SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM
2018 Recruitment Bottleneck Workshop

Summary

On 22 February 2018, the San Juan River Basin Recovery Implementation Program (SJRRIP) held a Biology Committee (BC) workshop to identify recruitment bottlenecks of the endangered fishes in the San Juan River and discuss potential management activities to alleviate these roadblocks to recovery. During the workshop participants generally agreed on two recruitment bottlenecks for Razorback Sucker (Figure 1). The limited contribution of stocked adult Razorback Sucker population to successful larval production (<3%) likely indicates a bottleneck to recruitment by lowering reproductive output of the population. Identification as a bottleneck still needs to be verified by comparison of these rates to other populations of Razorback Sucker and/or other native suckers in the San Juan River. Participants further concluded that available data from small-bodied fish surveys conducted to quantify recruitment of larvae into the fall indicates low survival of Razorback Sucker in the river between the larval and juveniles life stage as a second recruitment bottleneck. For Colorado Pikeminnow, participants concluded that low apparent survival of stocked juveniles was a recruitment bottleneck hindering efforts to increase the adult Colorado Pikeminnow population in the San Juan River (Figure 2). For each species the data to support the identification of these recruitment bottlenecks are provided in Appendix I.

Prior to the workshop, the SJRRIP Program Office (PO) provided a summary to the BC of potential hypotheses and explanations of what could be the cause of these recruitment bottlenecks (Appendix I). During the workshop, participants developed additional hypotheses and the group discussed the likelihood of each hypothesis. During this discussion, the most likely hypotheses were given “high” rankings based on available data and our current knowledge of the system (Tables 1 and 2). The PO had provided a partial list of actions that could potentially identify and/or alleviate recruitment bottlenecks prior to the workshop to facilitate further group discussions. During the workshop participants brainstormed potential additional paths forward (Tables 1 and 2).

The goal of this document is to communicate the workshop’s outcome. The identified paths forward can be used by the SJRRIP to plan for future implementation of recovery activities to alleviate recruitment bottlenecks. Additionally, the SJRRIP can use the paths forward for hypothesis testing by identifying a broad suite of potential ideas to guide RFPs, SOWs, and management actions to further understand and ameliorate recruitment bottlenecks in the San Juan River. Figures 1 and 2 provide a schematic of the SJRRIP’s paradigm to recover Colorado Pikeminnow and Razorback Sucker in the San Juan River (i.e., stocking to establish adult populations that ultimately reproduce in the wild) and the locations of the life-stage specific recruitment bottlenecks supported by data provided in Appendix I. All hypothesis rankings and additional paths forward are in the context of better identifying and/or alleviating the life-stage specific recruitment bottlenecks identified and agreed upon during the workshop. Future efforts in regards to identifying and ameliorating recruitment bottlenecks in the San Juan River may include refining proposed paths forwards, adding additional paths, and in advance of taking action on paths forward, identify potential outcomes and a suite of follow-up actions that would be undertaken in each case.

Razorback Sucker

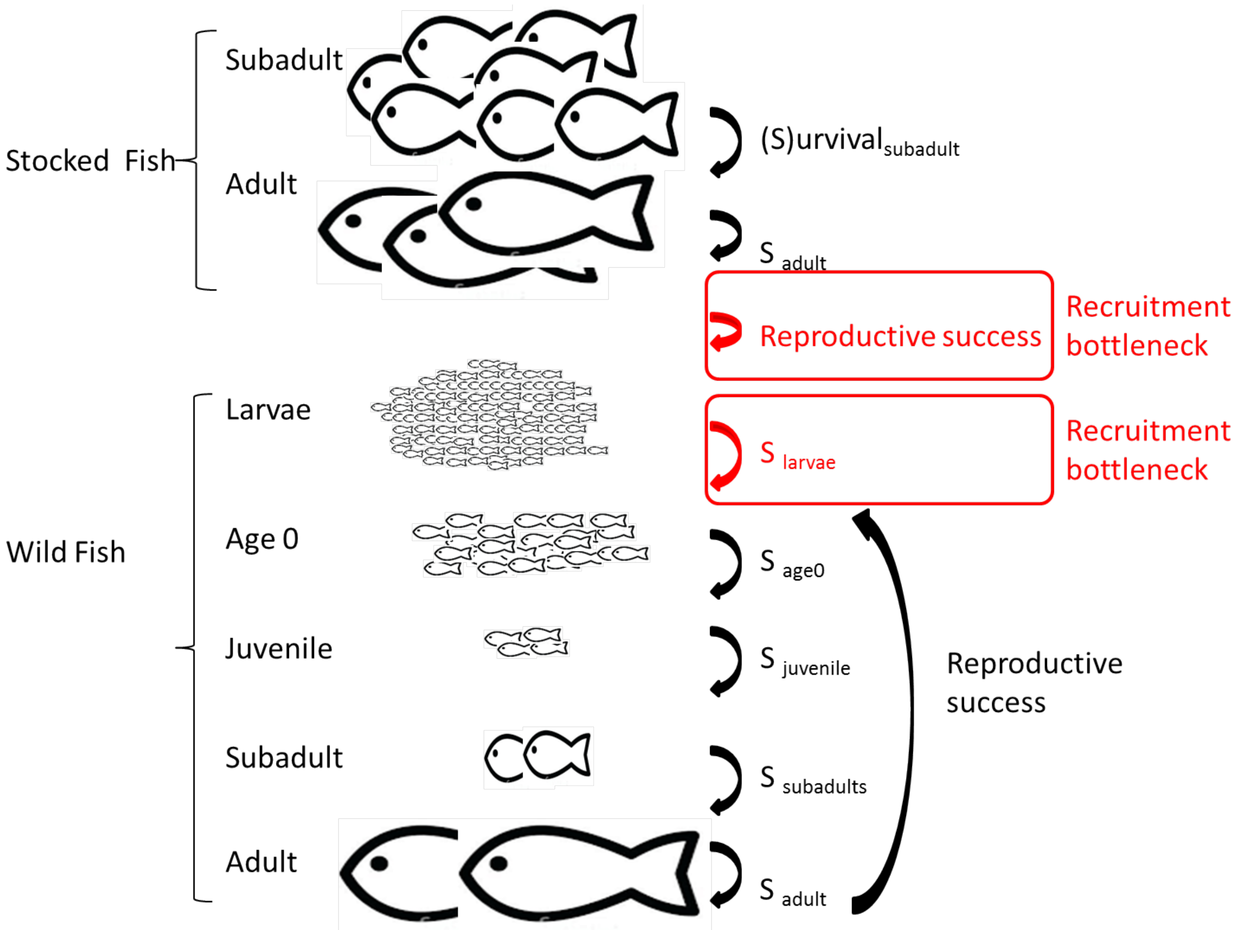

Figure 1. Conceptual model of the life cycle diagram of Razorback Sucker stocking in the San Juan River that results in a reproductive population, ultimately leading to wild recruitment. Recruitment bottlenecks supported by existing data discussed during the workshop are highlighted in red.

Table 1. Hypotheses developed to explain identified recruitment bottlenecks and potential activities to validate hypotheses or further identify factors and alleviate their effects limiting recruitment, or test validity of hypotheses. The three prioritized hypotheses for bottlenecks identified for Razorback Sucker (i.e., reproductive success and larval to juvenile survival over the summer to fall season) are identified in gray in no particular order.

Hypotheses	**Paths forward provided by PO prior to workshop**	**Additional paths identified at workshop**
Net rates of emigration/immigration of all life-stages affect rates of recruitment.	1. Provide upstream passage at the waterfall. 2. Estimate emigration rates as "mortality" of river population to assess priority to address.	
Recruitment is affected by reproductive output which is regulated by numbers of adult individuals spawning.	1. Increase upstream passage at PNM weir by making passage nonselective during the spring months. 2. Increase upstream passage at waterfall and into the Animas River.	1. For comparison, determine N_b for Flannelmouth Sucker and/or Bluehead Sucker. 2. At PNM fish passage increase spacing of bars to 8" rather than 4". 3. Quantify barriers to upstream movement such as APS weir.
Availability of rearing habitats affects rates of recruitment.	1. Test if elevated base-flows I) increase desired habitats and II) increase rates of recruitment. 2. Create artificial wetland to advance understanding of recruitment limitations.	1. Assess amount of habitat needed for these life-stages and current availability. 2. Prioritize secondary channels for which restoration actions would be most beneficial. 3. Develop programmatic environmental clearance to provide efficient restoration projects. 4. Map habitat at elevated base flows.*
Nonnative fish competition and choking hazards affect rates of recruitment.	1. Assess effects of competition.	
The availability of adequate trophic resources affects rates of recruitment.	1. Test if basal production is adequate to support larval and small-bodied fish in	1. Basal production in backwaters should be assessed in both the main

Hypotheses	**Paths forward provided by PO prior to workshop**	**Additional paths identified at workshop**
	backwaters. 2. Test if elevated base flows would increase availability of trophic resources.	channel and in flowing secondary channels for comparison purposes
Rates of entrainment into diversion structures and irrigation canals affect rates of recruitment.	1. Assess rates of entrainment 2. Minimize level of entrainment.	
Recruitment is affected by reproductive output, which is regulated by the quality and quantity of appropriate spawning and rearing habitat.		
Survival is hampered by negative genetic and/or behavioral hatchery effects.		
Low egg viability of hatchery fish contributes to poor recruitment into the larval stage.		
Thermal environments impact reproduction and survival.	**	
Contaminants decrease survival and recruitment.	***	
There is a handling and/or capture effect on fish survival.		

* This action is planned for fall 2018

** A temperature effects study on larval Razorback Sucker is planned for fiscal year 2019

*** U.S. Bureau of Indian Affairs selenium study results may be available at the end of fiscal year 2018.

Colorado Pikeminnow

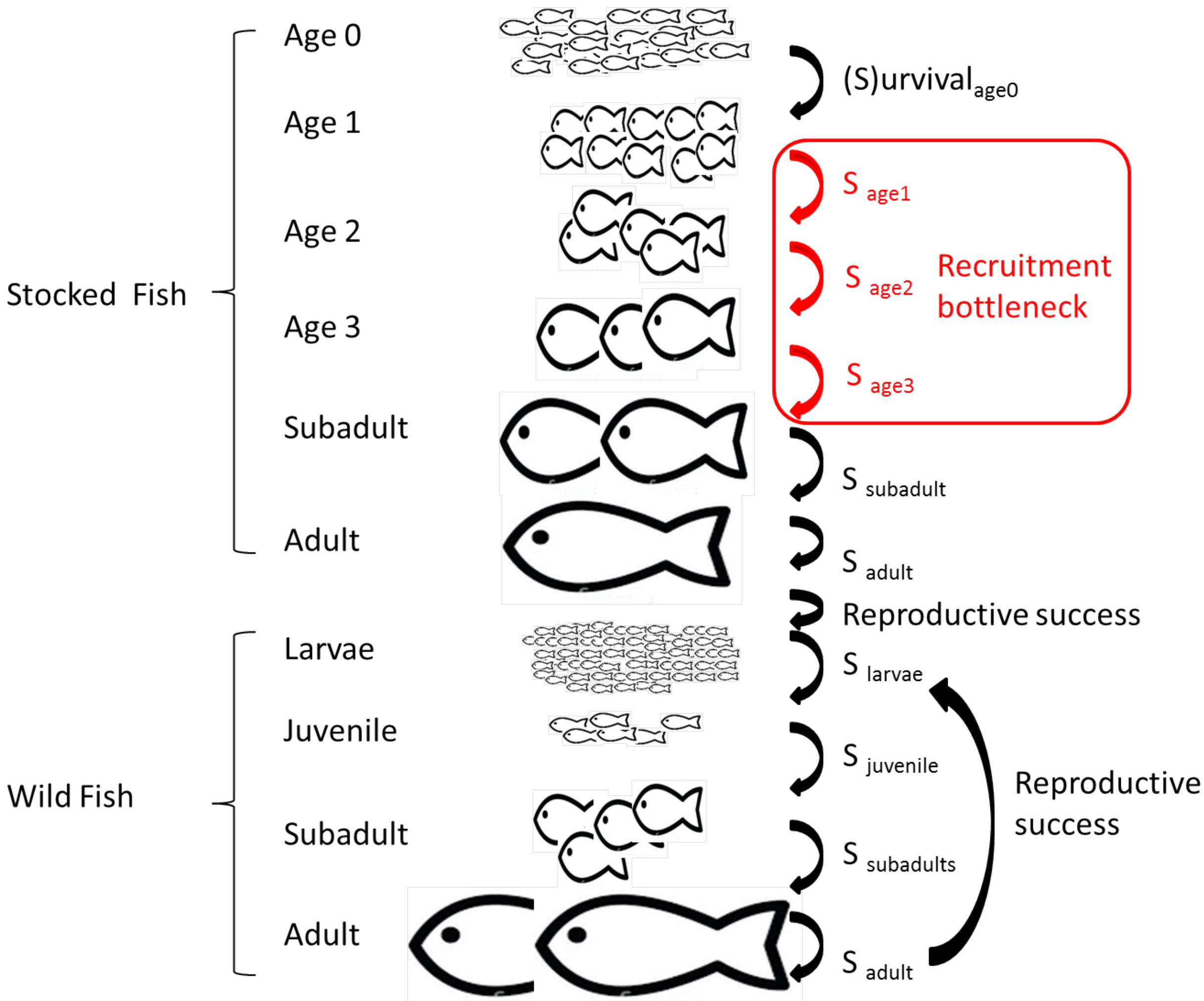

Figure 2. Conceptual model of life cycle diagram of Colorado Pikeminnow stocking in the San Juan River that results in a reproductive population, ultimately leading to wild recruitment. Recruitment bottlenecks supported by existing data discussed during the workshop are highlighted in red.

Table 2. Hypotheses developed to explain identified recruitment bottlenecks and potential activities to validate hypotheses or further identify factors and alleviate their effects limiting recruitment, or test validity of hypotheses. The four prioritized hypotheses identified for stocked juvenile Colorado Pikeminnow recruitment bottleneck are identified in gray in no particular order.

Hypotheses	**Paths forward provided by PO prior to workshop**	**Additional paths identified at workshop**
The availability of adequate trophic resources affects rates of recruitment.	1. Repatriate Roundtail Chub in the San Juan River system. 2. Stock larger, prey-trained fish with PIT tags. 3. Test if basal production is adequate to support larval and small-bodied fish in backwaters.	1. Modify stocking plan to test effect of density of stocking on survival.
Net rates of emigration/immigration of all life-stages affect rates of recruitment.	1. Provide upstream passage at the waterfall. 2. Estimate emigration rates as "mortality" of river population to assess priority to address.	1. At PNM fish passage increase spacing of bars to 8" rather than 4". 2. Quantify barriers to upstream movement such as APS weir.
Availability of rearing habitats affects rates of recruitment.	1. Test if elevated base-flows I) increase desired habitats and II) increase rates of recruitment. 2. Create artificial wetland to advance understanding of recruitment limitations.	1. Assess amount of habitat needed for these life-stages and current availability. 2. Prioritize secondary channels for which restoration actions would be most beneficial. 3. Develop programmatic environmental clearance to provide efficient restoration projects. 4. Map habitat at elevated base flows.*
There is a handling and/or capture effect on fish survival.	**	
Recruitment is affected by reproductive output which is regulated by numbers of adult individuals spawning	1. Increase upstream passage at PNM weir by making passage nonselective during the spring months. 2. Increase upstream passage at waterfall and	

Hypotheses	**Paths forward provided by PO prior to workshop**	**Additional paths identified at workshop**
	into the Animas River. 3. Investigate if there are mercury effects on reproduction.	
Nonnative fish competition and choking hazards affect rates of recruitment.	1. Assess effects of competition.	
Rates of entrainment into diversion structures and irrigation canals affect rates of recruitment.	1. Assess rates of entrainment 2. Minimize level of entrainment	
Recruitment is affected by reproductive output, which is regulated by the quality and quantity of appropriate spawning and rearing habitat.		
Survival is hampered by negative genetic and/or behavioral hatchery effects.		
Low egg viability of hatchery fish contributes to poor recruitment into the larval stage.		
Thermal environments impact reproduction and survival.		
Contaminants decrease survival and recruitment.		

* This action is planned for fall 2018
** In 2018 only age-1 and adult Colorado Pikeminnow will be captured based on Clark et al (in review) Colorado Pikeminnow survival analyses

Appendix I

Identifying bottlenecks limiting recovery of Razorback Sucker and Colorado Pikeminnow in the San Juan River: pre-SJRRIP Recruitment Bottleneck Workshop information.

The San Juan River Recovery Implementation Program (SJRRIP) has made significant progress towards recovering Colorado Pikeminnow and Razorback Sucker since its inception in 1992. At that time, both Colorado Pikeminnow and Razorback Sucker were functionally extirpated from the river but now wild larvae are produced by both species indicating successful reproduction can occur in the system. However, research and monitoring have revealed life-stage specific bottlenecks impeding each species' self-sustainability. A first step toward removing these roadblocks to recovery will be to identify and alleviate factors that contribute to these recruitment bottlenecks.

In preparation for a February 22, 2018 Biology Committee (BC) workshop on recruitment bottlenecks, the SJRRIP Program Office tried to succinctly describe where we think life-stage specific bottlenecks to recovery are occurring for both species. The bottlenecks identified were those for which we think evidence indicates a population level effect is likely occurring. We did not identify nonnative fish predation as a bottleneck because the SJRRIP is currently in the process of quantifying that impact. Attached to this document is a set of hypotheses that highlight general categories of factors contributing to these bottlenecks and potential activities to elucidate or alleviate these impediments to recovery. This partial list of activities does not include approved projects that are addressing potential factors contributing to bottlenecks (i.e., determination of water temperature and selenium on Razorback Sucker larval development). This document is intended to provide starting points for discussions at the recruitment bottleneck workshop. It is also provided so participants have time in advance to consider whether other bottlenecks or activities to elucidate or alleviate impediments to recovery could be identified. The goals of the workshop are to:

1. Reach consensus as to when and where recruitment bottlenecks occur.
2. Develop hypotheses that explain life-stage specific recruitment bottlenecks for Colorado Pikeminnow and Razorback Sucker.
3. Prioritize activities to alleviate or further identify factors contributing to bottlenecks.

<u>Wild Razorback Sucker Larval Recruitment Bottleneck</u>

Collection of larval Razorback Sucker has occurred in the San Juan River every year for the past 18 years but only one juvenile has been captured during standardized fall sampling (2016), likely indicating a recruitment bottleneck between the larval and juvenile life-stages. During the last seven years, the mean annual number of larval Razorback Sucker captured was ~ 27% (SD=13%) of that for both Flannelmouth Sucker and Bluehead Sucker. Unlike Razorback Sucker, the two common sucker species consistently recruit to the juvenile stage as they have been collected in all years as age-0 fish in the fall. Although direct comparisons among species are problematic as the Animas River populations of Flannelmouth Sucker and Bluehead Sucker likely subsidize downstream captures, the proportional reduction in Razorback Sucker juvenile captures compared to the other suckers indicates a lower apparent survival for larval Razorback Sucker (Figure 1a). Additionally, a reduction in Razorback Sucker larvae from May to July compared to Flannelmouth Sucker and Bluehead Sucker suggests relatively high mortality rates within larval ontogeny (Figure 1b) and is likely a factor contributing to a lack of recruitment to the juvenile life-stage over the spring-summer months.

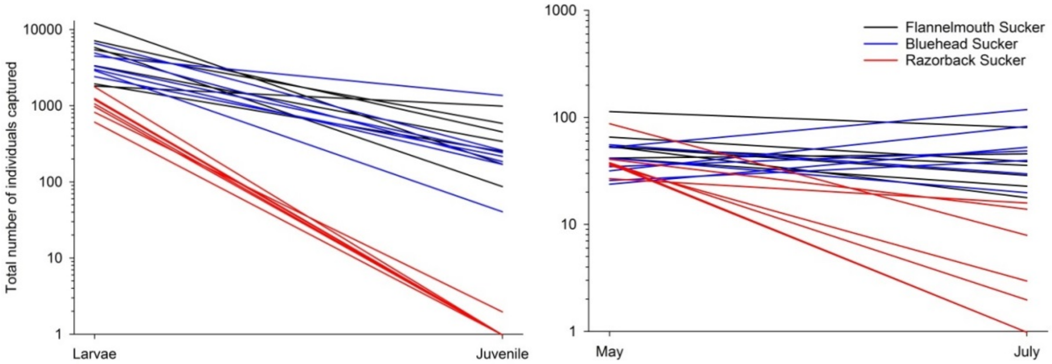

Figure 1. Total captures of native catostomids in the San Juan River 2010-2016. Panel a) depicts larval monitoring (Farrington et al. 2017) and small-bodied monitoring juvenile captures (≤125 mm total length; Zeigler and Ruhl 2017). Panel b) is May and July larval monitoring captures. Each line for each species represents a different year. To facilitate plotting on a log scale, 1.0 was added to every value. Note the magnitude of the y-axis is different between panels.

<u>Stocked Razorback Sucker Reproduction Bottleneck</u>

In 2017, the SJRRIP funded Southwestern ARRC to estimate the annual effective number of breeding (N_b) Razorback Sucker using larvae collected from standardized sampling (Diver et al. in prep). When compared to the annual mean estimated population of adult Razorback Sucker (Schleicher 2017, SJRRIP 2017) in the majority of the San Juan River the mean annual effective proportion of adults successfully contributing to larval production was <3% (Figure 2), not including the population of Razorback Sucker below the waterfall (Cathcart et al. in review). Thus, the annual failure of more than ~97% of adult Razorback Sucker to effectively contribute to larval fish production suggests a reproduction bottleneck for this species.

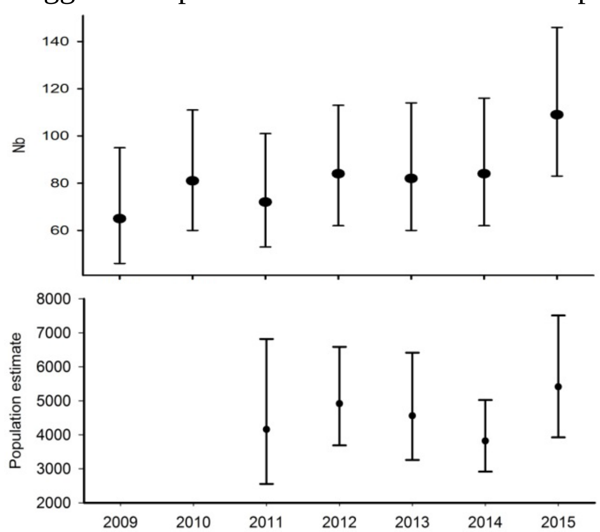

Figure 2. Estimated mean (95% CI) effective number of breeding (N_b) Razorback Sucker in the San Juan River (Diver et al. in prep; top panel) and adult population estimates from adult

monitoring annual captures using trip-specific capture probabilities (Schleicher 2016, SJRRIP 2017; bottom panel). Trip-specific detection probabilities for 2009 and 2010 were not available so population estimates were not calculated for those years.

Stocked Colorado Pikeminnow Bottleneck to Recovery

Unlike stocked adult Razorback Sucker, stocked Colorado Pikeminnow that survive to maturity do not appear to be confronted with a severe reproduction or spawning bottleneck. Estimates of annual adult population sizes and N_b for Colorado Pikeminnow suggest the effective breeding contribution of the adult population to larval fish was ~20% (Diver et al in prep, Schleicher 2016, SJRRIP 2017). Whereas it is currently unclear if wild-spawned Colorado Pikeminnow will recruit past age-0, the nominal accumulation of adult Colorado Pikeminnow from the five million hatchery fish stocked since 1996 potentially limits the reproductive output of this species. The low rate of recruitment of stocked fish to adulthood is probably due to a consistent and relatively low apparent survival of age 1-3 fish (0.19–0.25; Figure 3; Clark et al. in review). This relatively low apparent survival and absence of an appreciable increase between ages 1-3 significantly slows accumulation of mature Colorado Pikeminnow in the San Juan River and functions as a bottleneck to efficient and effective species recovery.

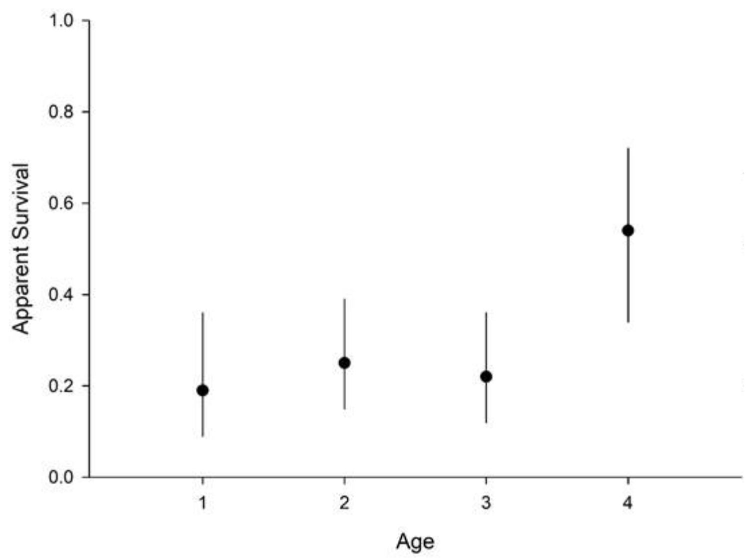

Figure 3. Age-specific apparent survival estimates for age1-4 Colorado Pikeminnow stocked into the San Juan River (Clark et al. in review)

Literature Cited

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	Predictions		Example paths forward	
Hypotheses	**Colorado Pikeminnow**	**Razorback Sucker**	**Colorado Pikeminnow**	**Razorback Sucker**
1. The availability of adequate trophic resources affects rates of recruitment.	Increased densities of 'available' fish prey would increase recruitment of stocked and wild juveniles.	Increased "availability" of trophic resources would increase recruitment.	1. Repatriate Roundtail Chub in the San Juan River system. 2. Stock larger, prey-trained fish with PIT tags. 3. Test if basal production is adequate to support larval and small-bodied fish in backwaters.	1. Test if basal production is adequate to support larval and small-bodied fish in backwaters. 2. Test if elevated base flows would increase availability of trophic resources.
2. Net rates of emigration/immigration of all life-stages affect rates of recruitment.	Reduced emigration rates or the ability to immigrate into the river would increase recruitment.	Reduced emigration rates or the ability to immigrate into the river would increase recruitment.	1. Provide upstream passage at the waterfall. 2. Estimate emigration rates as "mortality" of river population to assess priority to address.	1. Provide upstream passage at the waterfall. 2. Estimate emigration rates as "mortality" of river population to assess priority to address.
3. Recruitment is affected by reproductive output which is regulated by numbers of adult individuals spawning in adequate habitats.	Instream barriers to migration are limiting potential reproductive output.	Instream barriers to migration are limiting potential reproductive output.	1. Increase passage at PNM weir by making passage nonselective during the spring months. 2. Increase passage at waterfall and into the Animas River. 3. Mercury effects on reproduction	1. Increase passage at PNM weir by making passage nonselective during the spring months. 2. Increase passage at waterfall and into the Animas River.
4. Availability of rearing habitats affects rates of recruitment.	Increased juvenile rearing habitat will increase rates of recruitment.	Increased juvenile rearing habitat will increase rates of recruitment.	1. Test if elevated base-flows I) increase desired habitats and II) increase rates of recruitment. 2. Increase frequency of flowing secondary channels and backwaters.	1. Test if elevated base-flows I) increase desired habitats and II) increase rates of recruitment. 2. Create artificial wetland to advance understanding of recruitment limitations.
5. Nonnative fish competition and choking hazards effect rates of recruitment	Reduced abundances of nonnative fish will increase rates of recruitment	Reduced abundances of nonnative fish will increase rates of	1. Assess effects of competition and rates of choking	1. Assess effects of competition

	Predictions		Example paths forward	
Hypotheses	**Colorado Pikeminnow**	**Razorback Sucker**	**Colorado Pikeminnow**	**Razorback Sucker**
		recruitment		
6. Rates of entrainment affect rates of recruitment	Reduction in entrainment rates will increase recruitment	Reduction in entrainment rates will increase recruitment	1. Assess rates of entrainment 2. Minimize level of entrainment	1. Assess rates of entrainment 2. Minimize level of entrainment
TBD				
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