AN AUGMENTATION PLAN FOR COLORADO PIKEMINNOW IN THE SAN JUAN RIVER

Final Report

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U. S. Fish and Wildlife Service

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EXECUTIVE SUMMARY

This document outlines an augmentation plan for Colorado pikeminnow in the San Juan River. Colorado pikeminnow is a scientifically documented member of the San Juan River fish community in New Mexico, Colorado, and Utah. However, numbers of wild Colorado pikeminnow extant in the San Juan River are very low.

In order to facilitate studying Colorado pikeminnow in the San Juan River, approximately 827,449 age-0 and larval Colorado pikeminnow were stocked into the San Juan River by the Utah Division of Wildlife Resources (UDWR) from 1996-2000. Another 197 adult Colorado pikeminnow were stocked into the San Juan River by the U.S. Fish and Wildlife Service (USFWS) in 1997 (n = 49) and 2001 (n = 148). Data collected on these stocked fish indicated that a full-scale augmentation effort for Colorado pikeminnow in the San Juan River was warranted.

The need to augment and expand the range of the wild San Juan River Colorado pikeminnow population is addressed in several places in both the new and old versions of the San Juan River Recovery Implementation Program (SJRIP) Long Range Plan as well as the Program Document. The goal of this augmentation plan is to outline a stocking regime that will establish a multiple year-class population of Colorado pikeminnow in the San Juan River, via intensive stocking. It is hoped that establishment of such a population will help lead to the recovery of this species in the San Juan River.

Certain risks, both genetic and ecological, are inherent when stocking hatchery-produced Colorado pikeminnow in a system that already has a population of wild fish. These risks, though identified herein, have essentially been accepted by the SJRIP through its earlier stockings of large numbers of Colorado pikeminnow into the San Juan River.

Colorado pikeminnow to be stocked into the San Juan River will be produced using two different broodstocks, the “1981" and “1991" broodstocks, currently being held at Dexter, National Fish Hatchery (NFH). These two broodstocks could both potentially be used in spawning operations each year. As many viable adult fish as possible will be used to produce young fish for this augmentation effort, thus insuring the maximum amount of genetic diversity possible among stocked fish. Using the fish at Dexter NFH represents augmentation using the “nearest geographic neighbor” approach. The use of a nearest geographic neighbor stock for augmentation of Colorado pikeminnow in the San Juan River is an acceptable approach that follows recommendations made in the ***Genetics Management Plan For The Endangered Fishes Of The San Juan River***.

Young Colorado pikeminnow will be reared at Dexter NFH until early November of the year they are produced. They will then be stocked into the San Juan River, freeing up needed hatchery space for the next year-class of fish to be produced. Stocking age-0 Colorado pikeminnow in the fall should allow sufficient growth for approximately 50-55 mm TL fish to be stocked in November.

The ***Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan*** published by the U. S. Fish and Wildlife Service (2002) identify a population of > 800 adult (age-7+) Colorado pikeminnow in the San Juan River as being the necessary demographic criteria to delist this species basin-wide. The San Juan River Biology Committee has decided to adopt an adult population of > 800 adult (age 7+) fish as the target of this augmentation plan.

Survival curves used in this plan predict that for every 100,000 stocked age-0 Colorado pikeminnow, 114.5 will recruit into the first year of adulthood (age-7). So, stocking of 200,000 age-0 fish should result in 229 fish at

age-7. This number – 200,000 age-0 fish – will be the minimum number of fish to be stocked in any given calendar year of this augmentation effort. Assuming the survival curves used in this plan are correct, stocking 200,000 age-0 fish annually for a period of eight years would provide a six-year window with > 800 age 7+ fish (calendar years 2013-2018) in the San Juan River that are a direct result of this augmentation effort. Dexter NFH is scheduled to produce at least 200,000 age-0 fish to be stocked in calendar year 2002.

However, the preferred course of action is to stock 300,000 (or possibly more) age-0 Colorado pikeminnow during each calendar year of this augmentation effort. Assuming the survival curves used in this plan are correct, stocking 300,000 age-0 fish annually for a period of eight years would provide a 10-year window with > 800 age 7+ fish (calendar years 2011-2020)in the San Juan River that are a direct result of this augmentation effort. Beginning in 2003, it is recommended that Dexter NFH try to produce at least 300,000 age-0 Colorado pikeminnow for stocking in each remaining calendar year of this augmentation effort.

Whether stocking 200,000 or 300,000 age-0 fish annually, the windows for achieving the goal of > 800 age 7+ fish can be extended (by either one or two years, respectively) if stocking is extended from an eight- to a nine-year stocking period (as proposed in Nesler 2001).

In early November, age-0 Colorado pikeminnow will be stocked in roughly equal numbers within the bounds of two stocking areas in the San Juan River. The upstream stocking area is from RM 180.2-170.0 and is completely upstream of the PNM Weir (RM 166.6). The downstream stocking area is from RM 158.6-148.0 and is downstream of all water diversion structures in the San Juan River. Both stocking areas are located in New Mexico.

The SJRIP already has a long-term monitoring framework in place that will allow researchers to track general Colorado pikeminnow population trends until Colorado pikeminnow become more abundant in the San Juan River. More specific studies may be performed under separate workplans (if approved by the San Juan River Biology Committee) to obtain more detailed information on post-stocking dispersal, survival, age-growth relationships, etc. during periods of the calendar year not already covered by existing monitoring studies. It is recommended that as early as calendar year 2007, an intensive riverwide mark-recapture study be initiated to obtain high-precision point estimates to determine the number of adult fish in the San Juan River Colorado pikeminnow population. It is recommended that this sampling should encompass the San Juan River from RM 180.0-0.0. Additionally, it is recommended that the mechanical removal of all nonnative fishes encountered during monitoring and research studies be continued. This should help promote increased post-stocking survival of age-0 Colorado pikeminnow by minimizing competitive and predative interactions with nonnative fishes.

As with all management- and recovery-related actions being performed under the SJRIP, this augmentation plan is subject to the adaptive management approach. This plan (including its goal and objective) 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.

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INTRODUCTION

The Colorado pikeminnow (Ptychocheilus lucius), formerly known as the Colorado squawfish (Nelson et al. 1998), was historically widespread and abundant in large streams and rivers throughout the Colorado River Basin (Miller 1961, Platania et al. 1991). Physical alterations of riverine habitats, impoundments, modified flow and thermal regimes, introduction of nonnative fish species, and increased levels of contaminants have all contributed to the decline of these native species (Platania 1990, Ryden and Pfeifer 1994b). Populations of Colorado pikeminnow are extant in the upper Colorado River basin (UCRB; Holden and Wick 1982, Platania et al. 1991). A very small, but reproducing population of Colorado pikeminnow is present in the San Juan River (Platania 1990, Platania et al. 1991). Colorado pikeminnow is federally-listed as endangered under the Endangered Species Act. This species is also protected by state laws in Arizona (AZ), California (CA), Colorado (CO), Nevada (NV), New Mexico (NM), Utah (UT), and by the Navajo Nation. Critical Habitat was designated for this species in the San Juan River from the confluence of Animas River in Farmington, NM to Neskahai Canyon in Lake Powell, UT (U. S. Fish and Wildlife Service {USFWS} 1994).

Information on the historic distribution and abundance of the Colorado pikeminnow in the San Juan River Basin is sparse. The number of early fishery surveys conducted in the San Juan River was relatively low compared to the rest of the Colorado River basin, likely because a large percentage of the river runs through Indian reservation land and much of the lower San Juan River is canyon-bound and difficult to access (Maddux et al. 1993). Historic accounts of Colorado pikeminnow in the San Juan River are based on regional accounts of the ichthyofauna, descriptions by anglers, and a handful of specimens of varying life-stages collected before 1980 (Table A-1 in Appendix A). Reports of Colorado pikeminnow ascending the Animas River (the San Juan River’s largest tributary) as far upstream as Durango, CO (Jordan 1891) are

unsubstantiated by museum specimens. Specimens collected by an angler in 1959 place the known range of the Colorado pikeminnow in the mainstem San Juan River as far upstream as three miles downstream of the town of Rosa, NM near the CO-NM state line (Koster 1960). This location is now inundated by Navajo Reservoir. Three juvenile Colorado pikeminnow (72-73 mm SL) collected in 1936 (Platania 1990) place the known, downstream distribution limits of Colorado pikeminnow in the San Juan River at Alcove Canyon, UT about 32 river miles (RM) upstream of the historic confluence of the San Juan and Colorado rivers. This location is now inundated by Lake Powell. Collections of San Juan River fishes during pre-impoundment rotenone applications in the Navajo Dam area in 1962, documented the presence of both juvenile (n = 4, 175-200 mm) and adult (n = 4 photographed specimens, all > 300 mm TL) Colorado pikeminnow upstream of Farmington as late as 1961 (Olson 1962). Although scientifically verified historic collections of this species are few, they document a resident, reproducing population, of varying size-classes, whose known range in the San Juan River was reduced almost in half by the construction of Navajo Reservoir and Lake Powell in the 1960s.

The limited number of Colorado pikeminnow taken in the San Juan River after the closure of these two reservoirs (Minckley and Carothers 1979, Platania et al. 1991) led some researchers to report this species as being extirpated in the San Juan River drainage (Tyus et al. 1982, Holden and Wick 1982). However, collections by the states of NM and UT, and by the University of New Mexico (Meyer and Moretti 1988, Platania 1990) in 1987 documented the persistence of both early life-stage and adult Colorado pikeminnow in the San Juan River from downstream of Shiprock, NM to Lake Powell (summarized in Tables A-2 through A-4 in Appendix A). This information led to the re-initiation of Section-7 consultations, under the Endangered Species Act, on several large water development projects in the San Juan River drainage including the Navajo Indian Irrigation Project (NIIP) and the Animas-La Plata Project (ALP). In 1991, a seven-year, multi-agency, multi-discipline, research effort was begun to study Colorado pikeminnow and razorback sucker

(Xyrauchen texanus) in the San Juan River, to determine their status, range, habitat needs and preferences, and make flow recommendations based on this information for the reoperation of Navajo Reservoir. During 1991-1996 studies (prior to fall 1996 pikeminnow stocking efforts), 17 adult, 2 sub-adult, 2 age-1, and 27 young-of-the-year (YOY) wild Colorado pikeminnow were collected (summarized in Tables A-2 through A-4 in Appendix A).

The majority of adult fish were captured in NM upstream of Four Corners bridge (i.e., the Highway 160 bridge at RM 119.2). Radiotelemetry studies documented pre-spawning, or "staging", aggregations of several individual Colorado pikeminnow at the Mancos River confluence (RM 122.6) from mid-May to late June, and short spawning migrations of radiotelemetered Colorado pikeminnow to the "Mixer" area (RM 133.4-129.8) of the San Juan River in late June and early July (Miller 1995, Ryden and Ahlm 1996, Miller and Ptacek 2000). Two potential spawning areas were identified at RM 132.0 and 131.15 (Miller 1995). One longer migration was made by a female fish originally captured at RM 74.8 on 8 October 1993. This fish made a 57.5-RM migration between 9 June and 30 June 1994, stayed in the presumed spawning area for approximately two months, then swam 52.4 miles back downstream within ten days (Ryden and Ahlm 1996). The only other Colorado pikeminnow that demonstrated migratory behavior was captured at RM 0.0 in Lake Powell on 7 April 1987 and recaptured on 8 September 1987 at RM 79.0 (Platania 1990). While not all radiotelemetered fish appeared to stage or spawn every year, several individuals did repeat these behaviors in more than one year (including some in consecutive years), indicating that this was a seasonally repeated behavior (Ryden and Ahlm 1996). Miller (1995) contacted a single radiotelemetered Colorado pikeminnow just upstream of Cudei Diversion (RM 142.0), the most downstream of numerous instream diversion structures in the New Mexico portion of the San Juan River. This contact represents the only documented movement of a wild Colorado pikeminnow upstream past a man-made diversion structure in the San Juan River. Cudei Diversion was removed from the river in fall 2001.

Low velocity habitat seining and drift-netting studies done between 1987 and 1996 collected 47 YOY and 2 age-1 Colorado pikeminnow. Of these 49 fish, 44 (89.8%) were collected with seines and 5 from drift net sets (Table A-2 in Appendix A). As in other UCRB rivers, younger life-stages were generally found downstream of larger adult fish. Of the 44 YOY Colorado pikeminnow collected by seining, three (6.8%) were collected between RM 125.6 and 122.3, six (13.6%) between RM 83-89, and 35 (79.5%) from the lower 25.2 miles of the San Juan River. Twenty-nine (27 YOY and 2 age-1) of the 35 Colorado pikeminnow collected in the lower 25.2 RM of the San Juan River were collected from ephemeral backwaters created by sedimentation associated with Lake Powell. This sedimentation zone extends upstream to approximately RM 17.0. Ironically, the sedimentation in this area of the San Juan River has created suitable habitat for early life-stage Colorado pikeminnow where, likely, none existed historically (Lentsch et al. 1996). Larval fish drifting beyond these ephemeral habitats enter Lake Powell where their chances for survival are greatly reduced (Mueller et al. 2001). In addition, the lower San Juan River is dominated by nonnative fishes including large numbers of channel catfish (Ictalurus punctatus), common carp (Cyprinus carpio), and red shiner (Cyprinella lutrensis), as well as other less numerous but highly predacious species such as walleye (Stizostedion vitreum), striped bass (Morone saxatilis), and largemouth bass (Micropterus salmoides; Lashmett 1993, Ryden and Pfeifer 1996, Ryden 1996 unpublished data). All of these species are documented predators of sympatric native suckers (Tyus and Saunders 1996).

Although spawning by Colorado pikeminnow has been documented in the San Juan River, the number of early life-stage Colorado pikeminnow collected is few. Only two known wild age-1 and two known wild sub-adult Colorado pikeminnow were collected between 1987 and 1996 (prior to stocking efforts) indicating that numbers of wild fish recruiting into the adult population is extremely low (Tables A-2 through A-4 in Appendix A) and probably not self-sustaining. The low numbers of wild Colorado pikeminnow in the San Juan River make this population susceptible to catastrophic loss of either natural

or man-made origin. In addition, as fish are lost to old age, angling, or other causes, their genetic material is lost from the already limited gene pool. Low numbers of wild fish have also frustrated research efforts to answer basic life history questions about this species in the San Juan River. Intensive surveys from 1995-2000 yielded only a single wild adult fish (Ryden 2000a, 2000b).

Factors limiting natural reproduction and recruitment of Colorado pikeminnow in the wild are not completely understood, but likely include: 1) loss of river complexity due to a combination of reduced flows in the San Juan River (Platania 1990), bank stabilization by nonnative plant species (i.e., salt cedar [Tamarix spp.] and russian olive [Elaeagnus angustifolia]; Platania 1990), and by human encroachment (R. Bliesner and V. Lamarra personal communication); 2) probable predation on early life-stage Colorado pikeminnow by nonnative fish species, including channel catfish, red shiner (Hendrickson 1994, Tyus and Saunders 1996), walleye, and striped bass; 3) changes in levels of various natural and human-introduced contaminants (summarized in Holden and Masslich 1995); 4) loss of nursery habitat in the lower San Juan River due to the construction of Lake Powell (Ryden and Pfeifer 1994b); 5) loss of adult fish to angling (Koster 1960, Quartarone 1993) or choking on the spines of ingested channel catfish (McAda 1983, Pimental et al. 1985, Quartarone 1993, Ryden and Smith 2002); and, 6) range and habitat partitioning by dams and smaller instream diversion structures (Platania 1990).

Limiting factors are currently being addressed through several management actions. Nonnative fish species are being mechanically removed from the San Juan River during research and monitoring trips. In addition, 197 adult Colorado pikeminnow were stocked at RM 180.2 in Farmington, NM, above all major instream diversion structures in the San Juan River (on 23 September 1997 [n = 49] and on 11 April 2001 [n = 148]). These 197 adult fish were stocked to study their ability to retain in this upstream section of the San Juan River, negotiate instream barriers, and find and utilize appropriate feeding and spawning habitat in this section of the river.

While limiting factors are being quantified and corrected, bolstering the wild population through augmentation is the most prudent course of action for protecting genetic material, adapting future broodstock to riverine conditions, and offsetting possible catastrophic scenarios.

Experimental Stockings Of Colorado Pikeminnow In The San Juan River

Because of the lack of wild, early life-stage Colorado pikeminnow in the San Juan River, the Utah Division of Wildlife Resources (UDWR) initiated a study to evaluate habitat use of age-0 Colorado pikeminnow among the different geomorphic reaches (as defined by Bliesner and Lamarra 1995) of the San Juan River through experimental stocking (Lentsch et al. 1996).

1996 -- On 4 November 1996, 100,000 YOY (or age-0) Colorado pikeminnow were stocked into the San Juan River, half each at Shiprock, NM (RM 148.0) and Mexican Hat, UT (RM 52.0; Table 1). These YOY fish had a mean TL of 55 mm (range = 25-85 mm TL). The Colorado pikeminnow stocked on 4 November 1996 were the largest of all the fish that UDWR would stock over the five-year period, 1996-2000. All 100,000 stocked YOY fish were marked with external flourescent spray marks and internal tetracycline marks.

1997 –- On 15 August 1997, an additional 116,878 YOY Colorado pikeminnow were stocked by UDWR – 62,578 at RM 148.0 and 54,300 at RM 52.0 (Table 1). These YOY fish had a mean TL of 45 mm (range = 35-55 mm TL). All 116,878 stocked YOY fish were marked with external flourescent spray marks and internal tetracycline marks.

A second group of Colorado pikeminnow were also stocked in 1997, by the USFWS. Forty-nine adult Colorado pikeminnow (mean TL = 644 mm; range = 550-753 mm TL) were stocked at RM 178.8 on 23 September 1997 (Table 1). These 49 individuals were 1981 year-class fish that had been held at Dexter National Fish Hatchery (NFH), then later were used for various experimental purposes.

Table 1. Stockings of Colorado pikeminnow in the San Juan River, 1996-2001.

Date	Number Stocked	River Mile Stocked At	Mean Total Length (mm)	Range Of Total Lengths (mm)	Responsible Agency[a]
11/04/1996	~50,000	148.0	55	25-85	UDWR
11/04/1996	~50,000	52.0	55	25-85	UDWR
08/15/1997	62,578	148.0	45	35-55	UDWR
08/15/1997	54,300	52.0	45	35-55	UDWR
09/23/1997	49	180.2	644	550-753	USFWS
07/02/1998	10,571	148.0	24	18-28	UDWR
07/07/1999	~500,000	158.6	“Larvae”	Not Specified	UDWR
06/11/2000	~105,000	141.9	“Larvae”	Not Specified	UDWR
04/11/2001	148	180.2	540	442-641	USFWS

[a] UDWR = Utah Division of Wildlife Resources, Moab, UT; USFWS = U.S. Fish and Wildlife Service, Grand Junction, CO

These adult fish were stocked to determine if suitable habitats existed in this portion of the San Juan River to fulfill the various life history needs of adult Colorado pikeminnow, especially spawning. Each stocked adult Colorado pikeminnow was implanted with a PIT tag prior to stocking.

1998 -- On 2 July 1998, 10,571 YOY Colorado pikeminnow were stocked by UDWR, all at RM 148.0 (Table 1). These YOY fish had a mean TL of 24 mm (range = 18-28 mm TL). These 10,571 stocked YOY fish were not marked with external flourescent spray marks or internal tetracycline marks.

1999 -- On 7 July 1999, approximately 500,000 “larval” Colorado pikeminnow were stocked by UDWR at RM 158.6, immediately downstream of Hogback Diversion in NM (Table 1). These larval fish were not measured before stocking, nor were they marked with external flourescent spray marks or internal tetracycline marks.

2000 -- On 11 June 2000, approximately 105,000 more “larval” Colorado pikeminnow were stocked by UDWR at RM 141.9, immediately downstream of Cudei Diversion (RM 142.0) in NM (Table 1; Jackson 2001). These larval fish were not measured before stocking, nor were they marked with external flourescent spray marks or internal tetracycline marks.

2001 -- On 11 April 2001, 148 adult Colorado pikeminnow were stocked by USFWS at RM 178.8 in NM (Table 1). These 148 individuals (mean TL = 540 mm; range = 442-641 mm TL, based on 35 measured fish) were 1991 year-class fish that had been held at Dexter NFH as broodstock. These fish became available when broodstock lots were being culled. Like the 49 adult Colorado pikeminnow stocked in 1997, these 148 fish were stocked to determine if suitable habitats existed in this portion of the San Juan River to fulfill the various life history needs of adult Colorado pikeminnow, especially spawning. Each stocked adult Colorado pikeminnow was implanted with a PIT tag prior to stocking. Eight of these fish were implanted with radio tags (four-year life-span).

Follow-up monitoring of stocked, early life-stage Colorado pikeminnow documented overwinter survival of a small percentage of these stocked fish (Table A-4 in Appendix A; Archer et al. 2000). However, numbers of stocked

Colorado pikeminnow recaptured by seining declined on each successive trip and distribution of stocked fish over time shows a large downstream displacement of most stocked YOY fish (Archer et al. 2000, Jackson 2001). This is in keeping with results of previous stockings of small size-class Colorado pikeminnow throughout the Colorado River basin (Hendrickson 1993 and 1994, Masslich and Holden 1996). However, as late as 1999, a few stocked juvenile Colorado pikeminnow were still being recaptured on a fairly regular basis via electrofishing during razorback sucker monitoring and adult/sub-adult large-bodied fish community monitoring (known as "adult monitoring") trips (Ryden 2000b). In 2000 however, very few stocked Colorado pikeminnow of any size-class were recaptured. Less than ten Colorado pikeminnow were collected during all sampling trips combined for all studies in 2000 (Ryden 2001).

Several factors may have contributed to this precipitous drop in the number of recaptures of stocked juvenile Colorado pikeminnow. These may include: 1) stocked Colorado pikeminnow from the 1996-1998 stockings may now be large enough to avoid recapture; 2) stocked Colorado pikeminnow from the 1999 stocking may have moved downstream into Lake Powell during the high summer flows of August-September 1999; 3) the large number of striped bass in the San Juan River during summer 2000 may have eliminated many of the smaller stocked Colorado pikeminnow through predation; 4) the extremely low flows in 2000 may have precluded being able to sample at a sufficient rate of speed using electrofishing rafts to capture Colorado pikeminnow, a swift-swimming, highly-mobile species.

Relationship to Recovery Program

One of the two purposes of the San Juan River Recovery Implementation Program (SJRIP) is to protect and recover endangered fishes in the San Juan River basin, including Colorado pikeminnow and razorback sucker. In the SJRIP

Program Document, Item 3.2.2.2.b under RESEARCH AND RECOVERY ELEMENTS AND RECOVERY PROGRAM IMPLEMENTATION specifically identifies augmenting populations of Colorado pikeminnow as a suitable course of action for recovery of this species (SJRIP 1995a). The original SJRIP Long Range Plan (LRP) identified augmenting populations of Colorado pikeminnow by stocking as an activity for recovery of this species in the San Juan River (SJRIP 1995b). Specifically, Item 5.3.8.2 of that document identified the need to develop an augmentation plan for Colorado pikeminnow (SJRIP 1995b). In the updated SJRIP LRP (SJRIP 2002): Item 4.2.2 identifies the need to implement an augmentation plan to expand the size of the existing San Juan River Colorado pikeminnow population; Item 4.2.3 identifies the need to expand the current range of the San Juan River Colorado pikeminnow population by stocking fish in the "upper river" near Farmington, NM; Item 4.2.4 identifies the need to determine habitat use and limiting factors of the augmented Colorado pikeminnow population via radio telemetry; and Item 4.2.5 identifies the need to continue reducing numbers of nonnative fishes in the San Juan River in order to facilitate the success of the Colorado pikeminnow augmentation effort.

Once augmentation begins, all stocked Colorado pikeminnow and their progeny will be afforded the same protection as wild fish under the Endangered Species Act.

AUGMENTATION PLAN

This augmentation plan evolved from results obtained in several previous studies during the Seven-Year Research Program for Endangered Fish on the San Juan River (see Tables A-2 and A-3 in Appendix A and the INTRODUCTION section of this text) which provided detailed information on adult and early life history stages of the San Juan River Colorado pikeminnow population. It was determined that the large majority of wild adult Colorado pikeminnow were

occupying and spawning in a fairly small section of the San Juan River downstream of Cudei Diversion (RM 142.0) and upstream of the Four Corners bridge (RM 119.2; Ryden and Ahlm 1996, Miller and Ptacek 2000, Ryden 2000a). In addition, wild adult Colorado pikeminnow were very few in number and recruitment rates into this adult population were very low (Ryden 2000a). Studies on early life-history stages of Colorado pikeminnow documented that very few wild larval Colorado pikeminnow were being produced annually (Buntjer et al. 1993 and 1994, Lashmett 1993 and 1994, Platania et al. 2000). Those YOY that were produced were drifting long distances in a very short amount of time (about three days) into the lower San Juan River and Lake Powell after swim-up (Lashmett 1993 and 1994, Dudley and Platania 2000a and 2000b, Platania et al. 2000). This long downstream drift places young Colorado pikeminnow in an area of the San Juan River almost completely dominated by nonnative fishes, in particular riverine (channel catfish) and lacustrine (striped bass and walleye) predators (Ryden 2000a). Masslich and Holden (1996) discussed expanding the upstream range of Colorado pikeminnow as a possible solution to increasing numbers of this species in the San Juan River. Masslich and Holden suggested that this be done by removing instream diversions and stocking Colorado pikeminnow for the purpose of experimentation and/or augmentation. This led to the experimental stocking of early life-stage Colorado pikeminnow by the UDWR between 1996 and 2000 to study dispersal patterns, retention, survival, growth, and habitat use (Archer et al. 2000, Jackson 2001). The large majority of experimentally-stocked larval and YOY Colorado pikeminnow demonstrated long downstream movements post-stocking, but some did retain in the San Juan River and survival was better than originally expected (Archer et al. 2000, Jackson 2001). However, it was still felt that in order to increase chances for retention of young Colorado pikeminnow in the system, the range of Colorado pikeminnow should be increased upstream to near the Animas River confluence (RM 180.6; Masslich and Holden 1996, San Juan River Biology Committee pers. comm.).

Based on the UDWR data, the San Juan River Biology Committee decided to initiate a large-scale augmentation effort for Colorado pikeminnow in the San Juan River. This plan outlines activities for an eight-year (2002-2009) augmentation effort for Colorado pikeminnow in the San Juan River.

Due to the large numbers of fish to be stocked, difficulties in tagging small size-class fish, and the prohibitive labor and material costs, age-0 Colorado pikeminnow will not be tagged with Passive Integrated Transponder (PIT) tags before being released into the river. However, stocked Colorado pikeminnow that are recaptured in subsequent sampling/monitoring efforts will be implanted with PIT tags before release. Fish will be evaluated, prior to stocking, for pathogens and parasites that are currently on USFWS fish health forms. Transport and stocking of Colorado pikeminnow will conform to existing USFWS guidelines and protocols (e.g., Williamson 1991).

Goal, Objective, and Tasks

Goal

The goal of this eight-year augmentation plan is to establish a multiple year-class population of Colorado pikeminnow into the San Juan River between the Animas River confluence (RM 180.6) and Lake Powell (RM 0.0).

It is hoped that if this goal is attained, this multiple year-class population of Colorado pikeminnow will become self-sustaining, such that the criteria set forth in the ***Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan*** (hereafter referred to as “Recovery Goals”; USFWS 2002) can be met and this species can achieve recovery in the San Juan River. In general terms, a self-sustaining population can be defined as a population containing a stable

number of successfully-reproducing adult fish that contribute sufficient numbers of young to maintain the adult population via recruitment over an extended period of time and a variety of environmental conditions (D. Propst pers. comm.). Specific numbers of fish composing any given life-stage within a population will vary over time depending upon the long-term conditions that determine carrying capacity for a given species in any river system.

Objective

The objective of this augmentation plan is to stock sufficient numbers of Colorado pikeminnow into the San Juan River to 1) establish a multiple year-class population of Colorado pikeminnow into the San Juan River between the Animas River confluence (RM 180.6) and Lake Powell (RM 0.0), and 2) establish numbers of Colorado pikeminnow in the San Juan River that meet or exceed the demographic criteria for downlisting specified in the Recovery Goals (USFWS 2002) and the target number specified in this augmentation plan.

Tasks

As a follow-up to the augmentation efforts outlined in this plan, it is recommended that the SJRIP perform several tasks to allow for collection of post-stocking data (on survival, dispersal, retention) that will help refine outyears' stocking efforts (i.e., timing, locations, numbers), to determine success of individual years' stockings, and to enhance chances for survival and recruitment of stocked Colorado pikeminnow. These tasks are:

1) Determine habitat use and movement patterns of hatchery-reared Colorado pikeminnow in the wild.

2) Determine survival and growth rates of hatchery-reared, known-age Colorado pikeminnow in the wild.

3) Determine whether stocked, hatchery-reared Colorado pikeminnow will recruit into the adult population and successfully spawn in the wild.

4) Determine if stocked, hatchery-reared Colorado pikeminnow can lead researchers to their wild counterparts. Any wild Colorado pikeminnow that are captured should be weighed, measured, PIT-tagged, have their sex noted (if apparent), and checked for general health, before being released back into the wild.

5) Continue to remove nonnative fishes from the San Juan River in order to increase the chances for survival of stocked Colorado pikeminnow.

Risks

Releasing hatchery-reared fish into areas that are populated by wild fish is not without risks. These genetic and ecological risks must be acknowledged, prior to stocking, by the San Juan River Biology Committee and weighed against the potential beneficial end results to be obtained. Genetic risks posed by augmentation efforts are discussed in more detail in the ***Genetics Management Plan For The Endangered Fishes Of The San Juan River*** (hereafter referred to as the "Genetics Management Plan;" Crist and Ryden 2003). Genetic risks can be minimized by using appropriate stocks of Colorado pikeminnow for augmentation (following Crist and Ryden 2003). Some of the

potential risks include the following (Meffe 1986, Busack 1990, Burdick 1992, Ryden and Pfeifer 1994b):

Genetic Risks

Outbreeding Depression, Swamping, Maladaption:

The possibility exists that hatchery-reared fish will have become domesticated to a hatchery environment (domestication selection) and will be less fit to survive in the wild. Thus, if they reproduce with wild fish, the result could be outbreeding depression (i.e., reduced fitness in the F_1 progeny). However, when stocking age-0 fish, initial mortality rates are going to be very high. This combined with the process of natural selection over the next several years should serve to "weed out" any negative domestic traits by the time any surviving stocked fish reach spawning age (age 7+; USFWS 2002). Therefore, the probability of outbreeding depression associated stocking age-0 fish is likely very low.

A second possibility, genetic swamping, could occur if the broodstock used are actually part of a separate, distinct genetic stock from wild San Juan River fish. In that case, a large number of their stocked progeny could swamp the San Juan River stock with traits detrimental to survival under localized conditions (i.e., maladaption). Maladaption could be manifested in inappropriate timing of spawning behavior, smaller or larger body sizes, or other physical or behavioral deviancies. Swamping of genetic material unique to the San Juan River (if such exists) could be a distinct possibility, given the large number (> 800,000) of Colorado pikeminnow from other stocks that have already been stocked into the San Juan River combined with the large numbers of fish specified in this plan.

Inbreeding Depression:

If Colorado pikeminnow stocked into the San Juan River are too closely related to one another and they successfully reproduce in the wild, their progeny could suffer detrimental effects (reduced fitness or even death) from inbreeding. However, given the small number of wild adult fish that have been collected in the San Juan River, inbreeding depression may already be occurring among wild San Juan River fish. If this is the case, the introduction of additional genetic variability through stocking over the next several years would likely have a positive effect on the genetic integrity of a future San Juan River Colorado pikeminnow population.

, Guideline: Genetic risks are not deemed great enough to preclude augmentation from proceeding

Ecological Risks

Straying:

Hatchery-reared fish may disperse long distances after stocking resulting in their emigration to Lake Powell. This would result in stocked fish not contributing to recovery efforts. Also, fish that stray would not contribute to the collection of post-stocking information (habitat use, growth, survival, and dispersal) that will guide outyears' stocking efforts. Early life-stage Colorado pikeminnow from both natural reproduction efforts (Lashmett 1993, 1994) and previous stocking efforts (Mueller et al. 2001) have been collected in Lake Powell.

Competition With Wild Colorado Pikeminnow:

Stocked, fish could directly compete with the few remaining wild Colorado pikeminnow for food and habitat. Stocking large numbers of Colorado pikeminnow in the San Juan River could cause shifts in habitat use, distribution, and abundance among wild Colorado pikeminnow. However, given the small number of wild Colorado pikeminnow extant in the San Juan River and the fact that neither habitat nor food presently appear to be limiting factors, the risk of detrimental intraspecific competition would seem to be low.

Pathogen and Parasite Transmission:

Pathogens and parasites harbored by artificially-produced fish have the potential to adversely impact wild populations. Specifically, a resistant hatchery stock may carry pathogens into populations that have little or no resistance. However, at present hatchery stocks are not known to possess any diseases not currently present in wild fish. Additionally, wild Colorado pikeminnow in the San Juan River have already been exposed to this threat through several years of experimental stocking. Since it is currently anticipated that all Colorado pikeminnow to be stocked in fulfillment of this augmentation plan shall originate from the same source as previously stocked fish (i.e., Dexter NFH), they should pose no additional threat in this area.

Chemoreception:

Fidelity to specific spawning areas by Colorado pikeminnow has been documented for adult Colorado pikeminnow in the San Juan River (Ryden and Ahlm 1996). However, whether this is a learned behavior or due to chemical imprinting as eggs or larvae, is unknown. It seems likely that a species such as Colorado pikeminnow, which evolved in a highly dynamic river system, would be able to locate suitable spawning areas by keying on certain physical

characteristics of the river or chemical scents (pheromones) produced by other mature Colorado pikeminnow. Such is the case with sympatric, endangered razorback sucker in Lake Mead and the Green River (P. Holden, pers. comm.).

However, it is possible that stocked Colorado pikeminnow may not be able to locate suitable spawning habitat, if they are not imprinted to a specific area. Studies performed in the UCRB to answer this particular question proved inconclusive. If it is determined that Colorado pikeminnow imprint to specific natal areas, stocked fish may have to be artificially imprinted before stocking to facilitate their return to suitable spawning areas as adults. In this case, chemical "scent" stations would need to be used in the hatchery where fish are reared and later maintained in specific areas in the river. Also a change in stocking location may be required for stocked, imprinted fish. However, until it can be proven that chemoreception is vital to the spawning success of Colorado pikeminnow, stocked fish will not be chemically imprinted.

Loss To Predation:

A large body of evidence, both direct and indirect, exists to support the idea that nonnative fish species negatively impact native fish species in the UCRB (e.g., Tyus and Saunders 1996). This includes evidence of predation on early life-stage Colorado pikeminnow by several nonnative fish species that occur in the San Juan River, including channel catfish, green sunfish (Lepomis cyanellus), smallmouth bass (Micropterus dolomieu), largemouth bass, black bullhead (Ameiurus melas), and yellow bullhead (Ameiurus natalis).

Without a doubt the biggest threat among these nonnative species to early life-stage Colorado pikeminnow comes from channel catfish, due to their sheer numbers. Between 1991 and 1995, channel catfish were the second most abundant species collected in electrofishing surveys (Ryden and Pfeifer 1996). Predation upon sympatric native suckers by adult channel catfish in the San Juan River has been documented. Several stomach samples taken from adult

channel catfish contained flannelmouth sucker (Brooks et al. 2000) and one 550 mm TL adult channel catfish had consumed a 300 mm SL flannelmouth sucker -– a fish that was over half its own body length (Ryden unpublished 1997 data).

Other predatory fish species occur in the San Juan River that also pose a threat to stocked Colorado pikeminnow. Striped bass and walleye invaded the San Juan River from Lake Powell after the inundation of the waterfall at RM 0.0 in 1995. Like channel catfish, both of these species have been documented to consume sympatric native suckers (Ryden and Pfeifer 1996, Ryden 1996 unpublished data, Brooks et al. 2000). Walleye and striped bass are collected much more frequently in the lower San Juan River (i.e., in closer proximity to Lake Powell) where the large majority of early life-stage Colorado pikeminnow have been collected since 1987.

Choking:

Juvenile channel catfish may pose as great a threat to large juvenile and adult Colorado pikeminnow as larger channel catfish do to early life-stage Colorado pikeminnow. Direct observations have been made of large juvenile or adult Colorado pikeminnow that had choked or were choking on the spines of small channel catfish they had consumed (McAda 1983, Pimental et al. 1985, Quartarone 1993, Ryden and Smith 2002). It appears that mechanical removal of nonnative fishes, which began in 1996, has caused a marked downward shift in the length-frequency distribution of channel catfish in the San Juan River (Ryden 2000a, 2003 In Prep.). Small, juvenile channel catfish have become more prevalent in electrofishing samples in the last several years than they were previously, including becoming fairly common in river sections where they were rare or completely absent from samples prior to 1996. This has been attributed to the removal of, literally, thousands of large, adult channel catfish since 1996. The San Juan River channel catfish population now has a length-frequency distribution resembling that of a heavily-exploited fish population (i.e., being dominated by smaller fish; Gerhardt and Hubert 1991,

Pitlo 1997). An increase in smaller size-class channel catfish combined with a massive influx of young, hatchery-reared Colorado pikeminnow associated with an augmentation effort has the potential to markedly increase this negative interaction (i.e., choking) between the two species. However, despite this fact, the best management tool currently available to minimize the risk posed to Colorado pikeminnow (stocked and wild, young and adult) by nonnative fishes in the San Juan River, is intensive mechanical removal of all nonnative fishes encountered during all sampling and research efforts. These removal efforts should be continued for the foreseeable future.

Increased Competition With and Predation Upon Sympatric Native Fishes:

Stocking large numbers of Colorado pikeminnow, itself a top predator, will put more predation pressure upon sympatric native fish species, including native sucker species, roundtail chub (Gila robusta), and speckled dace (Rhinichthys osculus). This may be problematic in that native fish species are already subject to predation from nonnative fishes (see "Loss To Predation," above). Additionally, stocking of Colorado pikeminnow may complicate recovery efforts for razorback sucker by preying upon the progeny of stocked razorbacks. Stocked, age-0 Colorado pikeminnow may also compete for food resources (specifically invertebrates) with sympatric native fishes until they reach about 100 mm TL, at which time their diet switches almost exclusively to fish (USFWS 2002).

However, it is hoped that by introducing a native predator while continuing intensive mechanical suppression of nonnative predatory fishes, Colorado pikeminnow can supplant its nonnative competitors in the San Juan River. If this is the case, any negative impacts on the native fish community associated with the Colorado pikeminnow augmentation effort should be relatively short-term.

, Guideline: Ecological risks are not deemed great enough to preclude augmentation from proceeding

Source Of Fish

One way to augment a wild population of fish is to collect wild adults from the riverine environment, spawn them in captivity, and stock their progeny. At present however, this is not a viable option for the San Juan River. Only one wild adult Colorado pikeminnow has been captured from the San Juan River since October 1995, despite numerous intensive sampling efforts since that time.

The SJRIP currently has no hatchery or grow-out pond facilities in which to spawn, rear, or maintain Colorado pikeminnow. In addition, no efforts have been made to collect adult Colorado pikeminnow specifically for use as broodstock for the SJRIP. Until this happens, augmentation efforts for the San Juan River will have to rely on alternative sources of fish.

Colorado pikeminnow from the Colorado, Gunnison, Yampa, Green, White, and San Juan rivers were examined to determine if each system contained distinct (i.e., genetically differentiated) stocks. Based on analysis of geographic variability in allele frequencies, distinct stocks of Colorado pikeminnow could not be identified (Williamson et al. 1997). Since genetic differences were not detectable between different rivers in the UCRB, the San Juan River Biology Committee adopted the following priority criteria, at a meeting on 22 July 1997, to identify potential sources of Colorado pikeminnow suitable for use in augmentation efforts. These priority criteria were incorporated into the Genetics Management Plan (Crist and Ryden 2003). They are, in priority order, as follows:

Use locally-adapted stocks for broodstock if possible.

Using Colorado pikeminnow of San Juan River origin for augmenting the wild population would be, by far, the most preferable course of action. This could be done either through the collection of wild larvae, which could then be reared in hatchery facilities to an appropriate size before stocking, or by collecting wild adults which would be used to make appropriate paired matings. The progeny of these paired matings could then be stocked back into the San Juan River.

However, since the seven-year research program began in the San Juan River (i.e., in 1991), only 27 wild larvae have been collected, and those were only collected through intense sampling efforts in many different locations. Likewise, only one adult Colorado pikeminnow has been collected since October 1995, despite hundreds of hours of intensive electrofishing. Given the paucity of wild Colorado pikeminnow and the difficulty in collecting them, using wild San Juan River Colorado pikeminnow for augmentation broodstock does not seem to be a feasible option at this time.

The San Juan River Biology Committee also felt that the risk of possibly losing a wild Colorado pikeminnow due to the stresses associated with collection, handling, and transport posed too great a threat (in terms of loss of genetic material) compared to the possible gain. In other words, it was the opinion of the San Juan River Biology Committee that the local population of Colorado pikeminnow would be more harmed than helped by the removal of locally-adapted adult fish, especially given the small number of them remaining in the wild. Thus, any wild Colorado pikeminnow encountered during research or monitoring trips will be returned to the river.

, Guideline: Do not remove wild Colorado pikeminnow from the San Juan River

Use nearest geographic neighbor stocks for broodstock if locally-adapted stocks are unavailable.

The nearest geographic neighbors to the San Juan River are the Green and Colorado River populations. The use of nearest geographic neighbor sources for augmentation of Colorado pikeminnow closely follows recommendations given by the UCRB Genetics Panel for the augmentation of another endangered San Juan River fish, the razorback sucker (Ryden 1997). All Colorado pikeminnow that have been experimentally-stocked into the San Juan River to date, both by the UDWR and USFWS, were progeny of adults from the Green and Colorado rivers.

Genetics studies performed on Colorado pikeminnow from all UCRB rivers in the 1980's (Williamson et al. 1997) failed to find any detectable differences in the genetic makeup of Colorado pikeminnow populations between UCRB rivers. Thus the broodstock at Dexter NFH should be genetically compatible not only with the Colorado pikeminnow stocked between 1996 and 2000, but also with any wild Colorado pikeminnow extant in the San Juan River (Crist and Ryden 2003).

, Guideline: Use Colorado pikeminnow that are from the nearest geographic neighbor stocks (i.e., Green and Colorado rivers) to augment the San Juan River Colorado pikeminnow population

The Colorado pikeminnow that were experimentally stocked into the San Juan River over the last six years were obtained from Dexter NFH in Dexter, NM. The approximately 827,449 early life-stage Colorado pikeminnow stocked by the UDWR between 1996 and 2000 (Table 1) were F_2 progeny of adult Colorado pikeminnow being held at Dexter NFH as broodstock for the UCRB. The “1981 broodstock” used to produce the 827,449 fish stocked by UDWR were 1981 F_1 progeny of wild adult Colorado pikeminnow originally collected from the Green and Colorado rivers. The 49 adult Colorado pikeminnow stocked by the USFWS on 23 September 1997 were excess F_1 fish that had been culled from this same 1981 broodstock. The 148 adult Colorado pikeminnow stocked by the USFWS on 11

April 2001 (Table 1) were excess fish that had been culled from the "1991 broodstock" being held at Dexter NFH. These 1991 broodstock are F_1 progeny of wild adult Colorado pikeminnow originally collected from the "15-Mile Reach" of the Colorado River near Grand Junction, Colorado. Both the 1981 and 1991 broodstock lots at Dexter NFH, as well as their progeny, represent nearest geographic neighbor stocks (Crist and Ryden 2003).

The 1981 and 1991 broodstocks are currently the only source of Colorado pikeminnow available to the SJRIP for producing young fish for augmentation purposes. These two broodstocks will be used to produce all the young Colorado pikeminnow for this eight-year augmentation effort. Again, this will insure that all age-0 fish to be stocked are from nearest geographic neighbor stocks. The two broodstocks will be spawned either separately or in tandem (at the discretion of Dexter NFH personnel) to produce sufficient numbers of young for stocking. As many viable adults (male and female) as can be obtained in a given year will be used to perform paired matings in order to maximize the amount of genetic diversity in their progeny. This should help avoid inbreeding depression.

Spawning will take place as early in the calendar year as possible (again at the discretion of Dexter NFH personnel) in order to maximize growth before stocking. After spawning, young Colorado pikeminnow will be reared at Dexter NFH until early November. In order to address concerns raised by the SJRIP Biology Committee regarding fitness of hatchery-reared fish, pond-reared fish will be used for augmentation whenever possible, with shortfalls being made up from raceway-reared fish.

At some point in the future, excess Colorado pikeminnow that are being reared for an augmentation effort currently underway in the UCRB may become available to the SJRIP as lots are culled (T. Czapla pers. comm.). These fish (being reared at 24-Road Fish Hatchery in Grand Junction, CO and at the Mumma Fish Hatchery in Alamosa, CO) are all progeny of the Colorado pikeminnow broodstock lots being held at Dexter NFH (i.e., of the same lineage as the age-0 Colorado pikeminnow that will be stocked under this augmentation plan).

If these fish do become available to the SJRIP, they will be much larger than Colorado pikeminnow that are currently planned to be stocked under this augmentation plan, since Colorado pikeminnow in the UCRB are not being stocked until they reach age-3, or a minimum of 150 mm (Nesler 2001, T. Czapla pers. comm.). At this point in time, it is by no means certain that these fish will become available to the SJRIP, but if they do, the San Juan River Biology Committee will need to decide whether or not to accept and use these fish in this augmentation effort.

Size of Fish to Stock

Data collected on numerous stockings of endangered fishes in both the UCRB and lower Colorado River basin (LCRB) to date would seem to argue for stocking large juvenile fish whenever possible. Numerous stockings of Colorado pikeminnow (mostly fish from 35-172 mm TL) in both the UCRB and lower Colorado River basin (LCRB) between 1980 and 1994 proved to be largely unsuccessful (summarized in Masslich and Holden 1996). Researchers reported predation by nonnative fishes and large downstream displacements as the major factors for the virtual disappearance of small stocked Colorado pikeminnow and razorback sucker shortly after being stocked in LCRB rivers (Brooks 1986a and 1986b, Marsh and Brooks 1989, Hendrickson 1993 and 1994, Foster and Mueller 1999). Marsh and Brooks (1989) also noted that post-stocking survival of razorback sucker increased when fish size was increased from 68 to 113 mm TL. Small size-class Colorado pikeminnow stocked into the San Juan River by the UDWR between 1996 and 2000 generally demonstrated sharp declines in numbers shortly after stocking (Archer et al. 2000, Jackson 2001). However, among these stockings, the larger age-0 Colorado pikeminnow stocked by UDWR in 1996 and 1997 (mean TL = 55 and 45 mm) had much higher recapture rates (193 [81.8%] of 236 recaptures) through September 2001 than did fish stocked from 1998-2000

at smaller (mean TL < 25 mm TL) sizes (43 [18.2%] of 236 recaptures; Archer et al. 2000, Ryden 2000a, Ryden unpublished data). It appears that once stocked Colorado pikeminnow reach lengths of 150-200 mm TL (i.e., age-1), their survival rates increase, likely because they are less susceptible to factors such as predation and downstream displacement (Brooks 1986b, Hendrickson 1993 and 1994). Numerous recaptures (n = 208 [88.1%] of 236 recaptures) through September 2001 of Colorado pikeminnow from UDWR's 1996-2000 stockings that had reached sizes > 149 mm TL from would appear to support this (Ryden 2000a, 2000b, Ryden unpublished data). Comparatively, groups of razorback sucker stocked into the San Juan River between 1996 and 1999 at > 300 mm TL had much higher recapture rates (only 580 [11.4%] of 5103 fish stocked = 86.4% of all recaptures {n = 70 recaptured individuals}) in subsequent years than did razorback sucker stocked at < 301 mm TL (4523 [88.6%] of 5103 fish stocked = only 13.6% of all recaptures {n = 11 recaptured individuals}; Ryden 2000c and 2000d). Again, this argues for stocking larger size-class fish whenever possible.

Likewise, there also appears to be an age at which hatchery fish are too old to be successfully stocked into riverine habitats (refer to Genetic Risks: Outbreeding Depression section earlier in this text). Two stockings of Colorado pikeminnow outside the San Juan River that included larger fish (250-405 mm TL) were not very successful (summarized in Masslich and Holden 1996). Likewise, of the 49 16-year old adult Colorado pikeminnow stocked into the San Juan River in 1997 only nine were recaptured -- all within the first six months post-stocking. Fifteen radio-tagged individuals from this stocking had high mortality rates ($\geq$ 66.7%), with the survivors having large downstream displacements (> 46 RM in a 1-year time-span; Ryden 2000b, Ryden unpublished data). It should be noted, however, that the overall health of these 49 adult Colorado pikeminnow was poor at the time they were stocked.

However, this same trend was also observed among large adult razorback sucker (range = 451-536 mm TL, estimated to be about 10 years of age) that were harvested from a private pond (known as Etter Pond) in 1994 and stocked

into the upper Colorado (n = 20) and Gunnison rivers (n = 21; Burdick and Bonar 1997). Follow-up monitoring of these fish indicated mortality rates as high as 85% and 88%, respectively. Etter Pond had been isolated from the Colorado River since the last major flood event in 1984. Given the size of these fish at harvest, it appeared that these fish had likely been spawned and spent the entirety of their lives in this pond. The observed quick demise of these razorback sucker once they were stocked into a wild riverine environment was probably a direct result of domestication selection.

Based on the above information it would seem to make sense that survival rates of Colorado pikeminnow, post-stocking, could likely be increased if they could be held until fall of the year they were age-1 (requires two growing seasons in hatchery facility or grow-out pond), age-2 (three growing seasons), or, age-3 (four growing seasons; Nesler 2001) before being stocked. This would allow them to grow large enough to avoid predation, yet probably still be young enough to avoid their being domesticated to hatchery or grow-out facilities. Based on recaptures of fish stocked into the San Juan River by UDWR between 1996 and 2000 age-1 Colorado pikeminnow ranged from 75-235 mm TL in the fall and age-2 Colorado pikeminnow ranged from 242-336 mm TL in the fall (Table B-1 in Appendix B). In contrast to this, Nesler (2001) anticipated that age-3 Colorado pikeminnow would only be 150 mm TL. At about 150 mm TL, Colorado pikeminnow can be successfully PIT-tagged, so stocking this age fish would allow for marking all stocked individuals. Stocking Colorado pikeminnow at $\geq$ 150 mm TL is the approach espoused by Nesler (2001) in his stocking plan for Colorado pikeminnow in the Gunnison and Colorado rivers.

Unfortunately, in the case of the SJRIP, holding fish for longer than one growing season is currently not feasible. The SJRIP lacks sufficient hatchery and grow-out facilities of their own to rear both Colorado pikeminnow and razorback sucker (all nine grow-out ponds are currently being used for rearing razorback sucker) and Dexter NFH does not have sufficient room to hold young Colorado pikeminnow for more than one growing season.

Therefore, in order to make the most efficient use of the hatchery space available to the SJRIP, while still allowing for production of adequate numbers of fish to fulfill goal of this augmentation plan, augmentation will proceed with Colorado pikeminnow of the maximum size attainable in one growing season. In 1996, Dexter NFH injected adult Colorado pikeminnow with carp pituitary (one intraperitoneal injection at the rate of 4 mg/kg body weight; following Ball and Bacon 1954, Clemens and Sneed 1962, Hamman 1981a, Hamman 1981b), in order to allow age-0 Colorado pikeminnow to be produced earlier than they would have normally been produced in the wild. These 1996 year-class fish reached a mean of 55 mm TL (roughly 2⅛ in.) prior to stocking in November (Table 1). Colorado pikeminnow for this augmentation effort will be produced as early in the year as is feasible (probably late-June to mid-July) and stocked in early November to allow for the maximum amount of growth before stocking.

, Guideline: To most efficiently use the hatchery space available to the SJRIP, while still allowing for production of adequate numbers of fish to fulfill the goal of this augmentation plan, augmentation will proceed with Colorado pikeminnow of the maximum size attainable in one growing season.

Number Of Fish To Stock

Background

The historical ratio of Colorado pikeminnow to other native fish species in any of the UCRB rivers is unknown. It is obvious from several studies that adult Colorado pikeminnow tend to populate specific sections of UCRB rivers

more heavily than others (e.g., Ryden and Ahlm 1996, Osmundson et al. 1998). Therefore, determining what the numeric goal of an augmentation effort should be is difficult, at best.

Over a four-year study populations of Colorado pikeminnow in 185.1 miles of the Colorado River (between Palisade, CO and the Green River confluence), for both subadult (< 551 mm long) and adult (> 550 mm long) fish, were estimated at 600-650 fish, or 3.2-3.5 fish per mile (Osmundson and Burnham 1996). Densities of adult Colorado pikeminnow in the "upper reach" (RM 185.1-124.2) were estimated to be 4.0-4.2 fish per mile, while densities of both subadult and adult Colorado pikeminnow averaged together in the "lower reach" (RM 0.0-112.4) were estimated to be 3.1-3.4 fish per mile. Osmundson stated that "given the current low population size in comparison with historical accounts that suggest the species was formerly abundant, it is likely that recruitment has not kept pace with mortality" thus indicating that while the Colorado River population appears to be stable, it was probably larger historically than it is today (Osmundson and Burnham 1996).

A population estimate, using the Schnabel multiple-census population estimate model (Van Den Avyle 1993), was performed on the Colorado pikeminnow collected from RM 136.6-119.2 between 1991 and 1994. This estimate indicated a population of 19 adult Colorado pikeminnow (95% confidence intervals = 10-42 adult fish), or 1.1 adult fish per mile (range = 0.6-2.4 adult fish per mile), in this 17.4-mile section of the San Juan River (Ryden 2000a). Fourteen (82.4%) of 17 adult Colorado pikeminnow collected from 1991-1994 were collected from this 17.4-mile section of the San Juan River (Ryden and Ahlm 1996). Given the paucity of collections of adult Colorado pikeminnow from other areas of the San Juan River, it is extremely unlikely that other areas of the San Juan River support anywhere near the 1.1 adult fish per mile that were observed from RM 136.6-119.2 during 1991-1994.

Nesler (2001) proposed an adult population goal of approximately 1,700 adult Colorado pikeminnow over 150 RM of three river reaches in the upper Colorado River subbasin, including both the Gunnison and Colorado rivers. This would average out to 11.3 adult fish per RM.

Recovery Goals

Two sets of criteria (called “demographic criteria” and “recovery factor criteria”) that needed to be achieved to be able to downlist and delist Colorado pikeminnow were defined by the USFWS (2002) in the Recovery Goals. This document, which updates and amends the original Colorado squawfish Recovery Plan (USFWS 1991) was developed to provide “objective, measurable” criteria to achieve recovery of the Colorado pikeminnow in the Colorado River basin according to Section 4(f)(1) of the Endangered Species Act, as amended. In the Recovery Goals (USFWS 2002), the following demographic criteria are listed for Colorado pikeminnow in the San Juan River:

5.3.1.1.3 Demographic criteria for downlisting: San Juan River subbasin

1) A target of 1,000 age-5+ fish ($\geq$ 300 mm TL; number based on estimated survival of stocked fish and inferences about carrying capacity) is established through augmentation and/or natural reproduction.

5.3.2.1.2 Demographic criteria for delisting: upper Colorado River and San Juan River subbasins

1) A self-sustaining population that exceeds 1,000 adults (age-7+; ≥ 450 mm TL) is maintained in the upper Colorado River subbasin **OR** a self-sustaining population that exceeds 700 adults is maintained in the upper Colorado River subbasin and a self-sustaining population that exceeds 800 adults is maintained in the San Juan River subbasin, such that for each population (numbers of adults based on inferences about carrying capacity):

   a) the trend in adult point estimates does not decline significantly, and

   b) mean estimated recruitment of age-6 (400-499 mm TL) naturally produced fish equals or exceeds mean annual adult mortality.

The number of > 800 adults was an estimate of what the carrying capacity for adult Colorado pikeminnow in the San Juan River was, based on preliminary data from a population model being developed by Miller Ecological Consultants and Ecosystems Research Institute and "a majority opinion of members of the San Juan Biology Committee" (USFWS 2002) based on a discussion of that preliminary data. The target number of > 800 adults is "preliminary and subject to revision" (USFWS 2002). The SJRIP Biology Committee has agreed to adopt the number specified as the demographic criteria for delisting in the Recovery Goals (> 800 adults) as the target number for this augmentation plan. This target of > 800 adult Colorado pikeminnow in the San Juan River between the Animas River confluence (RM 180.6) and Lake Powell (RM 0.0) equals ≥ 4.44 adult fish per mile. It should be noted that if the goal of ≥ 4.44 adult fish per mile were achieved, it would be a slightly higher value than that observed among wild adult fish in the upper Colorado River by Osmundson and Burnham (1996), but still quite a bit less than the 11.3 adult fish per mile target proposed by Nesler (2001).

, Guideline: The Recovery Goals specify a population of > 800 adult (age-7+) Colorado pikeminnow in the San Juan River as the demographic criteria for downlisting of this species in the San Juan River

, Guideline: The SJRIP Biology Committee has agreed to adopt the number specified as the demographic criteria for delisting in the Recovery Goals as the target number for this augmentation plan (i.e., > 800 adult {age-7+} fish).

What Is An Adult Fish?

Confounding the question of numbers of fish needed to stock to reach > 800 adults is the fact that there is disagreement as to what actually constitutes an adult Colorado pikeminnow. Hawkins (1992) defined an adult Colorado pikeminnow as a fish > 428 mm TL. Length at age estimates done by Osmundson et al. (1996) indicate the majority of Colorado pikeminnow have attained 428 mm TL by age-7. Yet, Osmundson et al. (1996) define an adult Colorado pikeminnow as a fish that is $\geq$ 550 mm TL, a size that is not attained until, on average, age-10. Seethaler (1978) necropsied 147 Colorado pikeminnow between 184 and 652 mm TL and found that all fish > 503 mm TL were sexually mature and all fish < 428 mm TL were immature (USFWS 2002). Hawkins definition of a mature Colorado pikeminnow as those > 428 mm TL was, apparently, based on Seethaler's work (USFWS 2002, D. Osmundson pers. comm.). As is observed among many of the large-bodied fish species native to the UCRB, male Colorado pikeminnow mature at smaller sizes than do females (Hamman 1981b, pers. obs., D. Osmundson pers. comm.). Hamman (1981b) observed that male Colorado pikeminnow at Willow Beach NFH matured at age-5 (317-376 mm TL) while females matured at age-6 (425-441 mm TL). Thus, the 428 mm TL value (Seethaler 1978, Hawkins 1992) probably more appropriately reflects the age at

which the majority of male Colorado pikeminnow are mature and is likely not indicative of size at maturity among a majority of female Colorado pikeminnow.

The value of ≥ 550 mm TL, used by Osmundson et al. (1996) to define an adult fish, was based on observations of a larger sample of live Colorado pikeminnow, of both sexes, over a several-year period. Thus it would seem that the 550 mm TL value was the more valid of the two values. However, the recently published Recovery Goals (USFWS 2002) are based on classifying age-7 fish (≥ 450 mm TL) as adults.

Growth information from 229 known-age fish recaptured from the San Juan River between 1997 and 2002 indicates that when age-0 Colorado pikeminnow are stocked at large sizes (45-55 mm TL) late in late fall, they will grow larger in their first three to six years of life (Table B-1 in Appendix B, SJRIP database, D. Ryden unpublished data) than would be predicted by using length at age estimates performed for wild fish (Osmundson et al. 1996, USFWS 2002). This accelerated growth is likely due to hatchery-produced age-0 Colorado pikeminnow being spawned earlier than wild fish and being reared in warm, productive grow-out ponds, in a very warm southern climate (i.e., Dexter, NM), which enhances and extends their first growing season beyond that of wild age-0 Colorado pikeminnow.

So, there is still disagreement among researchers as to what length actually constitutes an adult wild Colorado pikeminnow in the UCRB. However, based on the accelerated growth rates observed among hatchery-produced Colorado pikeminnow stocked into the San Juan River and for purposes of consistency with the Recovery Goals (USFWS 2002), this augmentation plan will assume that adulthood among all Colorado pikeminnow stocked into the San Juan River will be reached by age-7 (≥ 450 mm TL).

, Guideline: For the purposes of this augmentation plan, Colorado pikeminnow that are age-7+ (≥ 450 mm TL) will be classified as adults.

Survival Rates

Another hurdle when trying to decide how many Colorado pikeminnow to stock is the issue of post-stocking survival. Very little is known about year-to-year survival of Colorado pikeminnow after they are stocked. Based on preliminary comparisons between numbers of stocked Colorado pikeminnow and numbers of recaptures in the San Juan River from 1997-2000 (i.e., years with roughly equal sampling efforts), average between-years survival of stocked Colorado pikeminnow was .1508 (i.e., 15%) in the first two years (i.e., from age-0 to age-1 and from age-1 to age-2; Ryden unpublished data). These values are based on only three years' data (i.e., three data points) and will undoubtedly vary under different sets of environmental conditions and among different lots of stocked fish. Yet they represent the only data available at this time concerning post-stocking survival of early life-stage Colorado pikeminnow in the San Juan River.

The best point estimate of annual survival of adult (i.e., > 550 mm TL, or about age-9+) Colorado pikeminnow in the "upper reach" of the Colorado River was 0.86 or 86.0% (Osmundson et al. 1996, Osmundson and Burnham 1998). This was very similar to the survival rate for adult Colorado pikeminnow > 550 mm TL – 0.85, or 85.0% — estimated by Osmundson et al. (1997) using a different approach. This same value, 0.85 (85.0%) is used by Nesler to estimate survival for age-7 and age-8 adult fish in the Colorado and Gunnison rivers (Nesler 2001). Another study estimates annual survival of adult Colorado pikeminnow in the Green River at 81.0% (Gilpin 1993). Actual differences in adult survival rate estimates between the Colorado and Green rivers may be much smaller than these values (0.86 vs. 0.81) would seem to indicate. Gilpin's (1993) sensitivity analysis indicated that an overestimate in his growth calculations would have resulted in underestimating adult survival rates (Osmundson and Burnham 1998). In other words, if adult growth averaged 10 mm in length per year (as previously estimated by Tyus 1988)

instead of the 15 mm per year estimated by Gilpin (1993), Gilpin's survival rates would increase to 0.87, or 87.0% (Osmundson and Burnham 1998). For the purposes of this stocking plan we will assume an adult survival rate of 0.86 or 86.0% for age-9+ fish.

So, we have some idea of the survival rate of stocked age-0 fish until they reach age-2 and of annual survival rates among age-9+ adult fish. However, there is currently no data for survival rates of Colorado pikeminnow (stocked or wild) between age-3 and age-9. The only numbers that are available are those used in a stocking plan developed by Nesler (2001). In Table 2, the survival rate numbers from Nesler's stocking plan were combined with those discussed earlier to make a comprehensive survival curve (with the exception of age-2 which was an educated guess). This survival curve was used to predict long-term post-stocking survival of stocked age-0 Colorado pikeminnow (Table 2).

Numbers Of Fish To Stock

This section discusses two possibilities (i.e., minimum and preferred) for numbers of age-0 Colorado pikeminnow to be stocked in the San Juan River on an annual basis. A wide range of possible numbers of fish to be stocked could be developed (and in reality will likely be used) when trying to figure out how many fish should, or can in reality, be stocked. These numbers are dependent upon many variables, some of which include: the number of ripe adult fish available for spawning each year; fecundity of broodstock used; relative success during fertilization, hatching, swim-up, and early-life-stage development; space available to hold and rear young fish; survival through the

Table 2. Estimated survival rates for various age-classes of Colorado pikeminnow, based on values reported in previous research as cited in the text of this report, in Nesler's stocking plan (2001) for Colorado pikeminnow, and those values that are an educated guess. The values for the comprehensive survival curve being used in this augmentation plan are in the far right column.

Age-Class And Anticipated[1] Total Length (Range In mm)	Previous Research	Nesler's Stocking Plan	Educated Guess	This Stocking Plan
Age-0 (29-47 mm)	0.15			0.15
Age-1 (39-103 mm)	0.15			0.15
Age-2 (82-181 mm)			0.30	0.30
Age-3 (136-259 mm)		0.50		0.50
Age-4 (205-374 mm)		0.60		0.60
Age-5 (298-453 mm)		0.70		0.70
Age-6 (375-472 mm)		0.80		0.80
Age-7 (396-507 mm)		0.85		0.85
Age-8 (440-532 mm)		0.85		0.85
Age-9 (523-564 mm)	0.86			0.86
Age-10+ ($\geq$ 540 mm)	0.86			0.86

[1] = Anticipated total length at age values presented in this table are taken from known length at age data for wild Colorado pikeminnow in other Upper Colorado River Basin rivers (see Table B-1 in Appendix B).

handling and transport processes; variable survival rates among year-classes of stocked age-0 fish; and, stochastic events (e.g., malfunctions of water circulation or aeration equipment or introduction of toxic substances such as chlorinated water during early life stage rearing, cannibalism rates among young Colorado pikeminnow, avian predation once fish are in ponds, etc.).

This augmentation plan has been developed based on an eight-year stocking period (2002-2009). A similar plan for augmenting Colorado pikeminnow populations in the Gunnison and upper Colorado rivers (Nesler 2001) recommends a nine-year stocking period. For comparisons sake, numbers for both eight- and nine-year stocking periods are examined under the "Minimum" and "Preferred" subheadings which follow.

Minimum Number Of Fish To Stock Annually

As discussed earlier, the SJRIP does not have a hatchery facility of its own, nor does it have grow-out ponds available in which to rear young Colorado pikeminnow (all nine grow-out ponds that the SJRIP does possess are currently dedicated to rearing endangered razorback sucker for a separate augmentation effort). Starting in 2002, the SJRIP has contracted with Dexter NFH to produce young Colorado pikeminnow for the duration of this augmentation effort. For the foreseeable future, Dexter NFH represents the only available source of young Colorado pikeminnow available to the SJRIP. Dexter NFH has identified that it is currently capable of producing and rearing 200,000 age-0 Colorado pikeminnow annually, but can likely increase the number of young Colorado pikeminnow they are able to produce in future years.

Table 3 shows a by-year contribution of each of the eight years' stockings to the eventual adult population in the San Juan River when stocking 200,000 fish annually. The two columns at the right of the page represent the anticipated total number of Colorado pikeminnow of all ages and the

Table 3. Estimated number of stocked Colorado pikeminnow surviving in each consecutive calendar year, 2002-2025, based on stocking 200,000 age-0 fish for eight consecutive years (i.e., 2002-2009). Estimated between-year survival values can be found in Table 2.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-7+
	1 (2002)	2 (2003)	3 (2004)	4 (2005)	5 (2006)	6 (2007)	7 (2008)	8 (2009)		
2002	200,000								200,000	0
2003	30,160	200,000							230,160	0
2004	4,548	30,160	200,000						234,708	0
2005	1,364	4,548	30,160	200,000					236,072	0
2006	682	1,364	4,548	30,160	200,000				236,754	0
2007	409	682	1,364	4,548	30,160	200,000			237,163	0
2008	286	409	682	1,364	4,548	30,160	200,000		237,449	0
2009	229	286	409	682	1,364	4,548	30,160	200,000	237,678	229
2010	195	229	286	409	682	1,364	4,548	30,160	37,873	424
2011	165	195	229	286	409	682	1,364	4,548	7,878	589
2012	142	165	195	229	286	409	682	1,364	3,472	731
2013	122	142	165	195	229	286	409	682	2,230	853
2014	105	122	142	165	195	229	286	409	1,653	958
2015	90	105	122	142	165	195	229	286	1,334	1,048
2016	78	90	105	122	142	165	195	229	1,126	1,126

Table 3. Estimated number of stocked Colorado pikeminnow surviving in each consecutive calendar year, 2002-2025, based on stocking 200,000 age-0 fish for eight consecutive years (i.e., 2002-2009). Estimated between-year survival values can be found in Table 2.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-7+
	1 (2002)	2 (2003)	3 (2004)	4 (2005)	5 (2006)	6 (2007)	7 (2008)	8 (2009)		
2017	67	78	90	105	122	142	165	195	964	964
2018	58	67	78	90	105	122	142	165	827	827
2019	49	58	67	78	90	105	122	142	711	711
2020	43	49	58	67	78	90	105	122	612	612
2021	37	43	49	58	67	78	90	105	527	527
2022	31	37	43	49	58	67	78	90	453	453
2023	27	31	37	43	49	58	67	78	390	390
2024	23	27	31	37	43	49	58	67	335	335
2025	20	23	27	31	37	43	49	58	288	288

anticipated number of adult (age-7+) Colorado pikeminnow in the San Juan River contributed by each year-class of stocked fish using the survival percentages presented in Table 2. Only the total number of adult Colorado pikeminnow (the far right column) in Table 3 count toward fulfilling the goal of > 800 adult fish.

Under the scenario laid out in Table 3 (eight years of stocking), the target number of > 800 adult Colorado pikeminnow in the San Juan River could be achieved as early as 2013 (assuming the survival curves used in Table 2 are correct). There would be a six-year window (from 2013 to 2018) when stocked Colorado pikeminnow would contribute > 800 adult (age-7+) fish to the total population in the San Juan River (Tables 3 and 4). Numbers of adult Colorado pikeminnow would exceed 800 fish by as little as 27 fish in 2018, a 3.4% buffer, and as many as 326 fish in 2016, a 40.8% buffer (Tables 3 and 4).

If stocking were increased to a nine-year period (as per Nesler 2001), the goal of > 800 adult Colorado pikeminnow could still be achieved in 2013, but the window when stocked Colorado pikeminnow would contribute > 800 adult (age-7+) fish to the total population in the San Juan River would increase from six to seven years (2013-2019; Table 4). Numbers of adult Colorado pikeminnow would exceed 800 fish by as little as 53 fish in 2013, a 6.6% buffer, and as many as 393 fish in 2017, a 49.1% buffer (Table 4).

Under an eight-year stocking scenario (2002-2009), the survivors of all eight years' stockings will have reached adulthood by 2016 (Table 3). Also during 2016, the number of adult Colorado pikeminnow in the San Juan River contributed by stocking will have reached its zenith of 1,126 fish (Table 3). Colorado pikeminnow from the first stocking in 2002 will reach adulthood and begin spawning in 2009 (Table 3). Young produced by these 2002 year-class fish should begin recruiting into the adult population by 2016. Thus by the time the number of adult Colorado pikeminnow in the San Juan River from the 2002-2009 stockings has dropped below 800 fish (i.e., in 2019), there should be young recruiting into the adult population that were spawned by adults from four of the eight years' stockings (i.e., 2002-2005; Table 3). Between the

Table 4. Calendar years and population values anticipated to meet or exceed the augmentation plan goal of > 800 adult fish. These numbers are based on the assumed survival curves in Table 2 applied to stocking 200,000 age-0 Colorado pikeminnow for either eight or nine years.

Augmentation Plan Goal: > 800 Adult (Age-7+) Colorado Pikeminnow					
8 Years Of Stocking 200,000 Age-0 Colorado Pikeminnow			9 Years Of Stocking 200,000 Age-0 Colorado Pikeminnow		
Year	Number Of Adult Fish	% Buffer	Year	Number Of Adult Fish	% Buffer
2013	853	6.6%	2013	853	6.6%
2014	958	19.8%	2014	958	19.8%
2015	1,048	31.0%	2015	1,048	31.0%
2016	1,126	40.8%	2016	1,126	40.8%
2017	964	20.5%	2017	1,193	49.1%
2018	827	3.4%	2018	1,022	27.8%
			2019	876	9.5%

number of adults remaining from the 2002-2009 stockings and the progeny of four separate year-classes (2002-2005), the adult (age-7+) population should be able to maintain itself above the level of 800 adult fish.

However, recruitment of progeny from 2002-2009 year-class adults should not be expected to be at a constant or reliable rate. Like wild fish observed in the Colorado River, spawning and recruitment success among stocked fish and their progeny will be a pulsed phenomena, with certain years providing large cohorts of young fish while others provide very few, depending upon the environmental variables (e.g., egg viability, instream flows, amount and quality of low-velocity habitat available, predator load, food availability) and stochastic events during any given year (Osmundson and Burnham 1998, USFWS 2002). This pulsed recruitment phenomena, called a “storage effect” (Gilpin 1993), enables long-lived populations to maintain themselves despite several consecutive years of failed or low reproductive success (USFWS 2002). However, unlike the Colorado River, the San Juan River has the added stochasticity of late-summer monsoonal rainstorms which bring heavy sediment loads into the river during the Colorado pikeminnow’s spawning season as well as the probability of large invasions of striped bass from Lake Powell in years when river flows remain low and clear in the absence of summer monsoons (Ryden 2001).

, Guideline: In order to accomplish the objectives of this augmentation plan, a minimum of 200,000 age-0 Colorado pikeminnow will be stocked annually for a period of eight years (2002-2009)

Preferred Number Of Fish To Stock Annually

The “preferred” number of fish to stock annually (i.e., 300,000) was derived by calculating how many age-0 Colorado pikeminnow would have to be stocked annually to have a minimum ten-year window during which the target of > 800 adult fish could be met. Even though this number (300,000) is referred to here as a “preferred” number it should probably be called a “minimum preferred” number. While stocking 300,000 age-0 Colorado pikeminnow annually should achieve a ten-year window during which the target of > 800 adult fish could be met (assuming that the survival curves in Table 2 are correct), stocking > 300,000 age-0 Colorado pikeminnow annually would allow the San Juan River Colorado pikeminnow population to have an even larger buffer against years of poor reproductive effort or success, poor early life-stage survival, and poor recruitment. Unfortunately, at present, stocking 300,000 (or more) age-0 fish annually is an unrealistic goal, at least in calendar year 2002, since Dexter NFH will only be able to produce about 200,000 age-0 fish in 2002. However, the closer the SJRIP could come to meeting this preferred number of 300,000 age-0 fish annually (or even exceeding it), the greater the relative comfort level would be while achieving the target of > 800 adult Colorado pikeminnow in the river. In the very near future, it would behoove the SJRIP to either: 1) work with Dexter NFH to increase the number of age-0 Colorado pikeminnow that can be produced and reared annually at this facility; or 2) obtain ownership or use of additional hatchery and/or grow-out facilities sufficient to produce the difference in numbers of age-0 Colorado pikeminnow between what Dexter NFH can produce and the preferred annual target of 300,000 age-0 fish.

Table 5 shows a by-year contribution of each of the eight years’ stockings to the eventual adult population in the San Juan River when stocking 300,000 fish annually. The two columns at the right of the page represent the anticipated total number of Colorado pikeminnow of all ages and the

Table 5. Estimated number of stocked Colorado pikeminnow surviving in each consecutive calendar year, 2002-2025, based on stocking 300,000 age-0 fish for eight consecutive years (i.e., 2002-2009). Estimated between-year survival values can be found in Table 2.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-7+
	1 (2002)	2 (2003)	3 (2004)	4 (2005)	5 (2006)	6 (2007)	7 (2008)	8 (2009)		
2002	300,000								300,000	0
2003	45,240	300,000							345,240	0
2004	6,822	45,240	300,000						352,062	0
2005	2,047	6,822	45,240	300,000					354,109	0
2006	1,023	2,047	6,822	45,240	300,000				355,132	0
2007	614	1,023	2,047	6,822	45,240	300,000			355,746	0
2008	430	614	1,023	2,047	6,822	45,240	300,000		356,176	0
2009	344	430	614	1,023	2,047	6,822	45,240	300,000	356,520	344
2010	292	344	430	614	1,023	2,047	6,822	45,240	56,812	636
2011	248	292	344	430	614	1,023	2,047	6,822	11,820	884
2012	214	248	292	344	430	614	1,023	2,047	5,212	1,098
2013	184	214	248	292	344	430	614	1,023	3,349	1,282
2014	158	184	214	248	292	344	430	614	2,484	1,440
2015	136	158	184	214	248	292	344	430	2,006	1,576
2016	117	136	158	184	214	248	292	344	1,693	1,693

Table 5. Estimated number of stocked Colorado pikeminnow surviving in each consecutive calendar year, 2002-2025, based on stocking 300,000 age-0 fish for eight consecutive years (i.e., 2002-2009). Estimated between-year survival values can be found in Table 2.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-7+
	1 (2002)	2 (2003)	3 (2004)	4 (2005)	5 (2006)	6 (2007)	7 (2008)	8 (2009)		
2017	101	117	136	158	184	214	248	292	1,450	1,450
2018	86	101	117	136	158	184	214	248	1,244	1,244
2019	74	86	101	117	136	158	184	214	1,070	1,070
2020	64	74	86	101	117	136	158	184	920	920
2021	55	64	74	86	101	117	136	158	791	791
2022	47	55	64	74	86	101	117	136	680	680
2023	41	47	55	64	74	86	101	117	585	585
2024	35	41	47	55	64	74	86	101	503	503
2025	30	35	41	47	55	64	74	86	432	432

anticipated number of adult (age-7+) Colorado pikeminnow in the San Juan River contributed by each year-class of stocked fish using the survival percentages presented in Table 2. Only the total number of adult Colorado pikeminnow (the far right column) in Table 5 count toward fulfilling the goal of > 800 adult fish.

Under the scenario laid out in Table 5 (eight years of stocking), the target number of > 800 adult Colorado pikeminnow in the San Juan River could be achieved as early as 2011 (assuming the survival curves used in Table 2 are correct). There would be a 10-year window (from 2011 to 2020) when stocked Colorado pikeminnow would contribute > 800 adult fish to the total population in the San Juan River (Tables 5 and 6). Numbers of adult Colorado pikeminnow would exceed the > 800 fish target by as little as 84 fish in 2011, a 10.5% buffer, and as many as 893 fish in 2016, a 111.6% buffer (Tables 5 and 6).

If stocking were increased to a nine-year period (as per Nesler 2001), the goal of > 800 adult Colorado pikeminnow could still be achieved in 2011, but the window when stocked Colorado pikeminnow would contribute > 800 adult fish to the total population in the San Juan River would increase from 10 to 12 years (2011-2022; Table 6). Numbers of adult Colorado pikeminnow would exceed the > 800 fish target by as little as 38 fish in 2022, a 4.8% buffer, and as many as 994 fish in 2017, a 124.3% buffer (Table 6).

Under an eight-year stocking scenario (2002-2009), the survivors of all eight years' stockings will have reached adulthood by 2016 (Table 5). Also during 2016, the number of adult Colorado pikeminnow in the San Juan River contributed by stocking will have reached its zenith of 1,693 fish (Table 5). Colorado pikeminnow from the first stocking in 2002 will reach adulthood and begin spawning in 2009 (Table 5). Young produced by these 2002 year-class fish should begin recruiting into the adult population by 2016. Thus by the time the number of adult Colorado pikeminnow in the San Juan River from the 2002-2009 stockings has dropped below 800 fish (i.e., in 2021), there should be young recruiting into the adult population that were spawned by adults from six of the eight years' stockings (i.e., 2002-2007; Table 6). Between the

Table 6. Calendar years and population values anticipated to meet or exceed the augmentation plan goal of > 800 adult fish. These numbers are based on the assumed survival curves in Table 2 applied to stocking 300,000 age-0 Colorado pikeminnow for either eight or nine years.

Augmentation Plan Goal: > 800 Adult (Age-7+) Colorado Pikeminnow					
8 Years Of Stocking 300,000 Age-0 Colorado Pikeminnow			9 Years Of Stocking 300,000 Age-0 Colorado Pikeminnow		
Year	Number Of Adult Fish	% Buffer	Year	Number Of Adult Fish	% Buffer
2011	884	10.5%	2011	884	10.5%
2012	1,098	37.3%	2012	1,098	37.3%
2013	1,282	60.3%	2013	1,282	60.3%
2014	1,440	80.0%	2014	1,440	80.0%
2015	1,576	97.0%	2015	1,576	97.0%
2016	1,693	111.6%	2016	1,693	111.6%
2017	1,450	81.3%	2017	1,794	124.3%
2018	1,244	55.5%	2018	1,536	92.0%
2019	1,070	33.8%	2019	1,318	64.8%
2020	920	15.0%	2020	1,134	41.8%
			2021	975	21.9%
			2022	838	4.8%

number of adults remaining from the 2002-2009 stockings and the progeny of the six year-classes (2002-2007), the adult (age-7+) population should be able to maintain itself at or above the level of > 800 adult fish.

However, recruitment of progeny from 2002-2009 year-class adults should not be expected to be at a constant or reliable rate. Like wild fish observed in the Colorado River, spawning and recruitment success among stocked fish and their progeny will be a pulsed phenomena, with certain years providing large cohorts of young fish while others provide very few, depending upon the environmental variables (e.g., egg viability, instream flows, low-velocity habitat availability, predator load, food availability) and stochastic events during any given year (Osmundson and Burnham 1998, USFWS 2002). This pulsed recruitment phenomena, called a "storage effect" (Gilpin 1993), enables long-lived populations to maintain themselves despite several consecutive years of failed or low reproductive success (USFWS 2002). However, unlike the Colorado River, the San Juan River has the added stochasticity of late-summer monsoonal rainstorms which bring heavy sediment loads into the river during the Colorado pikeminnow's spawning season as well as the probability of large invasions of striped bass from Lake Powell in years when river flows remain low and clear in the absence of summer monsoons (Ryden 2001).

, Guideline: In order to accomplish the objectives of this augmentation plan, it would be preferable to stock 300,000 (or possibly more) age-0 Colorado pikeminnow annually for a period of eight years (2002-2009)

Stocking Areas

In early November, age-0 Colorado pikeminnow will be transported from Dexter NFH to the San Juan River and stocked in roughly equal numbers within two stocking areas: 1) RM 180.2 (the Highway 371 bridge in Farmington, NM) to

RM 170.0; and, 2) RM 158.6 (immediately downstream of Hogback Diversion, NM) to RM 148. A number of age-0 Colorado pikeminnow will be stocked at the upstream end of each stocking area, but the rest will be loaded onto rafts equipped with oxygenated live-wells. From there, these fish will be rowed downstream and stocked into numerous low-velocity habitats within ten RM of the upstream end of each stocking area. The reason for this is to hopefully reduce overcrowding in low-velocity habitats at any one stocking site, which can lead to either very high vulnerability to predation (e.g., Marsh and Brooks 1989), or rapid downstream displacement from a particular stocking site (e.g., Foster and Mueller 1999, Ryden 2000c).

The reasons for choosing the Farmington, NM stocking area are: 1) to expand the range of Colorado pikeminnow in the San Juan River (following Masslich and Holden 1996); 2) to examine whether or not the section of the San Juan River from RM 180.6-166.6 (Animas River confluence to the PNM Weir) has the characteristics capable of fulfilling the life history needs of this species; and 3) to examine whether or not hatchery-reared, age-0 Colorado pikeminnow can retain, survive, and grow to adulthood in the San Juan River upstream of the PNM Weir (RM 166.6).

Arrangements will be made with the operators of the Fruitland irrigation diversion (RM 178.5) to shut down the diversion's headgates for a period of several hours to several days immediately prior to stocking Colorado pikeminnow in this upstream area. This will allow age-0 Colorado pikeminnow to be stocked very near the upstream end of their designated Critical Habitat (USFWS 1994) while avoiding their being immediately diverted into the Fruitland irrigation canal. If it is not possible to get the headgates of the Fruitland irrigation diversion shut down prior to stocking, age-0 Colorado pikeminnow may then be stocked immediately downstream of the Fruitland diversion in order to avoid the loss of fish into the canal.

The reason for choosing the stocking area downstream of Hogback Diversion is to help supplement numbers of this species in the area of the San Juan River into which Colorado pikeminnow were previously stocked by the UDWR

from 1996-2000 (Table 1) and in which wild fish are still extant. The 1996-2000 stockings of Colorado pikeminnow by the UDWR show that even when stocked this high (RM 158.6) in the river, many juvenile Colorado pikeminnow will disperse downstream as far as Lake Powell. However, UDWR's 1996-2000 stockings also demonstrated that some stocked age-0 fish will retain, survive, and recruit in the San Juan River upstream of Lake Powell.

, Guideline: Age-0 Colorado pikeminnow will be stocked in roughly equal numbers within two stocking areas in the San Juan River, RM 180.2-170.0 and RM 158.6-RM 148.

Monitoring

Numbers of Colorado pikeminnow are currently well below the target number specified in this plan. Until numbers of Colorado pikeminnow in the San Juan River increase markedly over current numbers, monitoring efforts that are already in place for assessing stocked razorback sucker (Ryden and Pfeifer 2001) combined with the long-term fish community monitoring program that takes place each fall (Propst et al. 2000) should be sufficient to track general population trends among endangered fish populations. Simple, within-year population estimators (e.g., Schnabel and Petersen population estimates) can be used to determine the population of endangered fishes between RM 158.6 and 2.9 and these values can be extrapolated to the river as whole (i.e., RM 180.6-0.0). More specific studies may be performed under specific workplans (if deemed necessary and approved by the SJRIP Biology Committee) to obtain more detailed information on post-stocking dispersal, survival, age-growth relationships, and the like during periods of the calendar year not already covered by existing monitoring studies.

It is recommended that as early as calendar year 2007, the SJRIP initiate an intensive, riverwide, mark-recapture study (like the one being done in the UCRB beginning in 2003) to obtain high-precision point estimates for the number of adult Colorado pikeminnow present in the San Juan River. This sampling should encompass the San Juan River from the Animas River confluence downstream to Lake Powell.

Finally, in support of the Colorado pikeminnow augmentation effort, it is recommended that intensive, mechanical removal of nonnative fishes should be continued, on all research and monitoring trips. Mechanical removal of nonnative fishes can be done opportunistically during these trips at no additional cost to the SJRIP and requires no additional manpower.

Adaptive Management

As with all management- and recovery-oriented actions being performed under the SJRIP, this augmentation plan is subject to adaptive management. It is the intention of the SJRIP Biology Committee to always use the best science available at the time when making management- and recovery-related decisions. If at any point in the future, new data becomes available that indicates a change in approach or techniques is necessary to achieve the goal and objective of this augmentation plan (or if the goal or objective themselves should change), this augmentation plan can be revised to reflect the new information.

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APPENDIX A

Summary tables of Colorado pikeminnow collections in the San Juan River through 2000. These tables include historic collections of Colorado pikeminnow (i.e., those prior to 1987; Table A-1) and research period collections of Colorado pikeminnow (i.e., those from 1987-2000; Tables A-2 through A-4). Table A-4 also includes information on age-0 Colorado pikeminnow stocked by UDWR from 1996-2000 and recaptured as the end of 2000.

Table A-1. Summary data for historic collections and reports of Colorado pikeminnow in the San Juan River, New Mexico, Colorado, and Utah (summarized in Platania 1990).

Date	Source Report	Number of Fish	Life Stage	Location	Collection Technique
1891	Jordan 1891	Unknown	Unknown (assumed to be adult fish)	"Ascending Animas River to Durango"	None
1936 07/04/36	Platania 1990	3	juveniles: 72-73 mm SL	Alcove Canyon, UT "approximately 32 RM upstream of the Colorado-San Juan River Confluence, now inundated by Lake Powell"	Unknown (probably seining)
1941 prior to 07/24/41	Platania and Bestgen 1988	1	juvenile: 278 mm TL	New Mexico	Unknown
1955	Lemons 1955	1	adult: 5.4 kg (12 lbs.)	San Juan River near Four Corners	Unknown
1959 June 1959 08/29/59	Koster 1960	2	adults: male = 415 mm SL female = 590 mm SL	3 miles below Rosa, NM now inundated by Navajo Reservoir	Angling
1960 08/21/60	Sigler and Miller 1963	3	"young fish" = juveniles	Mexican Hat, UT approximate RM 53.0	Unknown
1961	Olson 1962	8	4 juveniles: 175-200 mm 4 adults: all 300+ mm	San Juan River below Navajo Reservoir and above Farmington, NM	Rotenone
1965	Platania 1990	1	adult: 500-600 mm	Bloomfield, NM approximate RM 189	Angling
1977	U.S. Fish and Wildlife Service 1981	1	adult: about 600 mm	San Juan River arm of Lake Powell	Unknown
1978	Meyer and Moretti 1988	1	Unknown	Mexican Hat, UT approximate RM 53.0	Unknown
1978 April	VTN Consolidated, Inc. and Museum of Northern Arizona 1978	1	juvenile: 177 mm TL	near Aneth, UT approximate RM 103.7	Unknown

Table A-2. Summary data for wild young-of-the-year and age-1 Colorado pikeminnow collected in the San Juan River between 1987 and 1996.

Date	Source Report	Year Class	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1987								
09/09/87	Platania 1990	1987	32	--	---	Seine	88.9[a]	Backwater
09/09/87	Platania 1990	1987	27	--	---	Seine	87.4[a]	Backwater/MC[b]
09/09/87	Platania 1990	1987	28	--	---	Seine	87.4[a]	Backwater/MC
09/09/87	Platania 1990	1987	27	--	---	Seine	83.2[a]	Backwater/MC
09/09/87	Platania 1990	1987	28	--	---	Seine	83.2[a]	Backwater/MC
09/09/87	Platania 1990	1987	29	--	---	Seine	83.2[a]	Backwater/MC
09/13/87	Platania 1990	1987	17.2	--	---	Seine	20.7[a]	Backwater/MC
09/20/87	Platania 1990	1987	25.6	--	---	Seine	12.5[a]	Backwater/MC
09/20/87	Platania 1990	1987	29	--	---	Seine	12.5[a]	Backwater/MC
09/24/87	Platania 1990	1987	29	--	---	Seine	8.2[a]	Backwater/MC
09/24/87	Platania 1990	1987	34.5	--	---	Seine	8.2[a]	Backwater/MC
09/24/87	Platania 1990	1987	25.7	--	---	Seine	8.2[a]	Backwater/MC
09/24/87	Platania 1990	1987	27.2	--	---	Seine	8.2[a]	Backwater/MC
09/24/87	Platania 1990	1987	--	--	---	Seine	8.2[a]	Backwater/MC
09/24/87	Platania 1990	1987	--	--	---	Seine	8.2[a]	Backwater/MC
09/26/87	Platania 1990	1987	--	--	---	Seine	5.3[a]	Backwater/MC
10/10/87	Platania 1990	1987	30	23.4	---	Seine	125.6[a]	Backwater/SC[b]
10/11/87	Platania 1990	1987	38.3	30	---	Seine	122.3[a]	Backwater/SC
1988								
08/21/88	Platania 1990	1988	19	--	---	Seine	10.1[a]	Backwater/MC
1989								
No young-of-the-year Colorado pikeminnow collected								
1990								
09/09/90	Buntjer et al. 1993	1990	34	--	---	Seine	8.3	Backwater
1991								
No young-of-the-year Colorado pikeminnow collected								
1992								
09/22/92	Lashmett 1993	1992	--	20	---	Seine	-6.3	Backwater/LP[b]

[a] These RM's are calculated approximations converted from the old system of RM reported in Platania (1990) to the new system of RM adopted by the SJRIP in 1992

[b] MC = Main channel, SC = side channel, LP = Lake Powell

Table A-2. Summary data for wild young-of-the-year and age-1 Colorado pikeminnow collected in the San Juan River between 1987 and 1996, continued.

Date	Source Report	Year Class	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1993								
07/26/93	Buntjer et al. 1994	1993	--	9.2	---	Drift Net	53.0	Shoreline/MC[b]
07/27/93	Buntjer et al. 1994	1993	--	9.2	---	Drift Net	53.0	Shoreline/MC
08/30/93	Lashmett 1994	1993	--	17	---	Seine	2.9	Backwater
08/31/93	Lashmett 1994	1993	24.4	19	---	Seine	-0.4	Backwater/LP[b]
09/01/93	Lashmett 1994	1993	18.5	18	---	Seine	1.8	Backwater
09/01/93	Lashmett 1994	1993	32.6	26	---	Seine	1.2	Backwater
09/02/93	Lashmett 1994	1993	18.5	15	---	Seine	-0.2	Backwater/LP
09/02/93	Lashmett 1994	1993	19.4	15	---	Seine	-0.1	Backwater/LP
09/02/93	Lashmett 1994	1993	21.4	17	---	Seine	-0.1	Backwater/LP
10/10/93	Lashmett 1994	1993	--	26	---	Seine	0.0	Backwater
10/12/93	Lashmett 1994	1993	--	24	---	Seine	3.0	Backwater
10/12/93	Lashmett 1994	1993	--	23	---	Seine	1.0	Backwater
10/12/93	Lashmett 1994	1993	--	29	---	Seine	1.0	Backwater
1994								
04/07/94	Archer et al. 1995	1993	59	--	---	Seine	11.6	Backwater
04/07/94	Archer et al. 1995	1993	49	--	---	Seine	11.6	Backwater
08/04/94	Archer et al. 1995	1994	14	--	---	Seine	122.6	Backwater
08/12/94	Archer et al. 1995	1994	19	--	---	Seine	25.2	Backwater
08/13/94	Archer et al. 1995	1994	17	--	---	Seine	9.8	Backwater
08/13/94	Archer et al. 1995	1994	21	--	---	Seine	9.8	Backwater
09/24/94	Archer et al. 1995	1994	24	--	---	Seine	8.0	Backwater
1995								
08/02/95	Platania 1996	1995	9.5	8.9	---	Drift Net	53.0	Shoreline/MC
08/03/95	Platania 1996	1995	9	8.1	---	Drift Net	53.0	Shoreline/MC
08/14/95	Archer et al. 1996[c]	1995	--	14	---	Seine	23.8	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	12	---	Seine	22.3	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	12	---	Seine	22.2	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	14	---	Seine	21.0	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	11	---	Seine	12.8	Backwater
1996								
08/02/96	Platania 1997	1996	8.6	8.1	---	Drift Net	128.0	Shoreline/MC

[b] MC = Main channel, SC = side channel, LP = Lake Powell

[c] These five fish were originally reported in Archer et al. 1996 as roundtail chub. Upon verification and curation at the University of New Mexico, Platania changed the identification of these fish to Colorado pikeminnow

Table A-3. Summary data for wild sub-adult and adult Colorado pikeminnow collected in the San Juan River between 1987 and 2000.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Sex[a]	First-Time Capture(C) or Recapture(R)	Gear[b]	River Mile	Tag Number[c]
1987									
04/07/87	Platania 1990	615	---	1,920	I	C	GN	0.0	0070
05/07/87	Platania 1990	540	445	1,100	I	C	EL	133.7[d]	1514
05/08/87	Platania 1990	780	645	>5,500	F	C	EL	122.7[d]	1821
09/08/87	Platania 1990	632	---	2,300	I	R	EL	79.0[d]	0070
1988									
03/25/88	Platania 1990	539	445	1,100	I	C	EL	134.5[d]	3241
03/26/88	Platania 1990	737	615	4,400	F	C	EL	127.7[d]	3207
04/23/88	Platania 1990	568	---	1,400	I	C	EL	114.1[d]	0040
10/23/88	Platania 1990	665	530	2,750	I	C	EL	144.7[d]	5002
1989									
05/23/89	Platania 1990	680	---	3,300	I	C	EL	103.7[d]	0006
1990									
No adult or sub-adult Colorado pikeminnow collected									
1991									
06/08/91	Ryden and Pfeifer 1993	571	480	1,650	M	C	EL	134.95	7F7D086412
06/09/91	Ryden and Pfeifer 1993	687	575	3,450	F	C	TN	122.6	7F7D026448
06/09/91	Ryden and Pfeifer 1993	702	590	3,350	F	C	TN	122.6	7F7D073422
06/09/91	Ryden and Pfeifer 1993	610	510	2,300	M	C	TN	122.6	7F7D075115
10/17/91	Ryden and Pfeifer 1993	660	555	2,750	F	C	EL	141.8	7F7D07737A
10/19/91	Ryden and Pfeifer 1993	615	507	1,695	F	C	EL	127.7	7F7D03060E
10/19/91	Ryden and Pfeifer 1993	945	805	5,035	F	C	EL	127.1	7F7D027A16
10/19/91	Ryden and Pfeifer 1993	647	540	2,500	F	C	EL	125.8	7F7D090D43
10/19/91	Ryden and Pfeifer 1993	576	478	1,450	M	C	EL	124.0	7F7D087E58

[a] F = Female, M = Male, I = Indeterminate

[b] EL = Electrofishing, GN = Gill Net, TN = Trammel Net

[c] All tags before 1991 were Carlin tags. All tags from 1991 to 2000 were PIT tags.

[d] These RM's are calculated approximations converted from the old system of RM to the new system of RM adopted by the SJRIP in 1992

Table A-3. Summary data for wild sub-adult and adult Colorado pikeminnow collected in the San Juan River between 1987 and 2000, continued.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Sex[a]	First-Time Capture(C) or Recapture(R)	Gear[b]	River Mile	Tag Number[c]
1992									
05/14/92	Ryden and Pfeifer 1993	519	430	1,250	M	C	EL	130.5	7F7F187D20
06/28/92	Ryden and Pfeifer 1993	595	495	1,855	M	C	EL	131.4	7F7D226615
10/08/92	Ryden and Pfeifer 1993	690	705	3,000	F	C	EL	138.2	7F7D1E1C05
10/09/92	Ryden and Pfeifer 1993	527	450	1,120	M	R	EL	128.0	7F7F187D20
1993									
04/13/93	Ryden and Pfeifer 1994a	527	450	1,200	M	R	TN	130.6	7F7F187D20
04/14/93	Ryden and Pfeifer 1994a	797	685	5,550	F	C	EL	128.8	7F7D225E24
04/14/93	Ryden and Pfeifer 1994a	948	820	8,050	F	R	EL	126.2	7F7D027A16
05/13/93	Ryden and Pfeifer 1994a	764	643	4,760	F	C	EL	122.1	7F7D075167
10/03/93	Ryden and Pfeifer 1994a	820	700	5,510	F	R	TN	129.3	7F7D225E24
10/08/93	Ryden and Pfeifer 1994a	753	642	3,900	F	C	EL	74.8	7F7D075651
1994									
04/12/94	Ryden and Pfeifer 1995	820	695	5,810	F	R	EL	133.2	7F7D225E24
04/14/94	Ryden and Pfeifer 1995	754	628	4,450	F	R	EL	120.6	7F7D073422
04/15/94	Ryden and Pfeifer 1995	617	510	2,000	M	C	EL	133.2	7F7D077A18
05/16/94	Ryden and Pfeifer 1995	759	642	4,000	F	R	EL	76.0	7F7D075651
10/04/94	Ryden and Pfeifer 1995	630	528	2,100	F	R	EL	128.1	7F7D03060E
10/05/94	Ryden and Pfeifer 1995	823	695	4,370	F	C	EL	123.6	1F74387F36
10/09/94	Ryden and Pfeifer 1995	762	642	3,800	F	R	EL	74.4	7F7D075651
1995									
04/26/95	Ryden and Pfeifer 1996	824	695	4,350	F	R	EL	123.1	1F74387F36
04/27/95	Ryden and Pfeifer 1996	754	628	3,550	F	R	EL	122.6	7F7D073422
1996									
06/21/96	Ryden 2000a	363	305	700	I	C	EL	7.9	7F7B133B64
07/18/96	Ryden 2000a	432	357	688	I	C	EL	12.9	7F7D14061D
1997									
No adult or sub-adult Colorado pikeminnow collected									
1998									
09/29/98	Ryden 2000b	845	750	6,100	F	R	EL	137.6	7F7D225E24
1999									
03/23/99	Ryden 2000b	845	750	7,500	F	R	EL	131.5	7F7D225E24
2000									
07/25/00	Ryden 2001	846	750	6,850	F	R	EL	138.9	7F7D225E24

Table A-4. Synopsis of the numbers of individual Colorado pikeminnow (both wild and stocked) of various age-classes collected from the San Juan River between 1987 and 2000. Numbers of wild fish collected have no parentheses. Numbers in parentheses indicate all known recaptures of Colorado pikeminnow that were stocked by either the Utah Division of Wildlife Resources (1996-2000) or U.S. Fish and Wildlife Service (1997). Note: Subsequent recaptures of previously-tagged adult fish are not included in this table.

Year	YOY/AGE-0	AGE-1	AGE-2	AGE-3	AGE-4	Adult
1987	18	0	0	0	0	3
1988	1	0	0	0	0	4
1989	0	0	0	0	0	1
1990	1	0	0	0	0	0
1991	0	0	0	0	0	9
1992	1	0	0	0	0	3
1993	13	0	0	0	0	3
1994	5	2	0	0	0	2
1995	7	0	0	0	0	0
1996	1(909)	0	0	1	1	0
1997	0(1093)	0(452)	0	0	0	0(10)
1998	0(120)	0(193)	0(47)	0	0	0(2)
1999	0(260)	0(26)	0(6)	0(3)	0	0
2000	0(4)	0(2)	0(1)	0(2)	0	0
Total	47(2,386)	2(673)	0(54)	1(5)	1	25(12)

APPENDIX B

Length at age table for Colorado pikeminnow.

Table B-1. Known length at age values for various groups of Colorado pikeminnow, both wild and hatchery-reared, in the upper Colorado River basin.

Age	Total Length	Investigator	Area Or Population	Hatchery Or Wild Population
0	Mean: 40 mm Range: 29-47 mm	Valdez 1990; Tyus and Haines 1991	Cataract Canyon, Colorado River, UT; Green River, UT	Wild
	Mean: 55 mm Range: 25-125 mm by November	UDWR-Moab USFWS-Grand Junction	Stocked Into San Juan River 1996 And 2002	Hatchery
1	Mean: 44 mm Range: 39-54 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 71 mm Range: 50-103 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
	Range: 75-235 mm by October	USFWS-Grand Junction	Recaptured From San Juan River 1997-2001	Hatchery
2	Mean: 95 mm Range: 82-118 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Range: 90-123	Musker 1981; Hawkins 1992; USFWS 2002	Upper Colorado River Basin, CO And UT	Wild
	Mean: 181 mm (n = 1)	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
	Range: 242-336 mm by October	USFWS-Grand Junction	Recaptured From San Juan River 1997-2001	Hatchery
3	Mean: 162 mm Range: 136-189 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 233 mm Range: 190-259 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
	Range: 346-420 mm by October	USFWS-Grand Junction	Recaptured From San Juan River 1997-2001	Hatchery

Table B-1. Known length at age values for various groups of Colorado pikeminnow, both wild and hatchery-reared, in the upper Colorado River basin.

Age	Total Length	Investigator	Area Or Population	Hatchery Or Wild Population
4	Mean: 238 mm Range: 205-273 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 315 mm Range: 267-374 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
5	Mean: 320 mm Range: 298-372 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 376 mm Range: 326-453 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
	<u>Males</u> Range: 317-376 mm	Hamman 1981	Willow Beach National Fish Hatchery, NV	Hatchery
6	Mean: 391 mm Range: 376-464 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 406 mm	Seethaler 1978	Yampa and Green Rivers, CO And UT	Wild
	Mean: 407	Musker 1981; USFWS 2002	Upper Colorado River Basin, CO And UT	Wild
	Mean: 345 mm	Hawkins 1992; USFWS 2002	Upper Colorado River Basin, CO And UT	Wild
	Mean: 424 mm Range: 375-472 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
	Mean: 523 Range: 507-539	USFWS-Grand Junction	Recaptured From San Juan River 2002	Hatchery
	<u>Females</u> Mean: 429 Range: 390-441 <u>Males</u> Mean: 402 Range: 381-425	Hamman 1981	Willow Beach National Fish Hatchery, NV	Hatchery

Table B-1. Known length at age values for various groups of Colorado pikeminnow, both wild and hatchery-reared, in the upper Colorado River basin.

Age	Total Length	Investigator	Area Or Population	Hatchery Or Wild Population
7	Mean: 454 mm Range: 432-507 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 451 mm	Seethaler 1978	Yampa and Green Rivers, CO And UT	Wild
	Mean: 461	Musker 1981; USFWS 2002	Upper Colorado River Basin, CO And UT	Wild
	Mean: 396 mm	Hawkins 1992; USFWS 2002	Upper Colorado River Basin, CO And UT	Wild
	Mean: 456 mm Range: 430-479 mm	Osmundson et al. 1997	Colorado River upstream of Green River confluence	Wild
8	Mean: 499 mm Range: 487-532 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 440 mm	Hawkins 1992	Upper Colorado River Basin, CO And UT	Wild
9	Mean: 536 mm Range: 523-564 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
10	Mean: 570 mm Range: 568-583 mm	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild
	Mean: 540 mm Range: 442-641 mm by October	USFWS-Grand Junction	Stocked Into San Juan River 2001	Hatchery
11	Mean: 600 mm (n = 1)	Vanicek and Kramer 1969	Dinosaur National Monument, Green River, UT	Wild

APPENDIX C

PIT tag numbers and stocking information for adult Colorado pikeminnow stocked into the San Juan River by the U.S. Fish and Wildlife Service on 23 September 1997 and 11 April 2001 (Table C-1). Information for juvenile Colorado pikeminnow stocked by the Utah Division of Wildlife Resources between 1996 and 2000 and recaptured and PIT-tagged on subsequent monitoring and research trips between August 1997 and May 2001 (Table C-2).

Table C-1. Stocking information for the 197 adult Colorado pikeminnow stocked on 23 September 1997 (n = 49) and 11 April 2001 (n = 148) by the U.S. Fish and Wildlife Service, Grand Junction, CO at RM 180.2 (the Highway 371 bridge) in Farmington, NM.

PIT Tag Number	Date Of Stocking	River Mile Of Stocking	Total Length In Millimeters	Year-Class
53247F682D	04/11/2001	180.2	527	1991
5327627C79	04/11/2001	180.2	543	1991
7F7B015C4C	04/11/2001	180.2	NOT MEASURED	1991
7F7B01613F	04/11/2001	180.2	NOT MEASURED	1991
7F7B022B0E	04/11/2001	180.2	NOT MEASURED	1991
7F7B02300C	04/11/2001	180.2	NOT MEASURED	1991
7F7B02301D	04/11/2001	180.2	NOT MEASURED	1991
7F7B025D78	04/11/2001	180.2	NOT MEASURED	1991
7F7B033152	04/11/2001	180.2	NOT MEASURED	1991
7F7B034A7B	04/11/2001	180.2	641	1991
7F7B03510B	04/11/2001	180.2	NOT MEASURED	1991
7F7B037643	04/11/2001	180.2	NOT MEASURED	1991
7F7B066234	04/11/2001	180.2	NOT MEASURED	1991
7F7B080C6F	04/11/2001	180.2	NOT MEASURED	1991
7F7B08150F	04/11/2001	180.2	NOT MEASURED	1991
7F7B08175A	04/11/2001	180.2	NOT MEASURED	1991
7F7B08231B	04/11/2001	180.2	506	1991
7F7B08235E	04/11/2001	180.2	505	1991
7F7B082A40	04/11/2001	180.2	NOT MEASURED	1991
7F7B0E4C63	04/11/2001	180.2	NOT MEASURED	1991
7F7B0F6874	04/11/2001	180.2	NOT MEASURED	1991
7F7B105D64	04/11/2001	180.2	NOT MEASURED	1991
7F7B10651A	04/11/2001	180.2	NOT MEASURED	1991
7F7B106826	04/11/2001	180.2	NOT MEASURED	1991
7F7B106F40	04/11/2001	180.2	NOT MEASURED	1991
7F7B107B59	04/11/2001	180.2	NOT MEASURED	1991
7F7B11041E	04/11/2001	180.2	NOT MEASURED	1991
7F7B112F27	04/11/2001	180.2	NOT MEASURED	1991
7F7B113439	04/11/2001	180.2	NOT MEASURED	1991
7F7B117D0F	04/11/2001	180.2	567	1991
7F7B122152	04/11/2001	180.2	502	1991
7F7B122208	04/11/2001	180.2	NOT MEASURED	1991
7F7B122465	04/11/2001	180.2	NOT MEASURED	1991
7F7B122D50	04/11/2001	180.2	NOT MEASURED	1991
7F7B122F11	04/11/2001	180.2	NOT MEASURED	1991
7F7B123634	04/11/2001	180.2	533	1991
7F7B124128	04/11/2001	180.2	NOT MEASURED	1991
7F7B12420E	04/11/2001	180.2	NOT MEASURED	1991
7F7B125010	04/11/2001	180.2	NOT MEASURED	1991
7F7B12667F	04/11/2001	180.2	NOT MEASURED	1991
7F7B127F34	04/11/2001	180.2	607	1991
7F7B13071A	04/11/2001	180.2	NOT MEASURED	1991
7F7B130C56	04/11/2001	180.2	492	1991
7F7B133C51	04/11/2001	180.2	465	1991
7F7B134F23	04/11/2001	180.2	NOT MEASURED	1991
7F7B135A7B	04/11/2001	180.2	573	1991
7F7B13714C	04/11/2001	180.2	NOT MEASURED	1991
7F7B137376	04/11/2001	180.2	NOT MEASURED	1991

Table C-1, continued.

PIT Tag Number	Date Of Stocking	River Mile Of Stocking	Total Length In Millimeters	Year-Class
7F7B14375A	04/11/2001	180.2	NOT MEASURED	1991
7F7B14382E	04/11/2001	180.2	NOT MEASURED	1991
7F7B143D00	04/11/2001	180.2	NOT MEASURED	1991
7F7B177C40	04/11/2001	180.2	NOT MEASURED	1991
7F7B177D17	04/11/2001	180.2	508	1991
7F7B180348	04/11/2001	180.2	NOT MEASURED	1991
7F7B194568	04/11/2001	180.2	542	1991
7F7B194D7E	04/11/2001	180.2	NOT MEASURED	1991
7F7B19551B	04/11/2001	180.2	NOT MEASURED	1991
7F7B19570C	04/11/2001	180.2	NOT MEASURED	1991
7F7B195B12	04/11/2001	180.2	NOT MEASURED	1991
7F7B195C63	04/11/2001	180.2	542	1991
7F7B195E42	04/11/2001	180.2	NOT MEASURED	1991
7F7B1A412B	04/11/2001	180.2	NOT MEASURED	1991
7F7B1A504F	04/11/2001	180.2	NOT MEASURED	1991
7F7B1A6C07	04/11/2001	180.2	NOT MEASURED	1991
7F7B1A7B59	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B002C	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B0B31	04/11/2001	180.2	506	1991
7F7B1B2072	04/11/2001	180.2	513	1991
7F7B1B2311	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B4E70	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B571E	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B614D	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B6436	04/11/2001	180.2	NOT MEASURED	1991
7F7B1B6E57	04/11/2001	180.2	NOT MEASURED	1991
7F7D11472D	04/11/2001	180.2	611	1991
7F7D126D61	04/11/2001	180.2	NOT MEASURED	1991
7F7D130F69	04/11/2001	180.2	NOT MEASURED	1991
7F7D131841	04/11/2001	180.2	NOT MEASURED	1991
7F7D131E0B	04/11/2001	180.2	NOT MEASURED	1991
7F7D132B69	04/11/2001	180.2	NOT MEASURED	1991
7F7D133831	04/11/2001	180.2	NOT MEASURED	1991
7F7D135820	04/11/2001	180.2	NOT MEASURED	1991
7F7D135971	04/11/2001	180.2	NOT MEASURED	1991
7F7D13692F	04/11/2001	180.2	NOT MEASURED	1991
7F7D136954	04/11/2001	180.2	NOT MEASURED	1991
7F7D137454	04/11/2001	180.2	NOT MEASURED	1991
7F7D13767D	04/11/2001	180.2	NOT MEASURED	1991
7F7D137946	04/11/2001	180.2	624	1991
7F7D14017E	04/11/2001	180.2	461	1991
7F7D140515	04/11/2001	180.2	542	1991
7F7D142C13	04/11/2001	180.2	NOT MEASURED	1991
7F7D142C5A	04/11/2001	180.2	NOT MEASURED	1991
7F7D152D56	04/11/2001	180.2	NOT MEASURED	1991
7F7D15303F	04/11/2001	180.2	591	1991
7F7D153A0E	04/11/2001	180.2	537	1991
7F7D153E26	04/11/2001	180.2	NOT MEASURED	1991
7F7D15424F	04/11/2001	180.2	NOT MEASURED	1991
7F7D15446A	04/11/2001	180.2	NOT MEASURED	1991
7F7D154555	04/11/2001	180.2	NOT MEASURED	1991

Table C-1, continued.

PIT Tag Number	Date Of Stocking	River Mile Of Stocking	Total Length In Millimeters	Year-Class
7F7D154556	04/11/2001	180.2	NOT MEASURED	1991
7F7D154613	04/11/2001	180.2	601	1991
7F7D1F054D	09/23/1997	180.2	650	1981
7F7D232352	04/11/2001	180.2	NOT MEASURED	1991
7F7D24216F	04/11/2001	180.2	531	1991
7F7D295E2E	04/11/2001	180.2	NOT MEASURED	1991
7F7D295F1E	04/11/2001	180.2	NOT MEASURED	1991
7F7D317277	04/11/2001	180.2	NOT MEASURED	1991
7F7D317958	04/11/2001	180.2	NOT MEASURED	1991
7F7D3B1537	04/11/2001	180.2	NOT MEASURED	1991
7F7D3C4762	04/11/2001	180.2	NOT MEASURED	1991
7F7D3F1146	04/11/2001	180.2	596	1991
7F7D3F7C79	04/11/2001	180.2	NOT MEASURED	1991
7F7D400665	04/11/2001	180.2	NOT MEASURED	1991
7F7D401014	04/11/2001	180.2	NOT MEASURED	1991
7F7D401478	04/11/2001	180.2	NOT MEASURED	1991
7F7D440C29	04/11/2001	180.2	NOT MEASURED	1991
7F7D441746	04/11/2001	180.2	NOT MEASURED	1991
7F7D441B26	04/11/2001	180.2	NOT MEASURED	1991
7F7D47314B	04/11/2001	180.2	555	1991
7F7D476661	04/11/2001	180.2	NOT MEASURED	1991
7F7D477548	04/11/2001	180.2	NOT MEASURED	1991
7F7D481D3C	04/11/2001	180.2	NOT MEASURED	1991
7F7D486259	04/11/2001	180.2	NOT MEASURED	1991
7F7D486365	04/11/2001	180.2	507	1991
7F7D486622	04/11/2001	180.2	NOT MEASURED	1991
7F7D487463	04/11/2001	180.2	542	1991
7F7D487779	04/11/2001	180.2	NOT MEASURED	1991
7F7D490018	04/11/2001	180.2	NOT MEASURED	1991
7F7D4B020A	04/11/2001	180.2	492	1991
7F7D4B662B	04/11/2001	180.2	NOT MEASURED	1991
7F7D4C3818	04/11/2001	180.2	NOT MEASURED	1991
7F7D4C391B	04/11/2001	180.2	NOT MEASURED	1991
7F7D4D544A	04/11/2001	180.2	NOT MEASURED	1991
7F7D4D652D	04/11/2001	180.2	NOT MEASURED	1991
7F7D4D707F	04/11/2001	180.2	NOT MEASURED	1991
7F7D4D7A21	04/11/2001	180.2	NOT MEASURED	1991
7F7D506D04	04/11/2001	180.2	NOT MEASURED	1991
7F7D51752B	04/11/2001	180.2	NOT MEASURED	1991
7F7D521A63	04/11/2001	180.2	442	1991
7F7D52321E	04/11/2001	180.2	561	1991
7F7D78355C	04/11/2001	180.2	NOT MEASURED	1991
7F7D783702	04/11/2001	180.2	527	1991
7F7D783728	04/11/2001	180.2	NOT MEASURED	1991
7F7D783B0E	04/11/2001	180.2	NOT MEASURED	1991
7F7D7C1429	04/11/2001	180.2	580	1991
7F7D7C195F	04/11/2001	180.2	NOT MEASURED	1991
7F7D7C2D6F	04/11/2001	180.2	NOT MEASURED	1991
7F7D7F4748	04/11/2001	180.2	NOT MEASURED	1991
7F7E6B0F63	04/11/2001	180.2	535	1991
7F7F067F30	09/23/1997	180.2	622	1981

Table C-1, continued.

PIT Tag Number	Date Of Stocking	River Mile Of Stocking	Total Length In Millimeters	Year-Class
7F7F082D0A	09/23/1997	180.2	753	1981
7F7F1E7179	09/23/1997	180.2	608	1981
7F7F1E7228	09/23/1997	180.2	685	1981
7F7F1E7557	09/23/1997	180.2	553	1981
7F7F1E766F	09/23/1997	180.2	660	1981
7F7F1E7701	09/23/1997	180.2	585	1981
7F7F1E784D	09/23/1997	180.2	734	1981
7F7F1E7D04	09/23/1997	180.2	742	1981
7F7F1F0001	09/23/1997	180.2	668	1981
7F7F1F0242	09/23/1997	180.2	593	1981
7F7F1F0A5E	09/23/1997	180.2	675	1981
7F7F1F0A63	09/23/1997	180.2	641	1981
7F7F1F0E25	09/23/1997	180.2	707	1981
7F7F1F0E7D	09/23/1997	180.2	641	1981
7F7F1F0F2C	09/23/1997	180.2	658	1981
7F7F1F0F3A	09/23/1997	180.2	640	1981
7F7F1F0F47	09/23/1997	180.2	622	1981
7F7F1F102E	09/23/1997	180.2	698	1981
7F7F1F1049	09/23/1997	180.2	625	1981
7F7F1F112C	09/23/1997	180.2	634	1981
7F7F1F1169	09/23/1997	180.2	734	1981
7F7F1F122B	09/23/1997	180.2	745	1981
7F7F1F1248	09/23/1997	180.2	552	1981
7F7F1F1315	09/23/1997	180.2	662	1981
7F7F1F1439	09/23/1997	180.2	568	1981
7F7F1F1503	09/23/1997	180.2	624	1981
7F7F1F1557	09/23/1997	180.2	669	1981
7F7F1F156F	09/23/1997	180.2	622	1981
7F7F1F181B	09/23/1997	180.2	598	1981
7F7F1F182D	09/23/1997	180.2	579	1981
7F7F1F1832	09/23/1997	180.2	550	1981
7F7F1F1861	09/23/1997	180.2	625	1981
7F7F1F1902	09/23/1997	180.2	629	1981
7F7F1F1A29	09/23/1997	180.2	741	1981
7F7F1F1B79	09/23/1997	180.2	572	1981
7F7F1F1C01	09/23/1997	180.2	698	1981
7F7F1F1D68	09/23/1997	180.2	587	1981
7F7F1F1D7A	09/23/1997	180.2	575	1981
7F7F1F1E1E	09/23/1997	180.2	671	1981
7F7F1F1F23	09/23/1997	180.2	620	1981
7F7F1F7572	09/23/1997	180.2	703	1981
7F7F32203C	09/23/1997	180.2	610	1981
7F7F323F5C	09/23/1997	180.2	673	1981
7F7F334E28	09/23/1997	180.2	601	1981
7F7F335601	09/23/1997	180.2	580	1981
7F7F336047	09/23/1997	180.2	605	1981
7F7F344148	09/23/1997	180.2	745	1981

Table C-2. Information for juvenile Colorado pikeminnow stocked by the Utah Division of Wildlife Resources, Moab, UT between 1996 and 2000 and recaptured and PIT-tagged on subsequent monitoring and research trips. The year-class is an educated guess based on size of fish at recapture. NOTE: This table includes information on second-time recaptures for fish that have been recaptured more than once.

PIT Tag Number	Date Of Recapture	River Mile Recapture	Total Length In Millimeters At Recapture	Year-Class
116E02257E	10/03/1998	96.0	179	1997
116E032C0F	10/03/1998	95.0	323	1996
1F40177F0B	08/13/1998	18.5	307	1996
1F40184C3D	09/29/1998	141.0	161	1997
1F40270971	09/29/1998	138.0	187	1997
1F41661A20	08/13/1998	19.4	274	1996
1F41721A14	09/29/1998	140.0	155	1997
1F43566662	05/06/1998	123.0	171	1997
1F46430E4A	05/08/1998	91.0	190	1997
1F5320036B	05/07/1998	112.0	208	1997
1F5A760B06	05/07/1998	110.0	162	1997
1F5A78147B	08/14/1998	9.4	295	1996
1F5A79721C	05/07/1998	110.0	163	1997
1F5B03562D	05/08/1998	95.7	218	1997
1F5B34775B	10/04/1997	104.3	203	1996
1F5B3B2229	10/04/1997	105.0	215	1996
1F5B442121	05/04/1998	149.4	184	1997
1F5B55131E	05/07/1998	107.6	168	1997
1F5B7E6B1D	05/08/1998	83.6	250	1996
1F5B7E7A0E	05/06/1998	124.1	168	1997
1F5C076717	05/07/1998	110.0	161	1997
1F5D26203E	05/07/1998	109.0	186	1997
1F606D1103	03/23/1999	127.7	148	1998
1F613E6C56	04/12/1999	150.0	141	1998
1F631D2549	04/12/1999	155.0	176	1998
1F631E3030	03/24/1999	127.7	156	1998
1F63564563	05/06/2001	109.0	351	1998
1F63723C50	08/14/1997	18.2	161	1996
1F65532504	03/24/1999	127.7	153	1998
1F660D7876	10/08/1997	63.8	213	1996
1F66226178	03/23/1999	134.0	151	1998
1F66536147	03/23/1999	134.0	117	1998
1F681D510B	10/07/1997	79.6	215	1996
1F681D510B	10/01/1999	86.0	367	1996
1F6B205D79	05/08/1998	93.0	205	1997
1F6B205D79	10/03/1998	95.0	276	1996
1F6B254E03	09/29/1998	140.0	188	1997
1F6B283717	08/13/1998	18.0	300	1996
1F6B2F4B7C	05/07/1998	104.6	176	1997
1F6D0E4C1A	09/29/1998	140.0	133	1997
1F6D193823	08/13/1998	19.0	315	1996
1F6D6E2660	10/08/1997	69.0	235	1996
1F717D787B	03/24/1999	127.7	167	1998
1F74425358	05/06/1998	127.0	150	1997
1F74730E6C	05/08/1998	94.0	207	1997

Table C-2, continued.

PIT Tag Number	Date Of Recapture	River Mile Recapture	Total Length In Millimeters At Recapture	Year-Class
1F75056C7B	05/06/1998	118.0	204	1997
1F75110457	08/12/1998	25.3	151	1997
4122214262	10/05/1998	75.0	360	1996
412222372C	10/02/1998	103.0	160	1997
4122232572	10/02/1998	103.0	280	1996
4122384657	10/02/1998	108.0	209	1997
4122445D39	10/02/1998	104.0	283	1996
4122465336	10/02/1998	103.0	305	1996
41537D7D6A	10/02/1998	98.0	170	1997
415A025664	10/02/1998	101.0	180	1997
415A043A29	10/06/1998	61.0	367	1996
415A175424	10/05/1998	75.0	286	1996
41650D312B	10/02/1998	99.0	210	1997
4165177603	10/07/1998	55.0	280	1996
416525042F	10/02/1998	103.0	265	1996
41652A6621	03/23/1999	131.8	156	1998
416C643C0F	10/05/1998	71.0	269	1996
416D076613	03/23/1999	131.8	137	1998
416E003A2C	10/02/1998	104.0	251	1996
416E0F3830	10/02/1998	102.0	242	1996
416E153B7B	10/02/1998	103.0	280	1996
416E391251	03/24/1999	127.7	149	1998
416F00195C	10/03/1998	89.0	300	1996
416F1C6310	10/02/1998	104.0	280	1996
416F23743D	10/04/1998	85.5	106	1997
4170496A0E	10/04/1998	83.0	285	1996
4170591971	10/02/1998	103.0	183	1997
4170687847	10/02/1998	103.0	325	1996
4170747202	10/05/1998	75.0	204	1997
420F251833	03/23/1999	131.0	166	1998
420F33165C	10/02/1998	99.0	201	1997
420F392732	10/02/1998	103.0	172	1997
420F430E7E	10/03/1998	97.0	207	1997
420F453E68	10/02/1998	107.0	171	1997
421307454B	10/03/1998	89.0	266	1996
4213144D12	10/03/1998	89.0	173	1997
421317322E	10/03/1998	97.0	296	1996
42143B000F	05/06/1998	122.0	176	1997
42143C1C39	10/01/1998	111.0	270	1996
4214485624	10/01/1998	117.0	192	1997
4215192C2F	09/29/1998	138.0	166	1997
512440727B	09/21/1999	149.0	207	1998
5124671D22	09/30/1999	97.0	157	1998
51246D5A66	10/07/1999	5.0	297	1997
51246F2B26	10/01/1999	83.0	215	1998
5124706D35	10/03/1999	58.0	279	1997
51247B0D6B	10/07/1999	5.0	273	1997
51247C5B3D	10/03/1999	58.0	277	1997
51247D4B57	09/21/2000	149.0	402	1997
51247F0A6A	09/30/1999	103.0	164	1998

Table C-2, continued.

PIT Tag Number	Date Of Recapture	River Mile Recapture	Total Length In Millimeters At Recapture	Year-Class
51247F0B49	10/01/1999	86.0	346	1996
512737211D	05/04/2000	97.0	220	1999
5127726507	07/11/2000	10.7	340	1998
5136472820	04/17/1999	85.0	294	1997
51364F392A	04/15/1999	117.0	151	1998
5136501D77	04/16/1999	110.0	163	1998
513A590906	04/14/1999	130.7	168	1998
520074553F	03/23/1999	132.5	153	1998
7F7A136847	06/15/1999	0.0	166	1998
7F7B016B19	05/05/1998	132.0	185	1997
7F7B03273A	05/05/1998	132.0	182	1997
7F7B065825	10/06/1998	63.0	304	1996
7F7B0A1741	10/01/1998	120.0	163	1997
7F7B0D241B	05/09/1998	82.0	226	1997
7F7B0D2C24	05/05/1998	131.0	163	1997
7F7B0D3C2B	05/06/1998	123.7	217	1997
7F7B0D4A00	08/13/1998	17.0	262	1996
7F7B105701	09/29/1998	140.0	258	1996
7F7B105926	10/01/1998	111.0	268	1996
7F7B10652C	09/30/1998	130.0	180	1997
7F7B106837	09/29/1998	142.0	174	1997
7F7B10752F	09/29/1998	143.0	181	1997
7F7B110F76	05/05/1998	133.0	187	1997
7F7B11277B	09/29/1998	143.0	162	1997
7F7B112D6F	09/29/1998	143.0	162	1997
7F7B11354A	10/01/1998	117.0	169	1997
7F7B113D5C	10/05/1998	75.0	282	1996
7F7B113D5C	07/25/2000	137.3	404	1996
7F7B113E28	09/30/1998	136.0	290	1996
7F7B114004	09/28/1998	148.0	336	1996
7F7B114870	10/01/1998	120.0	271	1996
7F7B117B35	09/30/1998	136.0	160	1997
7F7B12485C	10/01/1998	113.0	157	1997
7F7B126B4E	09/30/1998	123.0	258	1996
7F7B127541	10/02/1998	109.0	250	1996
7F7B127A38	09/30/1998	135.0	290	1996
7F7B13084D	10/02/1998	108.0	100	1997
7F7B134349	05/06/1998	123.0	181	1997
7F7B134543	09/30/1998	126.0	296	1996
7F7B134640	10/02/1998	107.0	169	1997
7F7B134840	09/29/1998	144.0	164	1997
7F7B135653	08/31/1998	162.3	183	1997
7F7B135A40	09/29/1998	143.0	175	1997
7F7B135E01	09/30/1998	130.0	270	1996
7F7B135F21	09/30/1998	127.0	299	1996
7F7B135F21	04/17/1999	81.3	302	1997
7F7B136C6C	09/29/1998	144.0	172	1997
7F7B137318	09/30/1998	132.0	163	1997
7F7B14226F	10/01/1998	111.0	194	1997
7F7B176A6A	10/01/1998	113.0	180	1997

Table C-2, continued.

PIT Tag Number	Date Of Recapture	River Mile Recapture	Total Length In Millimeters At Recapture	Year-Class
7F7B18080C	10/07/1998	58.0	304	1996
7F7B194838	09/30/1998	129.0	270	1996
7F7B195215	09/29/1998	138.0	162	1997
7F7B1A3769	09/29/1998	140.0	129	1997
7F7B1A4130	10/02/1998	109.0	245	1996
7F7B1A7405	09/29/1998	141.0	160	1997
7F7B1A7835	09/30/1998	136.0	256	1996
7F7B1B061A	09/28/1998	153.0	153	1997
7F7B1B141F	09/29/1998	143.0	163	1997
7F7B1B1D58	10/05/1998	71.0	328	1996
7F7B1B570A	10/02/1998	104.0	185	1997
7F7B1B577C	09/29/1998	142.0	179	1997
7F7B1B6603	09/29/1998	138.0	156	1997
7F7D031574	09/29/1998	143.0	151	1997
7F7D031D69	09/28/1998	152.0	160	1997
7F7D071A67	09/29/1998	143.0	242	1996
7F7D071A71	05/08/1998	91.0	200	1997
7F7D084A62	09/29/1998	143.0	155	1997
7F7D087E14	09/29/1998	140.0	182	1997
7F7D090038	05/08/1998	91.7	229	1997
7F7D153127	05/05/1998	140.0	173	1997
7F7D180E42	05/05/1998	138.0	154	1997
7F7D3C4C4D	05/08/1998	93.0	151	1997
7F7D3E7A0F	05/08/1998	84.0	182	1997
7F7D406402	05/08/1998	91.6	217	1997
7F7D441650	09/28/1998	147.0	173	1997
7F7D52113F	05/08/1998	90.9	197	1997

APPENDIX D

Estimated number of Colorado pikeminnow stocked between 1996 and 2000 (summarized in Table 1) assumed to be surviving through 2025. Table D-1 is for age-0 Colorado pikeminnow stocked in 1996 and 1997 by the UDWR and uses the survival curves presented in Table 2 to figure outyear's survival. Table D-2 is for larval Colorado pikeminnow stocked from 1997-2000 by the UDWR and uses all survival curve values from Table 2 to figure outyear's survival, except for at age-0. Survival at age-0 is assumed to 0.01 (1%) when Colorado pikeminnow are stocked as larvae in the summer.

Table D-3 is for adult Colorado pikeminnow stocked in 1997 and 2001 by the USFWS. This table assumes a very high mortality in the first two years, post-stocking. This assumption was based on reported losses among older (> 10-year old), stocked adult endangered fish as established by radio telemetry and post-stocking recapture history (Burdick and Bonar 1997, Ryden 2000b, and this report). A survival rate of just 0.15 (15%) is assumed for the first year and 0.50 (50%) for the second year. Thereafter, it is assumed that any of these older, stocked adults that are still surviving would have the same survival percentages as wild adults (i.e., 0.86 [86%]).

The deviations in survival rates used in Tables D-2 and D-3 (as opposed to those presented in Table 2) are purely conjecture. These numbers are presented here to try to get some rough idea of the number of Colorado pikeminnow stocked from 1996-2001 that ***MAY*** be surviving in the San Juan River during the augmentation effort outlined previously in this document.

Table D-1. Estimated number of age-0 Colorado pikeminnow stocked in 1996 and 1997 surviving in each consecutive calendar year, 1996-2025. Estimated between-year survival percentages can be found in Table 2.

Calendar Year	Stocking Number:		Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1996)	2 (1997)		
1996	100,000		100,000	0
1997	15,080	116,878	131,958	0
1998	2,274	17,625	19,899	0
1999	682	2,658	3,340	0
2000	341	797	1,138	0
2001	205	399	604	0
2002	143	239	382	0
2003	115	167	282	115
2004	97	134	231	231
2005	83	114	197	197
2006	71	97	168	168
2007	61	83	144	144
2008	53	72	125	125
2009	45	62	107	107
2010	39	53	92	92
2011	34	46	80	80
2012	29	39	68	68
2013	25	34	59	59
2014	21	29	50	50
2015	18	25	43	43
2016	16	21	37	37
2017	14	18	32	32
2018	12	16	28	28
2019	10	14	24	24
2020	9	12	21	21

Table D-1. Estimated number of age-0 Colorado pikeminnow stocked in 1996 and 1997 surviving in each consecutive calendar year, 1996-2025. Estimated between-year survival percentages can be found in Table 2.

Calendar Year	Stocking Number:		Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1996)	2 (1997)		
2021	7	10	17	17
2022	6	9	15	15
2023	5	7	12	12
2024	5	6	11	11
2025	4	6	10	10

Table D-2. Estimated number of larval Colorado pikeminnow stocked between 1998 and 2000 surviving in each consecutive calendar year, 1998-2025. Estimated between-year survival percentages can be found in Table 2, with the exception of the first-year survival rate, which is assumed to be 0.01 (1%) when fish are stocked as larvae in the summer.

Calendar Year	Stocking Number:			Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1998)	2 (1999)	3 (2000)		
1998	10,571			10,571	0
1999	106	500,000		500,106	0
2000	16	5,000	105,000	110,016	0
2001	5	754	1,050	1,809	0
2002	2	226	158	386	0
2003	1	113	48	162	0
2004	1	68	29	98	0
2005	1	48	17	66	1
2006	1	38	12	51	39
2007	1	32	10	43	43
2008	1	27	8	36	36
2009	0	24	7	31	31
2010	0	20	6	26	26
2011	0	17	5	22	22
2012	0	15	4	19	19
2013	0	13	4	17	17
2014	0	11	3	14	14
2015	0	10	3	13	13
2016	0	8	2	10	10
2017	0	7	2	9	9
2018	0	6	2	8	8
2019	0	5	2	7	7
2020	0	4	1	5	5
2021	0	4	1	5	5

Table D-2. Estimated number of larval Colorado pikeminnow stocked between 1998 and 2000 surviving in each consecutive calendar year, 1998-2025. Estimated between-year survival percentages can be found in Table 2, with the exception of the first-year survival rate, which is assumed to be 0.01 (1%) when fish are stocked as larvae in the summer.

Calendar Year	Stocking Number:			Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1998)	2 (1999)	3 (2000)		
2022	0	3	1	4	4
2023	0	3	1	4	4
2024	0	2	1	3	3
2025	0	2	1	3	3

Table D-3. Estimated number of adult Colorado pikeminnow stocked in 1997 and 2001 surviving in each consecutive calendar year, 1997-2025. Estimated between-year survival percentages used were 0.15 (15%) in year 1, 0.50 (50%) in year 2, and 0.86 (86%) in all following years.

Calendar Year	Stocking Number:		Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1997)	2 (2001)		
1997	49		49	49
1998	7		7	7
1999	4		4	4
2000	3		3	3
2001	3	148	151	151
2002	2	22	24	24
2003	2	11	13	13
2004	2	10	12	12
2005	1	8	9	9
2006	1	7	8	8
2007	1	6	7	7
2008	1	5	6	6
2009	1	4	5	5
2010	1	4	5	5
2011	0	3	3	3
2012	0	3	3	3
2013	0	2	2	2
2014	0	2	2	2
2015	0	2	2	2
2016	0	2	2	2
2017	0	1	1	1
2018	0	1	1	1
2019	0	1	1	1
2020	0	1	1	1
2021	0	1	1	1

Table D-3. Estimated number of adult Colorado pikeminnow stocked in 1997 and 2001 surviving in each consecutive calendar year, 1997-2025. Estimated between-year survival percentages used were 0.15 (15%) in year 1, 0.50 (50%) in year 2, and 0.86 (86%) in all following years.

Calendar Year	Stocking Number:		Total # Of Fish, All Ages	Total # Of Adult Fish
	1 (1997)	2 (2001)		
2022	0	1	1	1
2023	0	1	1	1
2024	0	0	0	0
2025	0	0	0	0

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Colorado River Fishery Project
764 Horizon Drive, Building B
Grand Junction, Colorado 81506-3946

IN REPLY REFER TO:

28 January 2003

To: Members of the San Juan River Biology Committee

From: Dale Ryden

Subject: Finalization of the report ***An Augmentation Plan For Colorado Pikeminnow In The San Juan River*** and response to Tom Wesche's comments on the draft final version of this report.

This letter accompanies the final version of the document ***An Augmentation Plan For Colorado Pikeminnow In The San Juan River***. The Draft Final of this document was distributed via the San Juan River Recovery Implementation Program's Biology Committee (SJRIP-BC) listserver on 9 December 2002, with a 30-day final comment period. Only one set of comments - from Tom Wesche - was received on the Draft Final (on 8 January 2003). Those comments were also distributed via the SJRIP-BC listserver. With the response to those comments (see below), this document is now final.

The author would like to thank all those individuals that responded with written and verbal comments. They greatly improved the quality of the final version of this augmentation plan. Specifically, thanks to Tom Wesche, who supplied valuable written comments (within specified deadlines) on every draft of this report.

Below are my responses to Tom Wesche's final set of comments, received 8 January 2003:

Tom Wesche's Comment #1
On page 5, you list a number of possible limiting factors for SJR pikeminnow, with many of the supporting literature citations dating back to 1990 and earlier. I recommend you use the Program Evaluation Report (PER, September 2000, p. 3-60 to 3-62) as your updated source of information on limiting factors. For example, while early in the program water quality/contaminants were thought to be possible limiting factors, the PER states on p. S-3 that "none of them proved to be important limiting factors". I feel we should attempt to be as consistent as possible from one program document to the next.

Response #1
While I agree with you that we should remain consistent across program documents, I feel that my discussion of limiting factors as it stands is valid for and applicable to the San Juan River. It is true that the Program Evaluation Report (PER) states on page S-3 that "none of them proved to be important limiting factors" (i.e., referring to fish health, water quality, and contaminants as limiting factors). However, while rereading pages 3-60 to 3-62 of the PER as your comment suggested, I found the following statements:

1) *On page 3-60 of the PER, 3rd full paragraph*. "Likewise, the factors that are limiting to the recovery of the rare fish species cannot be definitively determined. During the 7-year research period, the SJRIP attempted to define factors limiting the recovery of the endangered species, which are distinct from the factors that will limit their ultimate population expansion. At present, few, if any, factors can be definitively identified as limiting to the recovery of Colorado pikeminnow and razorback sucker, primarily because so few of these fishes currently exist in the San Juan River system."

2) *On page 3-61 of the PER, last paragraph*. "Therefore, just because some factors were not found to be limiting during the 7-year research period does not mean that they will not be limiting in the future."

3) Again, *on page 3-61 of the PER, last paragraph*. "The only factor that was eliminated for review during monitoring is fish health."

With the uncertainties presented in these sentences of the PER, I feel that it is appropriate to leave a "laundry list" of "likely" limiting factors in this report at this time, especially given that each "likely" limiting factor presented has citations and is applicable this species not only in the San Juan River, but basin-wide. Thus, no changes were made to this discussion in the augmentation plan.

Tom Wesche's Comment #2

I found the discussion regarding "What is an adult fish?" on p. 32 & 33 confusing. The Recovery Goals for Colorado Pikeminnow (USFWS 2002) clearly define "adult" as being $\geq$ 450 mm TL. While others may feel this value is too high or too low, I recommend we follow the Service's published definition. As we learn more about the maturation rate of pikeminnow in the SJR, this definition may need to be "adaptively managed", but for now the Recovery Goal value is the most acceptable.

Response #2

My purpose for including this discussion was to point out that while the published Recovery Goals may state that one specific value (i.e., age-7 and $\geq$ 450 mm TL) constitutes and "adult" Colorado pikeminnow, there is still disagreement among some fairly knowledgeable experts as to whether or not that value is valid (besides those experts cited in this section of the augmentation plan, I personally feel that the value of 450 mm TL is too low). I had also hoped to point out that given varying conditions, age at maturity among Colorado pikeminnow varies from case to case and river to river.

However, my "Guideline" on page 33 of the augmentation plan states that "For the purposes of this augmentation plan, Colorado pikeminnow that are age-7+ ($\geq$ 450 mm TL) will be classified as adults." This is consistent with the Recovery Goals criteria. I have added "($\geq$ 450 mm TL)" in both the "Guideline" and in the sentence immediately above it to help clarify what length/age combination will be considered an adult for purposes of this augmentation plan.

I would also like to point out that while the Recovery Goals are published, they are subject to periodic review and revision. Now whether that will actually happen or not is anybody's guess. However, when the author's of the Recovery Goals included those kind of sentences in their documents, I think they were acknowledging that they did not have all the hard and fast answers,

but that they had to start somewhere. So they used the best science available to them at the time and filled in the blanks with (highly) educated guesses. However, as we have seen time and again on the San Juan, ideas and perceptions can change substantially as new information becomes available.

Tom Wesche's Comment #3

Regarding "Size of Fish to Stock" (p. 25 to 28), most of your discussion supports the stocking of larger pikeminnow, but you default near the end of your argument to smaller fish (last paragraph on p. 27), based solely on the lack of adequate rearing facilities. I don't accept this temporary limitation as justification for a longterm (8 to 9 year) effort. If I interpret Table A-4 correctly, our recapture of juvenile fish stocked as 50mm or less has dwindled to virtually zero, suggesting very limited survival. Our experience with razorback has shown that larger fish need to be stocked. Likewise, the UCRB Program has adopted stocking only pikeminnow greater than 150 mm (Nesler, Christopherson, McAda, Pfeifer and Czapla, Nov 26, 2002). We should do the same. I agree that stocking 300,000+ 55 mm fish in 2003 is a step in the right direction due to our current lack of facilities. However, I feel that with the financial resources available to the SJRRIP, we need to begin planning now for enhancing our facilities to better our chances for pikeminnow recovery, much like we have done for razorback. Therefore, my suggestion is to present the stocking of the smaller fish as the short-term recommendation and to expand the facilities discussion to include specific guidance as to what the Program needs to do immediately to bring the necessary infrastructure online to produce the larger fish.

Response #3

I know this has been a consistent point of yours throughout the various drafts of this augmentation plan and that you feel very strongly about it. I do not necessarily disagree with you. That was why I had an option for stocking larger size-class Colorado pikeminnow in the 10 December 2001 draft of this augmentation plan. However, in large part, my discussion in the augmentation plan that supports stocking larger Colorado pikeminnow is based on results obtained with a surrogate species, razorback sucker. The results observed with stocking larger size-class razorback sucker may not, in real-life, have any bearing at all on what would happen if we stocked larger Colorado pikeminnow. Or they may have all the bearing in the world. The fact is, we just don't know at this point.

While it is true that the upper Colorado River basin Recovery Program (UCRB-RIP) is going to begin its augmentation program using Colorado pikeminnow that are $\geq$ 150 mm TL, they have not done so yet. Therefore, the assumptions made in their augmentation plans (regarding survival, sizes of fish to stock, etc.) are just that, assumptions. The fact is that the SJRIP has more experience stocking young Colorado pikeminnow than does the UCRB-RIP.

Additionally, it was by far the majority opinion of Biology Committee members that all other options for stocking other numbers and sizes of Colorado pikeminnow be removed from the final version of this augmentation plan. This was based on a combination of things. First, Paul Holden (and others?) adamantly espoused stocking smaller age-0 Colorado pikeminnow, because their survival up to about age-3 appeared to be quite good (much better than anticipated back in 1996) and by stocking younger fish, it would give the SJRIP a chance to identify where the bottleneck (if there really is one) in the survival of these young fish occurs. Second, since the SJRIP is currently

facilities-limited to rearing and stocking age-0 fish, the majority of Biology Committee members felt that the plan should reflect what is currently possible for us to accomplish.

As of last February, there was supposed to be a separately-produced "facilities document" (can't remember who was assigned to produce this) that would be a companion document to the species augmentation plans and the Genetics Management Plan. If I remember the conversations correctly, discussions about the need for new hatchery facilities and grow-out ponds were to be covered in this "facilities document" (i.e., what we have now versus what we need).

All that being said, in the final version of this augmentation plan, I did leave in a mechanism to initiate changes to future stocking efforts. That is the "Adaptive Management" section at the end of the augmentation plan. With the inclusion of this section, I wanted to make it clear that, if we get three years down the road and are having absolutely no success getting stocked age-0 Colorado pikeminnow to retain/survive, we can revisit/rewrite this augmentation plan to reflect the new direction that the SJRIP Biology Committee thinks we should go.