorado pikeminnow or bluehead sucker could not be detected with a power >0.80 (Figure 15). A 20% increase could be detected with a power >0.80 for speckled dace, channel catfish, red shiner, and flannelmouth sucker. The power to detect a 20% population decrease was < 0.40 for speckled dace and red shiner and at or near 0.00 for all other species.

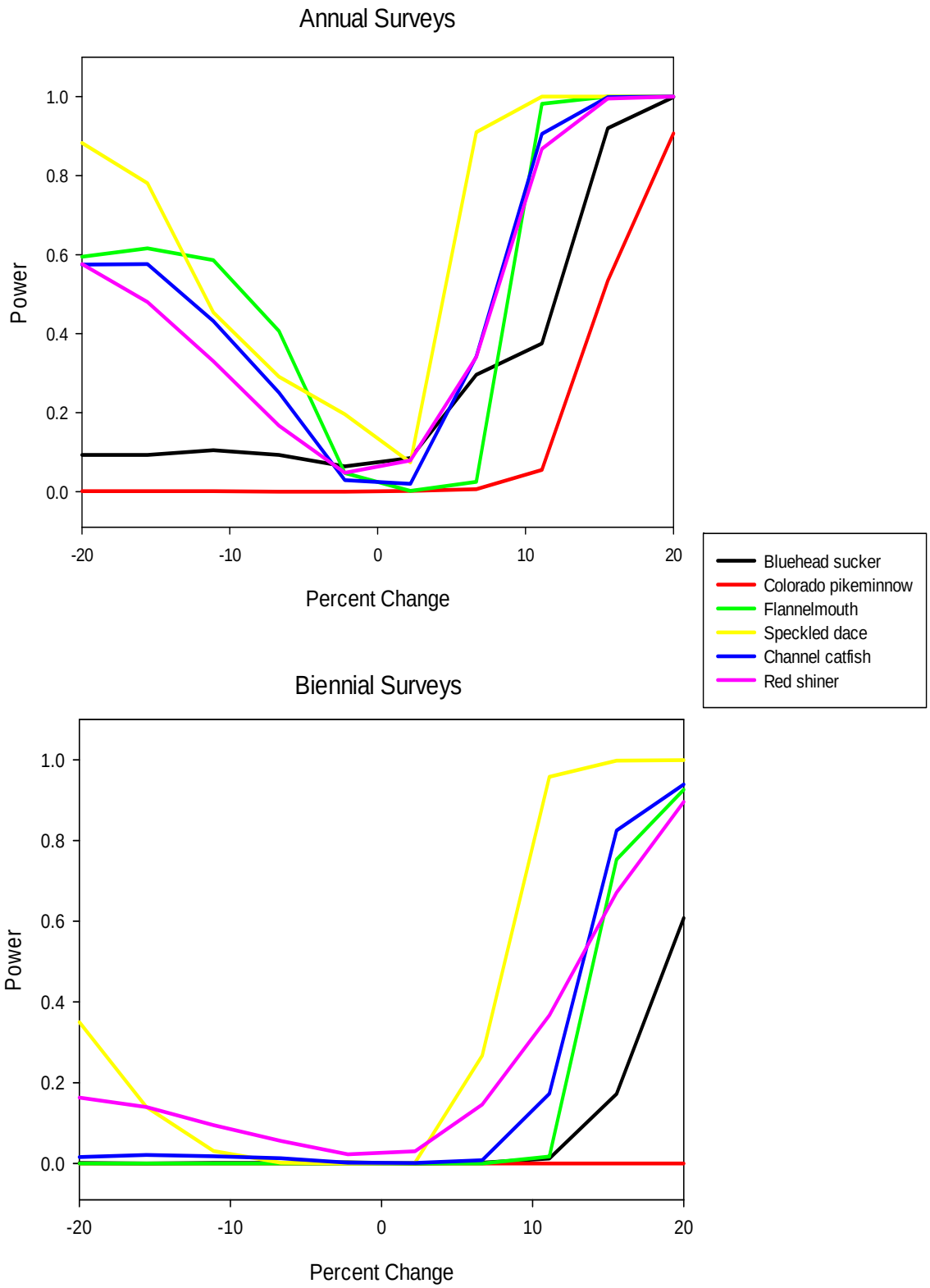

Figure 15. Comparison of power to detect a 20% annual change in the density of fishes in the San Juan River based on annual (top) and biennial (bottom) surveys.

DISCUSSION

Small-bodied monitoring data are used to determine and assess SJRIP management actions (SJRIP 2012b). The captures of juvenile Colorado pikeminnow and native/nonnative fishes are used to characterize and determine rearing areas and habitat used by juvenile Colorado pikeminnow and razorback sucker. The ability of young-of-year channel catfish captures to predict juvenile channel catfish recruitment supports the SJRIP's efforts to curtail this nonnative species. Other management actions that the SJRIP has undertaken in the most recent years include: 1) augmentation of Colorado pikeminnow and razorback sucker in the upper reaches of the San Juan River, 2) support of the River Ecosystem Restoration Initiative, 3) implementation of an experimental sampling technique, and 4) analyses of the most efficient sampling regime necessary to determine trends in small-bodied fish populations. This report provides details on the populations of small-bodied fishes in the San Juan River such that these management actions and progress to the recovery of Colorado pikeminnow and razorback sucker can be informed.

The density and distribution of young-of-year and juvenile Colorado pikeminnow varies in the San Juan River. Colorado pikeminnow are equally dense in all channel types and among geomorphic reaches. Analyses of the longitudinal distribution of Colorado pikeminnow indicated Colorado pikeminnow are more frequency captured (defined as percent of total captures) in Reaches 5 and 3; yet, there is no difference in the density of Colorado pikeminnow among geomorphic reaches. An investigation into other methods to determine whether Colorado pikeminnow is randomly distributed throughout the San Juan River should occur. This investigation could include assessing distribution by mesohabitats, associated small-bodied fish species, etc. Assessment of the density of Colorado pikeminnow annually is inconclusive and confounded by the number of fish stocked and timing of stocking. In future years, an attempt to

account for the number of fish stocked and timing should be investigated so that an estimate of overwinter survival can be calculated. This has been done for data collected through the sub-adult/adult monitoring and such methods may be useful in assessing the overwinter survival of Colorado pikeminnow captured during small-bodied monitoring.

Even though the density of Colorado pikeminnow does not differ between the primary channel and secondary channels, the fish communities were different. The DFA correctly predicted a primary channel sample 70% of the time. This indicates there is likely little variation in samples collected from the primary channel in either species richness or densities. Although species who were good predictors of a sample collected from a secondary channel, were mostly nonnative species, secondary channels samples were only correctly predicted 40% of the time. This indicates much more variation in species richness and densities is likely present in secondary channels. What the DFA does indicate is Colorado pikeminnow and razorback sucker would likely encounter different densities and combinations of potential prey between the primary channel and secondary channels as well as differing pressure from predators and competitors.

Time-lag analysis of channel catfish populations requires assumptions be made pertaining to the movement of this species and the effects of nonnative species removal. The analysis assumes movement in and out of geomorphic reaches is similar among years. This may be valid since small-bodied monitoring occurs at the same time each year and channel catfish movement data indicate a seasonal and directional trend in the movement of catfish (Duran et al. 2012; Morel 2012). Removal of adult and juvenile channel catfish may confound a time-lag analysis. Electrofishing, the method used to remove channel catfish, does not sample the juvenile size class as efficiently as it does adults (Duran et al. 2012). So although channel catfish removal

likely influenced the capacity of the analysis to predict recruitment from young-of -year to adults and from juveniles to adults, channel catfish removal may not have as strong an impact on the analysis when attempting to predict recruitment from young-of-year to juveniles.

The capture of young-of-year channel catfish through small-bodied monitoring suggests that these data can be used to predict the maximum potential recruitment of juveniles in the San Juan River. The time-lag analysis between young-of-year and juvenile catfish also indicated that there are other factors influencing either strong or weak recruitment of juveniles into the system. Further investigation into the cause of a strong or weak recruitment class and quantification of juvenile recruitment will be undertaken in future years. This can then be used to adjust levels of channel catfish removal and identify management actions that could control channel catfish populations.

Although no endangered fishes were captured in the upstream portion of the San Juan River, additional sampling in the San Juan River upstream of the confluence with the Animas River and the RERI channels suggest there are forage fishes available for Colorado pikeminnow. Based on the similarity in the species richness and density of fishes captured in the RERI and naturally flowing secondary channels, the RERI channels appear to be suitable habitat for small-bodied fishes in the San Juan River.

Block seining using a nine-meter seine was used to capture small-bodied fishes in 2007 and 2008 and had indicated that there was no significant difference between the collections made with this additional method (Paroz et al. 2009). The 2011 and 2012 results support previous studies. The experiment using the nine-meter block seining will be continued through 2013, at which time a determination will be made as to the whether this method should be incorporated into the standard sampling protocol.

Annual, rather than biennial, small-bodied monitoring is necessary to be able to detect a 20% annual increase in the density of Colorado pikeminnow and most other common fishes. Current densities of Colorado pikeminnow do not allow detection of a 20% decrease in the population whether annual or biennial sampling is conducted. Although annual monitoring of other small-bodied fish species such as speckled dace, in which a 20% decrease in the population could be detected, could indicate a possible reduction in habitat suitability of the San Juan river and thus a potential decline of Colorado pikeminnow. This could not be done if monitoring occurred on a biennial basis, as a 20% decrease could not be detected in any of the common species.

Various hypothesis exists as to why no young-of-year or juvenile razorback sucker has been captured during small-bodied monitoring. Captures of larval razorback has not occurred after 18 June for the last five years, with the exception of 2008 when captures occurred up to 18 July (Brandenburg and Farrington 2008, 2009, 2010, 2011; Brandenburg et. al 2012). One hypothesis is that the larvae do not survive to become young-of-year or juvenile fish and thus not subject to capture during autumn sampling. Another hypothesis is that some larval razorback do survive but at such low levels that they cannot be detected. While this could be true, small-bodied sampling has detected juvenile Colorado pikeminnow and roundtail chub, two species that are rare in the San Juan River.

It is also hypothesized that razorback sucker may be recruiting in the San Juan River but in habitat(s) that is/are not sampled. All identified low velocity meso-habitats are sampled by small-bodied monitoring. Faster water velocity habitats are sampled by the subadult/adult bodied monitoring simultaneously and this sampling has not resulted in capture of young-of-year or small juvenile razorback suckers. In both monitoring programs juvenile bluehead and

flannelmouth suckers, which could be considered surrogate species, have been captured. It is also of interest to note that in other portions of the Colorado River Basin, where razorback sucker are actually known to recruit, only a few captures of young-of-year or juvenile fish have occurred (Bestgen et. al 2012; Ryden 2013 pers. comm.).

Block net seining was initiated, on an experimental basis in 2011, to sample a faster flowing habitat not normally sampled during small-bodied monitoring. This habitat is the transitional zone between the low velocity water along the shoreline and the faster thalweg. Subadult/adult monitoring samples this habitat but uses electrofishing which may not sample small fishes effectively. Block net seining may also insure capture of faster swimming fish. As noted in this report, the technique has yet to result in the capture of a razorback sucker.

Razorback sucker has been captured in the San Juan River without a passive integrated transponder (PIT) tag even though almost all individual razorback suckers stocked into the San Juan River are inserted with a PIT tag before release. The SJRIP has undertaken studies to determine the retention rate of PIT tags in razorback sucker. It is also undertaking additional research to determine whether the natal origin (hatchery or San Juan River) of razorback suckers captured without PIT tags can be determined.

No matter what hypothesis a reader favors, it is important to note that a lack of captures is informative in and of itself. The sampling methods are sound and these data indicate young-of-year/juvenile razorback sucker are either not present or present but at such numbers as to not be detectable. Small-bodied monitoring does result in the capture of other rare species such as Colorado pikeminnow and roundtail chub and provides data to inform SJRIP management actions.

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APPENDICES

Appendix I. Summary of 1998-2011 Colorado pikeminnow captures in the San Juan River. Reaches 1 and 2 not sampled in 2011.

Year	*Length Category*	*Reach*						*Grand Total*
		6	*5*	*4*	*3*	*2*	*1*	
1998	N/A		2	2	2			6
1999	40			1				
	50							
	60							
	70							
	80							
	90				1			
	100							
	110							
	120		1					
	130							4
	140							
	150							
	160							
	170							
	180							
	190							
	200							
	210							
	220		1					
2000								
2001	N/A							0
2002	N/A							0
2003	N/A							0
2004	160		2					
	170			1				
	180		2					8
	200		1					
	210		1					
	230			1				

Year	Length Category	Reach 6	5	4	3	2	1	Grand Total
2005	170				1			3
	180			1				
	290					1		
2006	140	1	1					10
	150	1	1					
	180		1		1			
	190					1		
	200	1						
	210				1			
	280				1			
2007	40				6	2		59 Total, (*28 Recently Stocked YOY)
	50				17	2	1	
	120	2						
	130		1					
	140	1	4					
	150	2	6		2			
	160	2		1	1		1	
	170	1	1	3	1			
	180		1		1			
2008	130		1					10
	140	1	1	1				
	150		2	1	1			
	170		1					
	210				1			
2009	130	1					1	12
	170		1	1		1		
	180	1		1				
	190			1				
	200			2				
	210				1			
	330		1					
2010	120		1					49
	130	2	1	1				
	140	2	2	1	3			
	150	1	3	4	1			
	160		2		2	1		
	170		3	2	1			
	180		2		1	1		

Year	Length Category	Reach 6	5	4	3	2	1	Grand Total
2010 Cont'd	190			1	3	1		
	200		2		1			
	210				1			
	220							
	230				1			
	240							
	250			1				
	260				1			
2011	100	2	1					
	110	4	5					
	120	3	10					
	130	5	2	2				
	140	2	7	1				
	150		5	1	1			
	160		2	1				
	170							
	180			2				
	190							
	200							
	210							62
	220							
	230		1					
	240	1		1				
	250							
	260							
	270				1			
	280							
	290							
	300				1			
	360		1					
Reach Totals		**36**	**81**	**33**	**54**	**10**	**3**	

Appendix II. Number, Mean CPUE (fish/m^2) and Standard Error of fishes collected in San Juan River primary channel during autumn inventories, 2003– 2012.

	2003			2004			2005			2006			2007			2008			2009			2010			2011			2012		
Species	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*
AMEMEL				2	0.0005	0.0004	1	0.0006	0.0006	3	0.0004	0.0004				1	0.0005	0.0005							4	0.0005	0.0004			
AMENAT																						4	0.0008	0.0006						
CATDIS	27	0.0068	0.0021	283	0.0463	0.0056	90	0.0267	0.016	154	0.0404	0.0229	53	0.0066	0.0017	58	0.0158	0.0098	245	0.0289	0.0069	201	0.0218	0.0061	33	0.0059	0.0022	145	0.0102	0.0033
CATLAT	140	0.0622	0.0231	255	0.0441	0.0072	111	0.0289	0.0131	62	0.012	0.0028	227	0.0221	0.0073	101	0.0117	0.0039	216	0.0249	0.0078	594	0.0624	0.0189	104	0.0111	0.0021	276	0.0179	0.0046
CYPCAR				6	0.0012	0.0006	3	0.0005	0.0004							2	0.0006	0.0004	1	0.0001	0.0001									
CYPLUT	1706	0.5243	0.0801	9830	1.8335	0.3551	2521	0.8478	0.2573	164	0.0357	0.0061	204	0.031	0.0072	190	0.0314	0.0084	2568	0.3993	0.0862	218	0.0208	0.0043	250	0.0400	0.0086	412	0.0236	0.0732
FUNZEB	21	0.0056	0.0028	30	0.0051	0.0034	1	0.0003	0.0003							2	0.0001	0.0001	13	0.0009	0.0009	3	0.0002	0.0002	2	0.0006	0.0004	18	0.0010	0.0005
GAMAFF	37	0.0093	0.0059	127	0.0239	0.0075	16	0.0067	0.0035	4	0.0009	0.0007	8	0.0012	0.0009	5	0.0034	0.0028	39	0.0061	0.003	3	0.0004	0.0003	44	0.0093	0.0049	145	0.0080	0.0025
ICTPUN	366	0.0912	0.0144	603	0.0887	0.0161	401	0.096	0.0245	336	0.0695	0.009	697	0.0835	0.0109	533	0.0718	0.0096	122	0.0208	0.0069	460	0.0563	0.0091	493	0.0622	0.0097	105	0.0062	0.0017
LATxDIS	1	0.0002	0.0002																											
LEPCYA	2	0.0004	0.0003	1	0.0004	0.0004	1	0.0003	0.0003							1	0.0001	0.0001	7	0.0009	0.0004	1	0.0001	0.0001	2	0.0003	0.0002	2	0.0002	0.0002
MICSAL				4	0.0009	0.0005							1	0.0004	0.0004				4	0.0007	0.0004				1	0.0010	0.0006	3	0.0002	0.0002
PIMPRO	90	0.0353	0.0137	1119	0.2416	0.0749	281	0.092	0.0322	44	0.0058	0.0049	32	0.0043	0.0026	24	0.0053	0.0036	62	0.0088	0.0051	12	0.0014	0.0008	3	0.0004	0.0002	33	0.0016	0.0006
PTYLUC				4	0.0005	0.0002	2	0.0003	0.0002	8	0.0013	0.0005	23	0.0031	0.001	3	0.0004	0.0002	10	0.0013	0.0005	28	0.0029	0.0008	38	0.0029	0.0007	24	0.0018	0.0006
RHIOSC	511	0.1655	0.0292	4690	0.7643	0.1026	1234	0.2689	0.0412	2401	0.7378	0.488	2177	0.2653	0.0377	1192	0.2007	0.0244	2964	0.4338	0.0609	2007	0.2105	0.0329	658	0.1033	0.0176	1485	0.1259	0.0554
SALTRU																			1	0.0001	0.0001	2	0.0001	0.0001				2	0.0002	0.0001
XYRTEX							1	0.0003	0.0003																					
Total N	2913			17042			4639			3175			2766			2217			6252			3533			1632			2653		
Total Area	3994			7768			5985			5446			9038			7469			8483			11292			10160			16250		
Density	0.73			2.19			0.78			0.58			0.31			0.36			0.74			0.31			0.29			0.16		

Appendix III. Number, Mean CPUE (fish/m^2) and Standard Error of fishes collected in San Juan River secondary channels during autumn inventories, 2003– 2012.

	2003			2004			2005			2006			2007			2008			2009			2010			2011			2012		
Species	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*
AMEMEL	9	0.0057	0.0024	6	0.005	0.0031	3	0.0045	0.0031	4	0.0049	0.003				3	0.0018	0.0013	1	0.0009	0.0009				9	0.0024	0.0017	1	0.0004	0.0004
AMENAT							1	0.001	0.001							3	0.0017	0.0011	5	0.0023	0.0016							3	0.0008	0.0005
CATDIS	24	0.0167	0.0082	123	0.0827	0.0259	7	0.0064	0.0033	62	0.0256	0.0134	13	0.0057	0.0024	87	0.0202	0.0115	100	0.0367	0.0098	173	0.0517	0.017	218	0.0327	0.0162	47	0.0132	0.0034
CATLAT	145	0.1103	0.0531	124	0.0899	0.0293	25	0.0278	0.0099	61	0.0296	0.0131	87	0.041	0.0205	195	0.0602	0.0295	78	0.029	0.0091	281	0.1341	0.0496	66	0.0105	0.0023	204	0.0551	0.0219
CYPCAR	2	0.0016	0.0011	10	0.0088	0.004										5	0.0029	0.0015	4	0.0018	0.0009									
CYPLUT	1636	1.6186	0.4463	7171	4.2304	0.6358	921	0.9532	0.3283	154	0.1205	0.0368	168	0.0691	0.0194	221	0.082	0.0434	1869	1.0995	0.3286	378	0.1102	0.0668	194	0.0362	0.0136	36	0.0887	0.0223
FUNZEB	11	0.0048	0.0025	32	0.0295	0.0173										4	0.0021	0.0014				1	0.0004	0.0004	16	0.0022	0.0022	2	0.0005	0.0004
GAMAFF	32	0.0258	0.0099	154	0.1584	0.0618	45	0.0463	0.0437	4	0.0058	0.0038	1	0.0004	0.0004	80	0.0236	0.0088	27	0.0148	0.0068	28	0.013	0.0082	221	0.0321	0.0275	229	0.0939	0.0521
GILROB																									1	0.0007	0.0007	1	0.0002	0.0002
ICTPUN	79	0.0551	0.0139	116	0.0991	0.0278	114	0.2099	0.1086	42	0.0193	0.0053	225	0.0935	0.0163	110	0.0387	0.0119	141	0.0823	0.0632	116	0.0449	0.0096	168	0.0383	0.0089	14	0.0035	0.0013
LEPCYA				1	0.0007	0.0007													2	0.0006	0.0006				3	0.0004	0.0002	2	0.0012	0.0012
MICSAL	1	0.0016	0.0016	6	0.0037	0.002										10	0.0073	0.0052	6	0.0042	0.0023	2	0.0002	0.0002	6	0.0010	0.0006	6	0.0018	0.0014
PIMPRO	325	0.2417	0.093	2239	1.88	0.7865	106	0.1218	0.0502	27	0.0347	0.0233	4	0.0017	0.0017	117	0.0383	0.0183	18	0.0109	0.0057	50	0.0294	0.0183	22	0.0030	0.0025	75	0.0273	0.0131
PTYLUC				4	0.0046	0.0023	1	0.0005	0.0005	2	0.0011	0.0008	15	0.0083	0.0027	6	0.0013	0.0006	1	0.0004	0.0004	18	0.0065	0.0019	22	0.0020	0.0007	2	0.0004	0.0003
RHIOSC	238	0.2454	0.06121	1364	7976	0.1667	172	0.2013	0.0507	251	0.2131	0.041	821	0.4256	0.1042	1017	0.5288	0.1178	1073	0.5093	0.118	886	0.3724	0.096	553	0.0918	0.0185	225	0.0607	0.0120
Total N	2464			11109			1400			607			1334			1858			3325			1933			1499			1147		
Area	1438			1789			1009			1679			2525			2619			2387			2760			2424			3888		
Density	1.71			6.21			1.38			0.36			0.53			0.71			1.39			0.70			0.76			0.30		

Appendix IV. Number, Mean CPUE (fish/m^2) and Standard Error of fishes collected in San Juan River backwaters during autumn inventories, 2003– 2012.

	2003			2004			2005			2006			2007			2008			2009			2010			2011			2012		
Species	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*	*N*	*CPUE*	*SE*
AMEMEL	12	0.0472	0.0445																121	0.0822	0.0811	8	0.012	0.0084	6	0.0018	0.0015			
AMENAT													1	0.0036	0.0036				1	0.0011	0.0011	1	0.001	0.001	1					
CATDIS	3	0.0431	0.0276	2	0.0081	0.0022	69	0.1346	0.0265				1	0.001	0.0002	6	0.0126	0.0011	20	0.0178	0.0113				1152	0.1703	0.1340	13	0.0272	0.0247
CATLAT	6	0.0431	0.0276	1	0.0038	0.001	114	0.1556	0.0207				4	0.0049	0.0005	26	0.0654	0.0071	39	0.043	0.0161	55	0.0644	0.0311	15	0.0016	0.0008	1	0.0024	0.0024
CYPLUT	301	1.7454	0.4953	1033	3.6789	0.1984	566	1.2821	0.2102	3	0.0725	0.0513	67	0.0845	0.0054	288	0.5588	0.1032	2081	1.799	0.5392	199	0.2203	0.0965	742	0.2368	0.1578	218	0.3192	0.2745
CYPCAR				3	0.0102	0.002	1	0.0053	0.0012				1	0.0032	0.0005	2	0.0051	0.0008	3	0.0029	0.0017	1	0.0023	0.0023						
FUNZEB	1	0.0043	0.0043	24	0.0603	0.0098	3	0.0034	0.0008							1	0.0033	0.0033				3	0.0065	0.0057	11	0.0013	0.0009	15	0.0202	0.0137
GAMAFF	20	0.1342	0.0812	17	0.0583	0.0059	26	0.0499	0.0077							23	0.0156	0.01	440	0.3973	0.3173	24	0.0205	0.0166	163	0.0352	0.0178	460	1.0394	0.4994
ICTPUN	10	0.0373	0.0305	10	0.0411	0.005	1	0.0022	0.0005				64	0.0991	0.0061	36	0.0773	0.0078	7	0.0071	0.0041	11	0.0104	0.0059	19	0.0029	0.0019			
LEPCYA	1	0.0108	0.0108													1	0.003	0.003	89	0.0741	0.0737				1	0.0001	0.0001	9	0.0139	0.0139
MICSAL							2	0.0132	0.003							6	0.0154	0.0111	21	0.0188	0.015									
PIMPRO	241	2.4151	1.3993	319	1.0457	0.0721	122	0.2182	0.0163	2	0.0394	0.0063	12	0.0129	0.0015	35	0.1122	0.0691	182	0.1317	0.0614	24	0.041	0.0289	88	0.0100	0.0087	146	0.2380	0.1653
PTYLUC													21	0.028	0.0024	1	0.0026	0.0026	1	0.0006	0.0006	3	0.0061	0.0037	2	0.0002	0.0002			
RHIOSC	4	0.0182	0.0094	10	0.0345	0.0164	12	0.0179	0.011	1	0.0242	0.0242	30	0.0407	0.0159	116	0.2098	0.1114	39	0.0416	0.0141	19	0.0391	0.0292	96	0.0075	0.0029	11	0.0223	0.0073
Total N	490			1415			876			6			198			541			3044			348			2296			873		
Area	245			274			489			53			723			486			1021			728			1235			698		
Density	2			5.16			1.79			0.11			0.27			1.11			2.98			0.48			0.47			1.25		

Appendix V. River Ecosystem Restoration Initiative Restored and Control Secondary Small-bodied Fishes Catch Per Unit Effort

Density	Control 134.3	Control 133.5	RERI 132	Control 130.1	RERI 130.7A	RERI 130.7B	RERI 127	Control 122.7
Bluehead sucker	0.017	0.016			0.015	0.015	0.063	0.018
Flannelmouth sucker	0.029	0.048		0.061	0.015		0.110	0.018
Speckled Dace	0.040		0.015	0.031	0.031	0.061	0.110	0.009
Colorado pikeminnow			0.008			0.008		0.063
Roundtail chub	0.006							
Red shiner	0.253	0.064	0.015	0.046	0.054	0.008	0.071	0.089
Mosquito fish		0.741		0.031	0.023		0.016	
Green sunfish		0.032						
Channel catfish							0.024	0.009
Fathead minnow	0.012	0.290		0.008			0.024	
Yellow bullhead							0.008	
Species Richness								
Native Species Count	4	2	2	2	3	3	3	4
Nonnative Species Count	2	4	1	3	2	1	5	2
Total Species Count	6	6	3	5	5	4	8	6

Appendix VI. Small-bodied Fishes Capture Data from River Ecosystem Restoration Initiative Restored and Control Channel Statistical Comparisons.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Err. Difference	95% CI of the Difference	
									Lower	Upper
Speckled Dace	Equal var. assumed	2.112	0.196	1.498	6	.185	0.034	0.023	-0.022	0.090
	Equal var. not assumed			1.498	4.149	.206	0.034	0.023	-0.028	0.097
Red shiner	Equal var. assumed	3.112	0.128	-1.524	6	.178	-0.076	0.050	-0.198	0.046
	Equal var. not assumed			-1.524	3.608	.210	-0.076	0.050	-0.221	0.069
Flannel-mouth Sucker	Equal var. assumed	12.779	0.012	-1.452	6	.197	-0.745	0.513	-2.001	0.511
	Equal var. not assumed			-1.452	3.322	.234	-0.745	0.513	-2.293	0.802
Mosquito Fish	Equal var. assumed	2.474	0.167	-.563	6	.594	-0.442	0.786	-2.367	1.482
	Equal var. not assumed			-.563	4.644	.600	-0.442	0.786	-2.512	1.627

Mann-Whitney U Test Statistics

	Bluehead sucker	Flannelmouth sucker	Colorado pikeminnow	Channel catfish	Fathead Minnow
Mann-Whitney U	6.500	4.000	7.000	7.500	4.500
Wilcoxon W	16.500	14.000	17.000	17.500	14.500
Z	-.438	-1.162	-.333	-.189	-1.076
Asymp. Sig. (2-tailed)	.661	.245	.739	.850	.282
Exact Sig. [2*(1-tailed Sig.)]	.686[a]	.343[a]	.886[a]	.886[a]	.343[a]