

AUGMENTATION OF COLORADO PIKEMINNOW
(*Ptychocheilus lucius*) IN THE SAN JUAN RIVER:
PHASE II, 2010-2020



Augmentation Plan



AUGMENTATION OF COLORADO PIKEMINNOW
(*Ptychocheilus lucius*) IN THE SAN JUAN RIVER:
PHASE II 2010-2020

Augmentation Plan

Submitted to:
The San Juan River Basin Recovery Implementation Program
Biology Committee

By:
D. Weston Furr
United States Fish and Wildlife Service, Region 2
New Mexico Fish and Wildlife Conservation Office
3200 Commons Ave
Albuquerque, New Mexico 87109
Phone: (505) 342-9900
Weston_Furr@fws.gov

11 February 2010

EXECUTIVE SUMMARY

Colorado pikeminnow, *Ptychocheilus lucius*, is federally listed as endangered and is currently one of two species managed for through the San Juan River Basin Recovery Implementation Program (SJRIP). Due to low observed numbers of Colorado pikeminnow in the San Juan River, *An Augmentation Plan for Colorado pikeminnow in the San Juan River* was completed and approved in 2003 and subsequently amended in 2005 (Ryden 2003 and 2005). The SJRIP anticipated that augmenting the population for eight years, 2002 to 2009, would result in ≥ 800 adult fish persisting and contributing to the reproduction of wild spawned offspring. However, capture statistics on fish stocked during the augmentation period suggest relatively low retention and/or survival. In order to accomplish recovery goals the need to continue augmentation efforts has been identified by the SJRIP. This document outlines the second phase (Phase II) for augmentation of Colorado pikeminnow in the San Juan River. Phase II defines the continuation of Colorado pikeminnow augmentation and will exist as a 'living document' subject to review, amendment, and implementation as required for as long as the SJRIP deems it a necessary component of recovery.

The need to augment and expand the range of the wild San Juan River Colorado pikeminnow population is addressed in the SJRIP's Long Range Plan and the revised Colorado pikeminnow Recovery Goals (SJRIP 2008, USFWS 2008). The goal of this Phase II augmentation plan is to outline a stocking regime that will contribute to the establishment of a self-sustaining multiple year-class population of Colorado pikeminnow in the San Juan River.

The SJRIP Biology Committee decided to shift all Phase II augmentation efforts to the production and stocking of age-0 Colorado pikeminnow (SJRIP Biology Committee Meeting, January 2010; Farmington, New Mexico). This decision was, in part, based on a cost/benefit analysis of stocking age-0 and age-1+ Colorado pikeminnow (Scott Durst email 12/23/2009). Dexter National Fish Hatchery and Technology Center (Dexter NFH&TC) is currently the only facility rearing Colorado pikeminnow for the SJRIP. Under full production capacity it is expected that Dexter NFH&TC will provide $\geq 400,000$ age-0 fish annually to satisfy Phase II augmentation targets.

To better estimate the efficacy of augmentation efforts new retention factors were developed for Phase II to replace the Phase I survival curves. The retention factor for age-0 Colorado pikeminnow assumes a 90% loss within 1-4 weeks post-stocking and an additional 80% loss for the remaining fish in the first over-winter period (5 months post-stocking). This formula therefore

predicts that 98% of age-0 Colorado pikeminnow stocked in fall will not retain by the following spring. However, augmentation efforts, in spite of low retention, coupled with Colorado pikeminnow currently in the San Juan River could establish a self-sustaining population of ≥ 800 adult fish within ten years or less.

The Colorado pikeminnow Recovery Goals (USFWS 2008) identifies the criteria for delisting as it relates to the San Juan River as:

- (2) either the upper Colorado River subbasin self-sustaining population exceeds 1,000 adults

OR

the upper Colorado River subbasin self-sustaining population exceeds 700 adults and San Juan River subbasin population is self-sustaining and exceeds 800 adults (numbers based on inferences about carrying capacity) such that for each population

- (a) the trend in adult point estimates does not decline significantly, and
 - (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and
- (3) when certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Therefore, facilitating the establishment of a self-sustaining adult population of > 800 adult (age 7+; ≥ 450 mm TL) fish in the San Juan River is the ultimate objective of this Phase II augmentation plan. Under current SJRIP monitoring programs spatial and temporal trends of stocked Colorado pikeminnow will be evaluated. However, specific studies may be necessary in order to gather detailed information on dispersal, survival/retention, age-growth relationships, and population size. Phase II augmentation as part of the SJRIP is subject to review and revision under adaptive management and will be evaluated annually to incorporate new information and the best available science.

Table of Contents

EXECUTIVE SUMMARY	i
Phase I Summary	1
Stockings Numbers	1
Source of Fish	1
Phase I Discussion	2
Phase II	4
Stocking Numbers	4
Source of Fish	4
Phase II Discussion	5
Estimating Retention.....	5
Stocking Predictions.....	10
Monitoring and Adaptive Management.....	11
Literature Cited:.....	12

Tables and Appendices

Table 1 - Phase I estimates of between-year survival for every 100,000 age-0 Colorado pikeminnow stocked (Ryden 2003).	5
Table 2 - Phase II estimates of between-year retention for every 100,000 age-0 Colorado pikeminnow stocked.	6
Table 3 - Phase II retention factors showing between-year recruitment from age-0 to age-7 adults under differing stocking rates.	9
Table 4 - Phase II stocking target with varying first year retention factors and subsequent between-year recruitment from age-1 to age-7 adults under typical Phase II retention factors.	9
Table 5 - Phase II retention rates and expected between-year recruitment for 400,000 annually stocked age-0 Colorado pikeminnow over a 10 year effort.	10
Appendix 1 - Colorado pikeminnow stocked into the San Juan River under the Phase I augmentation plan.	14
Appendix 2 - A summary of Colorado pikeminnow that were stocked into the San Juan River, 1996-2009.	15

Phase I Summary

An Augmentation Plan for Colorado pikeminnow in the San Juan (Ryden 2003), hereafter referred to as Phase I, covered in great detail the San Juan River Basin Recovery Implementation Program's (SJRIP) investigation into, and justification for, the implementation of an aggressive stocking policy. This document will concentrate on new information and management actions to facilitate recovery through augmentation and will only minimally reiterate information provided by, and contained in, Phase I.

Stockings Numbers

Phase I called for 300,000 age-0 (250,000 in 2002, and 300,000 from 2003-2009) Colorado pikeminnow to be stocked annually. An addendum to the Phase I plan (Ryden 2005) requested that a subset of each year's age-0 fish be retained so that $\geq 3,000$ of these fish could be stocked in spring and/or fall as age-1 or older fish (age1+). The stocking of age-0 and age-1+ fish was implemented from fall of 2006 through fall 2009 (see Appendix 1). Opportunistic stockings of age-1+ have occurred since 1997 and have contributed to the overall numbers of fish stocked under all augmentation efforts (see Appendix 2).

Source of Fish

Under Phase I all Colorado pikeminnow were produced and reared at Dexter National Fish Hatchery & Technology Center (Dexter NFH&TC). However, opportunistic stockings capitalized on excess fish from the Colorado Division of Wildlife's Mumma Native Species Hatchery and the Arizona Game and Fish Department's Bubbling Ponds Hatchery.

Phase I Discussion

Calculations used to determine the number of age-0 Colorado pikeminnow to stock under Phase I were based off of survival curves that predicted 114.5 (rounded down to 114) fish would recruit into the first year of adulthood (age-7) for every 100,000 age-0 fish stocked (Ryden 2003). A minimum annual stocking target was established at 200,000 age-0 fish with a preferred target of 300,000. This was expected to result in a range of 228 to 342 adult fish recruiting into the population every subsequent seventh year post stocking. Having stocked these numbers annually for eight years, and assuming survival curves were accurate, there would be a six year period (calendar years 2013-2018) when ≥ 800 age-7+ fish would inhabit the San Juan River as a direct result of Phase I augmentation efforts (Ryden 2003).

Utilizing estimated survival curves approximately 287 adult (age-7+) Colorado pikeminnow were expected to recruit from age-0 stocked fish at the end of Phase I augmentation efforts (2009), 846 adults two years after the cessation of stockings (2011), and 1,685 adult fish in 2016 (Ryden 2003, Furr unpublished data). However, during Phase I multiple opportunistic stockings of older Colorado pikeminnow occurred prior to the addition of age-1+ fish to the augmentation targets (Appendices 1 and 2). Including all fish stocked since 2003, Phase I survival curves estimated 1,299 fish would recruit into age-7 or older by 2009, 2,397 in 2011, and 3,022 in 2016.

Analysis of annual fall monitoring recapture data from 2002 to 2008 suggests that the total number of adult Colorado pikeminnow in the San Juan River is much lower than projected. Moreover, no fish over the age of 5 has been collected during this same period of annual monitoring (Ryden 2009). Ryden (2008) reported that catch per unit effort of Colorado pikeminnow after one over-winter period, when scaled for numbers of fish stocked, has remained consistent from 2004 to 2008 and that no fish are collected after a fourth over winter period. The low number of recaptures of adult fish could be due to either, or both, of two reasons; **1)** actual numbers of adult Colorado pikeminnow in the sampled areas of the San Juan River are low (adult fish are moving upstream, downstream, or into side channel or tributaries that are outside of the normally sampled area, mortality is higher than estimated, etc.), and/or **2)** capture probability of adult Colorado pikeminnow in the sampled areas of the San Juan River is low (avoidance, limitations in sampling gear, sampling methodology, etc). However, a total of 329 Colorado pikeminnow collected in 2009 during nonnative removal efforts from RM 166.6 - 53.3 ranged in size from 290 to 616 mm total length. Some of these adult and sub-adult fish have persisted in the river for four or more over-winter periods (Davis unpublished data). These findings emphasize the

importance of continued analysis of recapture data to better gauge the efficacy of the Phase I augmentation effort and how it will shape Phase II efforts.

The final stocking of age-0 and age-1+ Colorado pikeminnow under Phase I occurred on November 9, 2009. During Phase I a total of 2,531,953 Colorado pikeminnow were stocked into the San Juan River; 2002-2009 (Appendix 1). This total represents the combination of 2,496,440 age-0 fish (6.2% above stocking target) and 36,513 age-1+ fish (204.3% above stocking target) stocked over eight years. Utilizing Phase I survival curves and calculating from the actual numbers of age-0 and age-1+ fish stocked there were expected to be 1,109 adult fish in the San Juan River in 2008 (all from age-1+ stocked fish), and 1,253 adult fish in 2009 (1,012 from age-1+, 241 recruited from age-0 stocked fish). By 2014, the theoretical ceiling for Phase I augmented adult fish will be reached with 1,520 adults recruiting from the age-0 stockings plus 1,812 adults from age-1+ stockings (including opportunistically acquired fish) for a total of 3,332 age-7+ fish in the San Juan River. Recapture and CPUE data does not suggest that there is currently over 1,200 age-7+ fish in the San Juan River and the probability of recruiting over 3,000 adult fish by 2014 is low. However, with continued augmentation and the recruitment of wild spawned fish, a self-sustaining population of ≥ 800 age-7+ Colorado pikeminnow may be achievable by 2020.

Phase II

Stocking Numbers

The SJRIP Biology Committee decided in January 2010 to shift all Phase II augmentation efforts to the production and stocking of age-0 Colorado pikeminnow. The Phase II annual stocking targets for age-0 fish are currently limited to what can be produced at Dexter NFH&TC in a single year. Production forecasts suggest $\geq 400,000$ age-0 Colorado pikeminnow will be available annually (Manuel Ulibarri, personal communication, January 22, 2010). This production target represents full utilization of available rearing space, currently 4 grow-out ponds, and the reproductive capabilities of the Colorado pikeminnow broodstock held on station. Considering these limitations Phase II annual stocking targets will be a minimum of 400,000 age-0 Colorado pikeminnow.

The SJRIP Biology Committee agreed that since Dexter NFC&TC had already held over 2009 year-class Colorado pikeminnow to fulfill 2010 age-1+ stocking obligations, the first year under the Phase II augmentation effort will stock 300,000 age-0 fish and 3,000 age-1+ fish in the fall of 2010. This will be the last scheduled augmentation effort involving age-1+ fish. Implementation of Phase II stocking modifications will take effect in 2011 with $\geq 400,000$ age-0 fish stocked annually. However, if circumstances arise for opportunistically acquired age-1+ fish to be stocked, those instances will be addressed independently.

Source of Fish

Dexter NFH&TC is currently the only facility contracted to provide Colorado pikeminnow for stocking into the San Juan River. Numbers of age-0 fish that can be stocked annually is limited to what can be produced at Dexter NFH&TC in a single year. If it is determined that more than 400,000 age-0 fish are required to meet recovery goals of the SJRIP, more rearing space will need to be commissioned, either at Dexter NFH&TC or another facility, and the current broodstock will need to be augmented. Augmenting the current broodstock could occur through on-station development, which may take upwards of 7 years (Manuel Ulibarri, personal communication), or through collection of adult fish from a donor population (nearest geographical neighbor population), as was done with the initial broodstock taken from the upper Colorado River basin (Ryden 2003).

Phase II Discussion

Estimating Retention

The Phase I augmentation plan utilized the best available data to estimate survival curves between years in order to predict the number of fish that would recruit into the successive age-classes. According to these survival curves there is predicted to be over 1,500 age-7+ Colorado pikeminnow in 2010 that have 'survived' from Phase I augmentation efforts (Furr unpublished data). However, recent monitoring data suggests that recruitment into various age-classes may not fit that predicted model if 'survival' is the only criteria used in estimations (Ryden 2009).

The San Juan River basin is highly stochastic, both physically and biologically. Multiple factors influence retention and survival of fish between years (predation, disease, emigration, flow, turbidity, temperature, etc.). In an attempt to synthesize the myriad components influencing stocked Colorado pikeminnow 'retention factors' were developed to replace Phase I 'survival curves'. Available data and information was combined with some inference and professional opinion to revise between-year recruitment rates for age-0 through age-2 Colorado pikeminnow (Tables 1 and 2). Currently there has not been a study designed specifically to determine actual between-year retention for these age-classes of Colorado pikeminnow in the San Juan River. Therefore, Phase II retention factors will have inherent limits to their accuracy without that specific data. Annual analysis of new information and data will be crucial in sharpening the resolution for determining retention amongst and between years and will be incorporated into successive augmentation efforts and models.

Table 1. Phase I estimates of between-year survival for every 100,000 age-0 Colorado pikeminnow stocked.
*Original estimates for between-year survival for age-1 and age-2 were calculated using 0.1508 rather than the rounded 0.15 (Ryden 2003). Numbers indicated here are taken directly from Phase I survival tables except that all fractions are rounded down to the nearest whole fish.

Age of Fish	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7
Survival Curve		0.15	0.15	0.30	0.50	0.60	0.70	0.80
# stocked 100,000		15,080*	2,274*	682	341	204	142	114

Table 2. Phase II estimates of between-year retention for every 100,000 age-0 Colorado pikeminnow stocked.

Bold indicates change from original Phase I survival curves.

Age of Fish	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7
Retention Factor		0.02	0.10	0.30	0.50	0.60	0.70	0.80
# stocked 100,000		2,000	200	60	30	18	13	10

Immediate post stocking losses account for the largest proportion of the reduction in the first year retention factor when compared to the original Phase I survival curve. These losses are attributed to a combination of factors including, but not limited to, emigration, predation, and low levels of mortality due to handling and hauling stress. Golden et al. (2006) observed “high initial loss/mortality of stocked fish”, and attributed that loss to a combination of downstream drift and mortality. Most of the loss was documented in the first few weeks following stocking and declined between 5 and 9 months post stocking. Low numbers of recaptures during their mark/recapture study was attributed to a combination of low levels of detection and lower survival than anticipated (Golden et al. 2006).

The initial loss after stocking due to *in situ* factors is attributed to the ‘freshman effect’; fish are naïve to wild conditions and succumb more easily to the various factors that reduce retention. Soft release protocols (allowing fish to acclimatize to riverine conditions prior to release) were implemented to ameliorate some of the initial downstream displacement common with recently stocked fish (Furr and Davis 2009). However, at least one acclimatized age-0 Colorado pikeminnow was collected during 2007 small-bodied fish community monitoring 127.6 miles downriver, a few miles up from the Clay Hills waterfall, just nine days after its release (Paroz 2008). Acclimatization may lessen the ‘freshman effect’ somewhat, but cannot guarantee retention in either the short or long term. Another negative aspect of the ‘freshman effect’ is the likelihood of predation on predator naïve hatchery reared fish (Marsh and Brooks 1989, Minckley 1983, Mueller 2007, Schlechte et al 2005). There are advantages to stocking hatchery reared age-0 Colorado pikeminnow in late fall: 1) fish will have acquired a larger body-size which could limit predation by smaller gaped piscivores, and 2) cooler water temperatures will decrease metabolic demands of piscivores thus curbing predation throughout the winter months. Furthermore, nonnative removal efforts conducted under the SJRIP specifically target, and attempts to lessen, the predation threat from nonnative fishes. Unfortunately, in spite of efforts taken, losses to predation by

nonnative fishes, and cannibalism by other Colorado pikeminnow, will persist and is considered to have a negative impact on survival as it relates to retention.

Immediate (1-4 weeks) losses to emigration or mortality for age-0 fish under Phase II are estimated to be 90%. This accounts for high initial losses, but is lower than the 93% initial emigration reported with hatchery reared rainbow trout stocked in a tailwater fishery (Bettinger, 2002). Furthermore, an additional 80% of remaining fish are estimated to be lost during the first over-winter period (within 5 months after stocking). This first over-winter loss is similar to Phase I estimated loss of 85% but is slightly lower due to the assumption that fish that have retained past 4 weeks are those fish that are less susceptible to the 'freshman effect' and thus stand a slightly better chance at retaining through their first over-winter period. Combining immediate and first over-winter period losses Phase II retention factors estimate that 98% of age-0 Colorado pikeminnow stocked in late fall are lost from the San Juan River by the following spring.

Analysis of recapture data from annual fall monitoring 2003-2008 suggests that mean first year survival and recruitment into age-1 for Colorado pikeminnow stocked as age-0 may be as low as 0.33% (Ryden 2009). Thus, the 2% retention factor is only utilized as a benchmark for first over-winter retention and will undoubtedly not remain constant between years and cohorts. Furthermore, it does not take into account continued losses over the first spring and summer periods due to increased predation or stochastic hydrological fluctuations. These continued losses are partially accounted for in the reduction in the age-1 to age-2 retention factor.

Assuming that the 'freshman effect' predominantly influences stocked fish during their first year in the river Phase II retention factors estimate 10% of age-1 will recruit to age-2. This represents a 5% reduction from Phase I survival curves for age-1 to age-2 to account for lingering 'freshmen effects' and any other continued emigration and mortality. For fish that retain past 2 years, recruiting into age-3 and older (see Table 5), it is predicted that retention factors will be the same as Phase I survival curves. However, after age-3 the term 'retention factor' still replaces 'survival curve' in order to more clearly attribute losses to both mortality and emigration. For example, Phase I survival curves anticipated that between ages 4 and 5 there would be 50% survival, the opposite of survival being mortality. Phase II anticipates 50% retention, the opposite of retention being no longer in the system for whatever reason (mortality **or** emigration). Mainly a matter of semantics, in either case the outcome is the same; 50% of fish should still be in the system.

With each consecutive year in the river there is a chance that an individual fish will survive but emigrate from the system. Emigration could explain the low observed retention of older Colorado pikeminnow. In the case of downstream movement once a fish passes over the waterfall below Clay Hills, UT it is entrained in Lake Powell without the ability to repatriate itself into the San Juan River. Thus, the argument could be made that between-year retention for Colorado pikeminnow in the San Juan River should decrease because of an increased likelihood of emigration from the system due to range expansion and roaming as fish grow. However, Osmundson et al. (1998) studying movements of sub-adult and adult Colorado pikeminnow in the upper Colorado River reported that most recaptures occurred within 10 km of previous capture/recapture sites and that most movements >10 km were in an upstream direction. Furthermore, distance traveled was inversely proportional to size of fish with sub-adult and smaller adult fish traveling further upstream than their larger adult counterparts. If movement patterns within the San Juan River are analogous to those in the upper Colorado River then the postulation that retention for Colorado pikeminnow increases with age should be valid.

A further explanation to the lack of recaptures for older Colorado pikeminnow is that they may exhibit a greater ability to avoid capture by the various sampling methods currently being employed by researchers. However, it is unlikely that avoidance behavior alone could account for the paucity of recaptures of age-7+ fish given an evenly distributed predicted density in 2009 of 7.2 adult fish per river mile (1,299 fish in 180 RMs) utilizing Phase I survival curves. Back-calculating Phase I augmentation numbers with Phase II retention factors, and assuming an immediate loss of 50% for age-1+ stocked fish (50% vs. 90% for age-0 is assuming older fish are a little less susceptible to the 'freshmen effect'), there would have been an expected 2.9 age-7+ fish per river mile (526 fish in 180 RMs). Recapture data does not indicate that adult numbers and densities are currently at either of these levels. Nevertheless, collections of sub-adult and adult Colorado pikeminnow confirm that fish stocked as part of augmentation efforts can, and in fact do, retain and grow within the San Juan River basin.

As stated earlier the retention factors estimated for Phase II are only a benchmark to create recruitment prediction models and help assess augmentation efficacy. Utilizing an adaptive management approach, retention factors will be reviewed and modified periodically to incorporate new information as it becomes available. Tables 3 and 4 illustrate potential recruitment under increased numbers of stocked age-0 Colorado pikeminnow and under varying retention factors for 400,000 stocked fish, respectively.

Table 3 Phase II retention factors showing between-year recruitment from age-0 to age-7 adults under differing stocking rates. **Bold** indicates Phase II stocking target and subsequent retention. All fractions rounded down to the nearest whole fish.

Age of Fish	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7
Retention Factor		0.02	0.10	0.30	0.50	0.60	0.70	0.80
# stocked	100,000	2,000	200	60	30	18	12	10
	200,000	4,000	400	120	60	36	25	20
	400,000	8,000	800	240	120	72	50	40
	600,000	12,000	1,200	360	180	108	75	60
	800,000	16,000	1,600	480	240	144	100	80
	1,200,000	24,000	2,400	720	360	216	151	120
	1,600,000	32,000	3,200	960	480	288	201	161

Table 4 Phase II stocking target with varying first year retention factors and subsequent between-year recruitment from age-1 to age-7 adults under regular Phase II retention factors. **Bold** indicates Phase II stocking target and retention factors. *Italics* indicate original Phase I survival curve estimates. All fractions rounded down to the nearest whole fish.

Age of Fish	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7
# stocked *(retention factor)			0.10	0.30	0.50	0.60	0.70	0.80
400,000(.005)		2,000	200	60	30	18	12	10
400,000(.01)		4,000	400	120	60	36	25	20
400,000(.02)		8,000	800	240	120	72	50	40
400,000(.03)		12,000	1,200	360	180	108	75	60
400,000(.05)		20,000	2,000	600	300	180	126	100
400,000(.075)		30,000	3,000	900	450	270	189	151
400,000(.10)		40,000	4,000	1,200	600	360	252	201
<i>400,000(.15)</i>	<i>60,000</i> <i>*(.15)</i>	<i>9,000</i>	<i>2,700</i>	<i>1,350</i>	<i>810</i>	<i>567</i>	<i>453</i>	
400,000(.20)		80,000	8,000	2,400	1,200	720	504	403

Stocking Predictions

2010 will be the first year under the Phase II augmentation effort but will be the last year that $\geq 300,000$ age-0 and $\geq 3,000$ age-1+ Colorado pikeminnow will both be stocked as part of the annual stocking target. Beginning in 2011 augmentation efforts will shift solely to stocking age-0 fish with the annual minimum stocking target of 400,000 fish. Table 5 illustrates recruitment into various age-classes over a 10 year augmentation effort utilizing Phase II retention factors. If Phase II retention factors closely represent actual recruitment then augmentation alone will not establish a population of ≥ 800 adult (age-7+) Colorado pikeminnow in the San Juan River. To satisfy delisting criteria it will require that adult fish recruit from both Phase I and Phase II augmentation efforts, reproduce in the wild, and maintain subsequent annual recruitment of wild progeny into adulthood.

Table 5 Phase II retention rates and expected between-year recruitment for 400,000 annually stocked age-0 Colorado pikeminnow over a 10 year effort. Recruitment of adults from Phase II stocked fish peaks in Year 17 (2027) and begins to decline in Year 18 (2028). Table 5 does not account for Colorado pikeminnow currently in the San Juan River or any wild spawned fish that may recruit into the population. Retention factors align with the 2011 column. All fractions rounded down to the nearest whole fish.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total fish all ages	Total # of age- 7+fish	Retention Factor
2011	400,000										400,000	0	
2012	8,000	400,000									408,000	0	0.02
2013	800	8,000	400,000								408,800	0	0.10
2014	240	800	8,000	400,000							409,040	0	0.30
2015	120	240	800	8,000	400,000						409,160	0	0.50
2016	72	120	240	800	8,000	400,000					409,232	0	0.60
2017	50	72	120	240	800	8,000	400,000				409,282	0	0.70
2018	40	50	72	120	240	800	8,000	400,000			409,323	40	0.80
2019	34	40	50	72	120	240	800	8,000	400,000		409,357	74	0.85
2020	29	34	40	50	72	120	240	800	8,000	400,000	409,386	103	0.85
2021	25	29	34	40	50	72	120	240	800	8,000	9,412	128	0.86
2022	21	25	29	34	40	50	72	120	240	800	1,434	149	0.86
2023	18	21	25	29	34	40	50	72	120	240	652	167	0.86
2024	15	18	21	25	29	34	40	50	72	120	428	182	0.86
2025	13	15	18	21	25	29	34	40	50	72	322	195	0.86
2026	11	13	15	18	21	25	29	34	40	50	262	206	0.86
2027	10	11	13	15	18	21	25	29	34	40	222	216	0.86
2028	8	10	11	13	15	18	21	25	29	34	191	184	0.86

Monitoring and Adaptive Management

The SJRIP has a long-term monitoring framework in place that will allow researchers to track spatial and temporal trends of stocked Colorado pikeminnow and their reproductive effort. Specific studies may be necessary to obtain information on post-stocking dispersal, survival/retention, age-growth relationships, and population size. Evaluation of the augmentation program should be conducted on a regular basis to determine whether stocking numbers are sufficient to facilitate recovery of Colorado pikeminnow in the San Juan River by 2023.

As with all management and recovery-related actions being performed under the SJRIP, this augmentation plan is subject to adaptive management. Stocking targets are subject to modification by the SJRIP as part of periodic augmentation assessments. This Phase II augmentation plan, including its goals and objectives, can be revised, in part or in full, at any time in the future if new information determines that this plan no longer represents the best available science.

Literature Cited:

- Bettinger, Jason M., Phillip W. Bettoli, 2002. Fate, Dispersal, and Persistence of Recently Stocked and Resident Rainbow Trout in a Tennessee Tailwater, *North American Journal of Fisheries Management* 22:425–432
- Furr, D. W and J.E. Davis. 2009. Stocking Plan and Protocol for the Augmentation of Colorado pikeminnow (*Ptychocheilus lucius*) in the San Juan River. Draft for the U.S. Fish and Wildlife Service, Albuquerque, NM. 9 pp.
- Golden, M. E., P. B. Holden, and B. Albrecht, 2006. Retention, Growth, and Habitat Use of Colorado Pikeminnow Stocked as Age-0 Fish in the San Juan River from 2002–2005: Final Summary Report . Prepared by BIO-WEST Inc. for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque. 171 pp.
- Marsh, Paul C. and James E. Brooks, 1989. Predation by Ictalurid Catfishes as a Deterrent to Re-Establishment of Hatchery-Reared Razorback Suckers. *Southwestern Nat.*, Vol. 34, No. 2 (Jun., 1989), pp. 188-195
- Minckley, W. L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorado River basin. *Southwestern Nat.*, Vol. pp 28:165-187, 1983
- Mueller, G.A., Carpenter, Jeanette, Krapfel, Robert, and Figiel, Chester, 2007, Preliminary testing of the role of exercise and predator recognition for bonytail and razorback sucker: U.S. Geological Survey Open-File Report 2007-1423, 37 p.
- Osmundson, D. B., R. J. Ryel, M. E. Tucker, B. D. Burdick, W. R. Elmblad, T. E. Chart, 1998. Dispersal Patterns of Subadult and Adult Colorado Squawfish in the Upper Colorado River. *Transactions of the American Fisheries Society* 127:943–956, 1998
- Paroz, Yvette M., David L. Propst, Stephanie M. Carman, and Nikolas D. Zymonas, 2008. Small-Bodied Fish Monitoring, San Juan River September – October 2007. Prepared by New Mexico Department of Game and Fish for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque. 74 pp.
- Ryden, D. W. 2003. An augmentation plan for Colorado pikeminnow in the San Juan River. U. S. Fish and Wildlife Service, Grand Junction, CO. 63 pp. + appendices.

- Ryden, D. W. 2005. An augmentation plan for Colorado pikeminnow in the San Juan River. Addendum # 1: Stocking age-1 fish to supplement ongoing augmentation efforts. U. S. Fish and Wildlife Service, Grand Junction, CO. 3 pp.
- Ryden, D.W. 2008. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2007. Final report for the SJRIP, U.S. Fish and Wildlife Service, Albuquerque, NM. 55 pp.
- Ryden, D.W. 2009. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2008. Final report for the SJRIP, U.S. Fish and Wildlife Service, Albuquerque, NM. 64 pp.
- San Juan River Basin Recovery Implementation Program. 2008. Long-range plan. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.
- Schlechte, J. Warren, Robert K. Betsill, and David L. Buckmeier, 2005. A Laboratory Evaluation of Poststocking Predatory Losses for Cultured Largemouth Bass. Transactions of the American Fisheries Society 2005; 134: 141-148
- U.S. Fish and Wildlife Service. 2008. Colorado pikeminnow (*Ptychocheilus lucius*) recovery goals (2008 revisions): Amendment and supplement to the Colorado squawfish recovery plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

Appendix 1 - Colorado pikeminnow stocked into the San Juan River under the Phase I augmentation plan.

Dates	Number Stocked & (Age-Class)	River Miles Stocked At	Mean Total Length (in mm)	Range Of Total Lengths (in mm)	Responsible Agency ^a
2002: 210,418 total fish stocked					
10/24/2002	105,209 (0)	180.2	51	32-127	USFWS-CRFP
10/24/2002	105,209 (0)	158.6	51	32-127	USFWS-CRFP
2003: 176,933 total fish stocked					
11/06/2003	155,764 (0)	180.2-170.5 & 158.6-148.5	58	38-100	USFWS-CRFP
11/06/2003	20,164 (0)	188.4-180.7 & 163.7-159.2	58	Unknown	BIO-WEST
11/06/2003	1,005 (1)	180.2	180	125-280	CDOW-Mumma
2004: 281,219 total fish stocked					
06/09/2004	1,219 (2)	180.2	218	144-278	CDOW-Mumma
10/21/2004	30,000 (0)	178.6-169.5 & 163.7-159.2	50	Unknown	BIO-WEST
10/21/2004 & 10/28/2004	250,000 (0)	180.2-170.5 & 158.6-148.5	50	35-116	USFWS-CRFP & BIO-WEST
2005: 306,811 total fish stocked					
07/07/2005	500 (1)	180.2	201	114-256	USFWS-Dexter
07/07/2005	1,491 (2)	180.2	204	121-281	CDOW-Mumma
10/20/2005	20,000 (0)	175.8, 167.5 & 167.4	55	32-151	BIO-WEST
10/20/2005 & 11/03/2005	282,270 (0)	180.2-170.5 & 158.6-148.5	55	32-151	USFWS-CRFP
11/10/2005	2,550 (2)	180.2	167	115-252	CDOW-Mumma
2006: 326,547 total fish stocked					
07/13/2006	3,247 (2)	180.2	200	119-278	CDOW-Mumma
07/13/2006	279 (3)	180.2	216	155-276	CDOW-Mumma
07/20/2006	3,986 (2)	180.2	211	117-297	CDOW-Mumma
08/03/2006	1,722 (5)	147.9	410	333-518	USFWS/AZG&F
09/06/2006	259 (5)	147.9	428	389-461	USFWS/AZG&F
10/03/2006	3,200 (1)	158.6	163	119-199	USFWS-Dexter
10/19/2006 & 11/02/2006	313,854 (0)	180.2-170.5 & 158.6-148.5	57	36-111	USFWS-CRFP
2007: 479,226 total fish stocked					
04/18/2007	1,590 (1)	134.5	176	137-228	Dexter & NMFWCO
10/03/2007	81,974 (0)	134.5	~55	Unknown	Dexter & NMFWCO
10/03/2007	1,666 (1)	134.5	~178	147-208	Dexter & NMFWCO
11/07/2007	199,717 (0)	180.2-170.5	58	38-146	USFWS-CRFP
11/14/2007	194,279 (0)	166.6	55	41-157	USFWS-CRFP
2008: 275,091 total fish stocked					
4/15/2008	2,057 (2)	134.9	209	Unknown	Dexter & NMFWCO
10/21/2008	2,800 (2)	134.3	299	Unknown	Dexter & NMFWCO
11/06/2008	270,234 (0)	166.6	55	Unknown	Dexter & NMFWCO
2009: 476,942 total fish stocked					
3/17/2009	1,442 (3)	133.5	240	Unknown	Dexter & NMFWCO
3/17/2009	1,500 (3)	133.5	240	Unknown	Dexter & NMFWCO
10/26/2009	4,000 (2+)	133.5	325	Unknown	Dexter & NMFWCO
10/26/2009	1,000 (2+)	133.3	325	Unknown	Dexter & NMFWCO
11/09/2009	468,000 (0)	166.6	~55	~50-60	Dexter & NMFWCO
11/09/2009	1,000 (2+)	180.2	325	Unknown	Dexter & NMFWCO
Total number of fish stocked from 2002-2009 = 2,531,953					

USFWS= U.S. Fish & Wildlife Service; CRFP = Colorado River Fishery Project, Grand Junction, Colorado; BIO-WEST = BIO-WEST, Inc., Logan, Utah; CDOW-Mumma = Colorado Division of Wildlife, J.W. Mumma Native Species Hatchery, Alamosa, Colorado; Dexter = Dexter National Fish Hatchery and Technology Center, Dexter, NM; AZG&F = Arizona Game and Fish Department, Bubbling Ponds Hatchery, Sedona, AZ; NMFWCO= New Mexico Fish & Wildlife Conservation Office, Albuquerque. ~ indicates estimates

Appendix 2 - A summary of Colorado pikeminnow that were stocked into the San Juan River, 1996-2009.

Year Stocked	Number Stocked	River Mile(s) Stocked At	Mean Total Length (in mm)	Range Of Total Lengths (in mm)	Age-Class & (Year-Class) Of Fish Being Stocked	Type Of Stocking	Entity/Agency Responsible For Stocking
1996	100,000	148.0 & 52.0	55	25-85	Age-0 (1996)	Experimental	UDWR
1997	116,878	148.0 & 52.0	45	35-55	Age-0 (1997)	Experimental	UDWR
1997	49	180.2	644	550-753	Age-16 (1981)	Opportunistic	USFWS
1998	10,571	148.0	24	18-28	Age-0 (1998)	Experimental	UDWR
1999	500,000	158.6	"Larvae"	Unspecified	Age-0 (1999)	Experimental	UDWR
2000	105,000	141.9	"Larvae"	Unspecified	Age-0 (2000)	Experimental	UDWR
2001	148	180.2	540	442-641	Age-10 (1991)	Opportunistic	USFWS
2002	210,418	180.2 & 158.6	51	32-127	Age-0 (2002)	Augmentation	USFWS
2003	175,928	180.2-170.5 & 158.6-148.5 (a) 188.4-180.7 & 163.7-159.2 (b)	58	38-100	Age-0 (2003)	Augmentation	USFWS (a) & BIO-WEST (b)
2003	1,005	180.2	180	125-280	Age-1 (2002)	Opportunistic	CDOW
2004	280,000	180.2-170.5 & 158.6-148.5	50	35-116	Age-0 (2004)	Augmentation	USFWS & BIO-WEST
2004	1,219	180.2	218	144-278	Age-2 (2002)	Opportunistic	CDOW
2005	302,270	180.2-170.5 & 158.6-148.5	55	32-151	Age-0 (2005)	Augmentation	USFWS & BIO-WEST
2005	500	180.2	201	114-256	Age-1 (2004)	Opportunistic	USFWS
2005	4,041	180.2	181	115-281	Age-2 (2003)	Opportunistic	CDOW
2006	313,854	180.2-170.5 & 158.6-148.5	57	36-111	Age-0 (2006)	Augmentation	USFWS
2006	3,200	158.6	163	119-199	Age-1 (2005)	Augmentation	USFWS
2006	7,233	180.2	207	117-297	Age-2 (2004)	Opportunistic	CDOW
2006	279	180.2	216	155-276	Age-3 (2003)	Opportunistic	CDOW
2006	1,981	147.9	411	333-518	Age-5 (2001)	Opportunistic	AZG&FD, USFWS & BIA
2007	475,970	180.2-170.5, 166.6 & 134.5	58	37-157	Age-0 (2007)	Augmentation	USFWS
2007	3,256	134.5	176	137-228	Age-1 (2006)	Augmentation	USFWS
2008	2,057	134.9	209	Unspecified	Age-2 (2006)	Augmentation	USFWS
2008	2,800	134.3/133.5	299	Unspecified	Age-2+ (2006)	Augmentation	USFWS
2008	270,234	166.6	55	Unspecified	Age-0 (2008)	Augmentation	USFWS
2009	2,942	133.5/133.5	240	Unspecified	Age-3 (2006)	Augmentation	USFWS
2009	5,000	133.5/133.3	325	Unspecified	Age-2+ (2007)	Augmentation	USFWS
2009	468,000	166.6	55	~50-60	Age-0 (2009)	Augmentation	USFWS
2009	1,000	180.2	325	Unspecified	Age-2+ (2007)	Augmentation	USFWS