Retention, Growth, and Habitat Use of Colorado Pikeminnow Stocked as Age-0 Fish in the San Juan River from 2002–2005: Final Summary Report

Age-1 Colorado pikeminnow.

Seining a backwater.

Stocking Colorado pikeminnow into an acclimation area.

Young-of-year Colorado pikeminnow.

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EXECUTIVE SUMMARY

In autumn 2002 the San Juan River Basin Recovery Implementation Program (SJRIP) began to implement an Augmentation Plan for Colorado pikeminnow (Ryden 2003). Based on research conducted in the mid-1990s, the Augmentation Plan called for stocking over 200,000 young-of-the-year (YOY) Colorado pikeminnow annually from 2002–2009. The objectives of the Augmentation Plan are to meet the Recovery Goals, which indicate the need for 800 adult Colorado pikeminnow throughout critical habitat in the San Juan River (USFWS 2002). In order to achieve an adult population of 800 fish, it has been hypothesized that Colorado pikeminnow must use the area of abundant native fish forage upstream from PNM Weir (Miller and Lamarra 2006). Therefore, the SJRIP began stocking fish at the confluence of the Animas River near Farmington, New Mexico, in addition to areas downstream of Hogback Diversion. The SJRIP funded this study to monitor these stocked YOY Colorado pikeminnow throughout the first few years of life, review data from existing research and monitoring programs, and collect additional data from 2002–2005.

Despite difficulties in making statistical inference because of the extremely skewed distribution of our catch data, we did identify several differences in retention within and among years. We found that the majority of Colorado pikeminnow appeared to be lost within the first few weeks after stocking, after which retention appeared to remain stable though the next 8–12 months. The combination of habitat availability, handling stress, and reduced swimming ability may be responsible for the large initial loss of stocked Colorado pikeminnow. The 2002 stocking effort appeared to have the least success, which we feel is related to the low availability of backwater habitat, combined with hard release stocking protocols. We feel the combined impacts of soft release protocols and increased habitat availability are probably responsible for the increase in scaled catch rates we saw after the 2003 and 2004 stocking efforts compared with the 2002 stocking effort. We feel that soft release protocols may also be responsible for a trend toward higher catch rates upstream from Hogback Diversion. Increases in the number of fish stocked appeared to account for the majority of the overall increase we saw in Colorado pikeminnow abundance between 2003 and 2004.

The size of Colorado pikeminnow at stocking had mixed impacts on retention. The small differences in the size of YOY Colorado pikeminnow stocked in each year did not appear to influence retention among years. However, 6,000 Colorado pikeminnow stocked at larger sizes (average size 200 mm) did appear to retain better than Colorado pikeminnow stocked as YOY fish. Return rates for three of four stocking efforts using larger fish showed that stocking larger Colorado pikeminnow provided an increased return rate, even after scaling for the increased cost of rearing them to larger sizes. We feel the SJRIP should use caution in early interpretation of these data, since the larger fish had been in the river only a few months prior to capture. The best size of Colorado pikeminnow to stock should be determined by the number of fish from each stocking effort that reach adulthood.

Colorado pikeminnow growth rates appeared to be related to changes in river conditions. Instantaneous growth rates showed little to no increase between stocking time and March of the following year. However, we found substantial growth between March and July of each study year. The Colorado pikeminnow we collected in the summer following the 2004 stocking effort were significantly smaller than those we collected after the 2002 and 2003 stocking efforts. The difference in size and growth of Colorado pikeminnow stocked in 2004 appeared related to the high spring runoff in 2005, which delayed water temperatures from reaching the critical point for growth by up to 2 months.

Colorado pikeminnow sizes appeared to substantially determine the collection efficiency of various gear types. After we collected only two Colorado pikeminnow during July sampling following the 2002 monitoring effort, we hypothesized that seining was not effective at collecting Colorado pikeminnow once they reached 100 mm TL. We collected higher numbers of Colorado pikeminnow in July after the 2003 and 2004 stocking effort using a larger seine with a block net ("block seining"), but use of backpack electrofishing proved time consuming and seemed inefficient. Data from all SJRIP research and monitoring activities indicated that seining was the most effective method for collecting Colorado pikeminnow less than 100 mm TL, block seining was most effective for collecting Colorado pikeminnow less than 150–200 mm TL, and raft-mounted electrofishing was most effective for collecting Colorado pikeminnow greater than 200 mm TL. The difference in efficiency between raft-mounted electrofishing and block seining for Colorado pikeminnow smaller than 150 mm TL appeared to be responsible for contradictory conclusions about retention to age 1 for fish stocked as YOY in 2004. Since Colorado pikeminnow grew more slowly in spring and summer 2005, fish from the 2004 stocking effort were less susceptible to capture by electrofishing in autumn 2005.

Soft release protocols appear to increase initial retention. Poor initial retention after the 2002 stocking effort prompted SJRIP cooperators to change stocking protocols by stocking fish directly into low-velocity habitats. We also began studies to determine whether acclimating YOY Colorado pikeminnow for 7 days after stocking could increase post-release retention. These stocking protocol changes appear to be at least partially responsible for increased catch rates after the 2003 and 2004 stocking efforts. We had difficulty streamlining our methods for acclimation studies; however, when we were able to hold fish for 7 days in appropriate habitats, the data indicate that acclimation helped increase additional retention and reduce downstream dispersal. Stocking protocol changes and acclimation studies both occurred above the Hogback Diversion, and our data show a trend toward increased catch rates at stations where SJRIP cooperators implemented soft release protocols.

While the data from SJRIP-funded research and monitoring can provide information on the relative success of each stocking effort, they do not provide solid information about the success of stocking efforts in reaching Recovery Goals. We recommend continuing the YOY Colorado pikeminnow monitoring project with specific changes designed to evaluate success of the

Augmentation Plan in reaching Recovery Goals. In the absence of true survival rates of different ages of fish following the various stocking efforts, we recommend continuing to experiment with pre-release treatments that may increase post-release survival including stocking Colorado pikeminnow at larger sizes and different times, as well as stocking exercise-conditioned Colorado pikeminnow. We feel the proposed changes in sampling methodologies will allow for a better evaluation of the success of the stocking program and that experimenting with new stocking protocols will help determine which methods maximize post-release retention.

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INTRODUCTION

In 1996 and again in 1997, the Utah Division of Wildlife Resources (UDWR) stocked approximately 100,000 young-of-year (YOY) Colorado pikeminnow (*Ptychocheilus lucius*) in the San Juan River. The UDWR stocked these fish in conjunction with the San Juan River Basin Recovery Implementation Program (SJRIP) to characterize Colorado pikeminnow growth and retention in the river, as well as to quantify and characterize the nursery habitat used by the stocked fish (Trammel and Archer 2000). They showed that habitat for YOY and juvenile Colorado pikeminnow was available and reasonably common in the San Juan River. The YOY Colorado pikeminnow stocked in 1996 and 1997 survived for at least 2 years and grew up to 250 mm total length (TL). Additionally, it appeared as though a large proportion of the stocked fish remained in the river rather than dispersing to Lake Powell. Trammel and Archer (2000) attributed the differences in survival and retention observed between sampling trips and years to storm events and flow patterns. Storm and runoff events reduced retention and moved the fish downstream. Colorado pikeminnow in the canyon section of the river below Bluff, Utah, seemed to be more susceptible to flow-induced changes in retention than those in the upper river between Bluff and Shiprock, New Mexico.

Based on the results and success of these experimental studies, the SJRIP drafted an Augmentation Plan for Colorado pikeminnow that calls for stocking 200,000-300,000 YOY Colorado pikeminnow annually between 2002 and 2009 (Ryden 2003a). In 2002 implementation of the Augmentation Plan began when SJRIP cooperators stocked 105,000 YOY Colorado pikeminnow near the Animas River confluence with the San Juan River and an additional 105,000 YOY Colorado pikeminnow near the Shiprock bridge. The SJRIP funded this study to follow the progress of the stocked Colorado pikeminnow seasonally through 2002-2003. The initial objectives of the study were to characterize the retention of the stocked Colorado pikeminnow and what changes, if any, should be made to the stocking protocols to increase retention. The stocking experiments in 1996 and 1997 focused on the area downstream of Shiprock. However, the adult Colorado pikeminnow Recovery Goal of 800 adult fish (USFWS 2002) was based on the assumption that Colorado pikeminnow could be expanded into the area above Shiprock, especially upstream of the PNM Weir, to utilize the abundant available forage (Miller and Lamarra 2006). Therefore, determining whether these upstream areas could retain stocked Colorado pikeminnow was also an important objective of this study.

Following apparent poor retention of the fish stocked in 2002 and using the principals of adaptive management, several changes were made to the study starting in 2003-2004 and new objectives were added (Golden et al. 2005, Golden and Holden 2005, Holden and Golden 2005). In addition, changes in stocking protocols were made by the U.S. Fish and Wildlife Service (USFWS) (Ryden 2004). The following report summarizes the results of the YOY Colorado pikeminnow monitoring project, along with the associated stocking protocol changes and experiments, from December 2002 through November 2005. In addition, we provide

recommendations for improving Colorado pikeminnow stocking and monitoring protocols to increase the success of future stocking and monitoring efforts.

OBJECTIVES

As mentioned above, we implemented several changes and additions to the study in attempts to increase post-stocking retention and survival of stocked Colorado pikeminnow, as well as improve our ability to measure the success of the stocking program. Since additional items were added during the study period, the list of objectives also grew and changed. Therefore, we list project objectives by study year.

2002–2003 Study Year

The objectives of the initial study year were:

1. Characterize retention and growth of stocked YOY Colorado pikeminnow during the first year after stocking in the San Juan River.

2. Attempt to identify what factors (river flow, storm events, and canal locations) are related to high or low retention of stocked YOY Colorado pikeminnow during the first year after stocking.

3. Make suggestions for fine tuning augmentation protocols for Colorado pikeminnow to improve retention and growth.

2003–2004 and 2004–2005 Study Years

Objectives in the 2003–2004 and 2004–2005 study years included the three objectives from the 2002–2003 study year, along with the following:

1. Characterize growth and retention of stocked YOY Colorado pikeminnow from all stockings as they reach age 1, age 2, and age 3.

2. Compare growth and retention of stocked fish from all stocking efforts and relate to changes in stocking protocol, river conditions, and habitat availability.

3. Compare growth and retention of stocked fish from all stocking efforts with historical stockings, and relate to changes in stocking protocol, river conditions, and habitat availability.

4. Experiment with augmentation protocols for Colorado pikeminnow to improve retention, especially in the upper river.

METHODS

Study Area

At the outset of the study in 2002–2003, we delineated eight stations for Colorado pikeminnow monitoring (Table 1). Seven of the stations were on the San Juan River between Bloomfield, New Mexico (RM 188.4), and Sand Island, Utah (RM 77.0). The eighth station was in the Lower Animas River. We chose the stations for their locations within different geomorphic reaches and proximity to put-in and take-out locations for 1-day sampling efforts (i.e., logistical and cost concerns). In 2003–2004 we enlarged the study area to encompass the San Juan River from near Bloomfield (RM 188.4) to Clay Hills Crossing (RM 2.9), Utah, because the UDWR had collected relatively large numbers of Colorado pikeminnow collected during nonnative removal efforts in summer 2003 (Table 2, Figure 1) (Jackson 2004, Golden et al. 2004). We chose stations within the canyon below Mexican Hat based on past research. We selected the John's Canyon (river mile [RM] 8-13) and Grand Gulch stations (RM 20-25) because they were nursery habitat reaches after the 1996 and 1997 stocking efforts (Trammel and Archer 2000). We chose the below Mexican Hat station because relatively high numbers of YOY Colorado pikeminnow from the 2002 stocking effort were found there in April 2003 during University of New Mexico (UNM) larval fish monitoring (Brandenburg et al. 2004). In addition to the three new monitoring stations, we sampled backwater habitats throughout San Juan Canyon (RM 52.9-2.9).

Table 1. Original stations sampled in the first study year (2002-2003).

STATION	RIVER MILES	GEOMORPHIC REACH
Lower Animas	0–3.5	n/a
Upper San Juan	180.7–188.4	7
Below Fruitland Diversion	169.5–178.6	6
APS Weir to Hogback Diversion	159.2–163.7	6
Shiprock to Cudei	140.5–147.9	5
Four Corners	119.2–127.5	5
Aneth	96.4–104.1	3
Bluff	76.4–83.0	3

Table 2. Additional stations sampled in the second study year (2003-2004).

STATION	RIVER MILES	GEOMORPHIC REACH
Below Mexican Hat	40.0–45.0	2
John's Canyon	20.0–25.0	2
Grand Gulch	8.0–13.0	1
Miscellaneous Canyon	2.9–52.9	1 and 2

The majority of the study area remained the same in 2004–2005 and 2005–2006. However, we discontinued sampling at the Upper San Juan and Lower Animas stations because stocked Colorado pikeminnow did not appear to be using these areas (Golden et al. 2004, Golden and Holden 2005). We also sampled the river between Clay Hills Crossing (RM 2.9) and the confluence of the San Juan River with Lake Powell in 2004–2005 and November 2005 to determine any Colorado pikeminnow use of the river below the waterfall barriers.

Stocking and Monitoring

Stocking

Stocking methodologies evolved over the study period in attempts to increase the initial retention and survival of Colorado pikeminnow. On October 24, 2002, SJRIP cooperators stocked approximately 210,000 Colorado pikeminnow en masse into the San Juan River's main channel at two locations: the confluence of the Animas River with the San Juan River (RM 180.2) and just downstream of the State Highway 64 bridge in Shiprock (RM 148.0).

After the 2002 stocking, the SJRIP changed general stocking protocols and we initiated several experiments with stocked fish. While the total number of fish stocked varied from year to year, the main stocking areas remained the same from 2003–2005 (Tables 3–5). During these 3 years, the USFWS stocked the majority of Colorado pikeminnow directly into low-velocity habitats, such as shoals, side channels, and backwaters, in two approximately 16-km (10-mile) reaches of river. The first reach extended from the confluence of the Animas River to the Hatch Trading Post, New Mexico, and the second extended from the Hogback Diversion to the Shiprock bridge. Additionally, BIO-WEST stocked 20,000 fish into acclimation areas between Bloomfield and Hogback Diversion in each year. BIO-WEST also used 10,000 of the Colorado pikeminnow stocked in 2004 in a study to evaluate potential stress and transport-related mortality (Holden and Golden 2005).

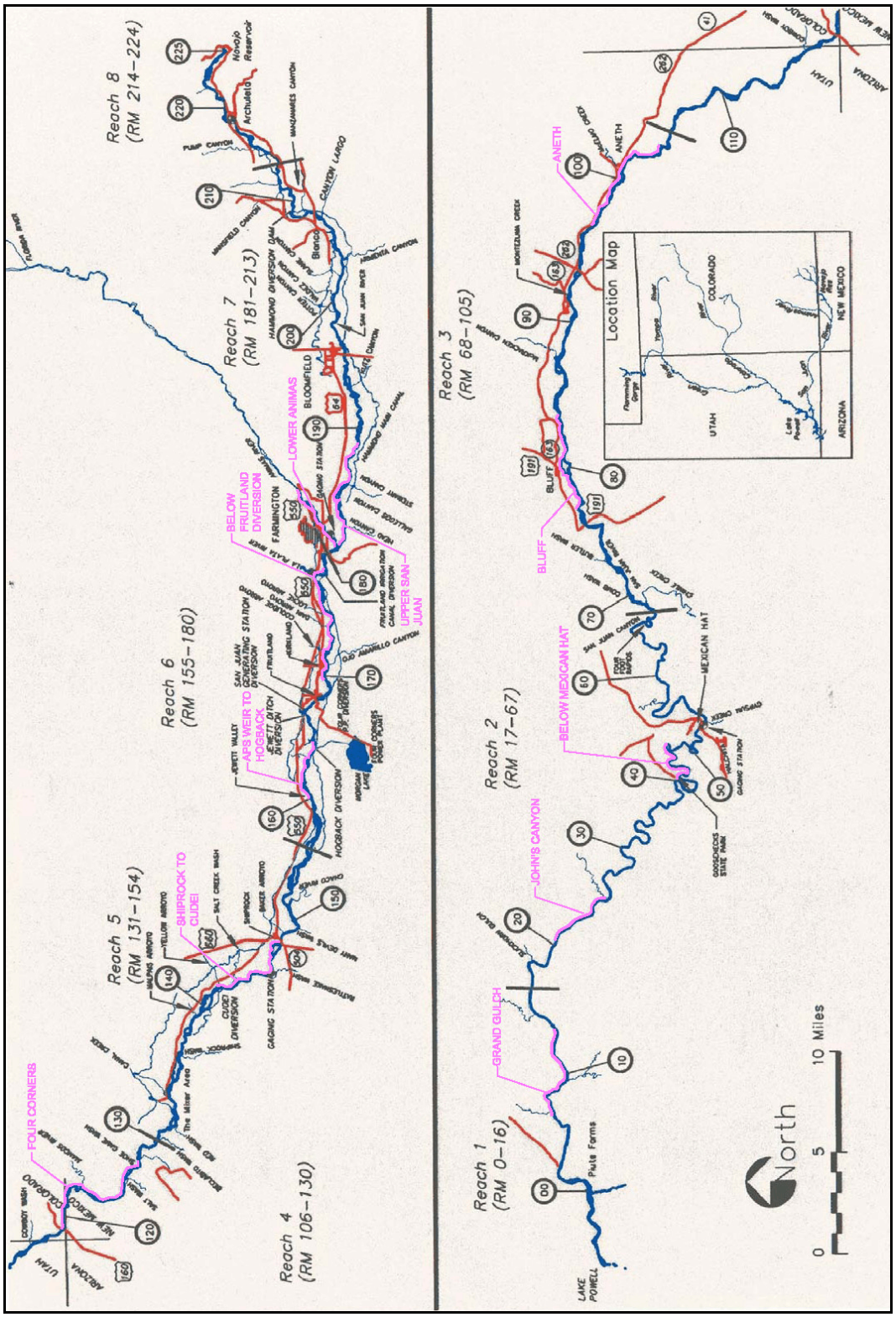

Figure 1. San Juan River New Mexico, Colorado, and Utah with locations of all sampling stations used during the study.

Table 3. Location and number of young-of-year (YOY) Colorado pikeminnow (PTYLUC) stocked on November 6, 2003.

AGENCY	AREA	RIVER MILES	NUMBER OF PTYLUC
BIO-WEST, Inc.	Upper San Juan	180.7–188.4	10,000
U.S. Fish and Wildlife Service	Animas River Confluence	180.2	20,000
U.S. Fish and Wildlife Service	Animas to Hatch Trading Post	180.2 – 169.5	60,000
BIO-WEST, Inc.	APS Weir to Hogback Diversion	159.2–163.7	10,000
U.S. Fish and Wildlife Service	Hogback Diversion	159.2	15,000
U.S. Fish and Wildlife Service	Hogback Diversion to Shiprock	159.2–147.9	60,000

Table 4. Location and number of young-of-year (YOY) Colorado pikeminnow (PTYLUC) stocked in October 2004.

AGENCY	AREA	RIVER MILES	NUMBER OF PTYLUC
	October 21, 2004		
U.S. Fish and Wildlife Service	Animas to Hatch Trading Post	180.2 – 169.5	60,000
BIO-WEST, Inc.	Fruitland Diversion to Lower Valley Lion's Club	178.6–174.0	10,000
BIO-WEST, Inc.	APS Weir to Hogback Diversion	159.2–163.7	20,000
U.S. Fish and Wildlife Service	Hogback Diversion to Shiprock	159.2–147.9	50,000
		TOTAL	**140,000**
	October 28, 2004		
U.S. Fish and Wildlife Service	Animas to Hatch Trading Post	180.2 – 169.5	100,000
U.S. Fish and Wildlife Service	Hogback Diversion to Shiprock	159.2–147.9	40,000
		TOTAL	**140,000**

In addition to the large number of age-0 Colorado pikeminnow stocked into the San Juan River between 2002 and 2005, the SJRIP also stocked over 6,500 age-1 and age-2 Colorado pikeminnow near the confluence of the San Juan and Animas rivers in the past 2 years (Table 6). Most of the age-1 and age-2 fish were excess fish from the John W. Mumma Native Aquatic Species Restoration Facility (Mumma) in Colorado, but the SJRIP also arranged for 500 age-1 fish from the Dexter National Fish Hatchery and Technology Center (DNFHTC) to be released into the San Juan River in July 2005.

Table 5. Location and number of Colorado pikeminnow (PTYLUC) stocked in October and November 2005.

AGENCY	AREA	RIVER MILES	NUMBER OF PTYLUC
	October 20, 2005		
U.S. Fish and Wildlife Service	Animas Confluence to Hatch Trading Post	180.2 – 169.5	80,550
BIO-WEST, Inc.	Side Channel below Fruitland Diversion	175.8	6,000
BIO-WEST, Inc.	Side Channel above PNM Weir	167.5 - 167.4	14,000
U.S. Fish and Wildlife Service	Hogback Diversion to Shiprock	159.2–147.9	34,000
		TOTAL	**134,550**
	November 3, 2005		
U.S. Fish and Wildlife Service	Animas Confluence to Hatch Trading Post	180.2 – 169.5	52,600
U.S. Fish and Wildlife Service	Hogback Diversion to Shiprock	159.2–147.9	115,120
		TOTAL	**167,720**

Table 6. Number of age-1 and age-2 Colorado pikeminnow stocked at RM 180.2 at different times between 2003 and 2005.

STOCKING DATE	HATCHERY ORIGIN	NUMBER OF AGE-1 FISH	NUMBER OF AGE-2 FISH
November 6, 2003	Mumma [a]	1,005	0
June 9, 2004	Mumma	0	1,219
July 7, 2005	DNFHTC [b]/Mumma	500	1,491
November 7, 2005	Mumma	0	2,399

[a] John W. Mumma Native Aquatic Species Restoration Facility.
[b] Dexter National Fish Hatchery and Technology Center.

Monitoring

After each of the YOY Colorado pikeminnow stocking efforts in 2002, 2003, and 2004, we made three sampling trips to observe the fate of the fishes stocked in those years (Table 7). In addition, we made one sampling trip after the 2005 stocking. We conducted the initial sampling trips were conducted approximately 1–6 weeks after stocking, in November and December of the stocking year. The second trip was 4–5 months after stocking but prior to spring runoff in March of the following year. We completed our third sampling trip over 9 months after stocking, in late July and/or early August of the following year.

Table 7. Dates of the young-of-year (YOY) Colorado pikeminnow monitoring trips conducted after stocking efforts in 2002, 2003, 2004, and 2005.

STOCKING YEAR	INITIAL TRIP	PRE-RUNOFF TRIP	POST-RUNOFF TRIP
2002	December 3–10, 2002	March 17–24, 2003	July 21–28, 2003
2003	December 1–13, 2003	March 14–26, 2004	July 19–31 2004
2004	November 1–6, 2004 (Upper six stations) November 16–23, 2004 (Canyon stations)	March 21–28, 2005	July 26–August 2, 2005
2005	November 11–17, 2005	N/A	N/A

During each trip we sampled each of the stations used in that year for 1 day, accessing each station with a 14-foot or 16-foot raft. Within each station we sampled as many backwaters, shoals, and other low-velocity habitats available for young Colorado pikeminnow as was practicable in a day (Trammel and Archer 2000). Throughout the canyon section of the river below Mexican Hat, we attempted to sample as many backwater habitats encountered between sampling stations as practicable. We used a similar method when sampling from Clay Hills Crossing to Lake Powell in 2004–2005 and December 2005 but concentrated on extremely low-velocity habitats. In 2002–2003 we used 4 m x 2 m x 3 mm and 3 m x 2 m x 3 mm double-weighted seines to sample low-velocity habitats during all three sampling trips. When it became apparent that Colorado pikeminnow larger than 100 mm TL were not susceptible to capture by these seines, we used a different methodology for the post-runoff (July) samples in 2003–2004 and 2004–2005. During these trips we used two 9 m x 2 m x 6 mm double-weighted seines for sampling. One seine was held at the bottom of the habitat unit, and we used the second seine to sample down to that seine in an attempt to block the escape of larger fish (block seining). In addition to block seining, we experimented with backpack electrofishing downstream into a 6 x 30 foot seine in July 2004 and July 2005. The few attempts we made with the backpack electrofisher in July 2004 had poor success, and equipment malfunctions prevented any large amount of comparative sampling. Additionally, in July 2005 use of the backpack electrofisher was too time consuming when we were obtaining seemingly good results with block seining. Therefore, we abandoned backpack electrofishing as a sampling method.

We collected the following information for each sample: river mile location, GPS location (UTM), habitat type, seine type, area sampled (length and width), average depth, maximum depth, and substrate type of the area sampled. Water temperatures were collected periodically throughout the day using a hand-held thermometer. We identified all fish collected to species and counted them. Occasionally we collected fish that were too small to identify to species in the field. We identified these specimens to the lowest practical level (usually family). We measured a minimum of 50 individuals of each species for standard length within each station

except for Colorado pikeminnow, all of which we measured. If we collected large numbers (> 100) of Colorado pikeminnow in a single seine haul (e.g., November 2004 and November 2005) after we had already recorded 100 Colorado pikeminnow lengths for that station, we only measured a subset of individuals so we could return the fish to the river faster. We returned native fishes to the river unharmed but sacrificed nonnative fishes. We used a separate data sheet for each seine haul. During the December 2003 sampling trip, we scanned every Colorado pikeminnow for the presence of the calcein dye using a SE-MARK detector device (Western Chemical, Inc.). During all sampling trips following the 2004 stocking effort, we examined all Colorado pikeminnow collected for the presence of visible implant elastomer (VIE) tags (Northwest Marine Technology, Inc.). We used a passive integrated transponder (PIT) tag reader to scan all Colorado pikeminnow over 150 mm captured during our sampling efforts, and we inserted a PIT tag into any Colorado pikeminnow larger than 150 mm (TL) without a PIT tag.

Other SJRIP cooperators also collected data on the Colorado pikeminnow stocked in each study year. The UNM's razorback sucker (*Xyrauchen texanus*) and Colorado pikeminnow larval fish surveys, the SJRIP small-bodied fish monitoring, and one sampling effort by the UDWR in conjunction with their nonnative removal sampling provided additional seining information. University of New Mexico crews sampled from Cudei Diversion (RM 142.0) to Clay Hills Crossing using a 1 m x 1 m x 1 mm larval seine (Brandenburg et al. 2004, Brandenburg et al. 2005). The UDWR sampled from Mexican Hat to Clay Hills Crossing in August 2004 using a 4 m x 2 m x 3 mm seine (Jackson 2004). Finally, NMGFD conducted SJRIP annual small-bodied fish monitoring from the confluence of Animas River to Clay Hills Crossing using 3 m x 2 m x 3 mm seines in September and October of each year (Propst et al. 2000a).

The USFWS New Mexico Fisheries Resource Office (NMFRO) and UDWR nonnative fish species removal projects, along with SJRIP standardized large-bodied fish monitoring, provided additional information via electrofishing captures of Colorado pikeminnow each year of the study. From March to November, the NMFRO used raft-mounted electrofishing to sample two sections of river: PNM Weir to Hogback Diversion (RM 166.7-RM 159.2) and Hogback Diversion to Shiprock (RM 158.7-RM 148.9) (Davis 2004). The UDWR used raft-mounted electrofishing to sample from Mexican Hat to Clay Hills Crossing from March to August in all study years (Jackson 2004). The SJRIP cooperators used raft-mounted electrofishing to sample from the confluence of the Animas River to Clay Hills Crossing for the SJRIP large-bodied fish monitoring in September and/or October of each study year (Ryden 2004). We used the data collected during these studies to provide a more complete picture of the fate of stocked YOY Colorado pikeminnow through their first 2–3 years in the river. Throughout the remainder of the report, we will refer to YOY, age-0, age-1, age-2, and age-3 Colorado pikeminnow. Age-0 and YOY Colorado pikeminnow refer to Colorado pikeminnow stocked from 50 mm and 60 mm TL at the time that they are stocked until May 1 of the following year. After this we use May 1 to April 30 to represent 1 year of age for stocked Colorado pikeminnow. For example stocked

Colorado pikeminnow enter age 1 on May 1 in the year following stocking and enter age 2 on May 1 of the following year.

As previously mentioned, the UDWR stocked YOY Colorado pikeminnow into the San Juan River in 1996 and 1997 (Trammel and Archer 2000). In both these years the UDWR stocked over 100,000 fish, which were split into two groups and stocked near Shiprock and Mexican Hat. The UDWR completed follow-up monitoring from Shiprock to Clay Hills Crossing. Their methods differed from those outlined for this study. During the 1996 and 1997 monitoring, they sampled two nursery habitats every 8 km (5 miles), except in four specific 8-km (5-mile) reaches where the sampled all nursery habitats. Trammel and Archer (2000) outline the details of this monitoring protocol. While collection methods differed slightly during monitoring after the 1996 and 1997 stocking efforts, we used their data on Colorado pikeminnow retention, growth, and survival as a baseline with which to compare our data collected from 2002–2005.

Stocking Experiments

Acclimation Studies

Following what was seen as poor retention of YOY Colorado pikeminnow stocked in 2002, we initiated an experiment to determine whether allowing stocked Colorado pikeminnow to adjust to their new environment in the river might decrease downstream displacement and increase initial retention. Several other studies have shown the potential benefits of such acclimation efforts (Cresswell and Williams 1983, Tipping 1988, Brown and Day 2002, Mueller et al. 2003). Therefore, in 2003, 2004, and 2005, we constructed a series of net pens in low-velocity habitats and used nets to block off low-velocity habitats prior to the arrival of Colorado pikeminnow from the DNFHTC. Concurrent with the main stocking effort, we stocked 20,000 Colorado pikeminnow into these habitats and attempted to hold them there for 7 days after they were stocked. In each year the Colorado pikeminnow we used in the acclimation studies were marked to distinguish them from the remainder of the stocked fish. Personnel from the DNFHTC marked the Colorado pikeminnow used in 2003 acclimation studies with a batch mark dye called calcein. In 2004 and 2005 personnel from BIO-WEST and the DNFHTC marked Colorado pikeminnow to be used in acclimation studies with green VIE tags.

In 2003 and 2004 we selected five to ten areas for marked Colorado pikeminnow acclimation throughout portions of two of our monitoring stations (Golden and Holden 2005, Holden and Golden 2005). In both years, low-velocity habitats, including backwaters, irrigation returns, side-channels, shoals, and eddies, were used for fish acclimation. We either blocked off the areas with a combination of rebar and 3 mm mesh netting or created net pens with rebar and the same netting (Figure 2). We placed the fish into these enclosures at the same time that the SJRIP stocked the main group of fish and tried to hold them for 7 days or until the enclosures failed.

Figure 2. Acclimation areas created by (a) netting off a backwater and (b) creating a net pen.

In 2005 we floated the 30-km (18- to 19-mile) section of river between the Fruitland and Hogback Diversions looking for the best habitats (large backwaters and extremely low-velocity side channels) in which to perform acclimation experiments. We only found two appropriate habitats and used them for acclimating all 20,000 Colorado pikeminnow. We stocked 6,000 VIE-marked Colorado pikeminnow into five net pens near RM 175.8 and 14,000 VIE-marked Colorado pikeminnow into a side channel between RM 167.5 and 167.4.

During our monitoring for stocked Colorado pikeminnow (see above), we looked for marked fish during each of our sampling trips following the acclimation periods. We noted the presence of marks on Colorado pikeminnow collected during monitoring to determine an increased retention success for Colorado pikeminnow used in acclimation studies.

Debris Pile Studies

December 2002 monitoring data indicated that the presence of cover, in the form of debris piles, may be important for retention of stocked Colorado pikeminnow during colder winter months (Golden et al. 2004). Therefore, we proposed a small field study to see whether we could increase retention in a monitoring station by adding debris piles to low-velocity habitats. In 2003 and 2004 we added debris piles to low-velocity habitats throughout the Shiprock to Cudei monitoring station 1–2 days prior to Colorado pikeminnow stocking efforts (Figure 3). We used downed tree limbs and limbs from abundant nonnative Russian olive (*Elaeagnus angustifolia*) and salt cedar (*Tamarix* spp.) trees to create debris piles in appropriate Colorado pikeminnow nursery habitats.

Pilot Population Estimate

In late summer and early autumn 2005, we conducted a pilot population estimate for age-1 and age-2 Colorado pikeminnow in conjunction with existing sampling programs. The “mark” period occurred during the July–August 2005 YOY Colorado pikeminnow monitoring project trip. We marked Colorado pikeminnow collected by block seining in all nine stations and at miscellaneous locations in the San Juan Canyon during that trip. In addition, SJRIP cooperators marked all Colorado pikeminnow collected by raft-mounted electrofishing during NMRFO nonnative removal efforts between Hogback Diversion and Shiprock from July 26–28, 2005, and UDWR nonnative removal efforts between Mexican Hat and Clay Hills Crossing from August 1–5, 2005. Before marking fish, cooperators scanned Colorado pikeminnow larger than 150 mm for PIT tags, recorded any PIT-tag numbers, and injected a PIT tag into any fish without one. We marked Colorado pikeminnow smaller than 150 mm with orange VIE tags.

Figure 3. Colorado pikeminnow nursery habitat (a) before and (b) after addition of woody debris piles.

The recapture period occurred during SJRIP annual fall monitoring, which took place from September 19–23, 2005, and October 3–12, 2005. The SJRIP cooperators scanned all Colorado pikeminnow collected with 2 x 4 m seines during small-bodied fish monitoring and with raft-mounted electrofishing during large-bodied fish monitoring for PIT or orange VIE tags. BIO-WEST compiled the mark and recapture information from all cooperators. We had planned to use Program MARK to develop a population estimate, but the number of recaptures was too small (Otis et al. 1978, Rexstad and Burnham 1992).

Data Analysis

We used SYSTAT 10.2, unless otherwise noted, and an α level of 0.05 for all the analyses described below. To examine average monthly temperature differences, we attempted to use analysis of covariance (ANCOVA) with year as the independent variable and day as the covariate. Prior to using ANCOVA we tested for homogeneity of slopes. If slopes were significantly different we used analysis of variance (ANOVA) instead of ANCOVA. We used Tukey's honestly significant difference multiple comparison test to compare all possible differences between means.

At the onset of the study, we had planned to use a nested ANOVA with Tukey's honestly significant difference multiple comparison test to examine differences in catch per unit (of) effort (CPUE) for YOY Colorado pikeminnow (and other species) between trips, among stations within trips, and within stations among trips. However, neither abundance nor CPUE data for Colorado pikeminnow (or other native fish species) were normally distributed. We attempted multiple transformations, but none allowed the data to approximate the normal distribution. We also examined the distribution of Colorado pikeminnow abundance and CPUE from backwater habitats but could not make those data approximate the normal distribution either. The large number of 0 values in the data was responsible for the lack of normality. We attempted a nonparametric analysis but, as explained in further detail in Golden et al. (2004), the large number of zero values seemed to prevent meaningful analysis of the data using nonparametric tests. We also examined the data in a variation of the SAS General Liner Models procedure called "GENMOD." The GENMOD command provides an analysis similar to the parametric ANOVA we had originally planned to use and allows for the use of a general linear model with underlying distributions other than the normal distribution. As discussed in further detail in Golden et al. (2004), the large number of zeros in our data set violated the assumptions of the other distributions (e.g., Poisson, Gamma, Negative Binomial) that can be used in GENMOD.

In the process of examining the distribution of our data, we decided to use the number of Colorado pikeminnow per seine haul (catch rate), versus the number per m^2, as the dependent variable in all analyses for several reasons. First, no matter how the number per m^2 data were transformed, the distribution was always more skewed than the catch rate data. In addition, other researchers found that using the number of YOY Colorado pikeminnow per m^2 does not provide

a precise and accurate measure of change (Tyus and Haines 1991, Haines and Modde 1996, Haines et al. 1998). We also felt that the length of our survey seine haul (i.e., area sampled) did not appear to be related to the number of Colorado pikeminnow collected. Instead, aspects of the habitat sampled appeared to be a more reliable indicator of the number of Colorado pikeminnow collected. To test this hypothesis, we created a scatterplot of Colorado pikeminnow abundance versus the area sampled. (Figure 4). We saw no trend toward increasing numbers with increasing area sampled. We transformed our Colorado pikeminnow abundance data into ranks and used a nonparametric correlation (Spearman's R) to examine for a relationship. The Spearman's R value was 0.09, indicating little if any relationship between the number of Colorado pikeminnow collected per seine haul and the area sampled by that seine haul.

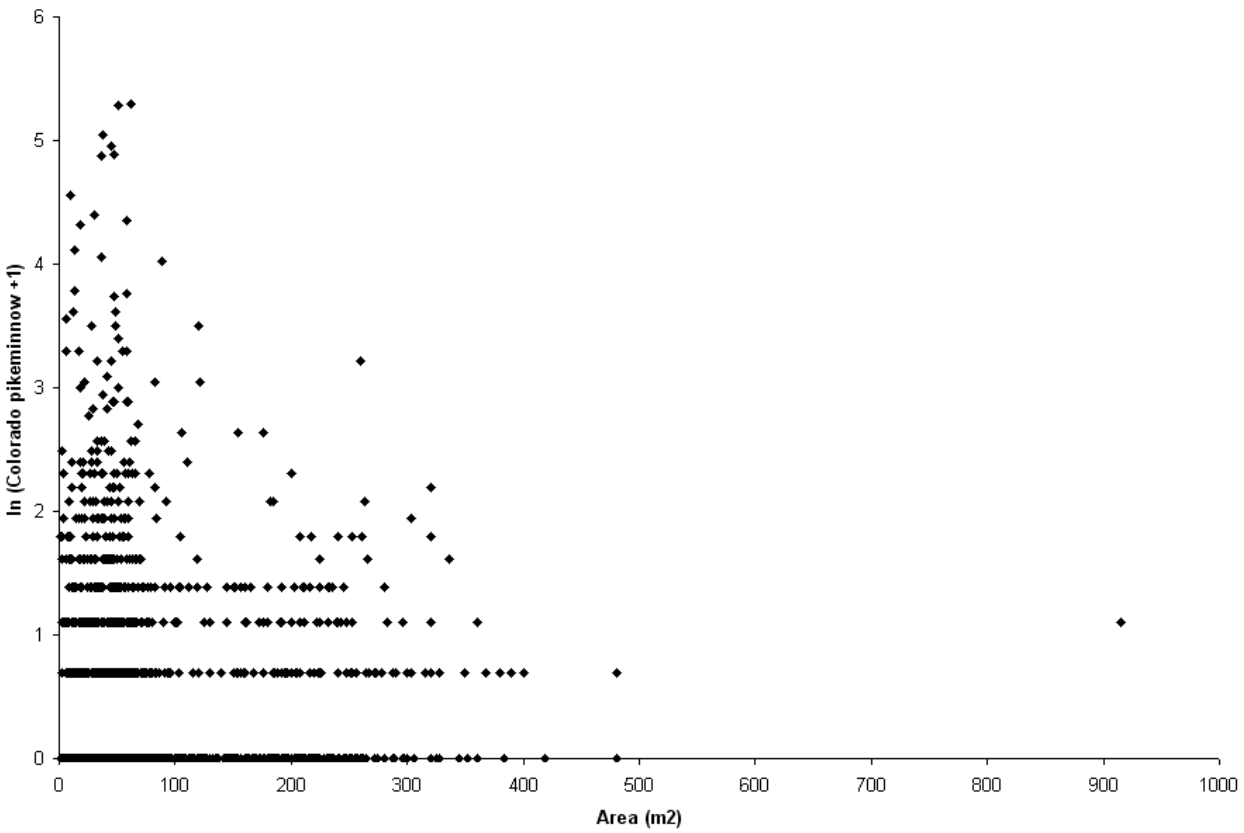

Figure 4. Scatterplot of the number of Colorado pikeminnow collected versus the area of the sample.

Prior to the analyses outlined below, we scaled all of our Colorado pikeminnow catch rate data in an attempt account for the different numbers of fish stocked in each year. Using the following equation, we transformed the number of Colorado pikeminnow collected in each seine haul to what it would have been had 100,000 fish been stocked:

$$SCPM = (100{,}000/N)CPM$$

where SCPM = the scaled number of Colorado pikeminnow, N = the total number of Colorado pikeminnow stocked in that year, and CPM = the number of Colorado pikeminnow in the seine haul.

In addition, we transformed the scaled catch rate data using the natural log of the scaled catch rate + 1 prior to all analyses.

The distributional problems outlined above prevented us from using parametric tests designed to examine differences between stations within trips and between trips within stations. However, we examined differences between trips by using the catch rate at each station within each sampling trip as the sample unit. From the station means we calculated a grand mean (or mean of means) for each sampling trip. The grand mean is normally distributed, so we used the originally proposed ANOVA with Tukey's honestly significant difference multiple comparison test to examine differences in the grand mean of Colorado pikeminnow catch rate between trips. We excluded the Lower Animas and Upper San Juan stations from this analysis since essentially no Colorado pikeminnow were collected there. We also excluded data collected below the waterfall in 2004 and 2005. Additionally, we compared the grand mean of Colorado pikeminnow catch rate between sampling trips calculated from the six stations sampled in all years to remove the influence of adding and removing stations during the life of the project.

While using the grand mean allowed us to provide some level of statistical inference with our data, it does have its drawbacks. By using stations instead of seine hauls as the sample unit we have severely reduced our sample size, which consequently reduced our ability to detect change.

In addition, by using the station means as the sample unit, we eliminated intra-site variability in catch, which may mask some trends in the data. Additionally, these analyses still did not allow us to statistically compare catch rates within years between stations and within stations between years.

Since we could not compare differences within stations among years using parametric or non-parametric statistics, we graphed the mean catch rate generated for each station during each trip, using each seine haul as the sampling unit. We also graphed the bootstrapped 95% confidence intervals around those means (Manly 1997, Resampling Stats for Excel 3.2). We used 10,000 iterations of the original data set to develop the bootstrapped confidence intervals. Even with

10,000 iterations the bootstrapped confidence intervals had a wide degree of overlap, so we did not proceed with any further randomization analyses.

We also included information on stocked Colorado pikeminnow captured during UNM spring-summer larval sampling efforts, NMFRO and UDWR nonnative species removal efforts, and September-October standardized monitoring efforts to provide a complete picture of the fate of the stocked fish. For electrofishing projects, we calculated the CPUE of Colorado pikeminnow as the number of fish per hour of electrofishing, scaled the CPUE for the number of Colorado pikeminnow stocked that year, and transformed it using the natural log of the scaled catch rate + 1, prior to calculating the mean and standard error. Similar to our seining data, the UNM larval fish data and the small-bodied fish monitoring data showed no relationship between the number of Colorado pikeminnow collected per seine haul and the area sampled by that seine haul (Spearman R = 0.08 and 0.06). Therefore, as with our data, we scaled the number of Colorado pikeminnow per seine haul (catch rate) data for the total number of fish stocked and used the natural log of the scaled catch rate + 1 when calculating the mean and standard error. Since all of these projects differed in collection methods and objectives, we presented the data graphically but did not attempt statistical comparisons.

As with our data, we attempted many transformations of the 1996 and 1997 catch rates so they would conform to the normal distribution. The only way we found for both data sets to approximate normality and be comparable was to calculate the grand mean of catch rate for each trip using geomorphic reach as the sample unit. We compared the grand mean of catch rates for each trip using an ANOVA with Tukey's honestly significant difference multiple comparison test. As outlined above, we excluded the Lower Animas and Upper San Juan stations, as well as data collected below the waterfall in 2004 and 2005, from this analysis. Also similar to the analyses outlined above, using the grand mean to make inferences is not ideal because of the reduced sample size and loss of intra-site variability. The UDWR sampling in 1996 and 1997 concentrated on extremely low-velocity habitats, whereas our sampling occurred in a wider array of habitat types. Therefore, we also tried to perform a comparison using habitats similar to those sampled after the 1996 and 1997 stocking efforts. We termed these "preferred habitats." Although we did not quantify the amount of habitat available for Colorado pikeminnow to determine true habitat preferences, we felt that work by Trammel and Archer (2000), as well as others, justified the designation of extremely low-velocity habitats as "preferred" (Haines and Tyus 1990, Tyus 1991, Tyus and Haines 1991, Haines and Modde 1996, Haines et al. 1998, Trammell and Chart 1999, Golden et al. 2004, Golden and Holden 2005). We compared the grand mean of Colorado pikeminnow catch rate between sampling trips from 1996 and 1997 with the grand mean of our catch rates from preferred habitats during the 2002–2005 sampling using an ANOVA with Tukey's honestly significant difference multiple comparison test.

We used a chi-square goodness-of-fit test to examine whether we collected acclimated Colorado pikeminnow in a higher proportion than would be expected based on the percentage they comprised of the total number of fish stocked. We used the proportion that acclimated fish comprised of the total number of fish stocked that year as the expected proportion and compared it to the proportion that acclimated fish comprised of the total number of Colorado pikeminnow collected in each sampling trip following stocking.

We used ANOVA with Tukey's honestly significant difference multiple comparison test to compare average standard and total lengths for Colorado pikeminnow at similar times after stocking among the different stocking efforts, as well as among different times after stocking within the same stocking effort. We also calculated instantaneous growth rates for Colorado pikeminnow from the initial trip after stocking to March of the following year, as well as between March and July of the following year. We used the following equation to calculate instantaneous growth rates:

$$GR = 100[(\ln L_f - \ln L_i)/(t)]$$

where GR = the instantaneous growth rate, L_f = the final average length, L_i = the initial average length, and t = the number of days elapsed between sampling periods (Moyle and Cech 2004).

We used the middle day of our sampling trip as the point to calculate the number of days elapsed between trips. We calculated instantaneous growth rates using the same equation for Colorado pikeminnow between stocking and the first, second, and third autumn they remained in the river. We calculated the total number of days elapsed for this comparison as the period between the last day of our initial sampling trip after stocking and the last day of the autumn SJRIP large-bodied fish monitoring.

We used a *t*-test to compare the grand mean of Colorado pikeminnow catch rate in side channel habitat vs. main channel habitat during each trip. We used a chi-square goodness-of-fit test to examine whether we collected stocked Colorado pikeminnow in a higher proportion of samples in side channel or main channel habitats than would be expected, based on the proportion of main and side channel habitats that we sampled. Similarly, we used a chi-square goodness-of-fit test to examine whether we collected a higher proportion of Colorado pikeminnow in different habitat types than would be expected based on the proportion of our samples taken in the different habitat types.

We used a chi-square goodness-of-fit test to compare whether Colorado pikeminnow were present in a higher proportion of backwater samples than expected, based on the total number of backwaters we sampled. We used a paired *t*-test with Bonferroni-adjusted probability values to compared the combined, scaled-average Colorado pikeminnow catch rate from each time period

after stocking. We performed similar analyses to determine Colorado pikeminnow use and abundance in habitats with and without cover. We also employed paired *t*-tests with Bonferroni-adjusted probability values to compare depth of all samples vs. the depth of samples containing Colorado pikeminnow. In all cases where the grand mean of Colorado pikeminnow catch rate was evaluated, samples collected in the Upper San Juan station, Lower Animas station, and below the waterfalls were excluded.

RESULTS

Discharge

A "water year" runs from October 1 of the preceding year to September 30 of the following year (i.e., the 2003 water year ran from October 1, 2002, to September 30, 2003). Therefore, fish stocked in a given year are subjected to the following water year (i.e., fish stocked in October 2002 were subjected to conditions of the 2003 water year, fish stocked in November 2003 were subjected to the conditions of the 2004 water year). The water years surrounding the 2002 stocking effort (2002 and 2003) were low-flow years, as was the 2004 water year (Figure 5). Conversely, the 2005 water year had substantially higher spring runoff than either 2003 or 2004. Flows in 2005 were similar to those that coincided with YOY Colorado pikeminnow stocking efforts in 1996 and 1997. The 1997 and 1998 water years had substantially higher spring runoff, higher summer flows, and more summer spike flows than the 2002–2004 water years. The 2005 water year was more similar to these years, but it had an earlier, shorter runoff and smaller summer storm peaks than 1997.

Discharge immediately following stocking and during acclimation experiments varied between years and may have directly impacted initial retention of Colorado pikeminnow (Figure 6). Average daily discharge was similar following the 2002 and 2004 stocking efforts. Average daily discharge was lower following the 2003 stocking effort and higher following the 2004 stocking effort. Within a week after at least one of the stocking efforts in 2002, 2003, and 2004 there was a 200–500 cfs increase in average daily discharge, after which daily discharge remained fairly steady into December. Conversely, when the SJRIP stocked Colorado pikeminnow in 2005, it was on the tail end of a relatively large (800 cfs) increase in average daily discharge, after which flows continued to decline for nearly 2 weeks and then remained steady into December 2005.

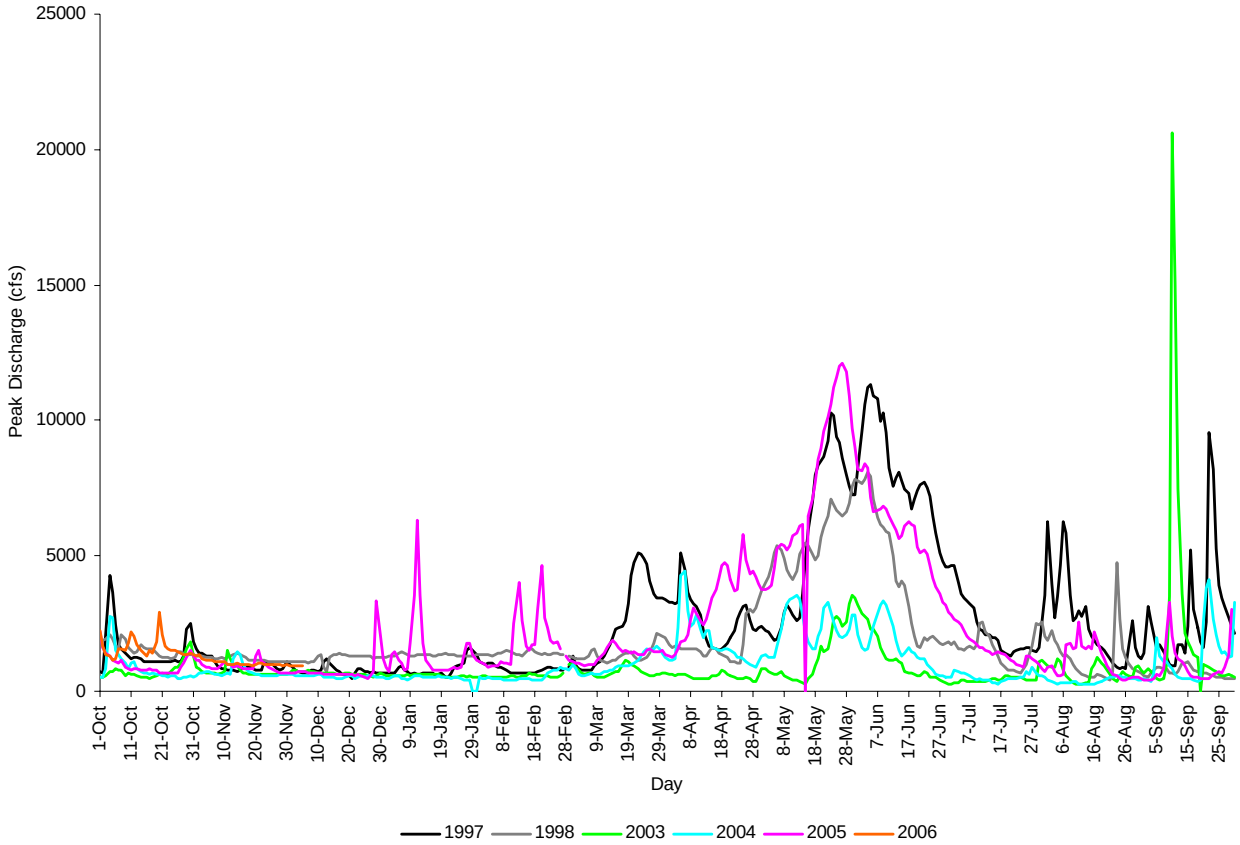

Figure 5. **Average daily discharge for the San Juan River near Bluff, Utah (USGS gage 09379500), for water years 1996-1997 and 2002-2006 (a water year is October 1-September 30).**

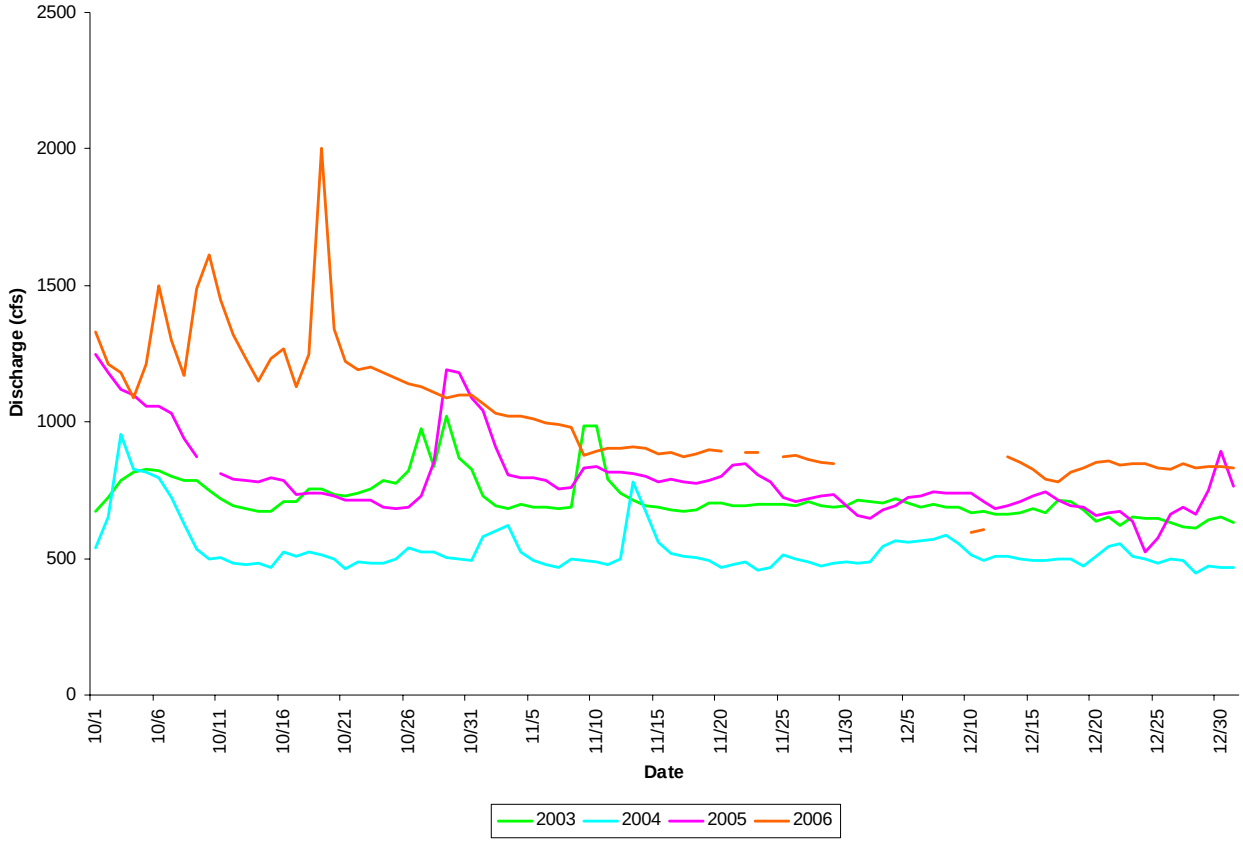

Figure 6. Average daily discharge between October 1 and December 31 for the San Juan River near Farmington, New Mexico (USGS gage 09365000), during water years 2003-2005 (a water year is October 1-September 30).

Temperature

As with discharge, the major difference in water temperature between recent stocking years was in water year 2005. The high spring runoff in 2005 depressed water temperatures 2–5°C from late April to early July during that year (Figure 7). The largest and most-consistent difference between 2003 and 2004 vs. 2005 was during May and June, a time period during which we saw high Colorado pikeminnow growth in 2003 and 2004 (Golden et al. 2004, Golden and Holden 2005). Mean average temperature in May was significantly lower (3–4°C) than in May 2003 and 2004 (Figure 8, ANOVA, $p < 0.001$). In June 2005 the mean average temperature was also significantly (4–5°C) lower than in June 2003 and 2004 (ANCOVA, $p \leq 0.001$). Mean average daily temperatures at Farmington in July were lowest in 2003 ($p < 0.001$). However, July temperature data from Shiprock showed that mean average daily temperature was not significantly different (less than or equal to 1°C) among the 3 years.

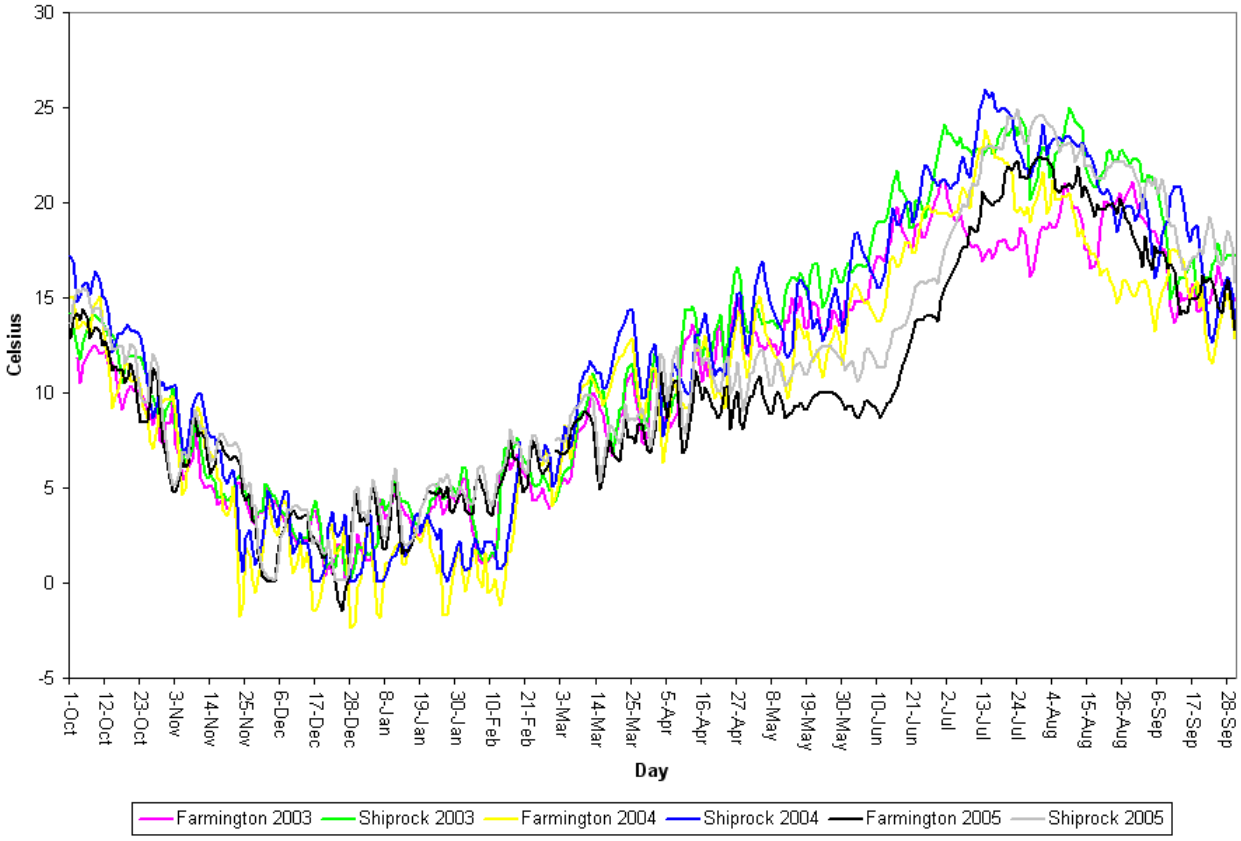

Figure 7. Average daily water temperatures near Farmington and Shiprock, New Mexico, during water years 2003-2005 (Keller-Bliesner Engineering data).

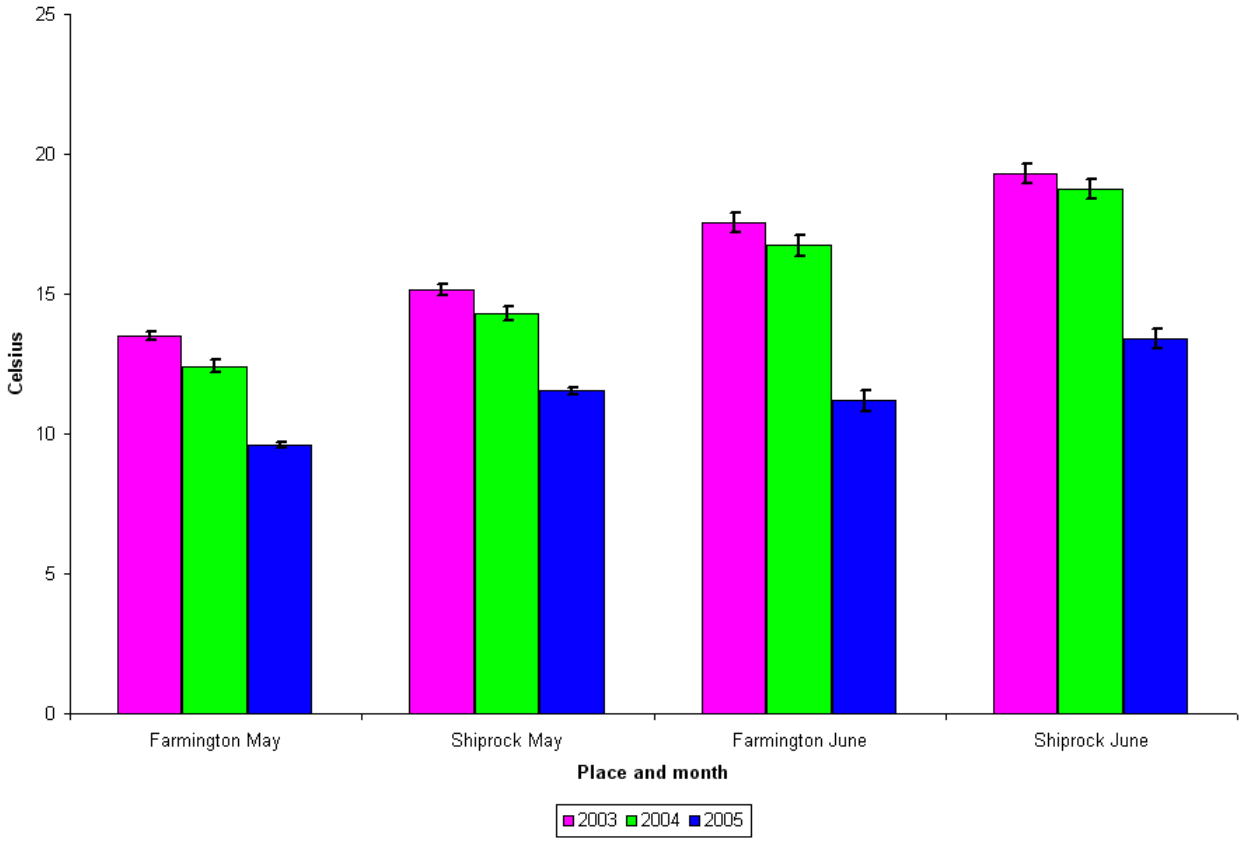

Figure 8. Mean average daily water temperature in May and June at Farmington and Shiprock, New Mexico, in 2003, 2004, and 2005 (Keller-Bliesner Engineering data). Error bars represent +/- 1 standard error.

Average water temperatures surrounding the stocking efforts may have impacted retention and survival of stocked YOY Colorado pikeminnow. Average daily temperatures the first week following the 2003 stocking effort were generally a few degrees cooler than temperatures following the 2002 stocking effort (Figure 9). This was caused in large part by the 2-week difference in stocking time between the two years. The 2002 stocking effort and the first phase of stocking in 2004 occurred about 3 weeks into October, and a similar range of average daily temperatures followed stocking. The second phase of stocking in 2004 occurred about 1 week later in the year than the 2002 stocking effort and 1week earlier in the year than the 2004 stocking effort, but temperatures for the week following stocking were more similar to temperatures after the 2003 stocking effort. Despite the small differences in temperatures immediately surrounding stocking efforts, mean average daily temperatures in October, November, and December were not significantly different in any of the study years (ANOVA). In addition, we found no significant difference in average daily temperatures among years when we compared the entire October–December time period (ANCOVA).

Figure 9. Average daily water temperatures near Farmington, New Mexico, in October, November, and December of water years 2003-2005 (Keller-Bliesner Engineering data).

The only continuous temperature data available from the main stem of the San Juan River during the 1996 and 1997 stocking period were from near Archuleta, New Mexico. Releases from Navajo Dam maintain fairly consistent temperatures in this area, so temperature comparisons using these data would probably provide little information on the magnitude of temperature differences in downstream areas between years.

Colorado Pikeminnow Retention

Stocked Young-of-Year (YOY) Colorado Pikeminnow

Young-of-Year (YOY) Colorado Pikeminnow Monitoring

We collected variable numbers of the stocked YOY Colorado pikeminnow during the different years of the study (Table 8). Since different numbers of fish were stocked each year, we would expect that different numbers of fish would be recovered, so we also compared the proportion of Colorado pikeminnow collected of the total number of fish stocked. Both the lowest number of Colorado pikeminnow and the smallest proportion of the total number of fish stocked were collected during sampling trips following the 2002 stocking effort. Despite this we still collected a few Colorado pikeminnow stocked in 2002 during sampling in 2003 and 2004. We collected the highest number of Colorado pikeminnow and the highest proportion of the total number of fish stocked during the first sampling trip after the 2004 stocking effort. We conducted the November 2004 sampling trip closer to the time of stocking than any other trip. Similarly, we collected the second highest number of Colorado pikeminnow and proportion of the total number of fish stocked during the November 2005 sampling trip, which we completed closer to the time of stocking than in 2002 or 2003. While we did not collect as high of a proportion of the total number of fish stocked during the initial trip following the 2003 stocking effort as we did during the initial trip after the 2004 stocking, the proportion of the total number of fish stocked was higher during March following the 2003 stocking effort than in March following the 2004 stocking effort. Additionally, the proportion of the total number of fish stocked was nearly equal during July following the 2003 and 2004 stocking efforts.

Effort during each sampling trip fluctuated with a variety of factors (Tables 9 and 10). More effort in both seine hauls and area sampled was put forth in March of each year than in November/December. Longer days and a wider variety of Colorado pikeminnow habitat use (see Habitat Use section below) were the major reasons for the increased effort in March. Increased effort (longer days) also occurred in July 2003. In July 2004 and 2005 the number of seine hauls was reduced, but a much larger area was sampled. This reflects the shift from using a 2 m x 4 m seine in regular fashion to using two 2 m x 10 m seines in block-seining fashion. The effort required to pull an individual block seine is greater, resulting in fewer samples. However, since a block seine covers twice the area of a regular seine, the area sampled increases dramatically.

Table 8. Number of Colorado pikeminnow stocked as age-0 fish from 2002-2005 collected during the young-of-year (YOY) Colorado pikeminnow monitoring project from 2002-2005, along with the proportion of the total number of stocked fish they comprised.

MONTH	YEAR STOCKED	2002–2003	2003–2004	2004–2005	2005–2006
November/December	2002	123	4	0	0
		0.0586%	0.0006%	0	0
March	2002	117	9	0	N/A
		0.0557%	0.0043%	0	N/A
July	2002	2	9	0	N/A
		0.0010%	0.0043%	0	N/A
November/December	2003	N/A	274 (262) [a]	9	0
		N/A	0.1557% (0.1489%)	0.0051%	0
March	2003	N/A	409 (219)	4	N/A
		N/A	0.2381% (0.1244%)	0.0023%	
July	2003	N/A	144 (106)	1	N/A
		N/A	0.0818% (0.0602%)	0.006%	
November/December	2004	N/A	N/A	1,429 (1,232)	11
		N/A	N/A	0.5104% (0.4400%)	
March	2004	N/A	N/A	461 (259)	N/A
		N/A	N/A	0.1646% (0.0925%)	N/A
July	2004	N/A	N/A	210 (174)	N/A
		N/A	N/A	0.0750% (0.0621%)	N/A
November/December	2005	N/A	N/A	N/A	1012, (958)
		N/A	N/A	N/A	0.3351% (0.3172%)

[a] The number and proportion in parentheses represents Colorado pikeminnow collected in the six stations sampled in all years.

Table 9. Number of seine hauls pulled in each of the young-of-year (YOY) Colorado pikeminnow monitoring project collections from 2002-2005.

MONTH	2002–2003	2003–2004	2004–2005	2005–2006
November/December	364 (273)[a]	489 (295)	394 (245)	402 (298)
March	411 (328)	666 (406)	604 (386)	N/A
July	464 (384)	329 (160)	301 (170)	N/A

[a] The number in parentheses represents the number of seine hauls pulled in the six stations sampled in all years.

Table 10. Total area (m^2) sampled in each of the YOY Colorado pikeminnow monitoring project collections from 2002-2005.

MONTH	2002–2003	2003–2004	2004–2005	2005–2006
November/December	10,483 (8,316)[a]	15,097 (9,720)	17,898 (11,703)	22,637(16,167)
March	18,119 (15,172)	25,977 (15,870)	24,075 (16,375)	N/A
July	19,168 (16,816)	62,255 (36,193)	57,563 (34,379)	N/A

[a] The number in parentheses represents the area sampled in the six stations sampled in all years.

As with Colorado pikeminnow abundance and the proportion of the total number stocked, the scaled catch rates for Colorado pikeminnow after the 2002 stocking effort were lower at all times than catch rates after the 2003 and 2004 stocking efforts (Figure 10). However, the only significant difference between trips was that the scaled catch rates from the November sampling trip following the 2004 stocking effort were significantly higher than those from all the sampling trips after the 2002 stocking effort (ANOVA, $p < 0.02$). Since the stations below Mexican Hat were not sampled after the 2002 stocking effort, we also compared the scaled Colorado pikeminnow catch rate only using data from the six stations sampled in all years (Figure 11). We found that scaled catch rates from the six stations sampled in all years were lower after the 2002 stocking effort, too. Scaled catch rates at the six stations sampled in all years were also significantly higher during the November sampling trip following the 2004 stocking effort than catch rates from all other sampling trips in 2002 (ANOVA, $p < 0.03$). Additionally, the scaled catch rate from the July sampling trip following the 2004 stocking effort was significantly higher than the July sampling trip following the 2002 stocking effort (ANOVA, $p < 0.01$). As mentioned previously, the change in sampling protocol from seining to block seining is probably at least partially responsible for this difference in July's scaled catch rates.

Catch rates of Colorado pikeminnow were the highest during the initial trips after stocking in 2004 and 2005. In addition to being significantly higher than all sampling trips after the 2002 stocking effort, the scaled Colorado pikeminnow catch rates from all stations and the six stations sampled in all years in November 2004 were significantly higher than scaled catch rates from the December sampling trip following the 2003 stocking effort and the March sampling trip

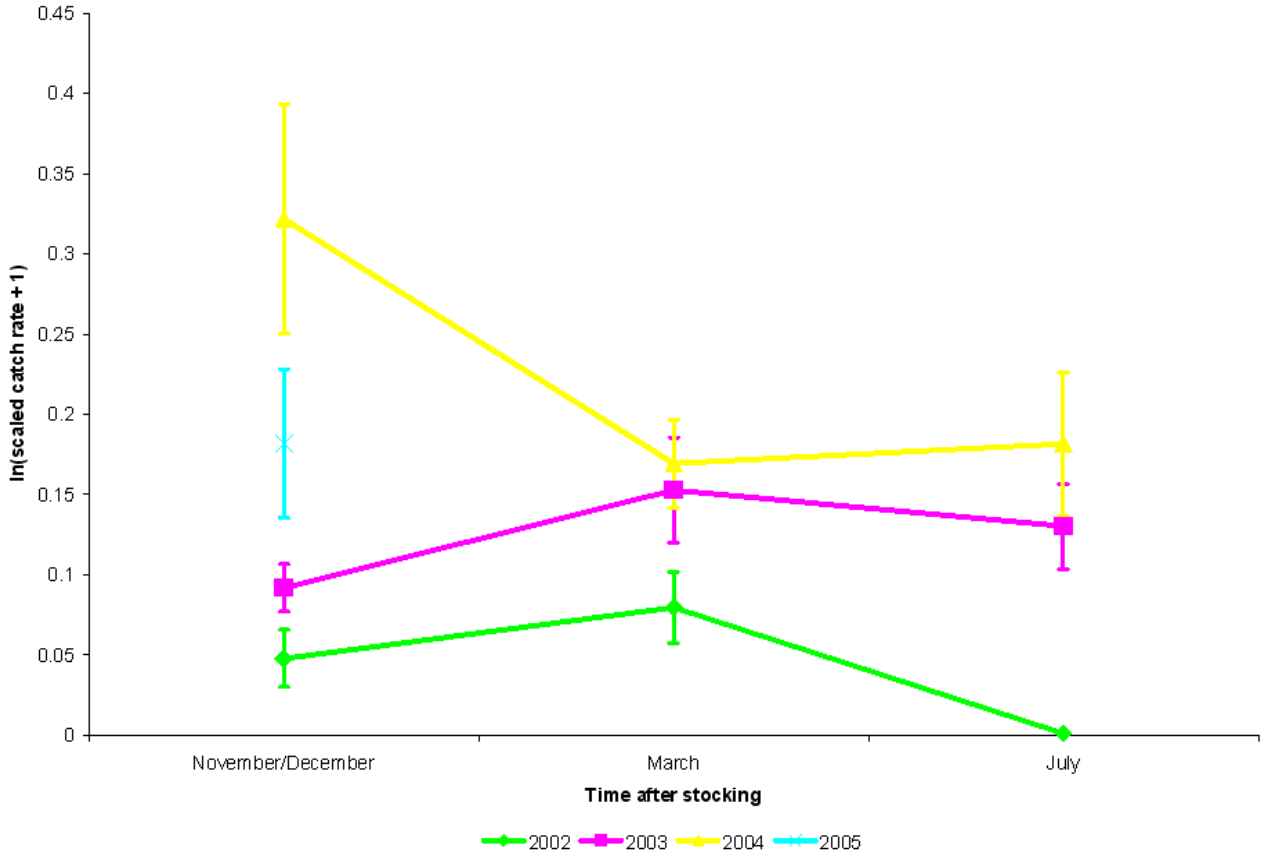

Figure 10. Scaled Colorado pikeminnow catch rate from the three sampling trips following stocking efforts in 2002-2004, as well as the first sampling trip after the 2005 stocking effort. Error bars represent +/- one standard error.

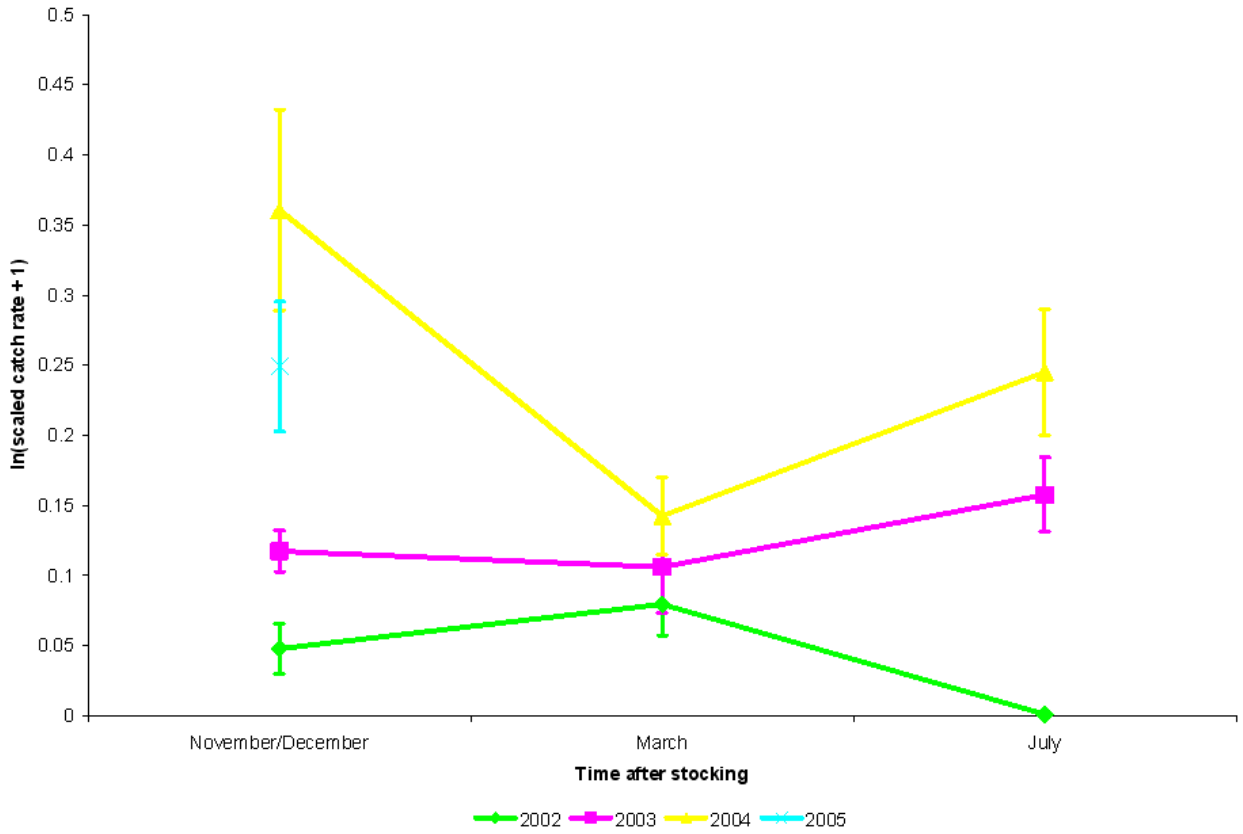

Figure 11. **Scaled Colorado pikeminnow catch rate only using data from the six stations sampled in all years from the three sampling trips following stocking efforts in 2002-2004, as well as the first sampling trip after the 2005 stocking effort. Error bars represent +/- one standard error.**

following the 2004 stocking effort ($p < 0.02$). During the November 2004 sampling trip, the scaled Colorado pikeminnow catch rate from the six stations sampled in all years was also significantly higher than catch rates during March 2003, July 2003, and March 2005 (ANOVA, $p < 0.03$). The scaled Colorado pikeminnow catch rate from all stations and the six stations sampled in all years appeared higher during the November sampling trip following the 2005 stocking effort than the December sampling trips following the 2002 and 2003 stocking efforts, but the differences were not significant. While there was a trend toward higher scaled catch rates during the March and July sampling trips after the 2003 and 2004 stocking efforts versus the March and July sampling trips following the 2002 stocking effort, the differences were not significant. Much of the difference between the July sampling trip catch rates is probably attributable to the change in sampling protocol from seining to block seining.

We found few significant differences between scaled Colorado pikeminnow catch rates, which would indicate that differences in the number of fish stocked accounted for any differences in the total number of Colorado pikeminnow collected in each year. The exception to this would be the November catch rates following the 2004 and 2005 stocking efforts and scaled catch rates in July. As mentioned several times, the change in gear from seines to block seines beginning in July after the 2003 stocking effort appears to be responsible for the higher catch rates following the 2003 and 2004 stocking efforts. Another change in sampling protocol may have resulted in the significantly higher November 2004 and November 2005 catch rates.

The proximity of our initial sampling trip to the time that SJRIP cooperators stocked fish in each study year appeared to account for the higher catch rates during November 2004 and November 2005. While we conducted the March and July sampling trips at roughly the same interval after stocking efforts in each year, the timing of initial sampling trips varied. We completed the initial sampling trips following the 2004 and 2005 stocking efforts much closer to the time that the SJRIP stocked fish, which may account for the increased catch rates we saw. To test this, we regressed the scaled average catch rate for the November/December trip following stocking effort from 2002–2005 against the number of days between the stocking effort and the beginning of our November/December sampling trip in each year. We found a strong, but not significant, negative relationship between the number of days the November/December sampling trip began after the stocking effort and the scaled catch rates for those trips when we included all stations in the analysis ($r^2 = 0.79$, $p = 0.11$) However, using only the scaled catch rates from the six stations sampled in all years, we found a strong, significant negative relationship between November/December trip scaled catch rates and the number of days our sampling trips began after the stocking effort in those years ($r^2 = 0.90$, $p = 0.04$, Figure 12). This would indicate that the proximity of our sampling trips to the stocking effort in a given year accounts for a substantial portion of the difference in scaled catch rates of the November/December sampling trips among years.

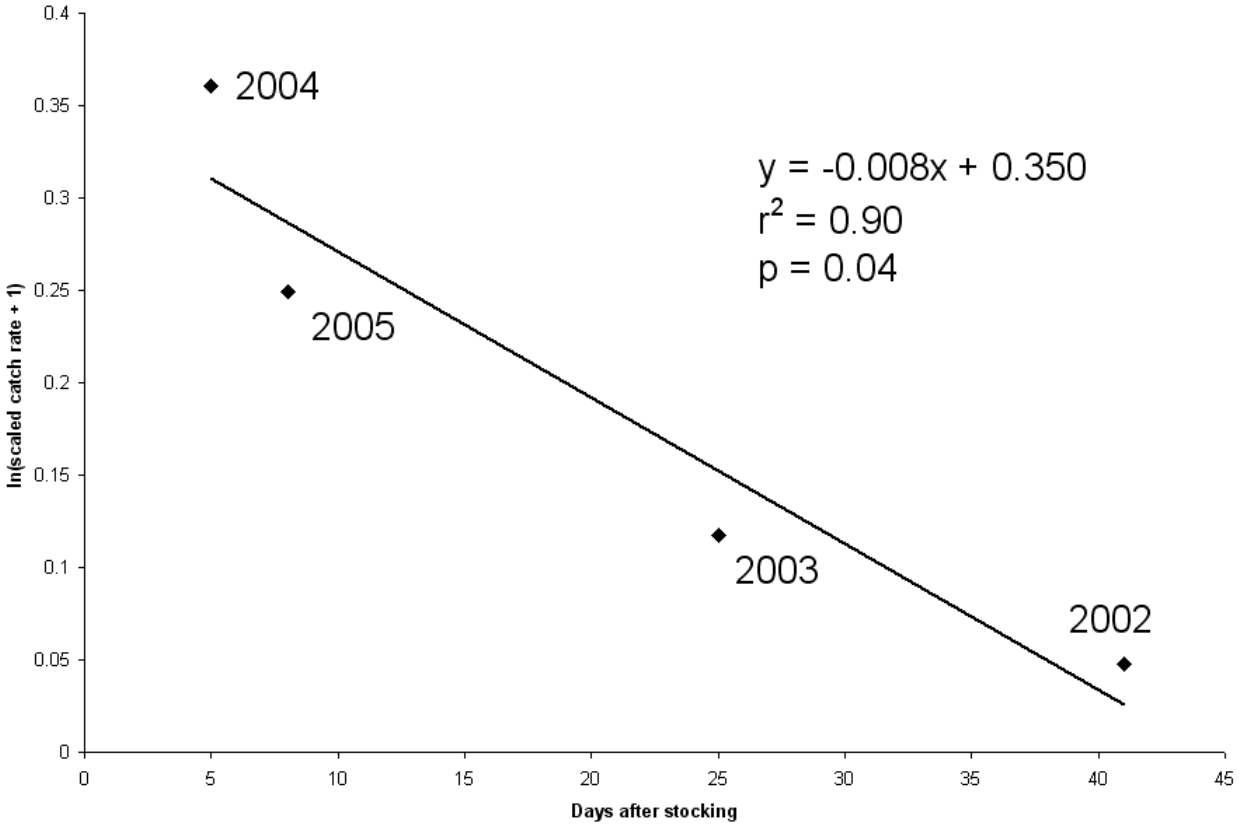

Figure 12. Scaled Colorado pikeminnow catch rates from the November/December sampling trips regressed against the number of days following the stocking effort that sampling trips began in 2002-2005.

Examining the bootstrapped confidence intervals around the scaled average catch rate values for each station during each sampling trip highlights the highly skewed and variable distribution of our data (Figures 13–22). In each case 0 fish was the lower bound of the 95% bootstrapped confidence interval, and in many cases the maximum catch rate at the station (or close to it) for a particular trip was the upper bound of the 95% bootstrapped confidence interval. Therefore, no significant differences could be found using randomization techniques. As we saw with the grand means calculated for each trip, the station means showed a trend toward higher catch rates in 2003 and 2004 versus 2002. The July sampling trip illustrated this trend better than the November/December and March sampling trips, but much of the increase during July can probably be attributed to using block seining in 2003 and 2004. As with the station means, we also saw a trend toward higher November/December catch rates in 2004 and 2005, especially at the upstream stations near where stocking took place. This makes sense in the context of our hypothesis that the higher catch rates in November 2004 and 2005 are attributable to sampling closer to the time of stocking.

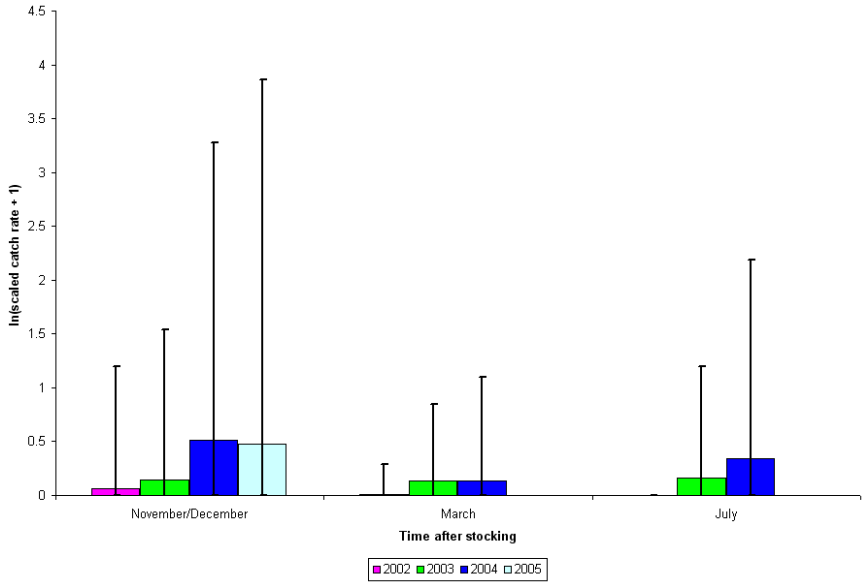

Figure 13. Average scaled catch rate at the Below Fruitland Diversion station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

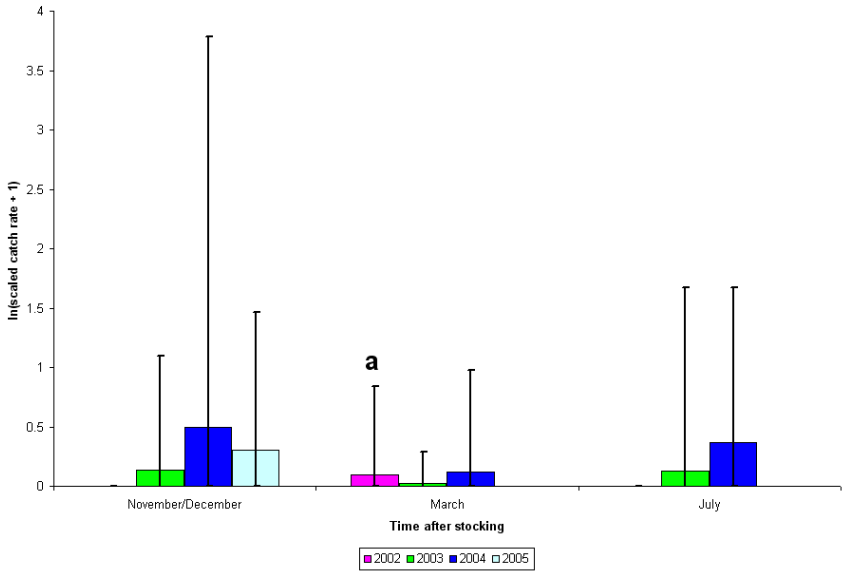

Figure 14. Average scaled catch rate at the APS Weir to Hogback station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

[a] Hogback Diversion to the Shiprock bridge was sampled during this trip.

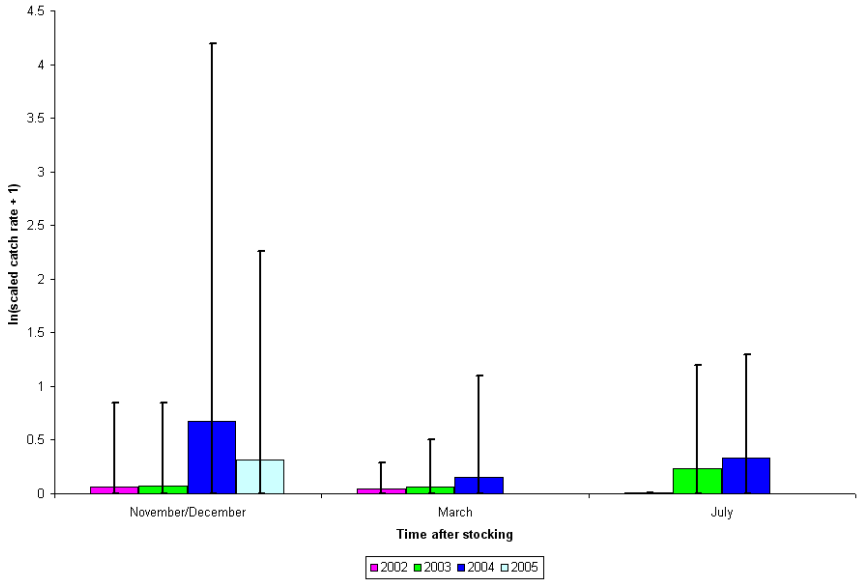

Figure 15. Average scaled catch rate at the Shiprock to Cudei station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

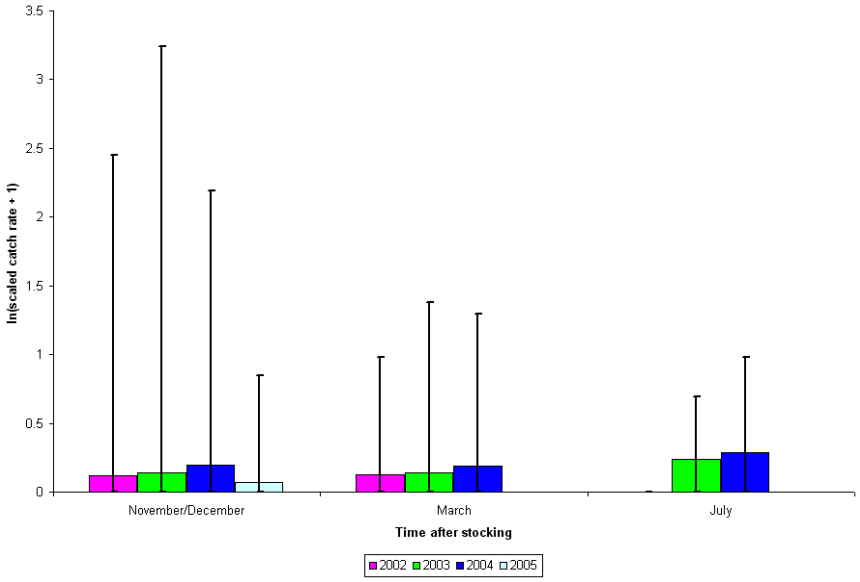

Figure 16. Average scaled catch rate at the Four Corners station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

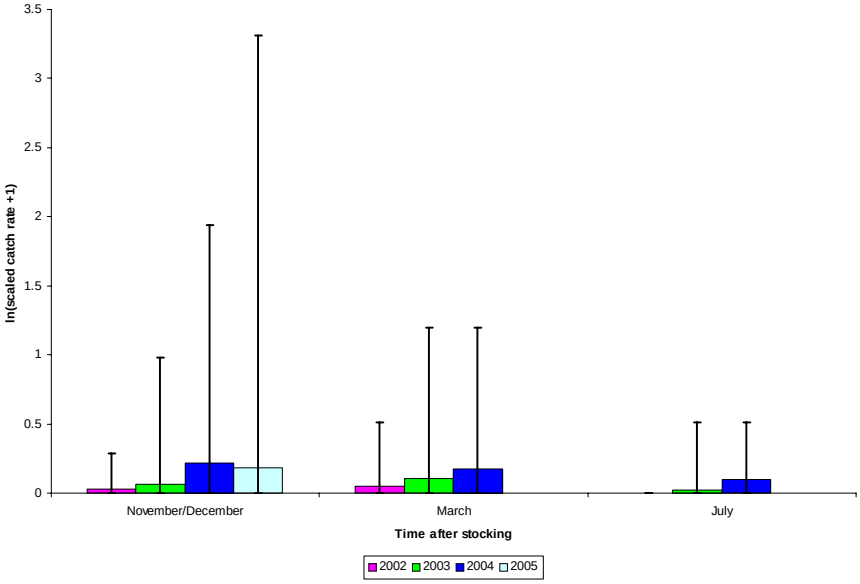

Figure 17. Average scaled catch rate at the Aneth station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

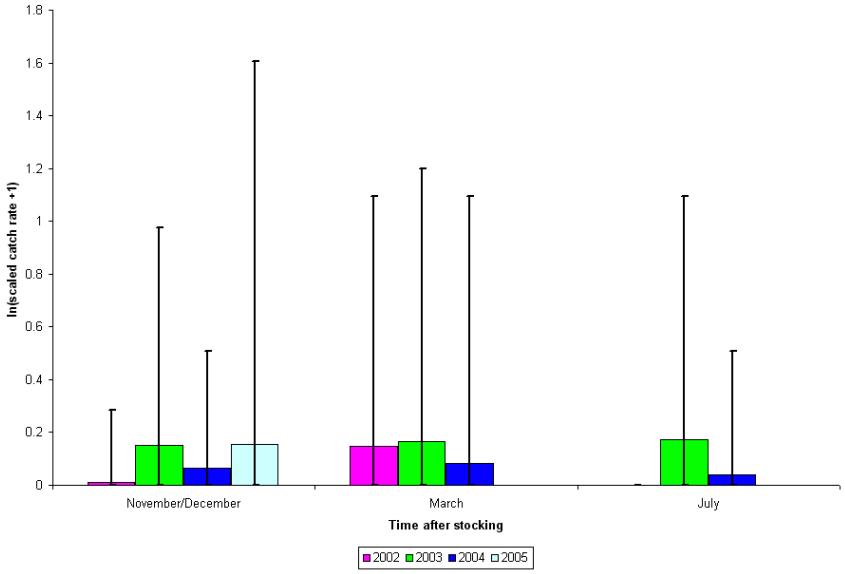

Figure 18. Average scaled catch rate at the Bluff station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.

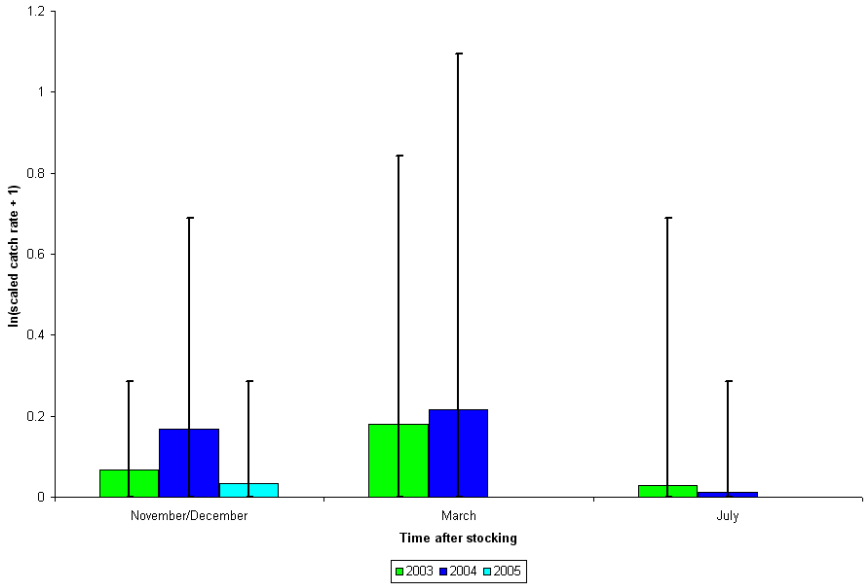

Figure 19. **Average scaled catch rate at the Below Mexican Hat station during all sampling trips from 2002–2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.**

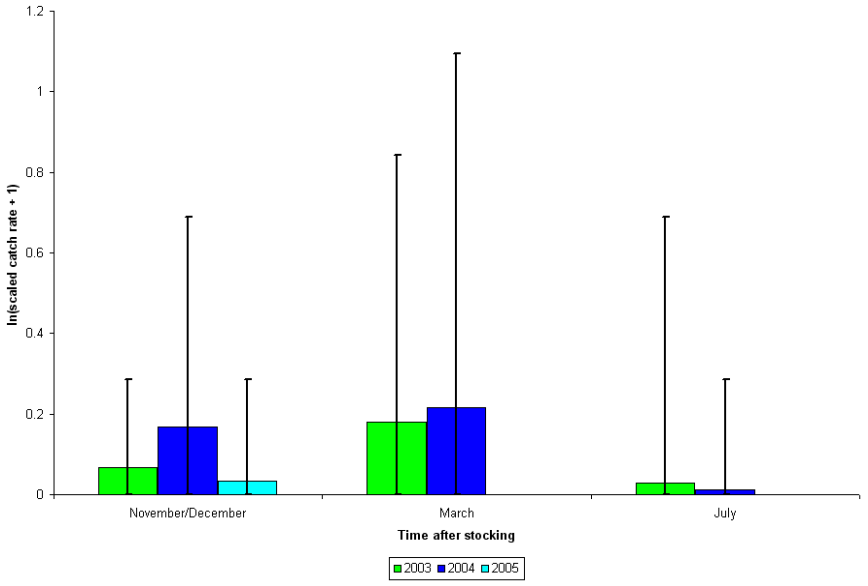

Figure 20. **Average scaled catch rate at the John's Canyon station during all sampling trips from 2002–2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.**

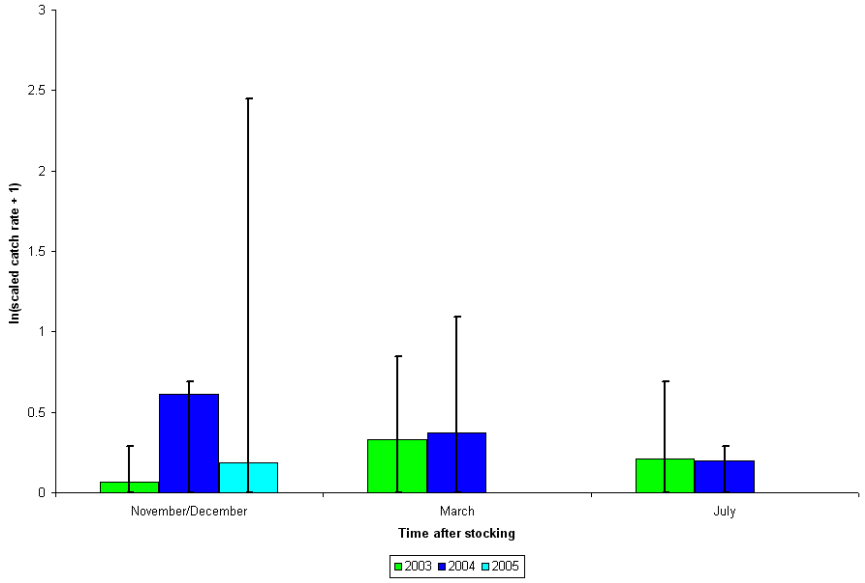

Figure 21. **Average scaled catch rate at the Grand Gulch station during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.**

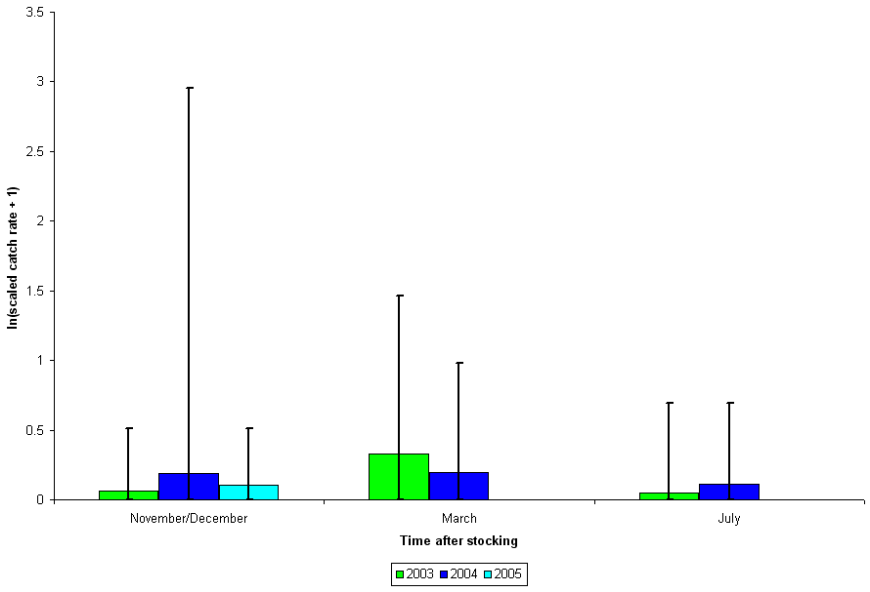

Figure 22. **Average scaled catch rate throughout the Canyon area below Mexican Hat, Utah, during all sampling trips from 2002-2005. Error bars represent the upper and lower bootstrapped 95% confidence intervals.**

When we sampled the Lower Animas River in 2002–2003 and 2003–2004, we did not collect any Colorado pikeminnow. Similarly, despite the fact that fish were stocked at the Animas confluence in both those years and some fish were stocked above the Animas confluence in November 2003, we did not collect any Colorado pikeminnow in the Upper San Juan station until July 2004. One of these was an age-1 fish stocked as an age-0 fish in November 2003, and the other was an age-2 fish that had been stocked a month earlier at the Animas confluence.

Other San Juan River Basin Recovery Implementation Program (SJRIP) Cooperators

Since other SJRIP cooperators use a variety of gear types and have a variety of objectives for their projects, we thought a discussion of the differences we observed in Colorado pikeminnow collection efficiency between projects was warranted. We found that the gear type used for an individual project appeared to account for the project's ability to collect Colorado pikeminnow. Seining does not appear to be effective for collecting age-1 and older Colorado pikeminnow. Between July and October 2002, no age-1 Colorado pikeminnow were collected during other SJRIP project seining efforts, whereas 80 age-1 Colorado pikeminnow were collected during raft-mounted electrofishing surveys conducted at roughly the same time. During small-bodied fish monitoring efforts (seining) in autumn 2004 and 2005, cooperators only collected 6.0% and 2.7% of the number of age-1 Colorado pikeminnow collected during cooperators' large-bodied fish monitoring efforts (electrofishing). When we used 2 m x 4 m seines without a block net to sample for Colorado pikeminnow in July 2003, we did not collect any Colorado pikeminnow, while cooperators using raft-mounted electrofishing captured between 4 and 40 Colorado pikeminnow in similar river reaches at roughly the same time. These data indicate that seining is not as effective as raft-mounted electrofishing for capturing Colorado pikeminnow once they reach age 1, or roughly 100 mm TL (Table 11).

Conversely, block seining appears to be equally as effective as, or more effective than, raft-mounted electrofishing for collecting age-1 Colorado pikeminnow. After we switched to block seining, we collected higher numbers of age-1 Colorado pikeminnow than cooperators conducting concurrent electrofishing surveys in July 2004 and July and August 2005. Cooperators using raft-mounted electrofishing, however, collected higher numbers of age-2 fish than we did using block seining in July and August 2005. Many more age-2 Colorado pikeminnow were captured during large-bodied fish monitoring than small-bodied fish monitoring in autumn 2004 (26 vs. 0) and 2005 (51 vs. 1). These data indicate that block seining may be more effective than electrofishing for collecting age-1 Colorado pikeminnow, and both these methods appear more effective for collecting age-1 Colorado pikeminnow than seining. Additionally, electrofishing appears more effective than seining and block seining for catching Colorado pikeminnow age 2 and older.

Table 11. Number of Colorado pikeminnow of different age classes (including fish stocked as age 1 and age 2) collected by seining, block seining, and electrofishing for different San Juan Recovery River Basin Implementation Program (SJRIP)-funded projects at similar times from 2003-2005.

PROJECT	GEAR	MONTH	REACH	AGE 1	AGE 2	AGE 3	OLDER
2002–2003							
NMFRO [a] Nonnative Removal	Electrofish	July	PNM Weir to Hogback Diversion	4	0	0	0
YOY [b] Colorado Pikeminnow Monitoring	Seine	July	APS Weir to Hogback Diversion	0	0	0	0
UDWR [c] Nonnative Removal	Electrofish	August	San Juan Canyon	44	0	0	0
UDWR additional sampling	Seine	August	San Juan Canyon	0	0	0	0
Large-bodied Monitoring	Electrofish	September/ October	River-wide	32	0	0	0
Small-bodied Monitoring	Seine	September/ October	River-wide	0	0	0	0
2003–2004							
NMFRO Nonnative Removal	Electrofish	July	PNM Weir to Hogback Diversion	1	3	0	1
YOY Colorado Pikeminnow Monitoring	Block seine	July	APS Weir to Hogback Diversion	19	0	0	0
UDWR Nonnative Removal	Electrofish	August	San Juan Canyon	9	5	0	0
YOY Colorado Pikeminnow Monitoring	Block seine	July	San Juan Canyon	40	6	0	0
Large-bodied monitoring	Electrofish	September/ October	River-wide	133	26	0	0
Small-bodied monitoring	Seine	September/ October	River-wide	8	0	0	0
2004–2005							
NMFRO Nonnative removal	Electrofish	July	PNM Weir to Hogback Diversion	1	12	0	0
YOY Colorado Pikeminnow Monitoring	Block seine	July	APS Weir to Hogback Diversion	40	1	0	0
UDWR Nonnative Removal	Electrofish	August	San Juan Canyon	7	18	1	0
YOY Colorado Pikeminnow Monitoring	Block seine	August	San Juan Canyon	35	4	0	0
Large-bodied Monitoring	Electrofish	September/ October	River-wide	75	51	2	0
Small-bodied Monitoring	Seine	September/ October	River-wide	2	1	0	0

[a] New Mexico Fisheries Resource Office.
[b] Young-of-year.
[c] Utah Division of Wildlife Resources.

As with the YOY Colorado pikeminnow monitoring in July 2003, the larval and small-bodied fish monitoring project methods did not appear effective for collecting Colorado pikeminnow once they reach age 1. Once Colorado pikeminnow exceed 100 mm TL, they seem to be able to avoid seines or have moved out of habitats where seining is effective (Figure 23). The scaled catch rate of Colorado pikeminnow collected during larval and small-bodied fish monitoring showed no real trend in abundance between the 3 years. Generally, a higher catch rate occurred during April and June 2004 sampling than in 2003 and 2005, while a higher catch rate occurred in July 2005 than in 2003 or 2004, indicating that perhaps Colorado pikeminnow were more susceptible to seining for a longer period in 2005.

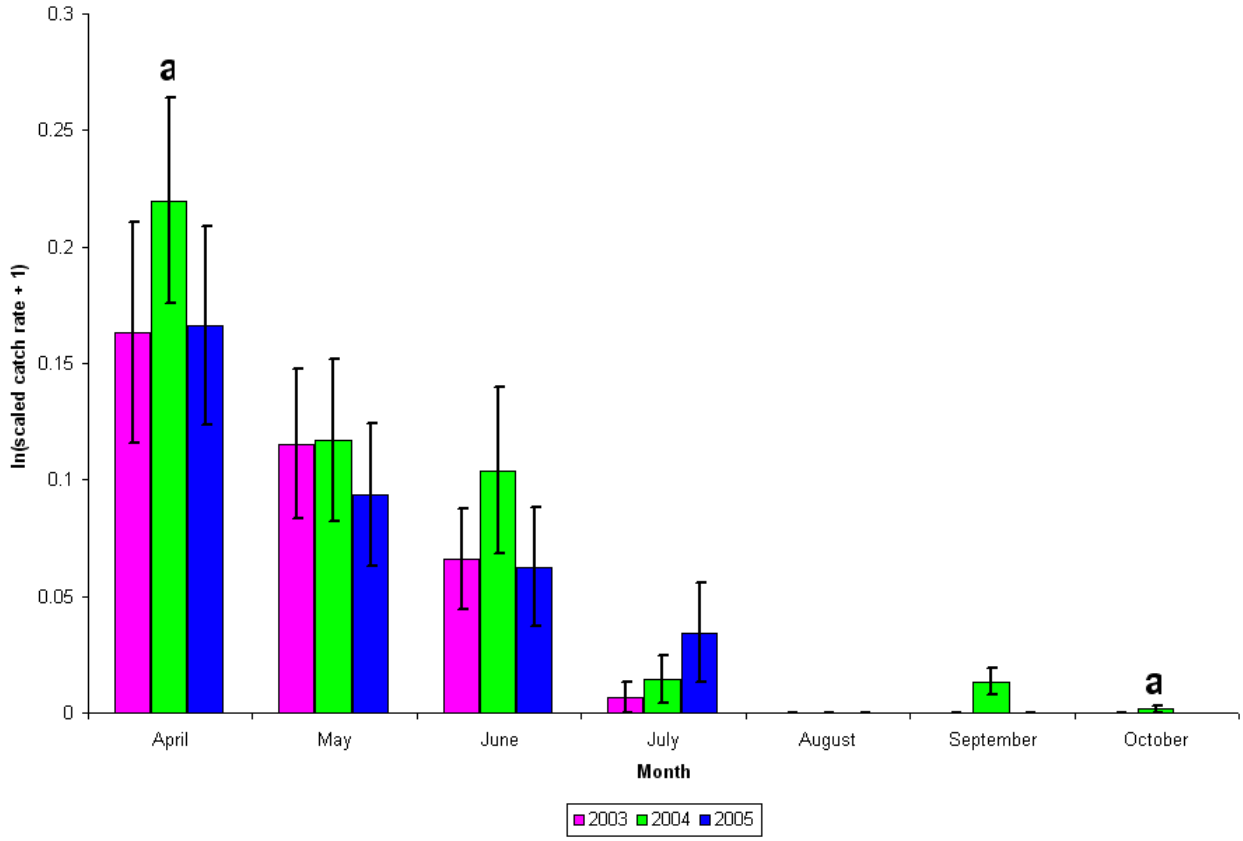

Figure 23. Scaled catch rates of age-0 and age-1 Colorado pikeminnow from the previous autumn's stocking effort that were collected with seines during larval fish monitoring (April to September) and small-bodied fish monitoring (September/October) from 2003-2005.

[a]At least one of these fish was from the previous year's stocking (i.e., an age-2 fish).

During SJRIP projects using raft-mounted electrofishing, Colorado pikeminnow stocked as age-0 fish from 2002–2004 were collected as age-1, age-2, and age-3 fish from 2003–2005 (Figures 24–26). These data are from the combined captures of UDWR and NMFRO nonnative removal efforts, along with large-bodied fish monitoring captures. As we saw in our catch rates for YOY Colorado pikeminnow, electrofishing data from SJRIP cooperators showed that catch rates for Colorado pikeminnow stocked in 2002 appeared to be lower than those stocked in 2003 and 2004. This trend was most apparent in the scaled mean CPUE in autumn one year after stocking. The trend toward a higher-scaled CPUE for Colorado pikeminnow stocked in 2003 versus those stocked in 2002 was also apparent in the spring and summer of the second year the fish were in the river. Colorado pikeminnow stocked in 2004 appeared to enter the electrofishing catch later than those stocked in 2002 and 2003.

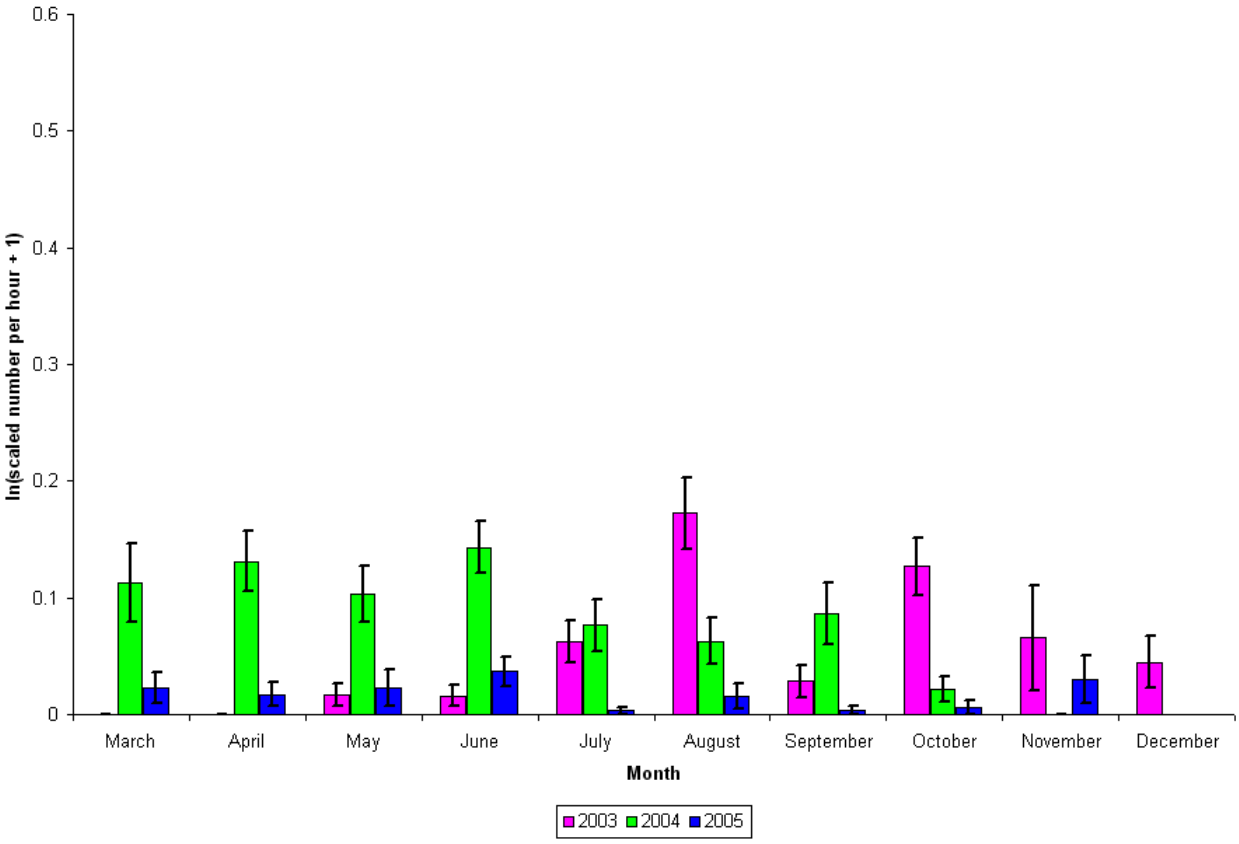

Figure 24. Scaled catch per unit effort (CPUE) for Colorado pikeminnow stocked in 2002 and captured during SJRIP projects using raft mounted electrofishing from 2003-2005. Error bars represent +/- one standard error.

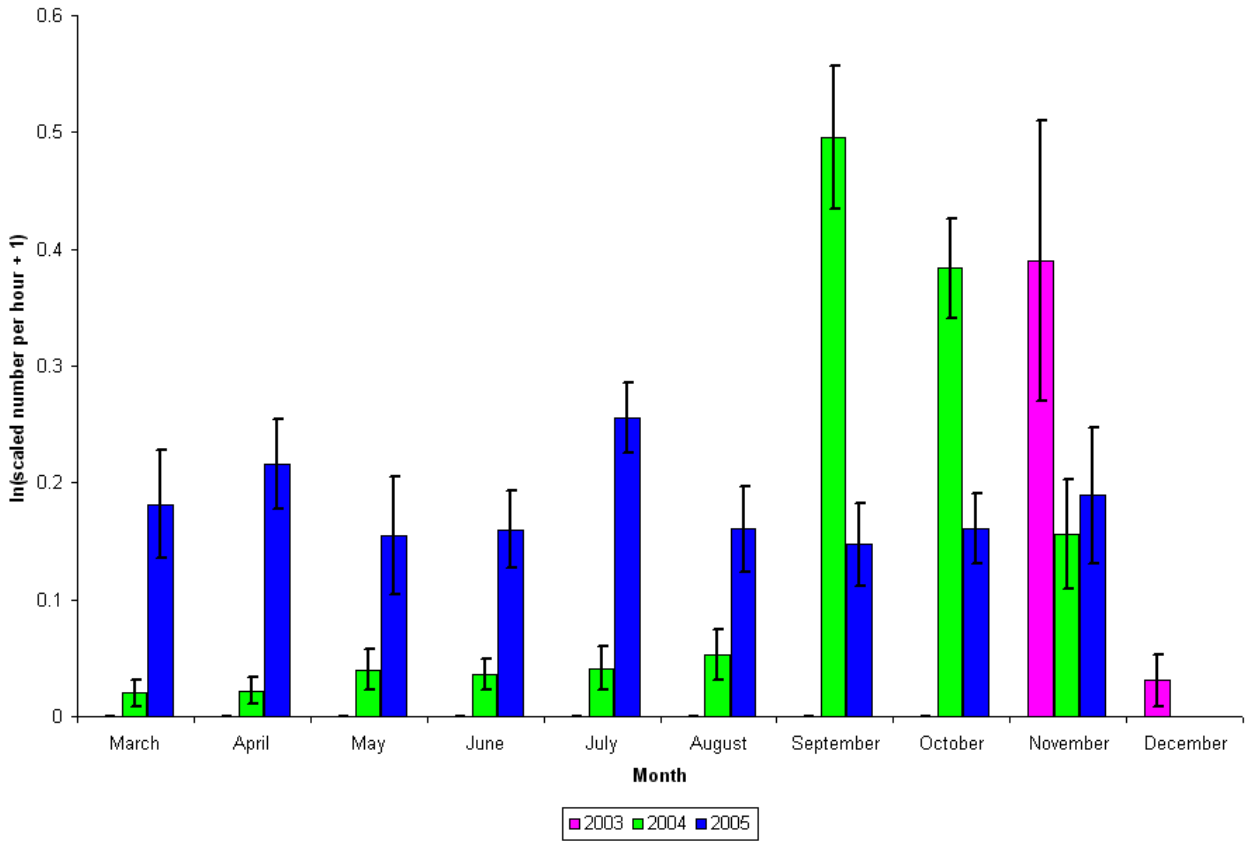

Figure 25. Scaled catch per unit effort (CPUE) for Colorado pikeminnow stocked in 2003 captured during SJRIP projects using raft mounted electrofishing from 2003-2005. Error bars represent +/- one standard error.

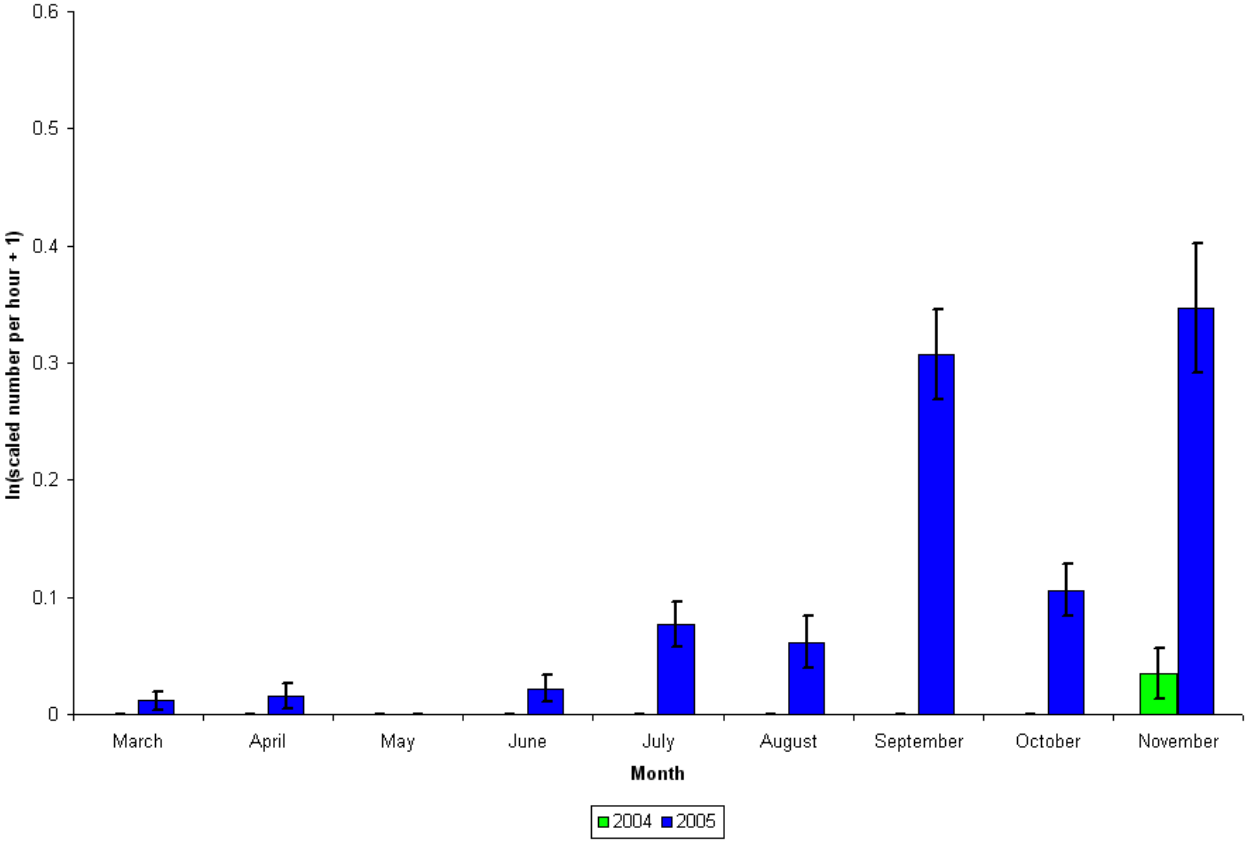

Figure 26. Scaled catch per effort (CPUE) for Colorado pikeminnow stocked in 2004 captured during SJRIP projects using raft mounted electrofishing from 2004-2005. Error bars represent +/- one standard error.

While Colorado pikeminnow were collected in all SJRIP project electrofishing surveys, the longest running and most consistent of those projects is the large-bodied fish monitoring. Therefore, we considered the scaled catch rate of the number of Colorado pikeminnow collected per hour in the fall monitoring as another measure of stocking success (Figure 27). Similar to data from the YOY Colorado pikeminnow monitoring project, the large-bodied fish monitoring showed a higher CPE for age-1 and age-2 Colorado pikeminnow from the 2003 stocking effort than from the 2002 stocking effort. Conversely, scaled CPE from the large-bodied fish monitoring indicated that fewer age-1 Colorado pikeminnow present after the 2004 stocking effort than after the November 2003 stocking effort. These data conflict with scaled catch rate data collected during our project in July/August 2005, which indicated that the number of age-1 Colorado pikeminnow produced by the 2003 and 2004 stocking efforts was the same.

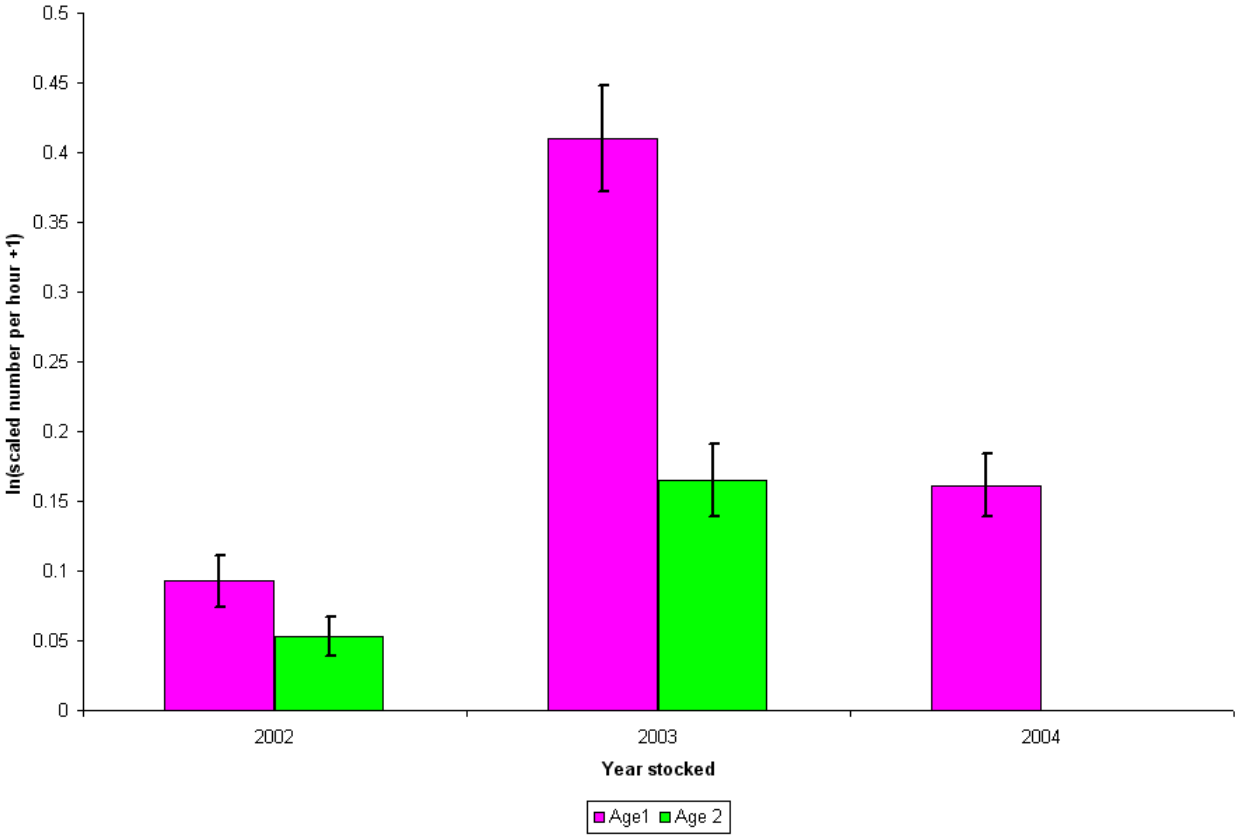

Figure 27. Scaled catch per unit effort (CPUE) for age 1 and age 2 Colorado pikeminnow for Colorado pikeminnow stocked as age 0 fish from 2002-2004 collected during SJRIP large-bodied fish monitoring. Error bars represent +/- one standard error.

Comparisons with Historical Data

In November 1996 and August 1997, 100,000 and 117,000 YOY Colorado pikeminnow were stocked into the San Juan River, respectively. The UDWR followed the fate of these stocked fish, which provides a historical comparison with more recently stocked fish. Using geomorphic reach as the sampling unit, we were able to statistically compare the grand mean of scaled average Colorado pikeminnow catch rates between sampling trips among all years that the SJRIP stocked YOY Colorado pikeminnow (Figure 28). The initial sampling trips following the 1996 and 2004 stocking efforts had the highest scaled average catch rates. The scaled catch rates from the initial trip after the 1996 and 2004 stocking efforts were significantly higher than those from the initial trip after the 2002 and 2003 stocking effort (ANOVA, $p < 0.05$). The scaled average catch rates from the initial trips following the 1996 and 2004 stocking effort were also significantly greater than the scaled average catch rate from sampling trips 9–11 months after the 1996, 1997, and 2002 stocking efforts (ANOVA, $p \leq 0.0001$). Scaled average catch rate 4–5 months after the 1997 stocking effort was significantly lower than during the initial sampling trip following the 1996 and 2004 stocking efforts, and the scaled average catch rate 4–5 months after the 2002 stocking effort was also significantly lower than after the initial sampling trip in 1996 (ANOVA, $p < 0.001$).

The scaled average catch rate 9–11 months after the 2003 and 2004 stocking efforts was nearly identical to what was seen 4–5 months after stocking in those years. Block seining was used in those years and appeared to be effective for collecting age-1 Colorado pikeminnow. If block seining had been used 9–11 months after stocking in prior years, we would expect that the catch rate would have been very similar to that seen 4–5 months after stocking in those years. Overall, it appears that the 1997 and 2002 stocking efforts were the least successful, while the 1996 stocking effort was probably the most successful.

Examining the scaled average CPUE for Colorado pikeminnow collected during SJRIP large-bodied fish monitoring provides another comparison between the 1996 and 1997 stocking efforts versus the more recent efforts. While catch rates from seining indicated that 1996 was the most successful stocking effort, large-bodied fish monitoring data indicated that the 2003 stocking effort produced the highest CPUE of age-1 Colorado pikeminnow (Figure 29). Seining data also indicated that the 1997 stocking effort was one of the least successful, but according to large-bodied fish monitoring data it produced the second-highest CPUE of age-1 individuals. While large-bodied fish monitoring showed CPUE for age-1 fish from the 1997 stocking effort was high, the CPE for age-2 fish was the lowest of all years. Conversely, the CPUE for age 2 fish was highest from the 1996 stocking effort. These data indicated that the 1996 and 2003 stocking efforts were more successful and support seining data collected by the UDWR and during our monitoring project. The 2004 stocking effort can not be evaluated in terms of age-2 fish until autumn 2006.

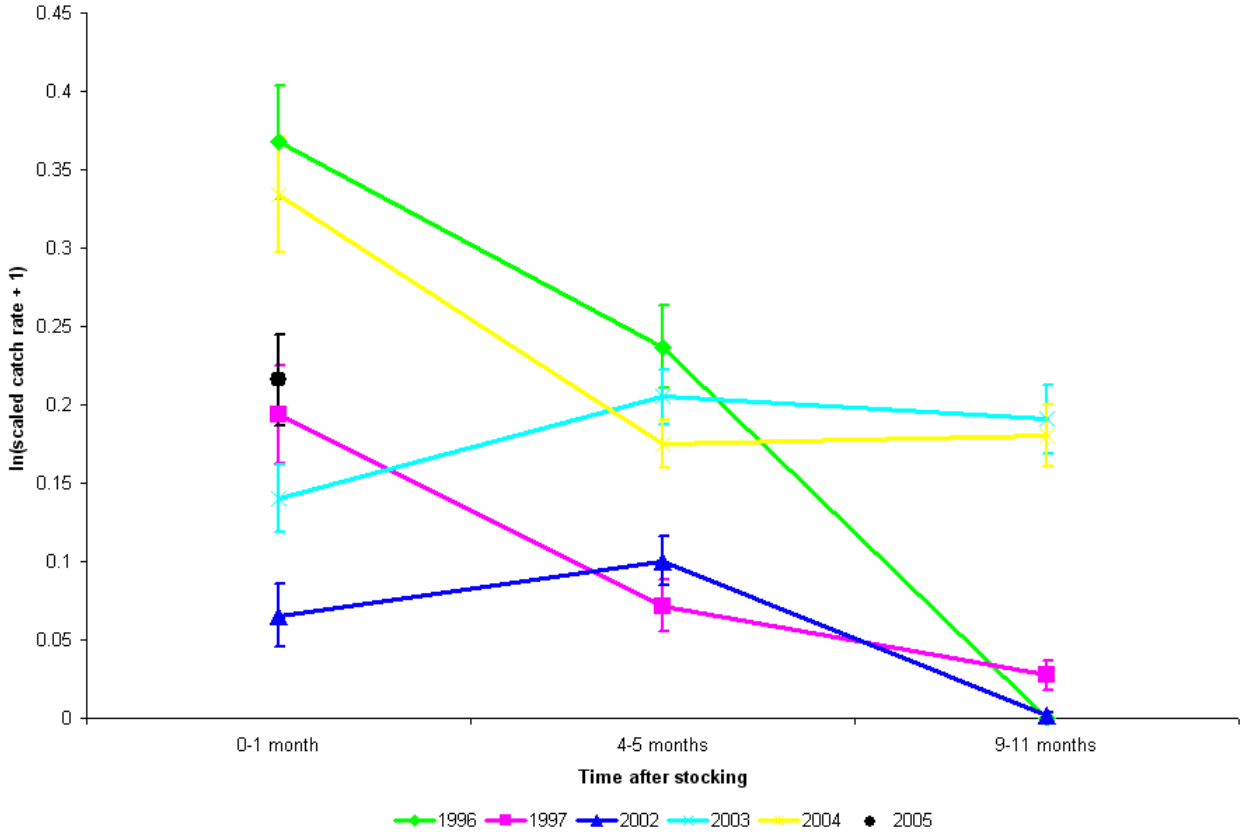

Figure 28. Scaled average catch rate of Colorado pikeminnow captured during monitoring at different times following stocking efforts in 1996, 1997, and 2002-2005. Error bars represent +/- one standard error.

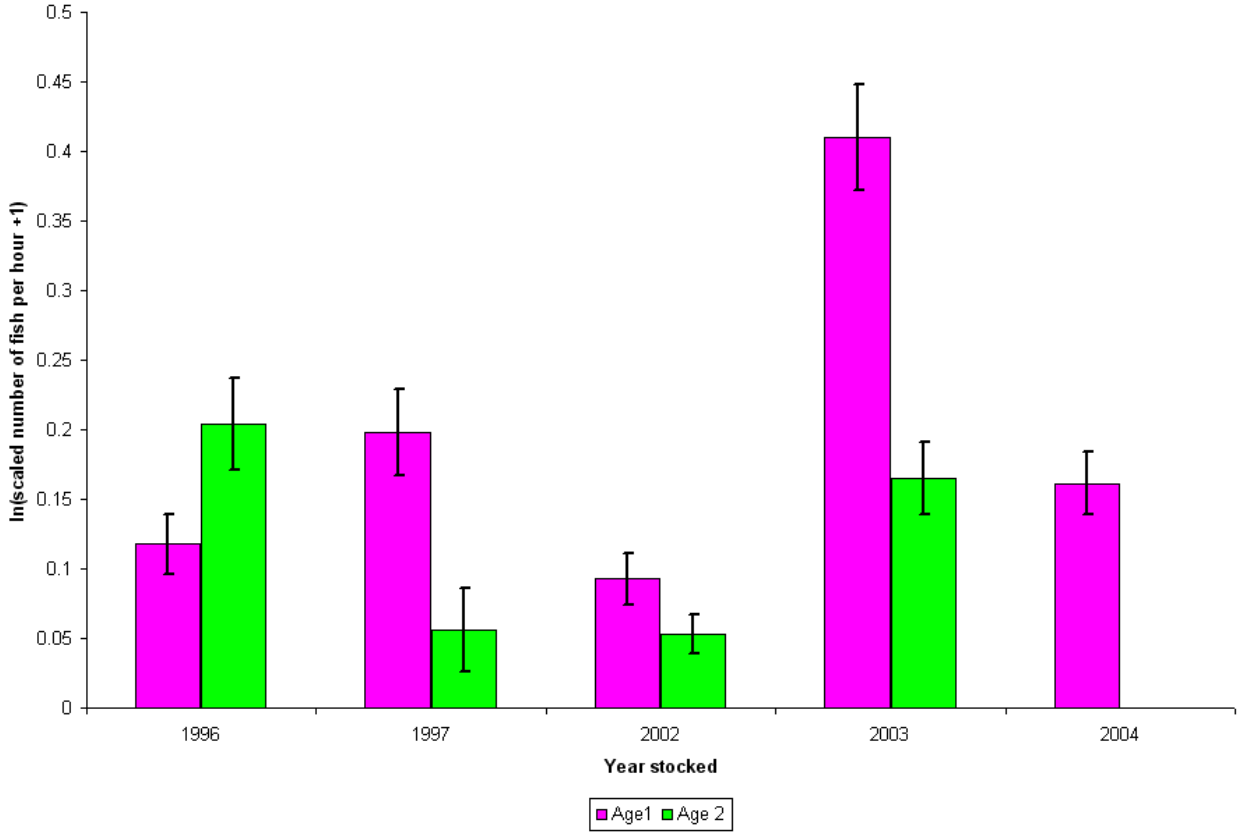

Figure 29. Scaled average catch per unit effort (CPUE) of Colorado pikeminnow stocked as age-0 fish in 1996, 1997, and 2002-2004, and collected as age-1 and age-2 fish during SJRIP large-bodied fish monitoring. Error -bars represent +/- one standard error.

In summary, our catch rate data were difficult to interpret because of their skewed distribution. Despite this, it appeared clear that retention after the 2002 stocking effort was lower than after stocking in other study years. We found that catch rate during our initial sampling trips following stocking appeared to be dependent upon the interval between stocking and sampling. After we began to use block seining as our July sampling method, it appeared that retention remained stable between the March and July sampling trips. Comparisons with historical data showed that catch rates after the 1997 stocking effort were similar to 2002 in terms of lower retention. Conversely, catch rates from the 1996 stocking effort may have been the highest of all.

Colorado Pikeminnow Stocked as Age-1 and Age-2 Fish

The SJRIP cooperators only recaptured three of the 1,005 age-1 Colorado pikeminnow stocked in November 2003. They collected all three of these fish within a little over 1 month after stocking. We collected one of these fish by seining during December 2003 YOY Colorado pikeminnow monitoring at RM 43.7, over 219 km (136 miles) downstream from the stocking location. After its collection we noted that the fish was in poor condition and had a misshapen head. The fish had difficulty maintaining equilibrium after we released it. The NMFRO collected the other two fish during nonnative removal efforts between PNM Weir and Hogback Diversion in December 2003. We also captured a couple of these age-1 Colorado pikeminnow immediately after they were stocked while performing ancillary sampling during acclimation studies in November 2003. While we did not have a PIT-tag reader, the misshapen heads (Figure 30) and collection location (RM 180.2) indicated that they were fish from the November 6, 2003, stocking.

Figure 30. Age-1 Colorado pikeminnow stocked on November 6, 2003.

During NMFRO and UDWR nonnative removal surveys, relatively large numbers of the 1,219 age-2 Colorado pikeminnow stocked in June 2004 were found immediately after their release (Table 12). The NMFRO recaptured the majority of these fish between PNM Weir (RM 166.6) and the Shiprock bridge (RM 148.0), less than 48 km [30 mi] downstream from the release site. However, within 2–3 weeks the UDWR collected five of these fish between Mexican Hat and Clay Hills Crossing. The lowermost capture occurred at RM 11.4, nearly 272 km [169 mi] downstream from the stocking location. The number of these fish captured during July and August nonnative removal efforts decreased, but cooperators recaptured nine 3–4 months after stocking during large-bodied fish monitoring in 2004. The SJRIP researchers continued to collect small numbers of these fish during electrofishing surveys throughout 2005 but recaptured only one of these fish during large-bodied fish monitoring (Table 13).

Table 12. Number of age-2 fish stocked on June 9, 2004, collected during subsequent sampling by San Juan River Basin Recovery Implementation Program (SJRIP) cooperators in 2004.

AGENCY [a]	JUN-04	JUL-04	AUG-04	SEP-04	OCT-04	NOV-04	DEC-04
B-W	N/A	4	N/A	N/A	N/A	0	N/A
NMFRO	37	2	0	1	N/A	N/A	N/A
SJRIP	N/A	N/A	N/A	6	3	N/A	N/A
UDWR	5	2	0	N/A	N/A	N/A	N/A
Total	**42**	**8**	**0**	**7**	**3**	**N/A**	**0**

[a] B-W = YOY Colorado pikeminnow monitoring, NMFRO = New Mexico Fisheries Resource Office nonnative removal, SJRIP = SJRIP large-bodied fish monitoring, UDWR = Utah Division of Wildlife Resources nonnative removal.

Table 13. Number of age-2 fish stocked on June 9, 2004 collected during subsequent sampling by San Juan River Basin Recovery Implementation Program (SJRIP) cooperators in 2005.

AGENCY [a]	MAR-05	APR-05	MAY-05	JUN-05	JUL-05	AUG-05	SEP-05	OCT-05	NOV-05
B-W	0	N/A	N/A	N/A	0	N/A	N/A	N/A	0
NMFRO	0	4		0	0	1	1	0	0
SJRIP	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A
UDWR	1	3	0	1	0	1	N/A	N/A	N/A
Total	**1**	**7**	**0**	**1**	**0**	**2**	**2**	**0**	**0**

[a] B-W = YOY Colorado pikeminnow monitoring, NMFRO = New Mexico Fisheries Resource Office nonnative removal, SJRIP = SJRIP large-bodied fish monitoring, UDWR = Utah Division of Wildlife Resources nonnative removal.

The SJRIP stocked 500 age-1 fish from DNFHTC and 1,491 age-2 fish from Mumma in July 2005. Unlike the June 2004 stocking effort, nonnative removal efforts 2–3 weeks after stocking did not document a large pulse of these fish, and the UDWR recaptured fewer of these fish below Mexican Hat (Tables 14 and 15). The UDWR did recapture one of the age-1 Colorado pikeminnow at RM 48.8, over 209 km (130 miles) downstream from the stocking site. Capture numbers remained low but consistent during NMFRO nonnative removal efforts from July through November 2005, and during the SJRIP large-bodied fish monitoring researchers collected more of the July 2005 stocked age-1 Colorado pikeminnow. Additionally, during large-bodied fish monitoring researchers collected nearly as many July 2005 stocked age-2 Colorado pikeminnow as researchers had during nonnative removal efforts immediately after stocking.

Table 14. Number of age-1 fish stocked on July 7, 2005, collected during subsequent sampling by San Juan River Basin Recovery Implementation Program (SJRIP) cooperators in 2005.

AGENCY [a]	JUL-05	AUG-05	SEP-05	OCT-05	NOV-05
B-W	2	N/A	N/A	N/A	0
NMFRO	7	2	1	1	0
SJRIP	N/A	N/A	2	9	N/A
UDWR	1	0	N/A	N/A	N/A
Total	**10**	**2**	**3**	**10**	**0**

[a] B-W = YOY Colorado pikeminnow monitoring, NMFRO = New Mexico Fisheries Resource Office nonnative removal, SJRIP = SJRIP large-bodied fish monitoring, UDWR = Utah Division of Wildlife Resources nonnative removal.

Table 15. Number of age-2 fish stocked on July 7, 2005, collected during subsequent sampling by San Juan River Basin Recovery Implementation Program (SJRIP) cooperators in 2005.

AGENCY [a]	JUL-05	AUG-05	SEP-05	OCT-05	NOV-05
B-W	7	N/A	N/A	N/A	1
NMFRO	13	2	5	5	5
SJRIP	N/A	N/A	1	10	N/A
UDWR	0	2	N/A	N/A	N/A
Total	**20**	**4**	**6**	**15**	**6**

[a] B-W = YOY Colorado pikeminnow monitoring, NMFRO = New Mexico Fisheries Resource Office nonnative removal, SJRIP = SJRIP large-bodied fish monitoring, UDWR = Utah Division of Wildlife Resources nonnative removal.

To reduce the influence of the number of fish stocked on the total number of fish collected, we calculated the percentage of age-1 and age-2 Colorado pikeminnow collected based on total numbers stocked. We found that the percentage of the age-2 fish stocked in June 2004 and July 2005 and collected during large-bodied fish monitoring that occurred 3–4 months after stocking in both years was similar (Figure 31). Conversely, the percentage of age-1 Colorado pikeminnow stocked in July 2005 and collected during large-bodied fish monitoring 3–4 months later was higher than the percentage of age-2 fish stocked at the same time, which may indicate better retention of age-1 fish from the DNFHTC versus age-2 fish from Mumma. Long-term retention (15 months post-stocking) of the age-2 Colorado pikeminnow stocked in June 2004 appeared markedly lower 3–4 months following stocking.

While SJRIP cooperators collected higher numbers of Colorado pikeminnow stocked as age-0 fish, SJRIP cooperators stocked substantially higher numbers of YOY Colorado pikeminnow (almost 970,000 age-0 fish vs. 1,500 age-1 and 5,100 age-2 fish). To account for this, we compared the percentage of the total number of fish stocked that were recovered during SJRIP fall monitoring and found that the return rates of Colorado pikeminnow stocked at larger sizes appeared to be considerably higher than those for Colorado pikeminnow stocked as age-0 fish. The exception to this was the November 2003 stocking of age-1 fish (average size at stocking = 180 mm TL). Researchers collected none of these fish as age 2 during SJRIP fall monitoring efforts but collected 17 (0.008%) of the Colorado pikeminnow stocked as age-0 fish in autumn 2002. Conversely, the return rate ratio for Colorado pikeminnow stocked as age-1 fish in July 2005 (average size at stocking = 201 mm TL) and YOY Colorado pikeminnow stocked the previous autumn (average size in November 2004 = 42 mm SL) was 29:1 during 2005 SJRIP fall monitoring efforts.

Return rates were consistently higher for Colorado pikeminnow stocked as age 2 than Colorado pikeminnow stocked as age 0. The return rate of age-2 Colorado pikeminnow stocked in June 2004 (average size at stocking = 219 mm TL) and YOY Colorado pikeminnow stocked in autumn 2002 (average size in December 2002 = 43 mm SL) was 49:1 during 2004 fall monitoring efforts. During large-bodied fish monitoring, researchers only recaptured one of each group as age-3 fish in 2005, which increased the return rate disparity to 172:1. The return rate ratio for Colorado pikeminnow stocked as age-2 fish in June 2005 (average size at stocking = 204 mm TL) and Colorado pikeminnow stocked as age-0 fish in 2003 (average size in December 2003 = 49 mm SL) was 33:1.

In summary, the retention of larger stocked Colorado pikeminnow, with the exception of the first stocking effort in June 2003, was higher than the retention of fish from the YOY stocking efforts within a few months of stocking. Whether that trend will continue as the fish are in the river longer remains to be seen.

Stocking Protocol Changes and Experiments

Debris Pile Studies

2003 Flows dropped nearly 100 cfs at the U.S. Geological Survey (USGS) gage near Shiprock between November 4, 2003, when we placed debris piles, and November 6, 2003, when SJRIP cooperators stocked YOY Colorado pikeminnow (Figure 32). Although there was a small increase, flows were still below the level at which we placed debris piles when we conducted our December 2003 monitoring trip. While the variation in flow levels appears small, it seemed to largely impact the debris piles themselves and the quality of the habitats in which debris piles were placed. During our December 2003 monitoring trip, we found that several debris piles were gone or covered with silt; several others were either out of the water or in extremely

Figure 32. Average daily discharge between November 1 and December 31, 2003, for the San Juan River near Shiprock, New Mexico (USGS gage 09368000).

shallow water, making most of them useless as Colorado pikeminnow habitat (Figure 33). As shown previously, bootstrapped 95% confidence intervals in the Shiprock to Cudei station heavily overlapped so no difference could be detected within stations among years, but we did not see an increase in the scaled average catch rate at the Shiprock to Cudei station between December 2002 and December 2003, before and after the addition of debris piles (Figure 15).

2004 In 2004 we placed debris piles on October 20, immediately after flows had dropped nearly 300 cfs. Flows remained at this level during the stocking effort and for approximately 5 days afterward (Figure 34). However, flows then rose over 700 cfs, which probably transformed many of the low-velocity habitats we used into higher-velocity, flow-through habitats. When we sampled the Shiprock to Cudei station on November 3, 2004, flows were still 300 cfs higher than when we had placed the debris piles. We observed that many of the habitats in which we had placed debris piles were no longer low-velocity habitats. Scaled average catch rates were higher in November 2004 than they were in December 2003 and 2002. However, the bootstrapped 95% confidence intervals showed no detectable differences among years. We found that the scaled average catch rates in March and July following the 2004 stocking effort were similar to those in March and July following the 2003 stocking effort, indicating that any increase in initial retention was not maintained.

Acclimation Studies

2003 The 2003 acclimation studies were unsuccessful because the majority of Colorado pikeminnow used in the experiments died and the batch marker failed. We used several habitats as acclimation areas in the APS Weir to Hogback Diversion and Upper San Juan stations, and stocked Colorado pikeminnow into these areas on November 6, 2003 (see Golden and Holden 2005 for more detail). When we floated the Upper San Juan station between 07:00 and 12:00 MST on November 7, 2003, most of our acclimation areas were in place and the fish in good health. However, when we floated the APS Weir to Hogback Diversion station from 13:00 to 17:00 MST, we found many dead and severely stressed Colorado pikeminnow. Signs of stress included gulping at the surface, loss of equilibrium, and a red coloration, especially on the chest. Many of the dead Colorado pikeminnow had a large red dot in the middle of the ventral surface between the pectoral fins.

We returned to one of the acclimation areas in the Upper San Juan station that evening and still saw no sign of stress or mortality at that site. However, the following morning (November 8, 2003), we found similar mortality and stress throughout the acclimation areas in the Upper San Juan station (Figure 35). Because several of the Upper San Juan station acclimation areas breached overnight on November 7, 2003, it is more difficult to quantify the number of mortalities vs. the number of escapees in that area. The bulk of the stress and mortality appeared to occur over the first 72 hours at both stations. Many of the mortalities retrieved after November 9, 2003, showed some decomposition, indicating they may have been mortalities from the first 72 hours that we did not find earlier.

Figure 33. Backwater area with added brush pile on (a) November 4, 2003, and (b) December 5, 2003.

Figure 34. Average daily discharge between October 1 and November 30, 2004, for the San Juan River near Shiprock, New Mexico (USGS gage 09368000).

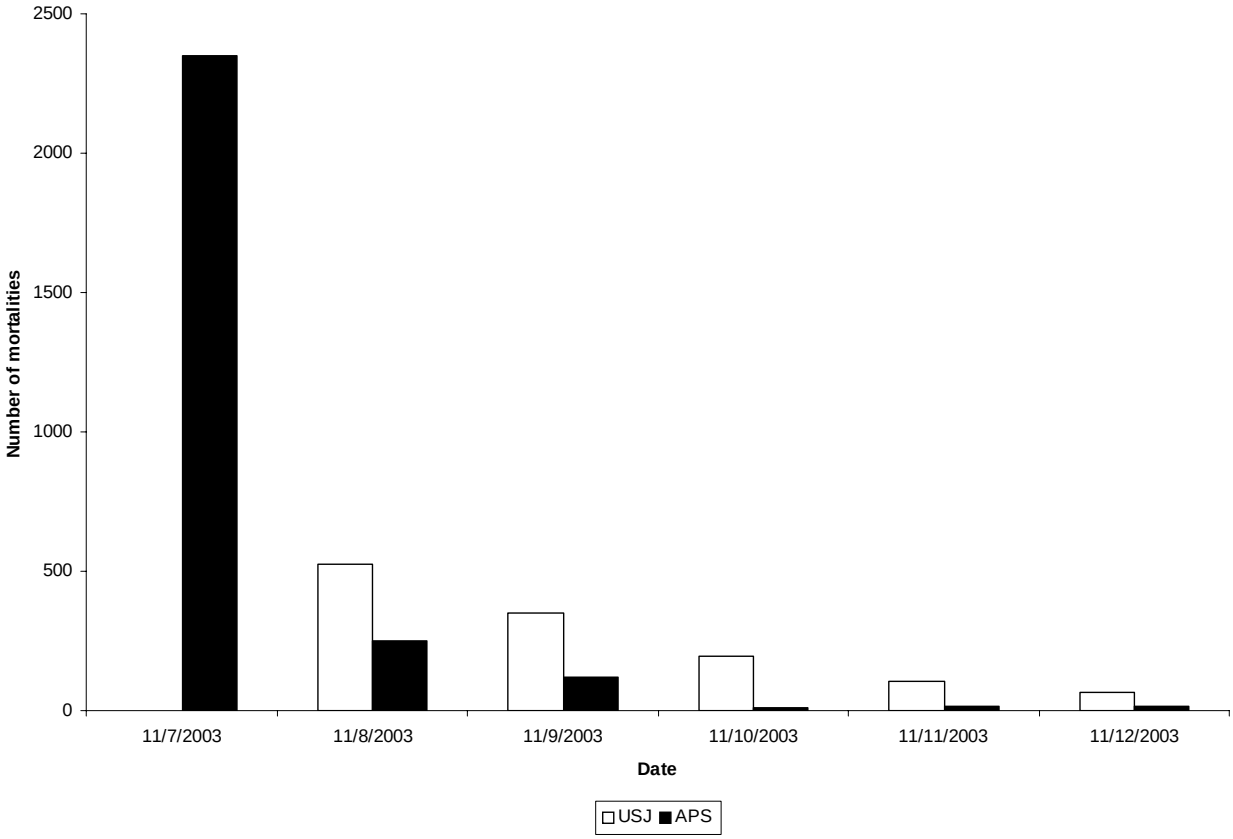

Figure 35. Number of Colorado pikeminnow mortalities observed during the acclimation experiments in November 2003. USJ = Upper San Juan station and APS = APS Weir to Hogback Diversion station.

When we released the remaining stocked Colorado pikeminnow from acclimation areas on November 12, 2003, we estimated the number of survivors. At best, we released around 2,200 Colorado pikeminnow from the Upper San Juan station acclimation areas and 3,200 Colorado pikeminnow from the APS Weir to Hogback Diversion station acclimation areas (Figure 36). We preserved 50–100 mortalities on dry ice and sent them to DNFHTC for necropsy. The fish appeared to have died from multiple internal organ hemorrhages, which is symptomatic of acute stress.

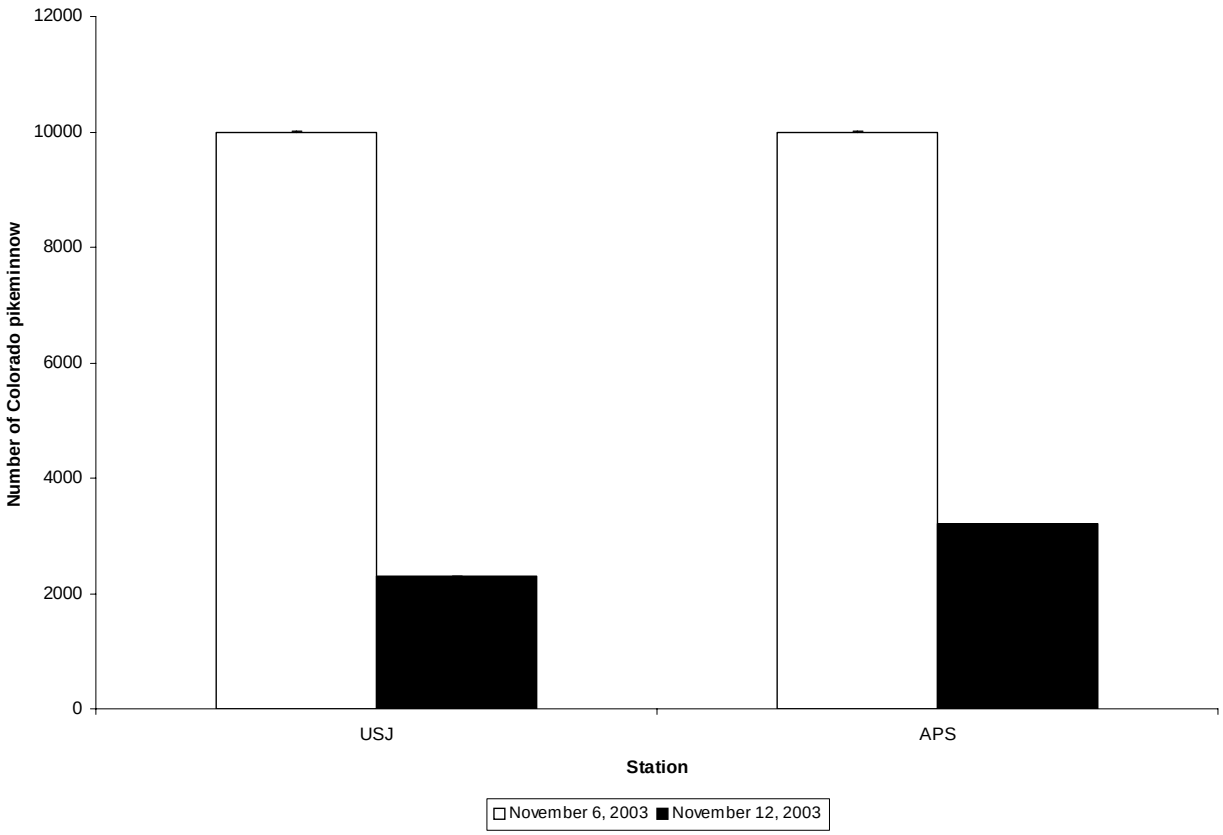

Figure 36. Number of Colorado pikeminnow stocked into acclimation areas on November 6, 2003, and the maximum estimated number released alive on November 12, 2003.

During the December 2003 sampling trip, we examined all YOY Colorado pikeminnow for the presence of the calcein dye, but we did not find any marked fish. In one APS Weir to Hogback Diversion station side channel, we were certain that we recaptured acclimated fish. We preserved one of these fish on dry ice and sent it to DNFHTC for further analysis. They found that the dye could be seen under laboratory conditions, but it could not be seen under field conditions. Therefore, we could not differentiate the acclimated fish from the general stocked fish population.

2004 We found very few good areas in which to acclimate fish in the two monitoring stations we chose for these studies in 2004 (Below Fruitland Diversion and APS Weir to Hogback), which was problematic. In attempts to find five to ten good acclimation areas in each station, we used some marginal side channels and other low-velocity shoreline habitats (Figure 37). Within the first 48 hours, we found that our nets had been noticeably breached or that marked fish were outside of the acclimation areas at all five areas in the Below Fruitland Diversion station and two of the three areas in the APS to Hogback station (Figure 38). Only one of our acclimation areas remained unbreached for the full 7 days. This area consisted of a large side channel in the APS to Hogback station at RM 160.9, where mortality experiments were also completed (see Holden and Golden 2005 for a more complete description). We had placed 7,000 of the VIE-marked YOY Colorado pikeminnow in this area.

Acclimated fish made up 9.5% of the YOY Colorado pikeminnow we collected during the November 2004 monitoring trip (Figure 39). Acclimated fish comprised 7.1% (20,000 of 280,000) of the total number of YOY Colorado pikeminnow stocked in October 2004, and we found no significant difference between the observed proportion and what we expected (chi square). During the March and July 2005 sampling trips we found that the proportion of the total number of acclimated Colorado pikeminnow declined, but no significant differences were detected between the observed and expected proportions.

We also compared the proportion of acclimated Colorado pikeminnow collected in the two monitoring stations where they were held with what would be expected based on the percentage of marked fish stocked at or above each station. The proportion of acclimated fish collected in the Below Fruitland Diversion station during our November 2004 sampling trip was similar (5.7%) to our expectations based on the number of fish stocked (5.9%). The USFWS stocked 160,000 Colorado pikeminnow in this station in the 2 weeks prior to sampling, 100,000 of which were stocked 4 days before we sampled this reach. The newly stocked fish could have been the majority of unmarked Colorado pikeminnow we collected in this reach. The proportion of acclimated fish we collected in March and July declined slightly, but it remained similar to our expectations based on the total number of fish stocked. We found no significant differences.

Figure 37. A marginal (a) shoal habitat and (b) side channel habitat used for Colorado pikeminnow acclimation in October 2004.

Figure 38. Breached side channel habitat during acclimation experiments in October 2004.

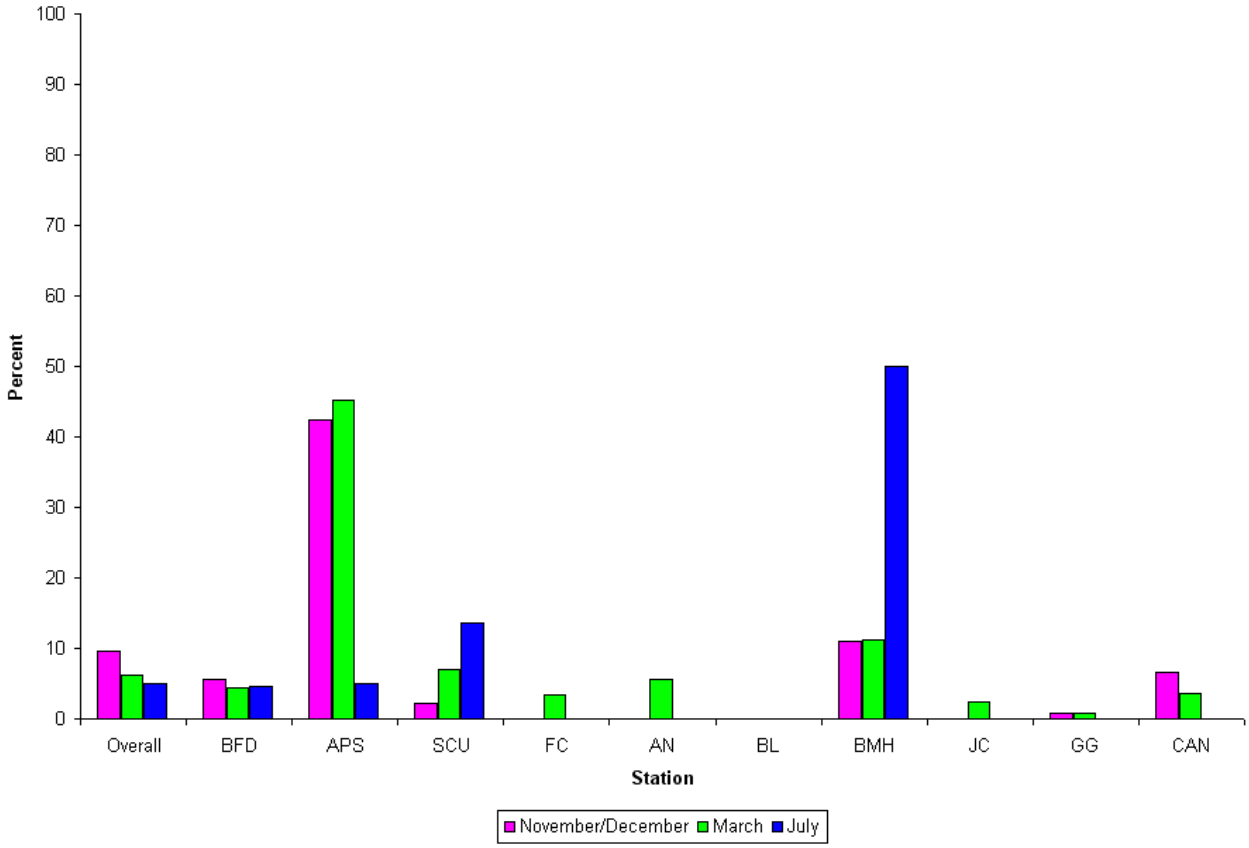

Figure 39. Percentage of the total number of Colorado pikeminnow collected at each station during monitoring trips following the 2004 stocking effort that had been previously marked with visible implant elastomer (VIE).

Contrary to the total proportion of acclimated fish collected and the proportion of acclimated fish collected in the Below Fruitland Diversion station, the proportion of acclimated fish we collected in the APS Weir to Hogback station appeared higher than we expected (10.5%) in both November 2004 and March 2005, but these differences were not significant. This station had the only acclimation area that held fish for the entire 7 days, which may explain the elevated proportion of acclimated fish collected in this reach. The proportion of Colorado pikeminnow collected in July in the APS Weir to Hogback station was more similar to what we expected based on the ratio of fish stocked, but by this time fish had had over 9 months to disperse and growth may have begun to reduce the visibility of the VIE marks.

2005 In 2004 we found that using acclimation areas less affected by flow change resulted in relatively high fish retention. Therefore, in 2005 we used two acclimation areas for 20,000 VIE-marked fish in October. We did not detect any breaches or marked Colorado pikeminnow outside the net pens at RM 175.8 throughout the entire 7-day acclimation period. We found breaches in the block nets at the side channel near RM 167.4 the day after fish were released and low numbers of fish outside the nets. We further secured the nets, and seining confirmed that large numbers of Colorado pikeminnow were still in the side channel. Therefore, we feel that the majority of the 20,000 Colorado pikeminnow were acclimated for the full 7 days.

Acclimated Colorado pikeminnow comprised 6.6% (20,000 of 302,000) of the total number of fish stocked, so we expected to catch a similar percentage of VIE-marked Colorado pikeminnow during our monitoring trips if acclimated and nonacclimated fish were retained at the same rate. Instead, we found that nearly 20% of the Colorado pikeminnow collected during the November 2005 monitoring trip were VIE marked (Figure 40), but this difference was not significant. The majority of these (182) were collected in the Below Fruitland Diversion station, where we acclimated 6,000 Colorado pikeminnow at RM 175.8. The proportion of marked fish we collected in the Below Fruitland Diversion station (41.7%) was higher than what we expected based on the proportion of marked fish stocked in that reach (7.0%), but again the difference was not significant. Recently collected data from March 2006 showed a similar trend of increased proportions of VIE-marked fish in the Below Fruitland Diversion and APS Weir to Hogback stations (BIO-WEST unpublished data).

We observed upstream movement of acclimated Colorado pikeminnow for the first time. We collected 109 VIE-marked Colorado pikeminnow between 0.16 and 1.29 km (0.1 and 0.8 mile) upstream from the acclimation area in the Below Fruitland Diversion reach. Both locations where fish were collected were on the opposite side of the river, indicating that the fish moved against the current to get to these locations. We feel that the primary reason for the movement was that the habitat in which we had acclimated the 6,000 Colorado pikeminnow had become shallow and clear (Figure 41). We only collected three Colorado pikeminnow from that area, one of which was marked. In addition to observing upstream movement, we found very few (eight) VIE-marked Colorado pikeminnow downstream from Hogback Diversion and none below RM 103.3, which may indicate less downstream drift by acclimated fish. Recently collected data from March 2006 also showed very few marked fish in areas downstream of Hogback Diversion (BIO-WEST unpublished data).

Combined Influence on Catch Rate

The goal of both the changes in stocking protocol and the acclimation studies was to increase the retention of Colorado pikeminnow in the upper portions of their critical habitat. Specifically, the SJRIP wanted to increase retention above the Hogback Diversion. Our Below Fruitland Diversion and APS Weir to Hogback Diversion stations are both above Hogback Diversion. No statistically significant differences can be identified among years at those two stations because of

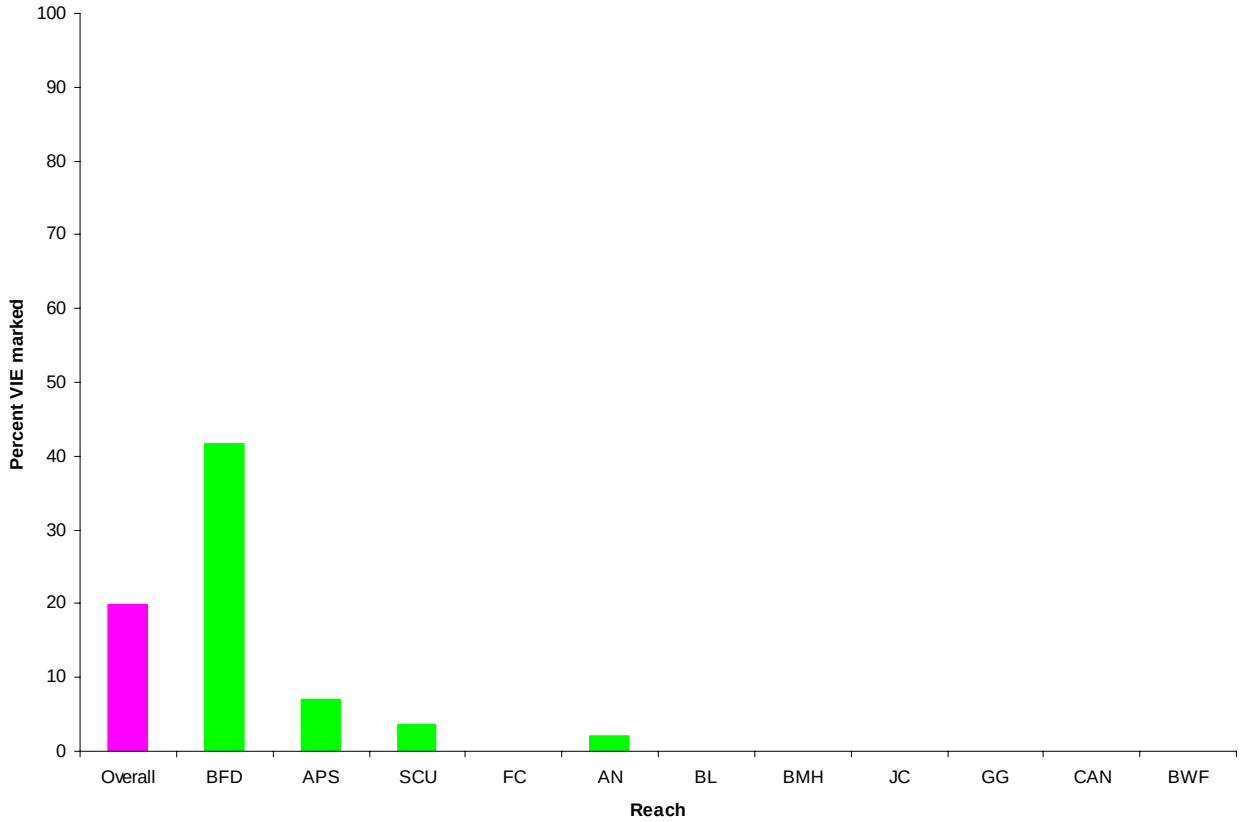

Figure 40. Percentage of the total number of Colorado pikeminnow collected at each station during the November 2005 monitoring trip that had been previously visible implant elastomer (VIE) marked.

Figure 41. October 2005 acclimation area at RM 175.8 in (a) October 2005 and (b) November 2005.

extremely wide bootstrapped 95% confidence intervals. However, scaled average catch rates increased at both stations after the 2003 and 2004 stocking efforts, compared with the 2002 stocking effort during all three sampling trips (Figures 13 and 14). In addition, scaled catch rates in March and July after the 2004 stocking effort appeared to be higher than in March and July after the 2003 stocking effort. When we examined the combined average catch rate of the two stations, the 95% bootstrapped confidence intervals remained very wide, so no significant differences among sampling trips could be detected. However, the combined scaled catch rate data also show an elevated catch rate in 2004 over 2003 (Figure 42). The apparent scaled catch rate increase from the 2002 to 2003 stocking effort may be related to the changes in stocking protocol, whereas additional apparent increases in scaled catch rates in 2004 may be related to the one successful acclimation area in the APS to Hogback station. Unfortunately, changes in environmental conditions and habitat availability between years confound interpretation of these data.

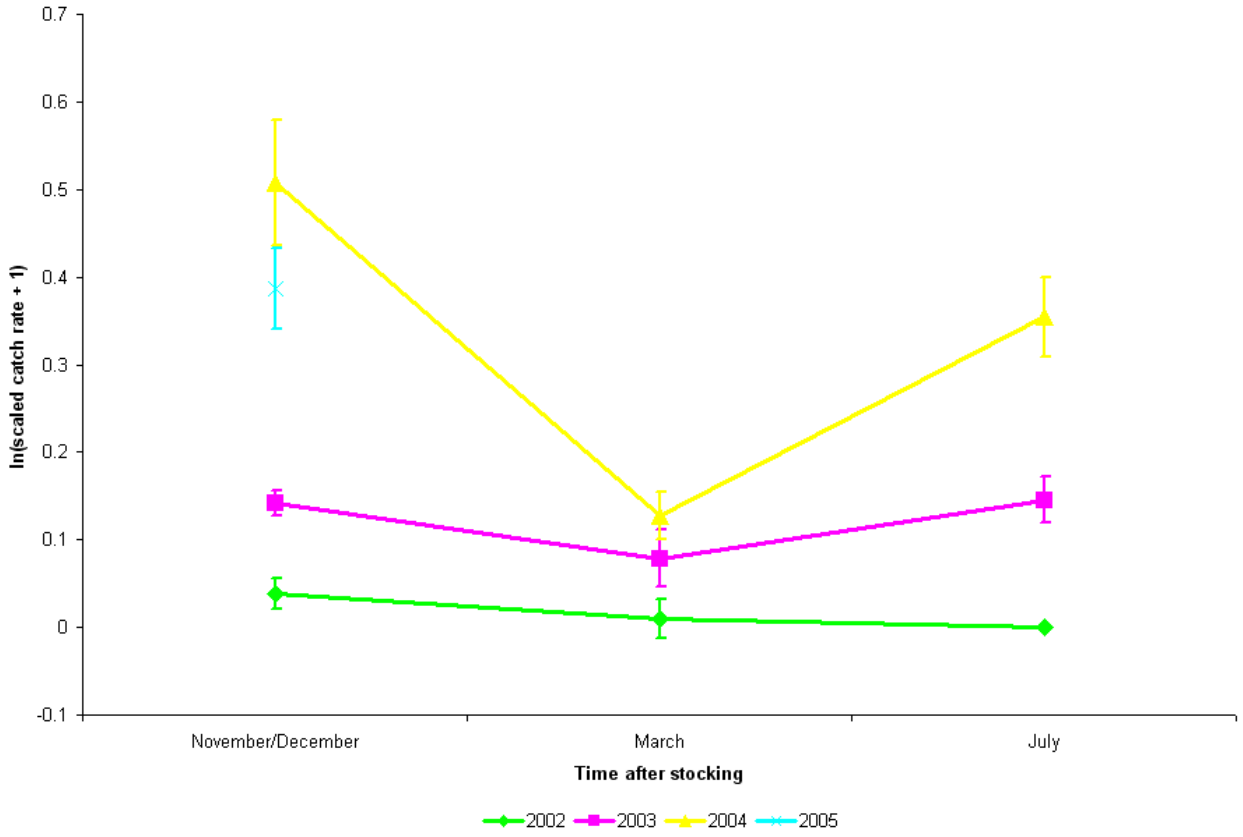

Figure 42. The combined scaled average catch rate at the Below Fruitland Diversion and APS Weir to Hogback Diversion stations during each monitoring trip between December 2002 and November 2005, using each seine haul as the sample unit. Error bars represent +/- one standard error.

Pilot Population Estimate

In summer and early autumn 2005, we attempted a pilot population estimate for age-1 and age-2 Colorado pikeminnow using mark and recapture methodologies. Cooperators from the SJRIP marked 281 Colorado pikeminnow during late July and early August 2005 (Table 16). The majority (73%) of these fish were smaller than 150 mm, and cooperators marked them with VIE tags. We collected 96% of the Colorado pikeminnow smaller than 150 mm by block seining, while other cooperators collected 73% of Colorado pikeminnow larger than 150 mm by electrofishing.

Table 16. Number of Colorado pikeminnow marked using visible implant elastomer (VIE) or passive integrated transponder (PIT) tags by cooperators in July/August 2005.

PROJECT [a]	GEAR TYPE	VIE TAGGED (< 150 mm total length)	PIT TAGGED (> 150 mm total length)	TOTAL
YOY Colorado Pikeminnow	Block Seine	198	20	218
NMFRO Nonnative Removal	Electrofishing	4	33	37
UDWR Nonnative Removal	Electrofishing	4	22	26
	Total	**206**	**75**	**281**

[a] YOY=young-of-year, NMFRO=New Mexico Fisheries Resource Office, UDWR=Utah Division of Wildlife Resources.

Cooperators collected less than half the number of Colorado pikeminnow during annual fall monitoring, which was the "recapture" portion of the study, compared with cooperators during the "mark" period in late July and early August (Table 17). Researchers collected 98% of these fish during large-bodied fish monitoring, and 92% were larger than 150 mm. During fall monitoring researchers only recaptured two Colorado pikeminnow (0.7%) marked during the July/August 2005 mark trip. The models in Program MARK have difficulty generating a population estimate with such a low number of recaptures, which lowers the precision of the population estimate and can cause a positive bias estimate (Ricker 1975). Capture probabilities, or the percentage of recaptures, should be greater than 10 percent to generate a precise estimate (Otis et al. 1978). Since our percentage of recaptures was less than 1%, we did not generate a population estimate from our data. However, SJRIP cooperators handled 409 individual Colorado pikeminnow during the mark and recapture periods, so that is the minimum population size.

Table 17. Total number of Colorado pikeminnow collected and number of recaptures collected from the July/August mark period during the September/October 2005 fall monitoring. Number in parentheses indicates the number of recaptures.

PROJECT	GEAR TYPE	LARGER THAN 150 mm	SMALLER THAN 150 mm	TOTAL
Large-bodied fish monitoring	Electrofishing	116 (2)	11 (0)	127 (2)
Small-bodied fish monitoring	Seine	3 (0)	0	3 (0)
	Total	**119 (2)**	**11 (0)**	**130 (2)**

Colorado Pikeminnow Growth

Young-of-Year (YOY) Colorado Pikeminnow Monitoring

Colorado pikeminnow grew little during the first 5 months following stocking, but the size of Colorado pikeminnow at stocking varied slightly among study years. The average size of age-0 Colorado pikeminnow we collected during the initial monitoring trip in 2003 and 2005 was 5–7 mm larger than in 2002 and 2004 (ANOVA, $p < 0.0001$, Figures 43 and 44). Colorado pikeminnow stocked in 2003 remained significantly larger than those stocked in 2002 and 2004 through the March sampling trip (ANOVA, $p < 0.05$). We did not observe a significant increase in standard length between the initial monitoring trip and the March monitoring trip after stocking in 2002 and 2003, but average standard length of Colorado pikeminnow stocked in 2004 increased by 2.5 mm between the initial monitoring trip and March ($p < 0.001$). However, instantaneous growth rates between the initial and March monitoring trips showed essentially no increase in length during between the initial sampling trip and the March sampling trip in all 3 years (Table 18).

Colorado pikeminnow grew to a significantly larger average size between March and July of all three study years (ANOVA, $p < 0.001$). This increase in growth was also apparent in the instantaneous growth rates between March and July of each year. Colorado pikeminnow stocked in 2004 had a slower rate of growth between March and July than Colorado pikeminnow stocked in 2002 and 2003. During July sampling trips average standard length of Colorado pikeminnow stocked in 2004 was significantly smaller (24 mm) than Colorado pikeminnow stocked in 2003, and 10 mm smaller than the two Colorado pikeminnow we collected in July after the 2002 stocking effort (*t*-test, $p < 0.001$).

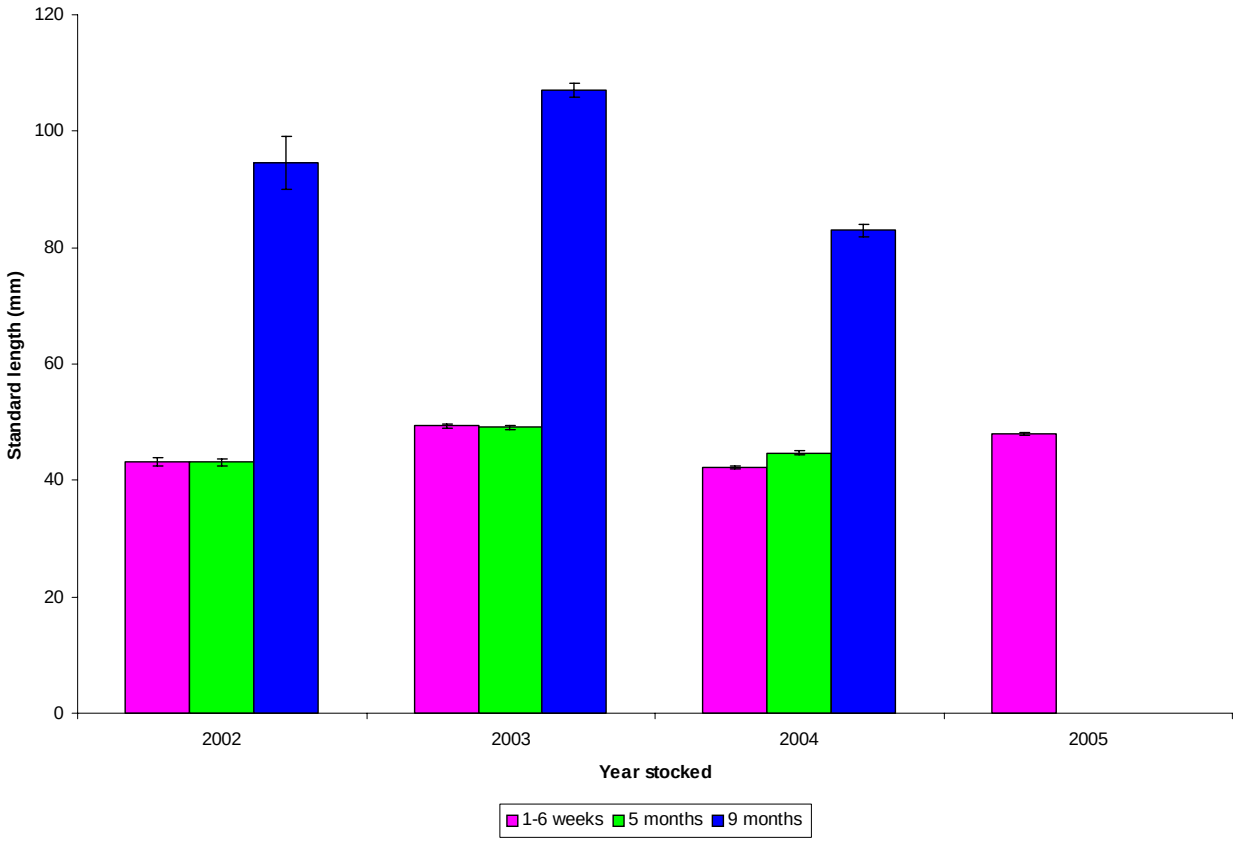

Figure 43. Average standard length of Colorado pikeminnow stocked at age 0 and collected at various time intervals after stocking in 2002, 2003, 2004, and 2005. Error bars equal +/- one standard error.

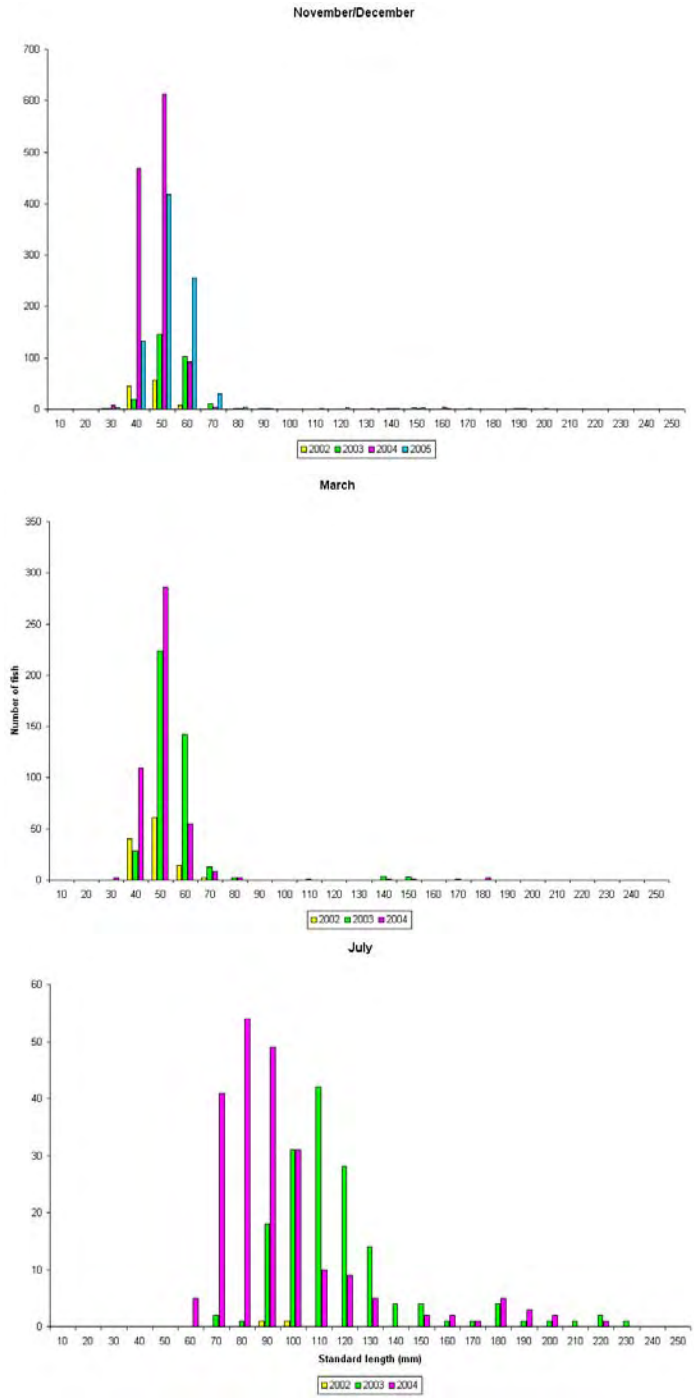

Figure 44. Length frequency histograms of standard length (mm) of Colorado pikeminnow caught in November/ December, March, and July following stocking efforts in all study years.

Table 18. Instantaneous growth rates between sampling trips after the 2002, 2003, and 2004 stocking efforts. Growth rates were calculated from average standard lengths of fish stocked as age-0 fish in those years.

Time period	2002	2003	2004
Dec–March	-0.001	-0.005	0.043
March–July	0.618	0.614	0.487

Other San Juan River Basin Recovery Implementation Program (SJRIP) Projects

As with catch rate information, cooperators conducting a variety of other SJRIP-funded projects collected data on the size of Colorado pikeminnow in the San Juan River. Prior to embarking on an examination of the additional information on Colorado pikeminnow growth, we felt it prudent to illustrate the size-related bias in the gear types used for the YOY Colorado pikeminnow project along with other SJRIP research and monitoring programs. Examining length data collected by different cooperators shows that the gear types are biased in regard to the size of Colorado pikeminnow that they most effectively collect. Seining is biased toward collecting smaller (< 100 mm TL) Colorado pikeminnow, which is well evidenced by our failure to collect many Colorado pikeminnow in July 2003, and by other SJRIP projects using seines as their primary methodology (Figure 45). Block seining and raft-mounted electrofishing are more effective at catching Colorado pikeminnow larger than 100 mm TL, but they also differ in their ability to collect different size classes of fish.

The NMFRO and the UDWR conducted nonnative removal electrofishing surveys roughly concurrent with our July Colorado pikeminnow surveys after the 2003 and 2004 stocking efforts. The average total length of Colorado pikeminnow collected during July UDWR and NMFRO raft-mounted electrofishing surveys was 77 mm and 91 mm larger, respectively, than Colorado pikeminnow collected using block seining during our concurrent YOY Colorado pikeminnow monitoring in 2004 and 2005 (Figure 46, $p < 0.001$). When looking specifically at age-1 fish from the prior autumn's stocking efforts, this difference is not as clear (Figure 47). While electrofishing cooperators collected significantly larger age-1 Colorado pikeminnow than block seining cooperators (115 mm vs. 106 mm, $p = 0.007$) in July 2005, block seining cooperators collected significantly larger age-1 Colorado pikeminnow in July 2004 (133 mm vs. 110 mm, $p < 0.03$). Part of the difference seen in July 2004 may have been a result of the low number of age-1 individuals ($n = 6$) collected using raft-mounted electrofishing.

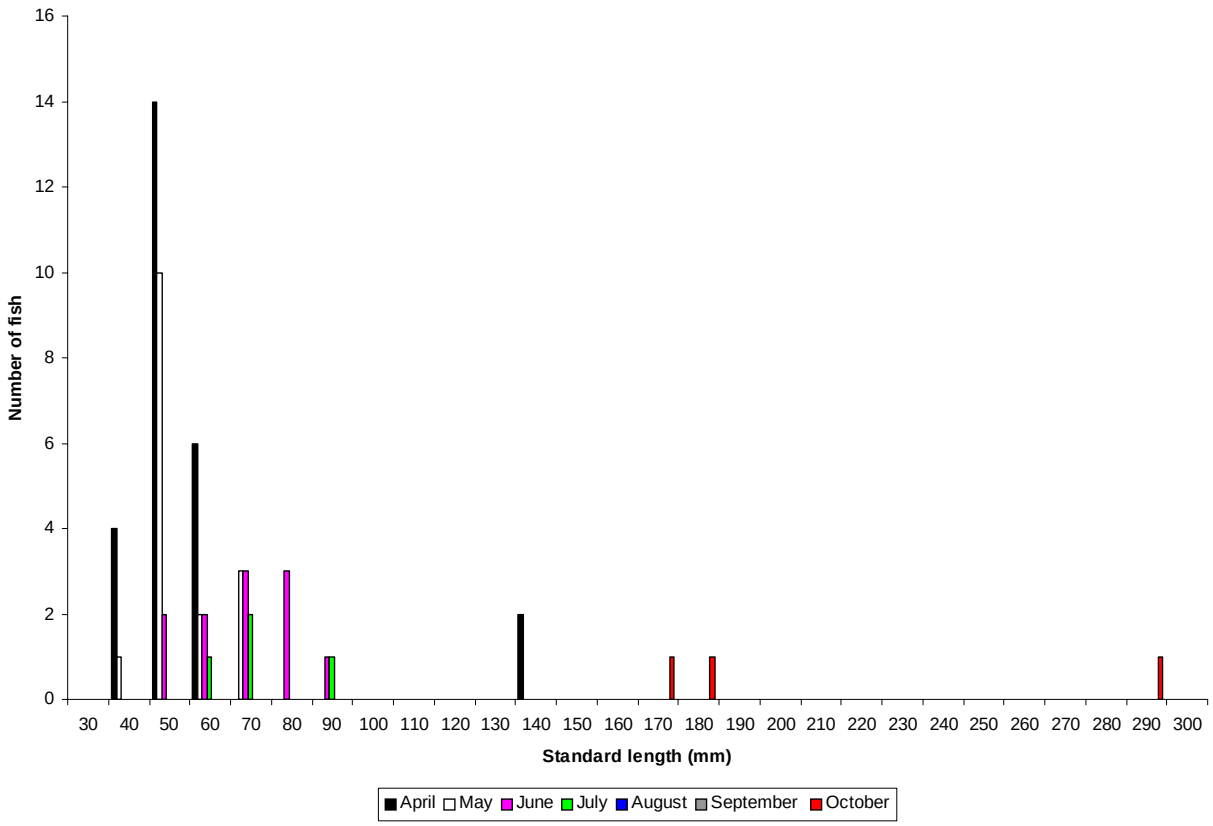

Figure 45. Length frequency histogram of the standard length of Colorado pikeminnow collected by seining from April–October 2005.

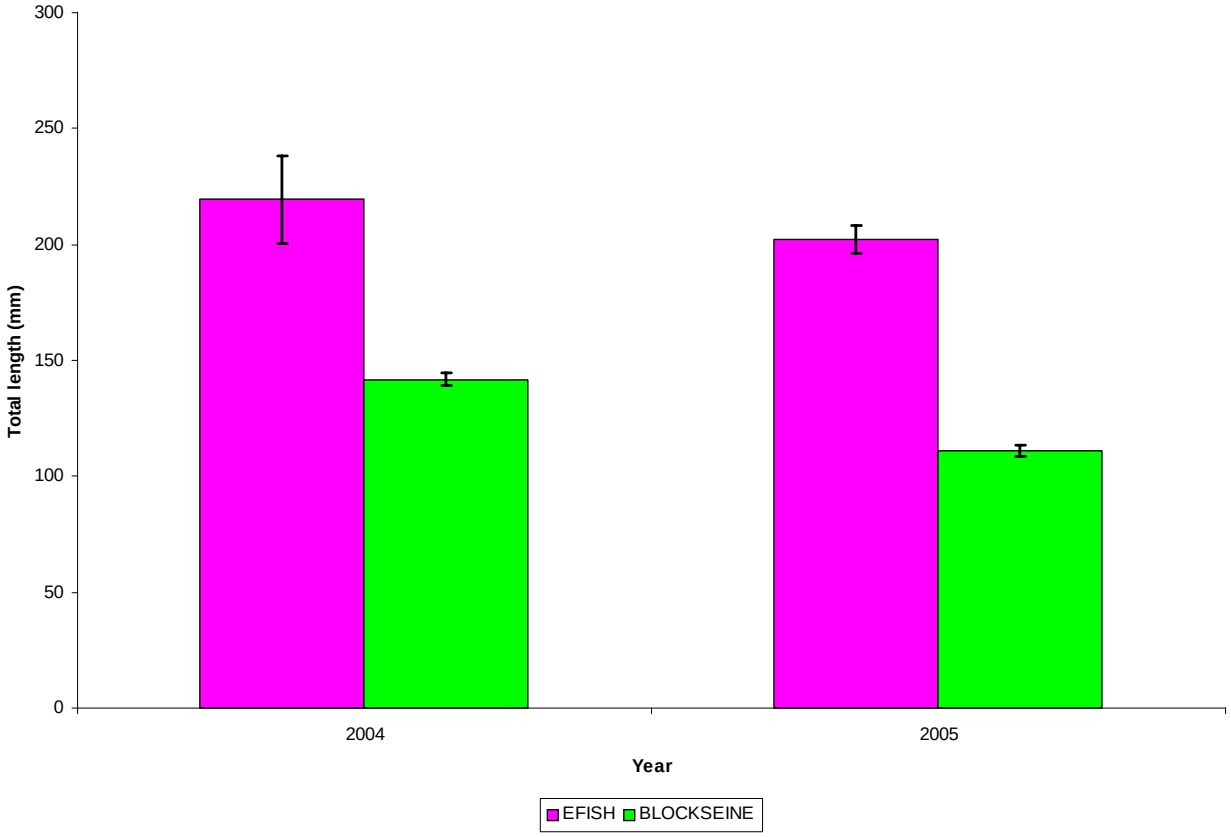

Figure 46. Average total length (TL) of all Colorado pikeminnow collected by raft-mounted electrofishing and block seining in July 2004 and 2005. Error bars represent +/- one standard error.

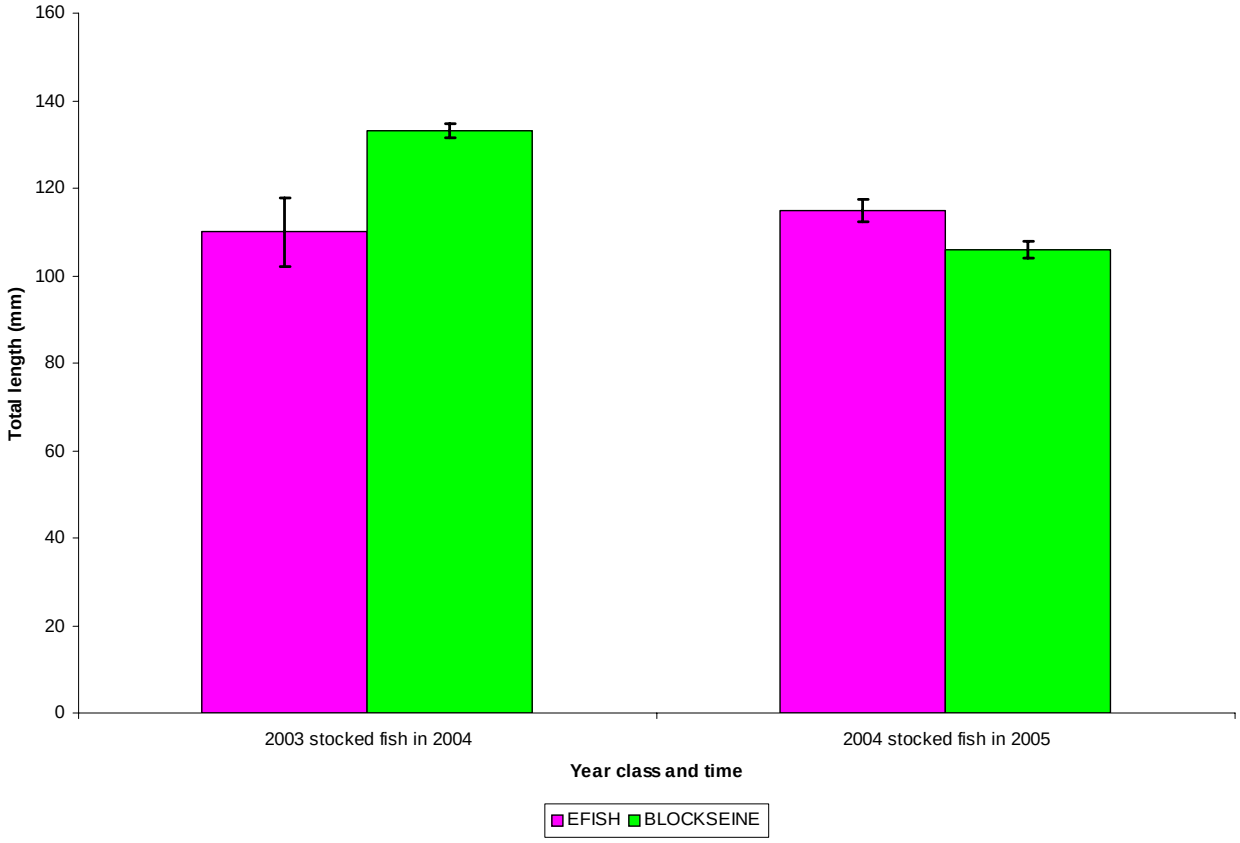

Figure 47. Average total length (TL) of Colorado pikeminnow stocked as age-0 fish in 2003 and 2004 collected as age-1 fish by raft-mounted electrofishing and block seining in July 2004 and 2005. Error bars represent +/- one standard error.

Since raft-mounted electrofishing appeared to be the most effective for collecting Colorado pikeminnow once they exceeded 150–200 mm TL, we decided to use data from electrofishing surveys in September and October 2003–2005 to further evaluate growth of Colorado pikeminnow stocked as age-0 fish from 2002–2004 (Figure 48). As with data from the July YOY Colorado pikeminnow monitoring trips, autumn electrofishing captures indicated that Colorado pikeminnow stocked in 2004 were significantly smaller in autumn one year after stocking than Colorado pikeminnow stocked in 2002 or 2003 (ANOVA, $p < 0.001$). In addition, while Colorado pikeminnow stocked in 2003 appeared to be the same size as Colorado pikeminnow stocked in 2002 one year after stocking, they were significantly smaller than Colorado pikeminnow stocked in 2002 two years after stocking (*t*-test, $p < 0.01$). We also found evidence that the Colorado pikeminnow stocked in 2004 grew more slowly over their first year than those stocked in 2002 and 2003 when we calculated instantaneous growth rates (Table 19). Instantaneous growth rate calculations indicated slower growth between our initial monitoring trip and the following autumn for Colorado pikeminnow stocked in 2003 and 2004.

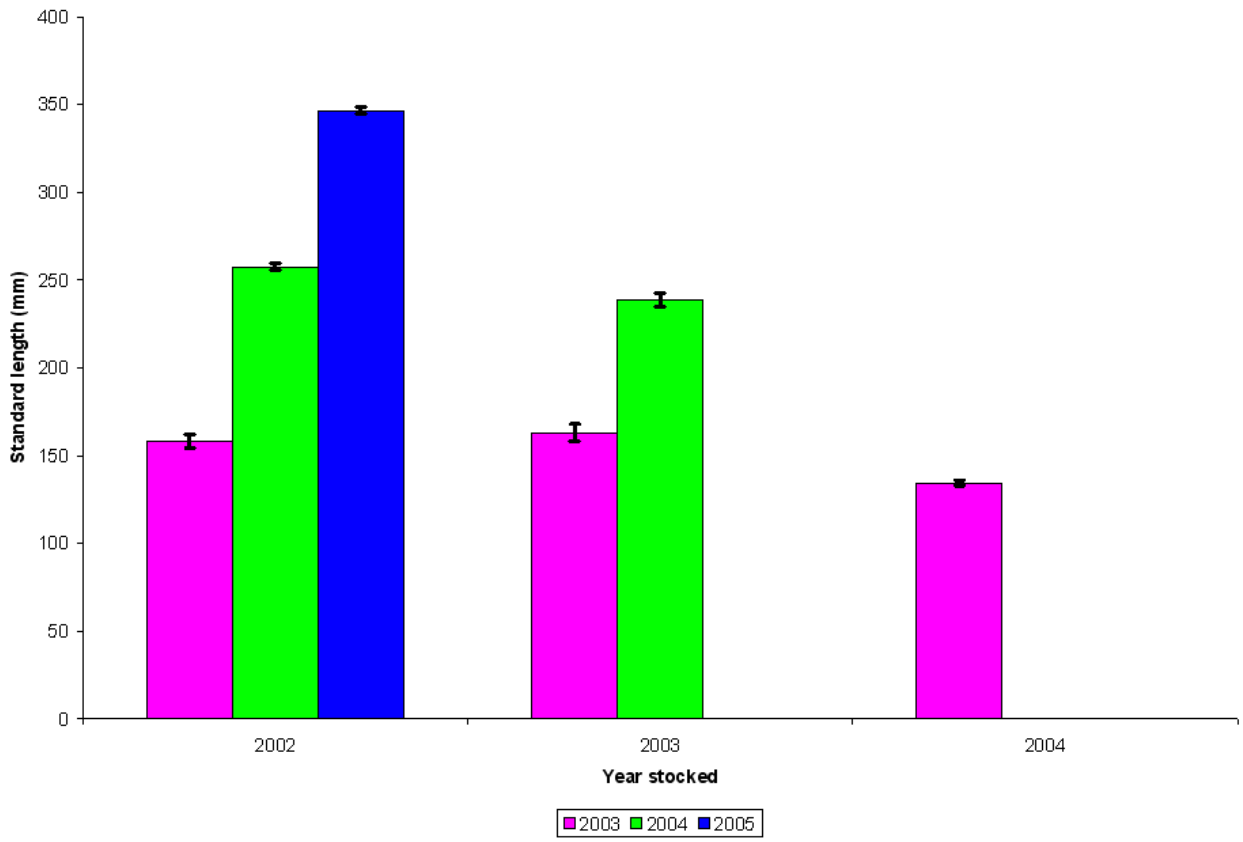

Figure 48. Average standard lengths of Colorado pikeminnow stocked as age-0 fish from 2002-2004 and collected during electrofishing surveys conducted in September and October 2003-2005.

Table 19. Instantaneous growth rates for Colorado pikeminnow stocked as age-0 fish from 2002-2004.

TIME	2002	2003	2004
Stocking to first autumn	0.42	0.39	0.35
First autumn to second autumn	0.13	0.10	
Second autumn to third autumn	0.08		

Colorado Pikeminnow Habitat Use

While much of the previous monitoring for YOY Colorado pikeminnow in the San Juan River focused on side channels and backwaters (Propst and Hobbes 1999, Trammel and Archer 2000), we attempted to sample a wider diversity of low-velocity habitats (Golden et al. 2004). The percentage of main channel and side channel habitats that we sampled varied among sampling trips (Figures 49–51). The initial sampling trips after stocking efforts had the most variability in the percentage of side channel vs. main channel habitat sampled. We sampled a higher percentage of side channel habitat after the 2003 and 2005 stocking efforts than after the 2002 and 2004 stocking efforts. The percentage of side channel habitat sampled in March and July of each study year was much more consistent among years.

Using all samples from all study years (excluding the Upper San Juan and Lower Animas stations), we compared the proportion of Colorado pikeminnow found in side channel and main channel habitats with the proportion of samples we took in those channel types. We found that a higher proportion of Colorado pikeminnow occurred in side channel habitats than we expected, based on the percentage of samples we performed in side channel habitats (Table 20, chi-square, $p < 0.001$). When we combined data from all years according to time after stocking, we found Colorado pikeminnow in a significantly higher proportion than we expected in side channel habitats during initial monitoring trips (November/December) and July monitoring trips, but not March monitoring trips. While Colorado pikeminnow were found more often than expected in side channel habitats, we found no significant differences in the grand mean of scaled Colorado pikeminnow catch rates between side channel and main channel habitats using station as the sampling unit.

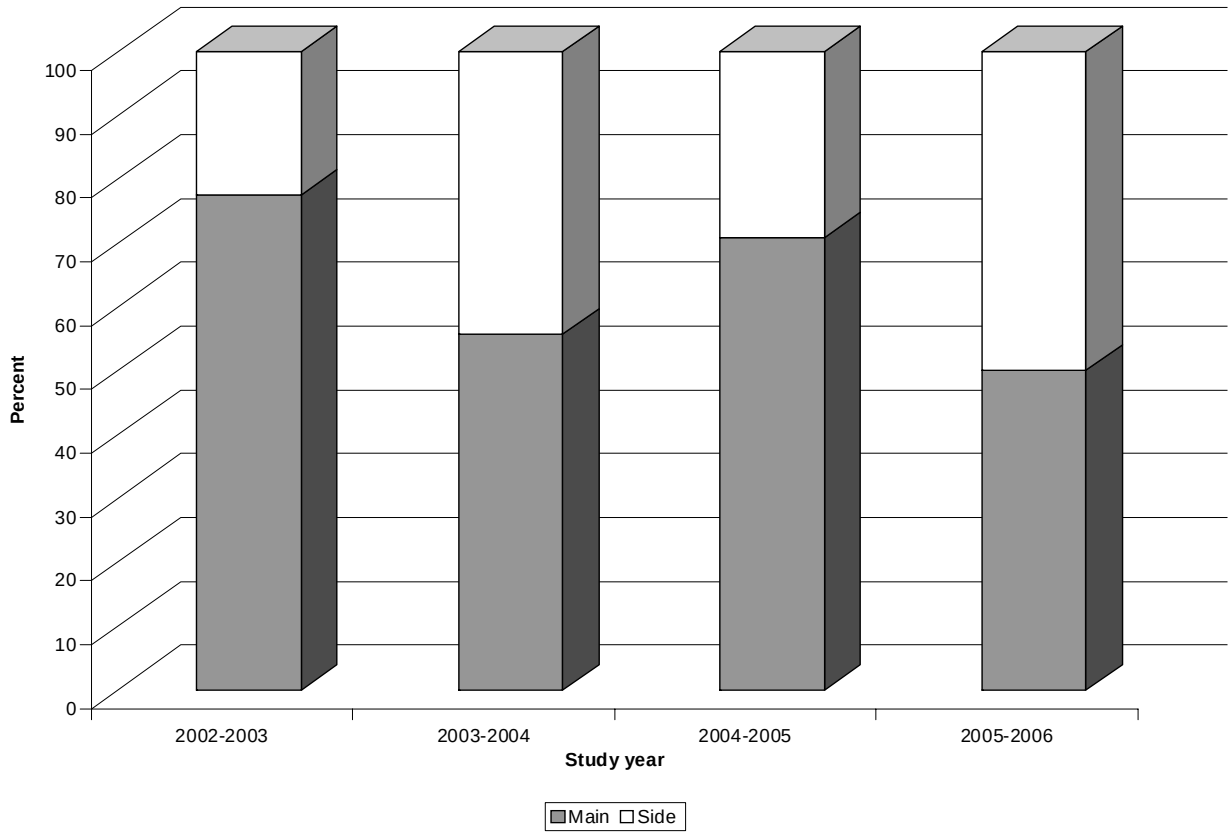

Figure 49. Percent of samples collected in the main channel and side channels during the initial sampling trip after stocking (November/December) from 2002-2005.

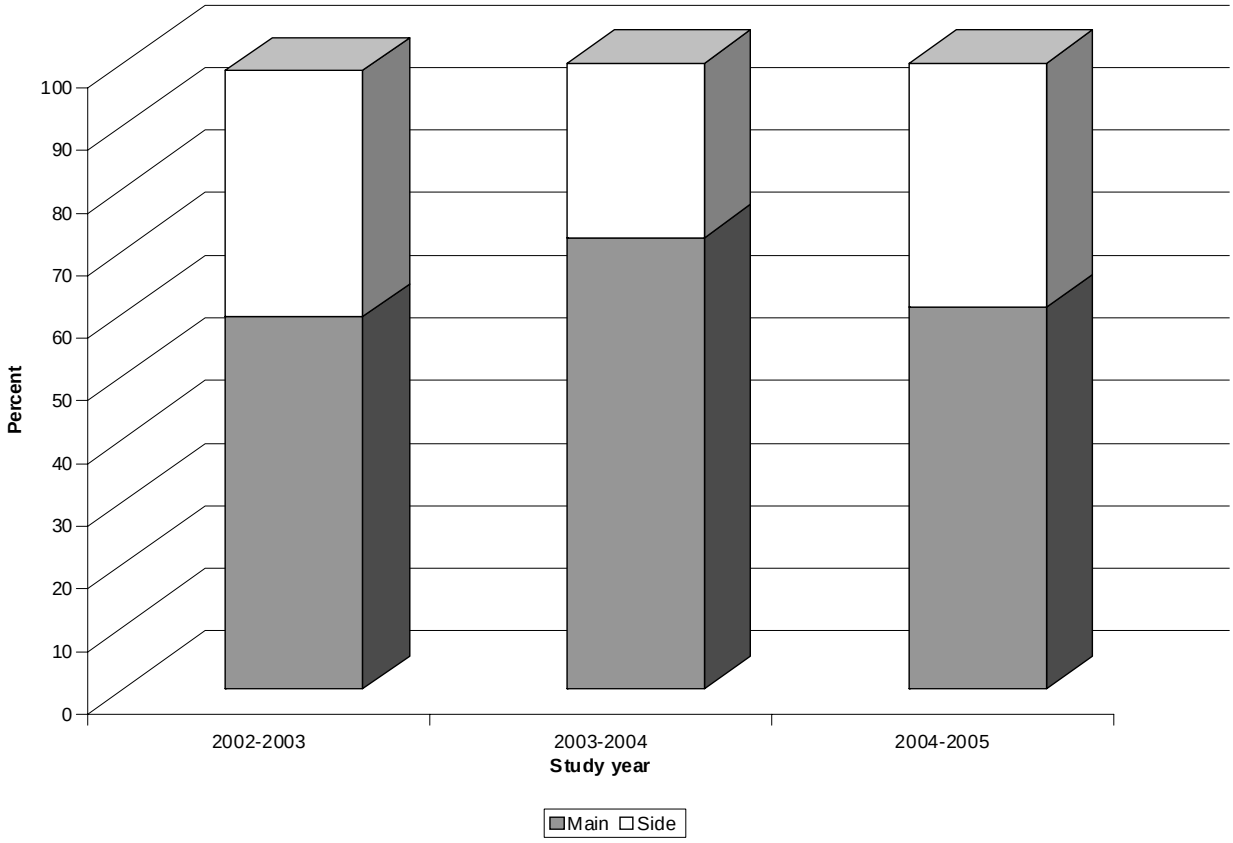

Figure 50. Percent of samples collected in the main channel and side channels during the March sampling trip after stocking (November/ December) from 2002-2005.

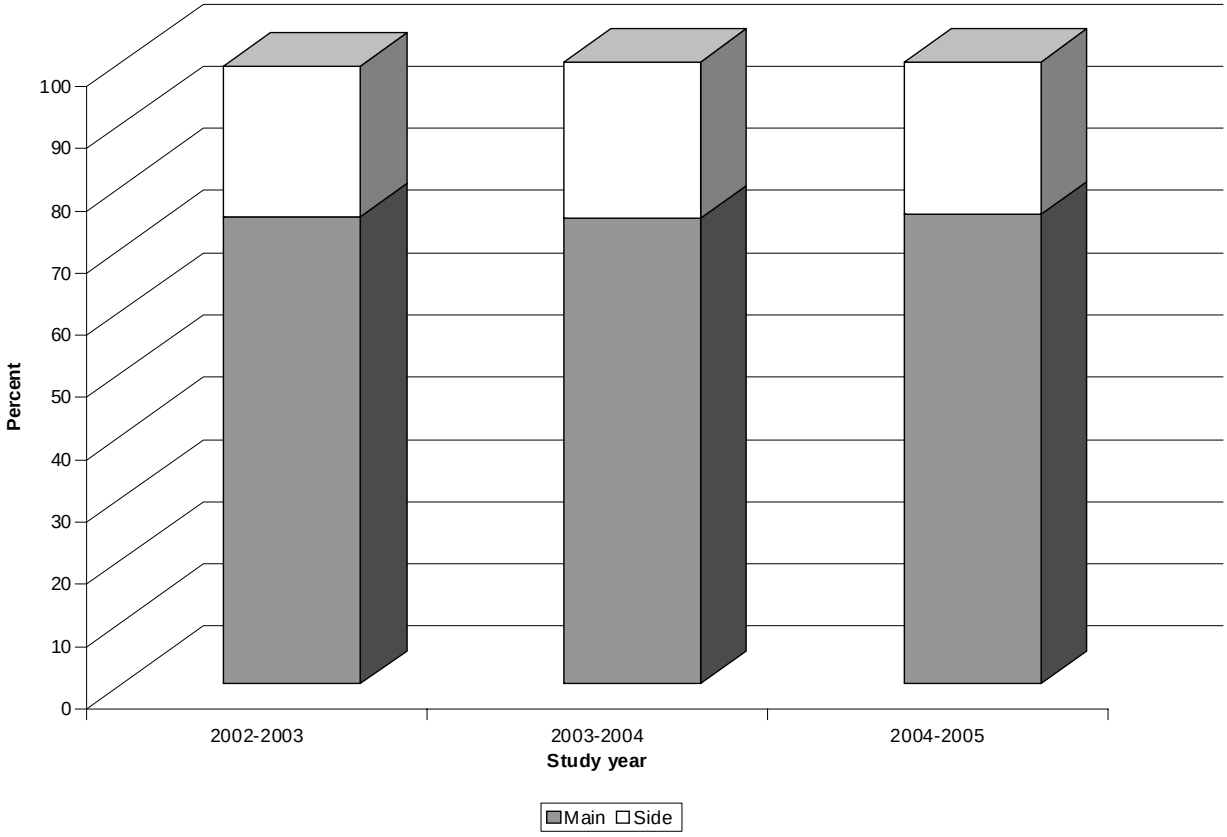

Figure 51. Percent of samples collected in the main channel and side channels during the July sampling trip after stocking (November/ December) from 2002-2005.

Table 20. Observed vs. expected number of samples containing Colorado pikeminnow (PTYLUC) in main channel habitats vs. side channel habitats.

SAMPLING TRIP	EXPECTED NUMBER OF SAMPLES WITH PTYLUC (main/side)	OBSERVED NUMBER OF SAMPLES WITH PTYLUC	CHI-SQUARE P-VALUE
All trips combined	541/269	456/354	< 0.001
November/December combined	179/106	134/151	< 0.001
March combined	234/124	218/140	0.07
July combined	125/41	104/62	< 0.001
December 2002	13/4	1/16	< 0.001
December 2003	33/26	19/40	< 0.001
November 2004	86/35	78/43	0.12
November 2005	44/44	36/52	0.08
March 2003	32/21	30/23	0.57
March 2004	107/42	107/42	0.94
March 2005	95/61	81/75	0.02
July 2003	1/0	1/0	0.57
July 2004	59/20	49/30	0.009
July 2005	65/21	54/32	0.006

Colorado pikeminnow showed trends in habitat use outside their use of main channel versus side channel habitats. We identified a wide variety of individual habitat types during sampling events from 2002–2005. For analysis purposes we condensed these habitats into 10 major types (Appendix A). We compared the proportion of habitats where Colorado pikeminnow were found in each habitat with the proportion of samples taken in each habitat type. In the initial (November/December) collections in all years, we found Colorado pikeminnow in a higher proportion of low-velocity habitats, particularly backwaters, than expected (Figures 52–54).

In December 2002, December 2003, March 2004, and March 2005, we found Colorado pikeminnow in a significantly higher proportion of backwater habitats than expected (chi-square, $p < 0.003$). In December 2002 and December 2003, we also found Colorado pikeminnow in a significantly higher proportion of debris type habitats than expected ($p < 0.003$). In March 2003, November 2004, and November 2005, we still found Colorado pikeminnow in a higher proportion of backwater type habitats than expected, but the differences were not

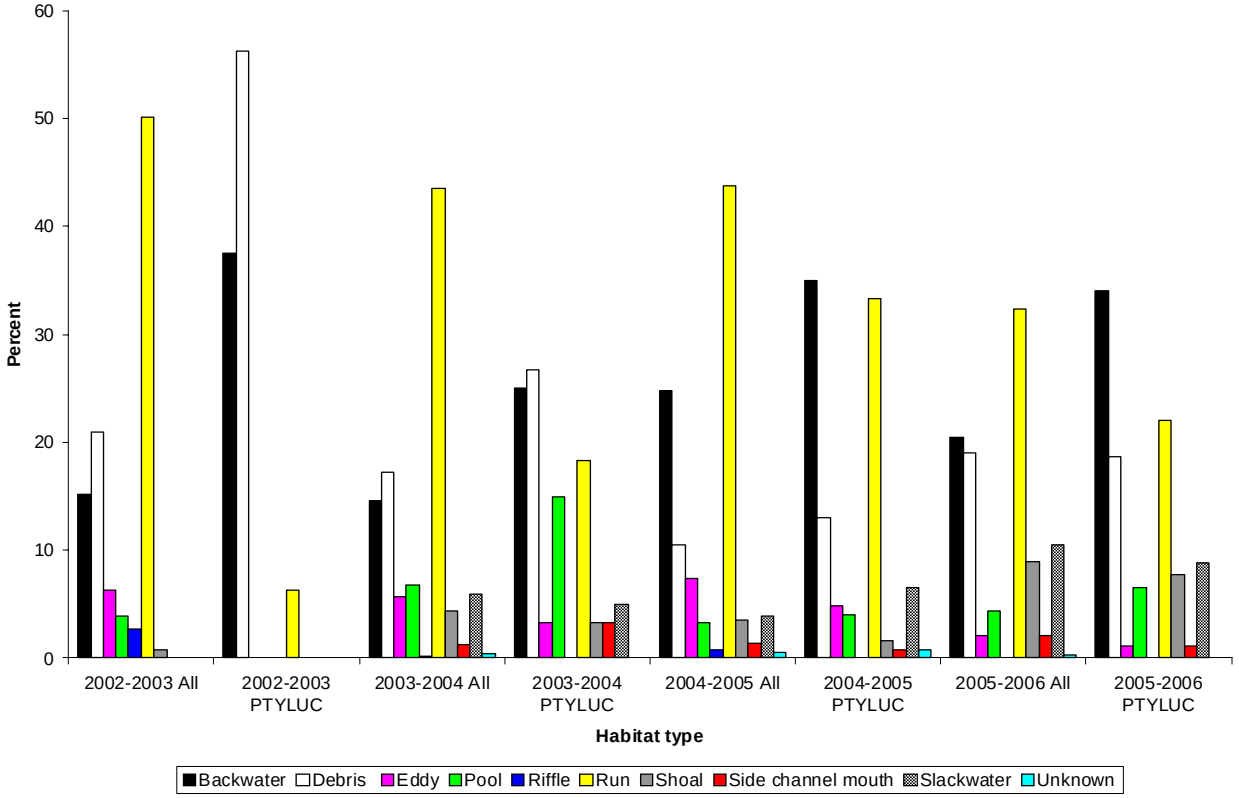

Figure 52. Proportion of all habitat types sampled and proportion of samples containing Colorado pikeminnow found in each habitat type during initial (November/December) monitoring trips in each study year. PTYLUC = Colorado pikeminnow.

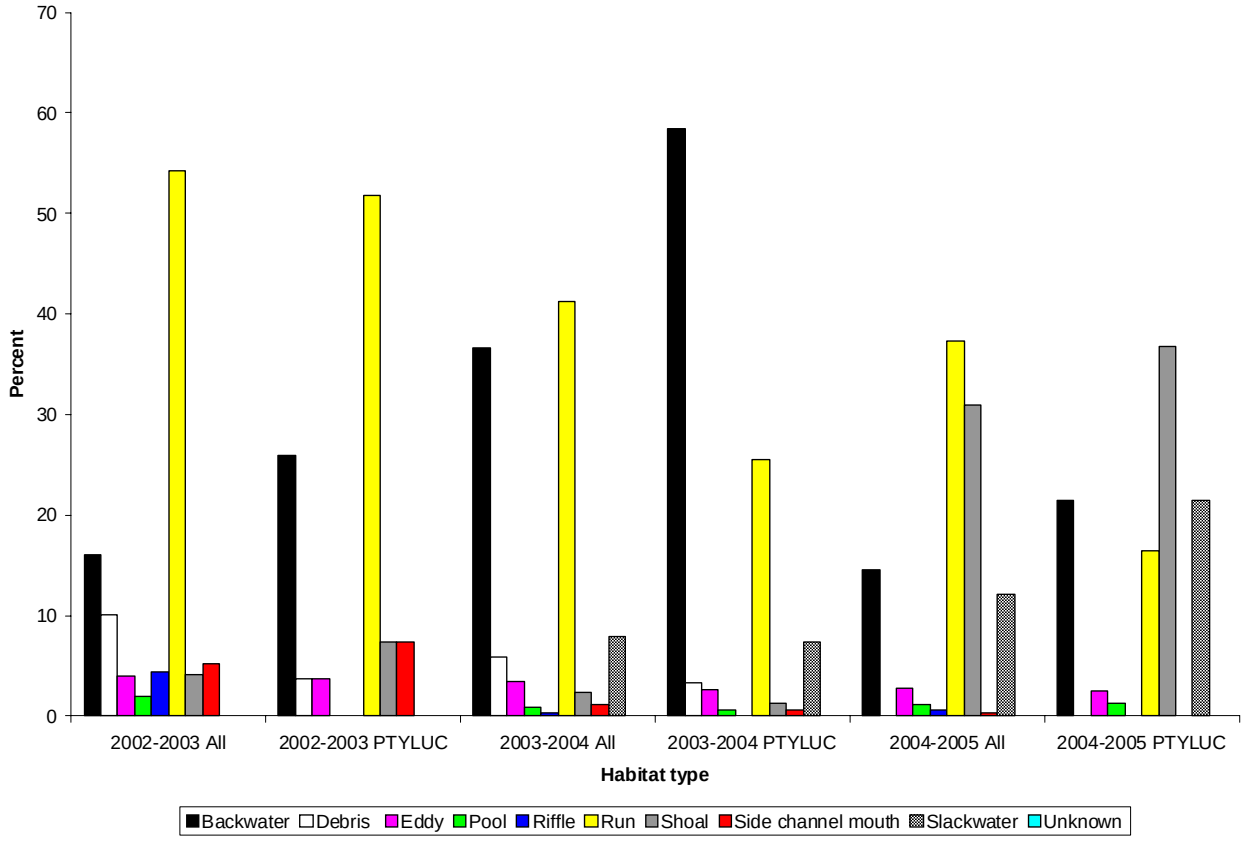

Figure 53. Proportion of all habitat types sampled and proportion of samples containing Colorado pikeminnow found in each habitat type during the March monitoring trips in each study year. PTYLUC = Colorado pikeminnow.

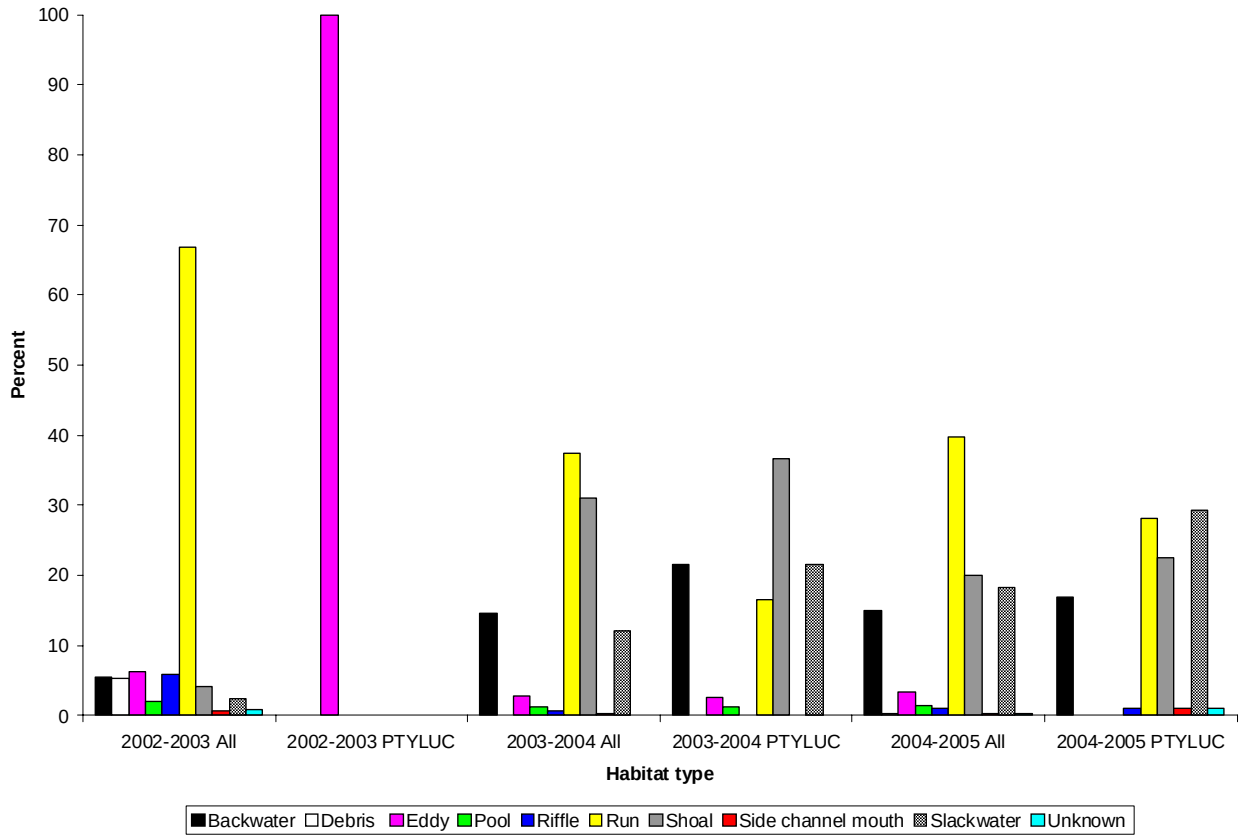

Figure 54. Proportion of all habitat types sampled and proportion of samples containing Colorado pikeminnow found in each habitat type during the July monitoring trips in each study year. PTYLUC = Colorado pikeminnow.

significant ($p = 0.08$ and $p = 0.09$). The importance of debris habitats appeared diminished during March sampling vs. December sampling.

In July 2003 we only collected two Colorado pikeminnow in one seine haul. Therefore, habitat use trends could not be determined. In July 2004 and July 2005, we found Colorado pikeminnow in a significantly higher proportion of slackwater habitats and lower proportion of run habitats than expected ($p \leq 0.05$). We also collected Colorado pikeminnow slightly more often than expected in shoal habitats in both years.

In addition to being found in a higher proportion of backwater habitats than expected, the grand mean of scaled Colorado pikeminnow catch rate from all trips was significantly higher in backwater habitats than in non-backwater habitats (*t*-test, $p < 0.001$). Colorado pikeminnow catch rate in backwater habitats was significantly higher than in non-backwater habitats during

the initial and March monitoring trips ($p < 0.01$) but not the July monitoring trips (Figure 55). Therefore, as we saw in the chi-square analysis of habitat use, scaled catch rate data indicated a higher abundance of Colorado pikeminnow in backwater habitats for the first 6 months after stocking. However, as Colorado pikeminnow reached larger sizes 9–10 months after stocking, we no longer found them to be as abundant in backwater habitats.

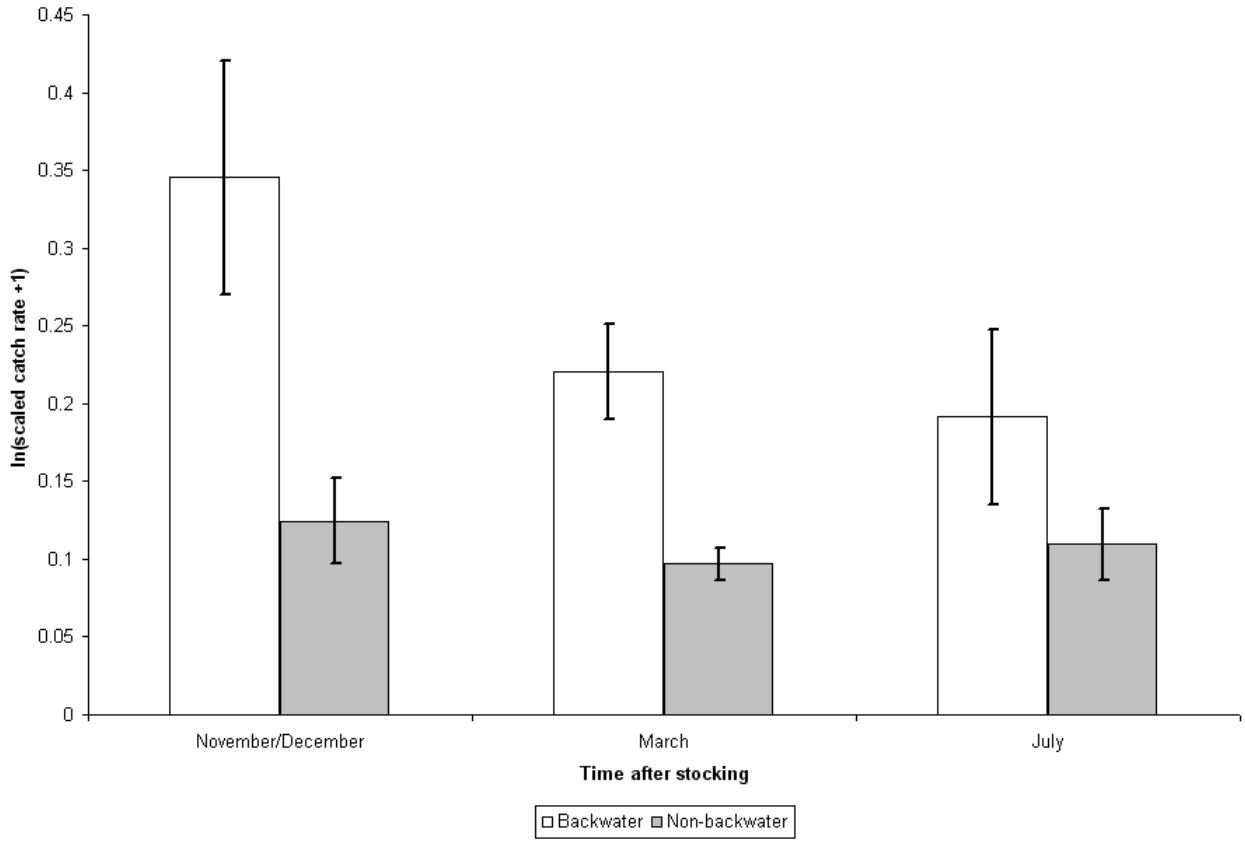

Figure 55. The scaled average Colorado pikeminnow catch rate in backwater and non-backwater habitats from all sampling trips during each different time after stocking. Error bars represent +/- one standard error.

Based on the apparent preference of Colorado pikeminnow for extremely low-velocity habitats, we combined a few other habitat types with backwater habitats to create a "preferred" habitat category that we intended to be more similar to the habitats sampled by Trammel and Archer (2000) (Appendix A). As with the grand mean of scaled Colorado pikeminnow catch rates from backwater habitats, the scaled catch rate from all trips in preferred habitats was also significantly higher than the catch rate from non-preferred habitats (Figure 56, *t*-test, $p < 0.001$). Scaled

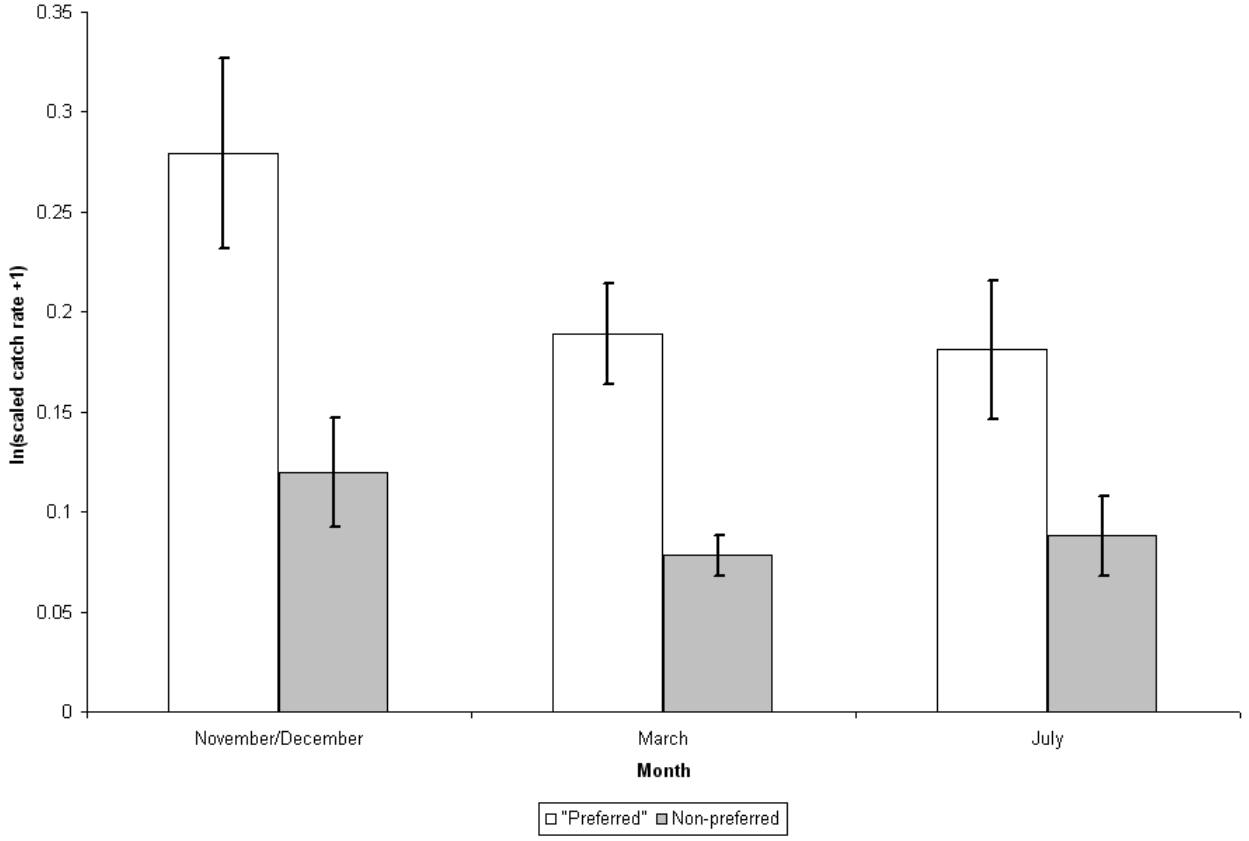

Figure 56. Scaled Colorado pikeminnow catch rate in preferred and non-preferred habitats from all sampling trips during each different times after stocking. Error bars represent +/- one standard error.

Colorado pikeminnow catch rate in preferred habitats was significantly higher than in non-preferred habitats during the initial (November and December), March, and July time periods after stocking events (*t*-test, $p < 0.03$), indicating that Colorado pikeminnow were more abundant in the extremely low velocity habitats we designated as preferred.

The preferred habitat category is more similar to the habitats targeted during monitoring following the 1996 and 1997 stocking efforts (Trammell and Archer 2000). As with scaled average catch rate from all habitats, scaled catch rates from preferred habitats in 1997 and 2002 were considerably lower than in the remaining stocking years (Figure 57). As with the scaled catch rates from all habitats, the only significant differences were for the initial catch rates after the 1996 and 2004 stocking efforts. The initial scaled catch rate from preferred habitats after the 1996 stocking effort was significantly higher than the scaled catch rates 4–5 months after the 1997 stocking effort and 9–11 months after the 1996, 1997, and 2002 stocking efforts (ANOVA, $p < 0.05$). The initial scaled catch rate from preferred habitats after the 2004 stocking effort was

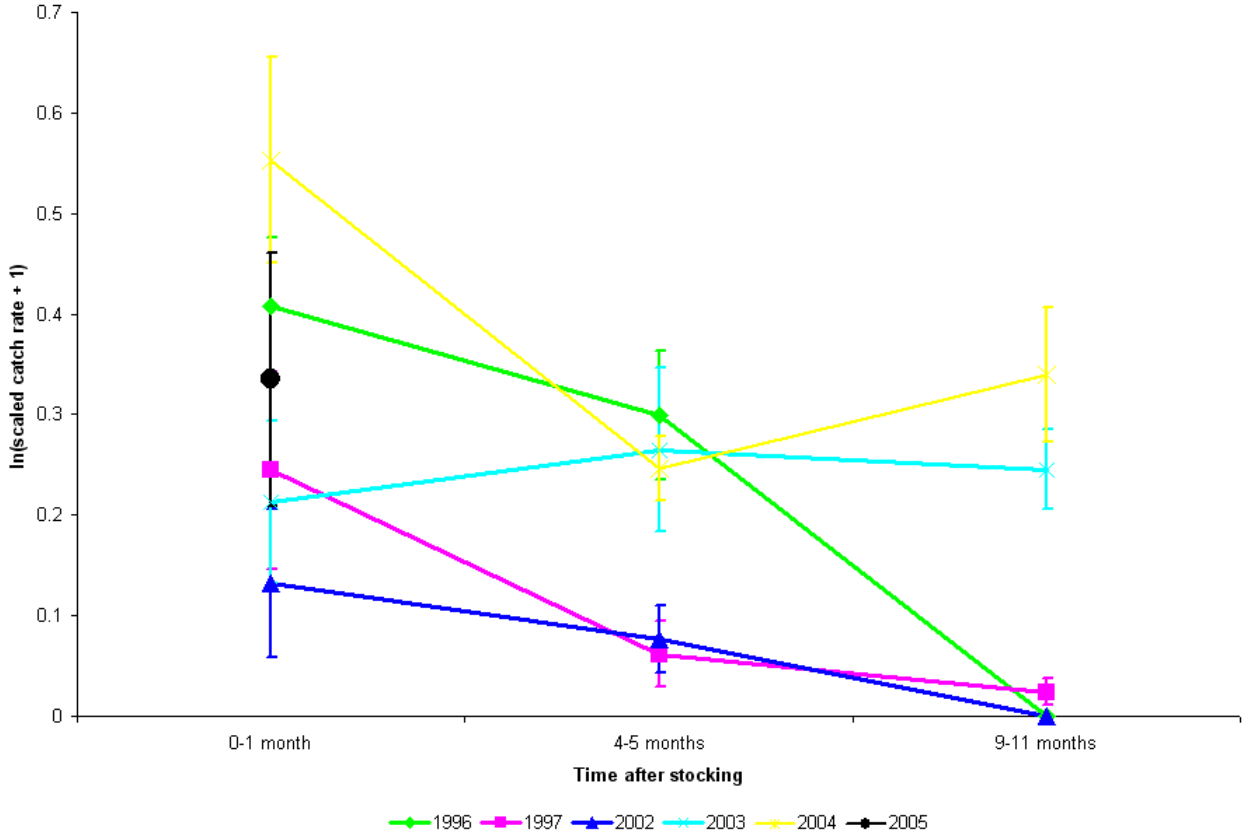

Figure 57. Scaled Colorado pikeminnow catch rates using geomorphic reach as the sampling unit, from all samples in 1996 and 1997, and preferred habitats from 2002-2005. Error bars represent +/- one standard error.

significantly higher than scaled catch rates for all time periods following the 2002 stocking effort, the initial time period following the 2003 stocking effort, 9–11 months after the 1996 and 1997 stocking efforts, and 4–5 months after the 1997 stocking effort. Interestingly, the initial scaled catch rate after the 2004 stocking effort from all habitats was lower than the initial catch rate from the 1996 stocking effort, but the initial catch rate after the 2004 stocking effort from preferred habitats was higher.

During the initial sampling trips of each study year, we found Colorado pikeminnow in areas with some type of cover (e.g., woody debris, overhanging or inundated vegetation, tires, boulders) in higher proportions than we expected (Figure 58). We found that this difference was significant in December 2002, December 2003, and November 2004 (chi-square, $p \leq 0.05$). While the difference was not significant ($p = 0.16$), Colorado pikeminnow were also found in a higher proportion of habitats with cover in November 2005. March and July samples showed no trend in Colorado pikeminnow use of habitats with cover, although we found Colorado

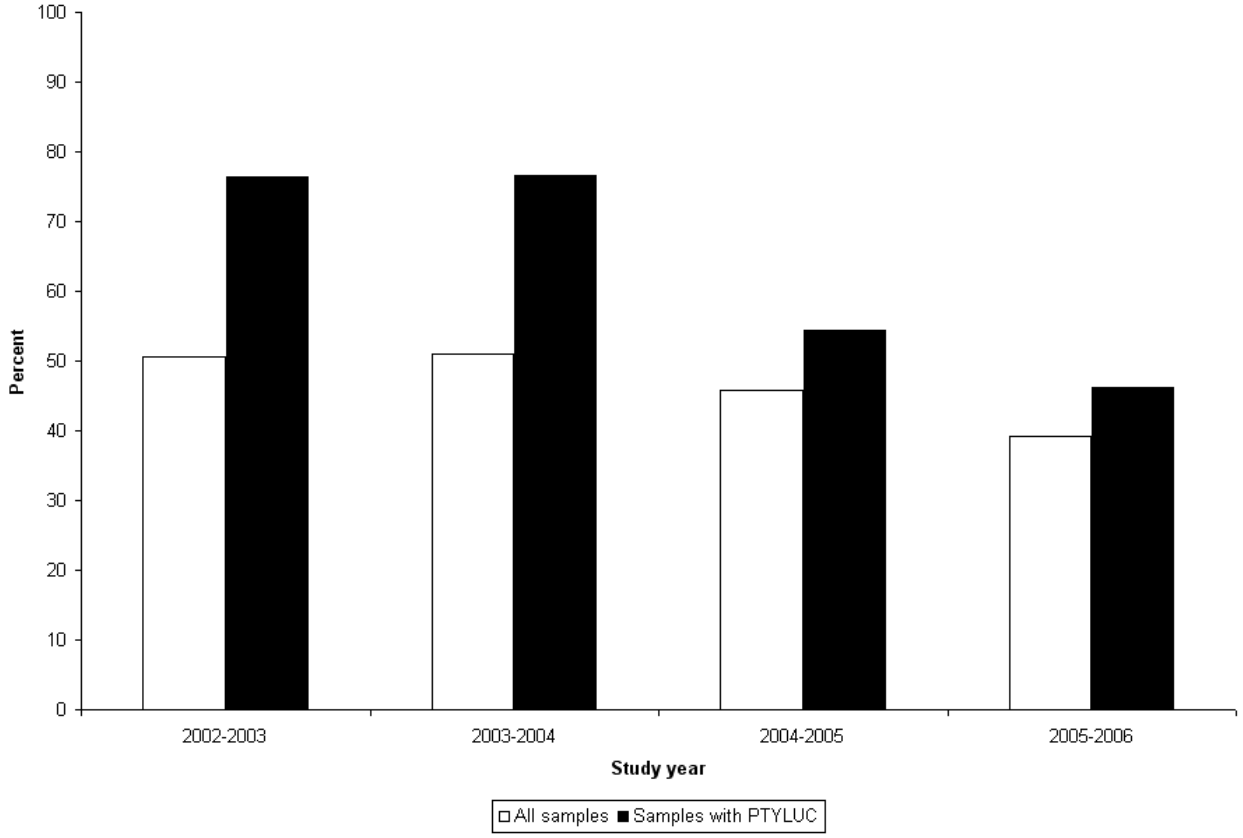

Figure 58. Proportion of all samples with cover and proportion of samples with cover where Colorado pikeminnow were collected during the initial sampling trip (November/December) in each study year.

pikeminnow in significantly higher proportions than expected in habitats that had cover in July 2004 ($p < 0.001$). The scaled average catch rate of Colorado pikeminnow was significantly higher (*t*-test, $p = 0.007$) in samples where cover was present. However, when we examined the different times after stocking, we found that the scaled Colorado pikeminnow catch rate was only significantly higher in samples with cover during the initial sampling trips (Figure 59, $p = 0.007$).

The average and maximum depths of all samples collected during the entire study where Colorado pikeminnow were found were not significantly different than those without Colorado pikeminnow (Figures 60 and 61). All samples containing Colorado pikeminnow in July had significantly greater average and maximum depths than samples that did not contain Colorado pikeminnow in July ($p \leq 0.05$). The only individual trips that had significant differences in the average and maximum depths between samples containing Colorado pikeminnow and samples without Colorado pikeminnow were November 2004, July 2005, and November 2005. During

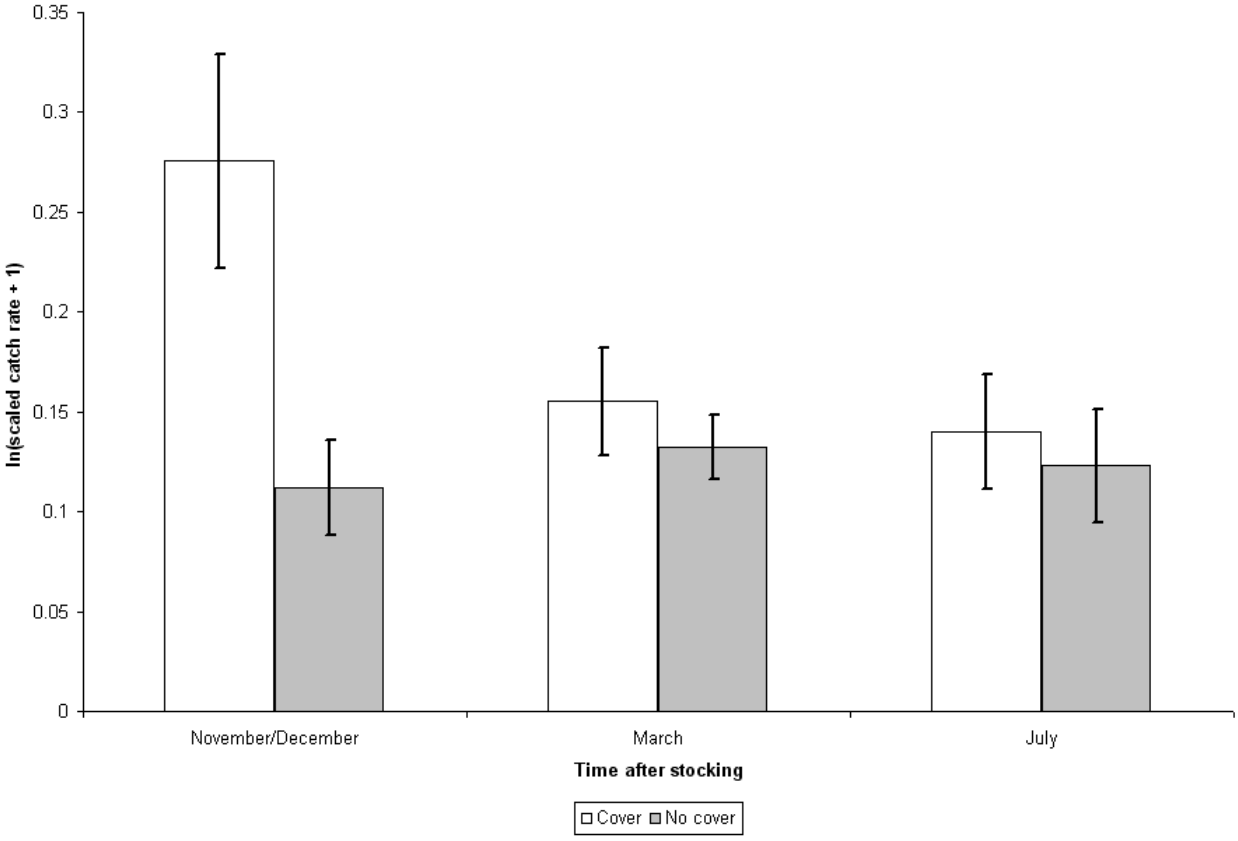

Figure 59. Scaled average catch rate for Colorado pikeminnow in samples with and without cover during the initial monitoring trip in each study year. Error bars represent +/- one standard error.

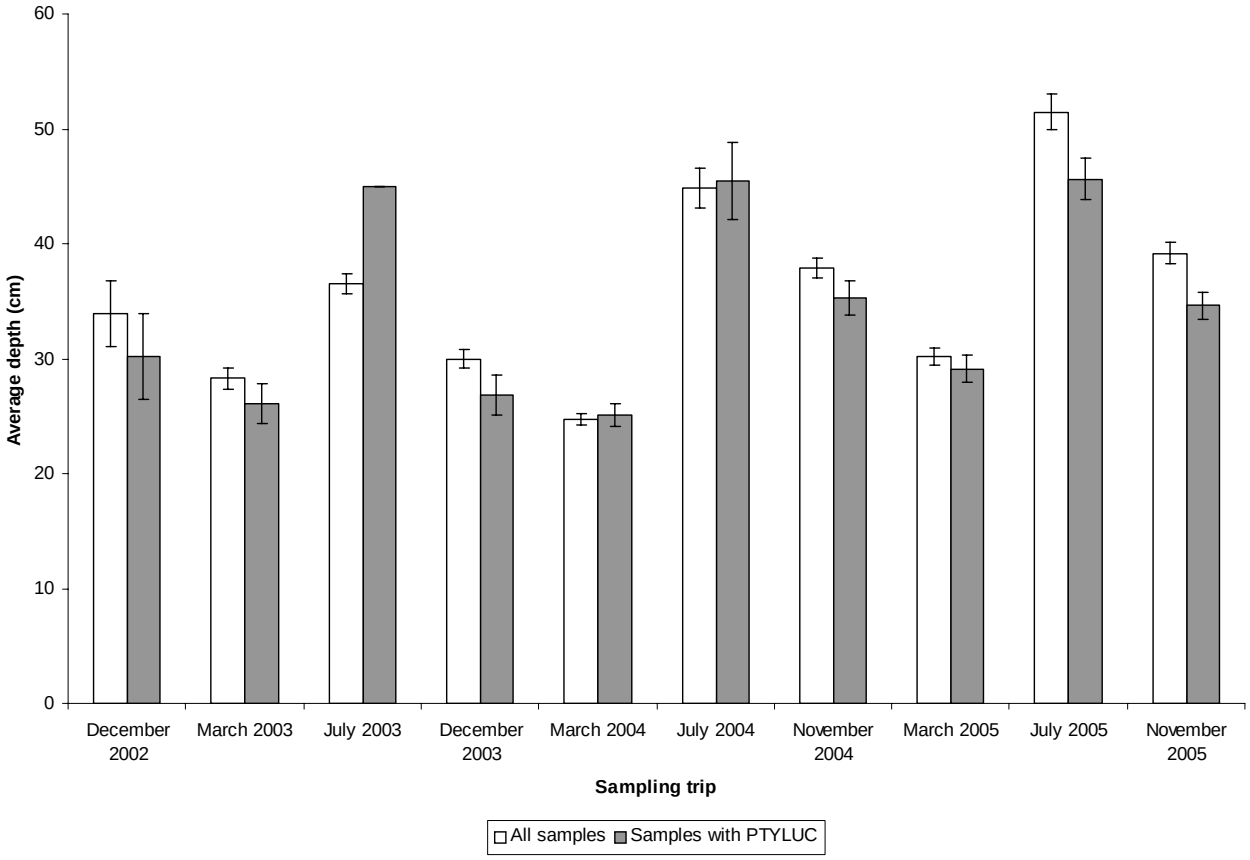

Figure 60. Mean average depth of all samples and samples where Colorado pikeminnow were collected during all sampling trips from 2002-2005. Error bars represent +/- one standard error.

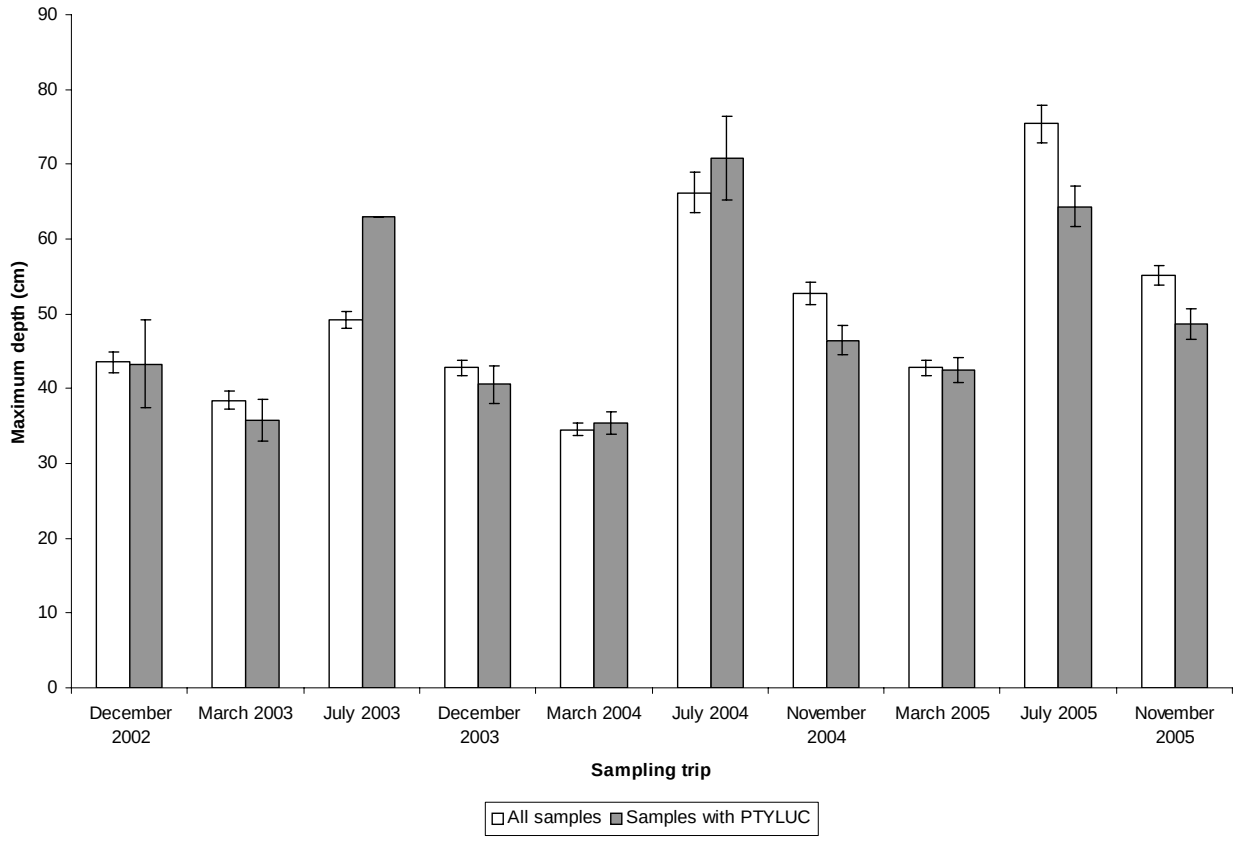

Figure 61. Mean maximum depth of all samples and samples where Colorado pikeminnow were collected in all sampling trips from 2002-2005. Error bars represent +/- one standard error.

each of these sampling trips, the average and maximum depths of samples where Colorado pikeminnow were collected were significantly lower than samples without Colorado pikeminnow ($p < 0.05$).

Since Colorado pikeminnow preferred backwater habitats, we examined the average and maximum depths of samples in these habitats, too (Figures 62 and 63). Using data from all samples, backwaters where Colorado pikeminnow were collected had significantly greater average and maximum depths than backwaters where Colorado pikeminnow were not collected (*t*-test, $p < 0.004$). However, if only samples from each monitoring time after stocking efforts are considered, only March samples showed significantly greater average and maximum depths in backwaters that contained Colorado pikeminnow ($p < 0.03$). July samples showed a significantly greater maximum depth, but not average depth, in backwaters where Colorado pikeminnow were collected ($p < 0.05$). When we examined data from individual trips, only July 2004 showed a significant difference, which was a greater maximum depth in backwaters where Colorado pikeminnow were collected ($p < 0.05$).

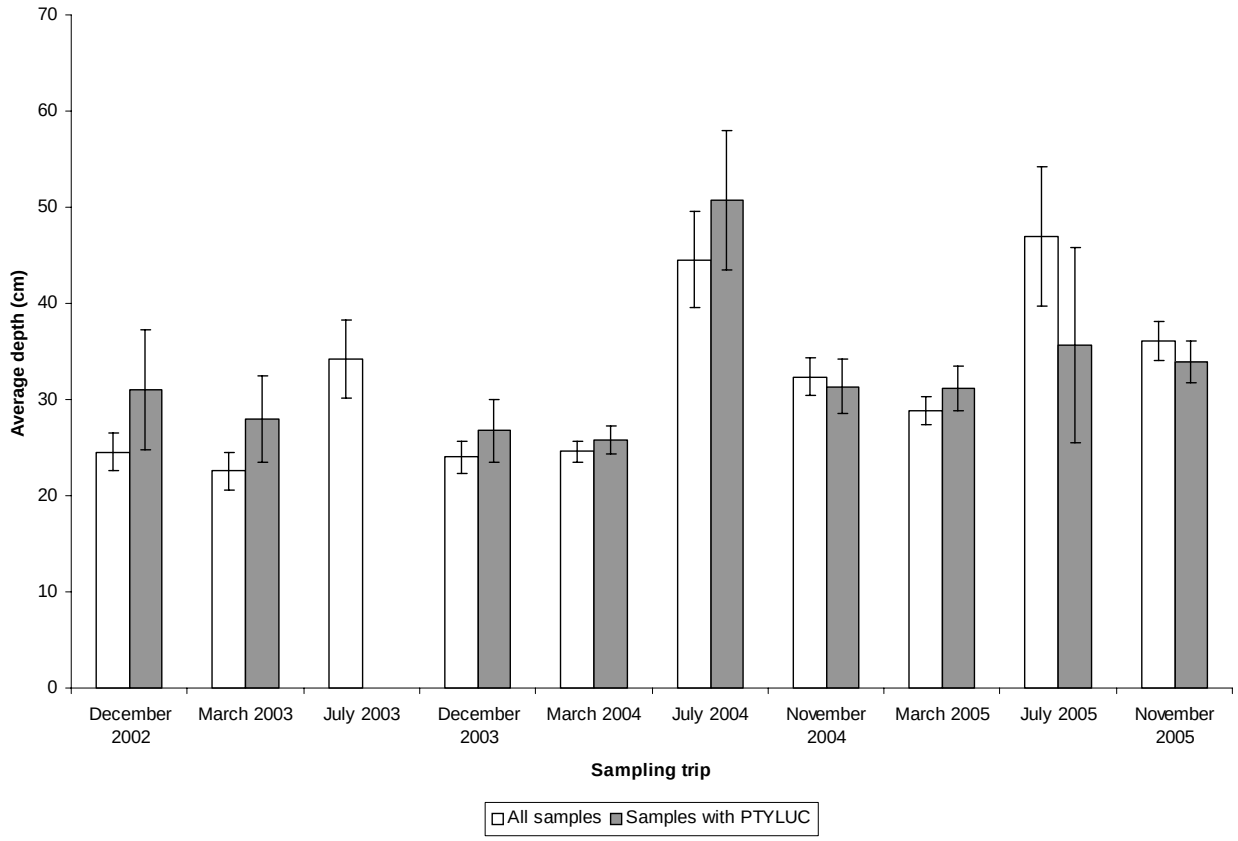

Figure 62. Mean average depth of all samples from backwater habitats vs. samples from backwater habitats where Colorado pikeminnow were collected during all sampling trips from 2002-2005. Error bars represent +/- one standard error.

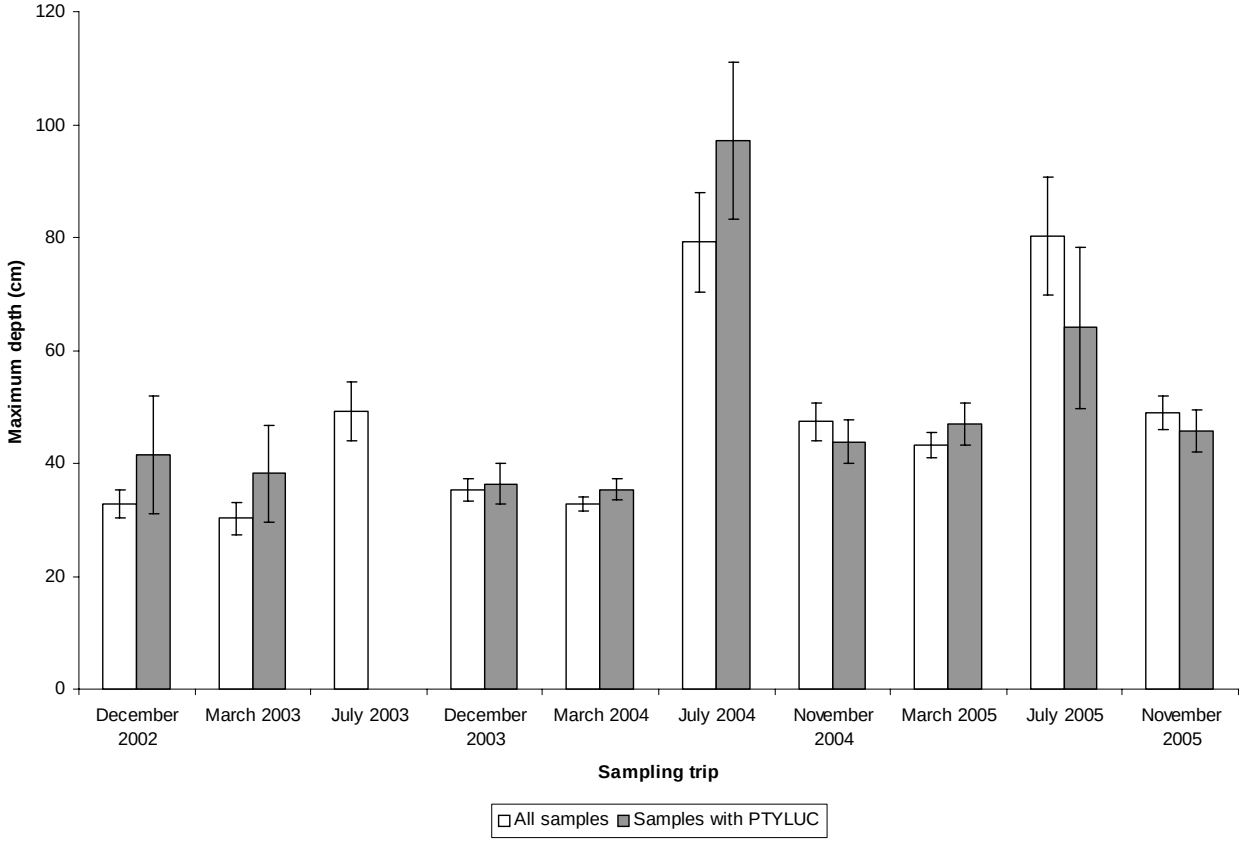

Figure 63. Mean maximum depth of all samples from backwater habitats vs. samples from backwater habitats where Colorado pikeminnow were collected during all sampling trips from 2002-2005. Error bars represent +/- one standard error.

In summary, we found Colorado pikeminnow in a higher proportion of samples from side channel habitats and preferred habitats than was expected, based on the proportion of samples taken in those habitats. Colorado pikeminnow catch rate and proportional use of habitats with cover were significantly higher in initial sampling trips following stocking. During March and July sampling trips, we generally found Colorado pikeminnow in habitats that were deeper than the average habitats sampled.

Clay Hills Crossing to Lake Powell

From November 2004 through November 2005, we sampled the section of river between Clay Hills Crossing and the interface of the San Juan River with Lake Powell at the end of each monitoring trip. We found Colorado pikeminnow below Clay Hills Crossing on every trip, except during November 2005 (Table 21). However, the majority of the Colorado pikeminnow

Table 21. Number of samples and fishes collected during sampling from Clay Hills Crossing to Lake Powell from November 2004 through November 2005.

TRIP	SEINE HAULS	CYPCAR [a]	CATDIS [b]	CATHYB [c]	CATLAT [d]	PTYLUC [e]	CYPLUT [f]	AMEMEL [g]	RHIOSC [h]	PIMPRO [i]	ICTPUN [j]
Nov. 2004	32	0	0	0	1	1	559	0	0	3	0
Mar. 2005	55	0	4	1	3	16	497	0	5	4	12
Jul. 2005	27	8	2	0	6	5	51	1	0	0	205
Nov. 2005	11	0	0	0	0	0	883	1	1	0	0

[a] CYPCAR = common carp.
[b] CATDIS = bluehead sucker.
[c] CATHYB = hybrid sucker.
[d] CATLAT = flannelmouth sucker.
[e] PTYLUC = Colorado pikeminnow.
[f] CYPLUT = red shiner.
[g] AMEMEL = black bullhead.
[h] RHIOSC = speckled dace.
[i] PIMPRO = fathead minnow.
[j] ICTPUN = channel catfish.

were found between Clay Hills Crossing and the uppermost waterfall (Table 22). Only three Colorado pikeminnow were collected below the waterfalls, none of which were YOY Colorado pikeminnow from the October 2004 stocking effort. All three of these fish appeared to be Colorado pikeminnow stocked as age 0 in November 2003. The Colorado pikeminnow collected in March 2005 were 210 mm and 212 mm TL, and the Colorado pikeminnow collected in July 2005 was 250 mm TL. None of the three Colorado pikeminnow had been previously marked.

We also found bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus lattipinnis*), and speckled dace (*Rhinichthys osculus*) below Clay Hills Crossing and the waterfalls. As with most of the river downstream from PNM Weir, red shiner (*Cyprinella lutrensis*) dominated most of our collections below Clay Hills Crossing, with the exception of July 2005 when YOY channel catfish (*Ictalurus punctatus*) were the dominant species.

Other Fish Data

During YOY Colorado pikeminnow monitoring events, we collected four native species other than Colorado pikeminnow: bluehead sucker, flannelmouth sucker, razorback sucker, and speckled dace (Appendix B). We collected 12 total razorback sucker throughout the study. Six of the fish probably came from SJRIP stocking efforts and ranged from 316–455 mm TL. All six had previously been PIT tagged. The other six razorback sucker were small, juvenile fish ranging between 81–120 mm TL (Table 23). We suspected that two of the six juveniles were hybridized with flannelmouth sucker.

Table 22. Number of samples and fishes collected during sampling below the waterfalls from November 2004 through November 2005.

TRIP	SEINE HAULS	CYPCAR [a]	CATDIS [b]	CATHYB [c]	CATLAT [d]	PTYLUC [e]	CYPLUT [f]	AMEMEL [g]	RHIOSC [h]	PIMPRO [i]	ICTPUN [j]
Nov. 2004	30	0	0	0	0	0	0	0	0	0	0
Mar. 2005	43	0	1	0	2	2	129	0	2	1	11
Jul. 2005	25	2	2	0	5	1	50	0	0	0	111
Nov. 2005	10	0	0	0	0	0	881	1	0	0	0

[a] CYPCAR = common carp.
[b] CATDIS = bluehead sucker.
[c] CATHYB = hybrid sucker.
[d] CATLAT = flannelmouth sucker.
[e] PTYLUC = Colorado pikeminnow.
[f] CYPLUT = red shiner.
[g] AMEMEL = black bullhead.
[h] RHIOSC = speckled dace.
[i] PIMPRO = fathead minnow.
[j] ICTPUN = channel catfish.

Table 23. Collection date, location, and size of small, juvenile razorback sucker and razorback sucker hybrids found in the San Juan River during the young-of-year (YOY) Colorado pikeminnow monitoring project.

DATE	RIVER MILE	HABITAT	STANDARD LENGTH (MM)	TOTAL LENGTH (MM)
March 25, 2004	17.5	Embayment	94	N/A
March 25, 2004	11.4	Backwater	95 [a]	120
July 20, 2004	37.4	Isolated pool	54	63
July 22, 2004	12.5	Backwater	68	86
July 22, 2004	12.5	Backwater	62 [a]	82
July 22, 2004	10.2	Backwater	64	81

[a] Possible razorback sucker X flannelmouth sucker hybrids.

The combined catch rate for native fishes was higher above Hogback Diversion in all years (Figures 64–67). However, higher native fish catch rates were seen in some of the canyon stations in 2004–2005 vs. 2003–2004, and lower native fish catch rates were seen in the upper

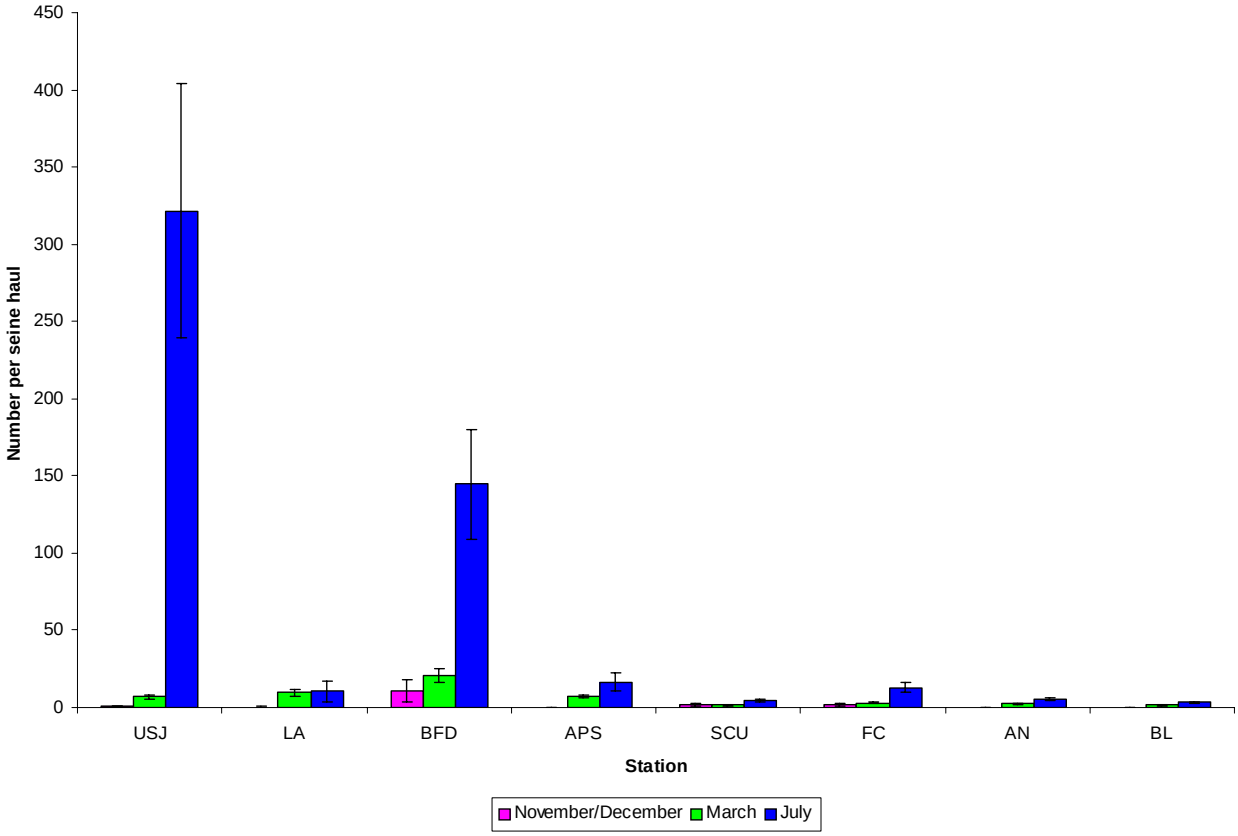

Figure 64. Combined native fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in December 2002, March 2003, and July 2003. Error bars represent +/- one standard error.

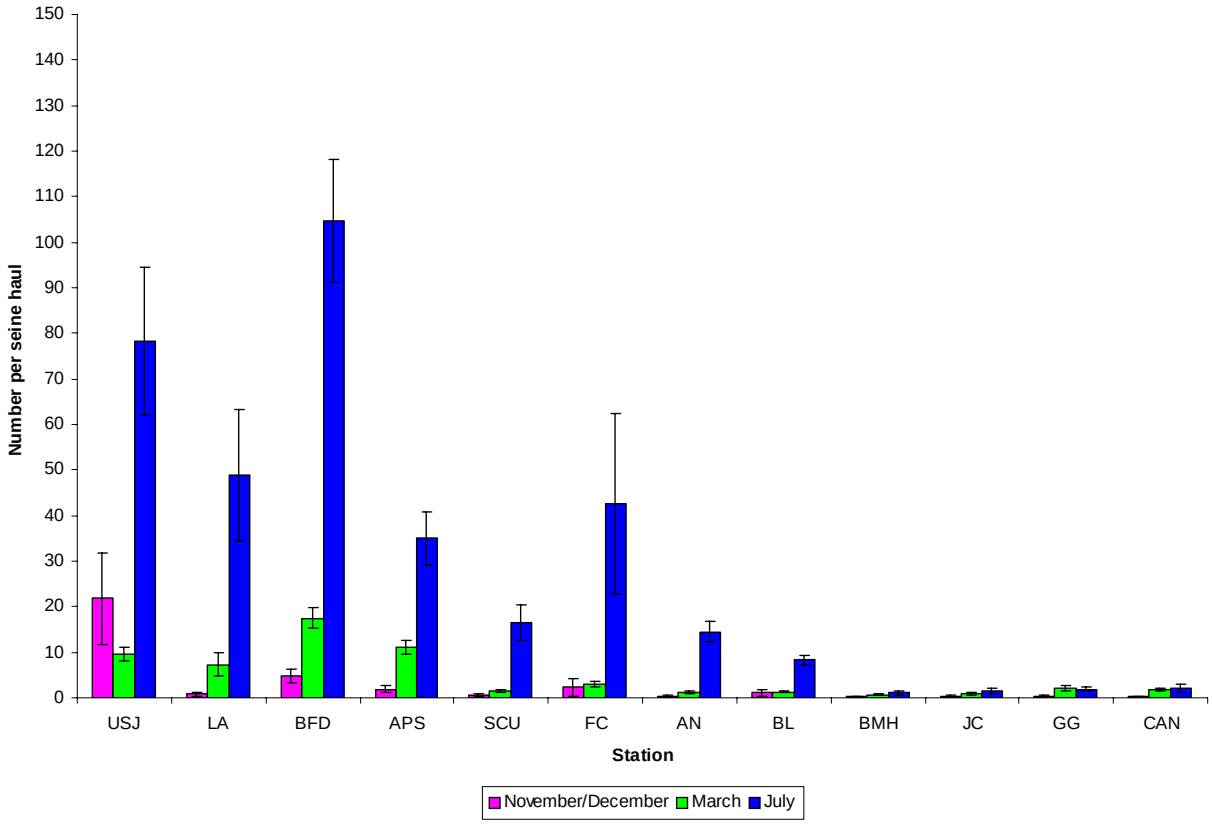

Figure 65. Combined native fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in December 2003, March 2004, and July 2004. Error bars represent +/- one standard error.

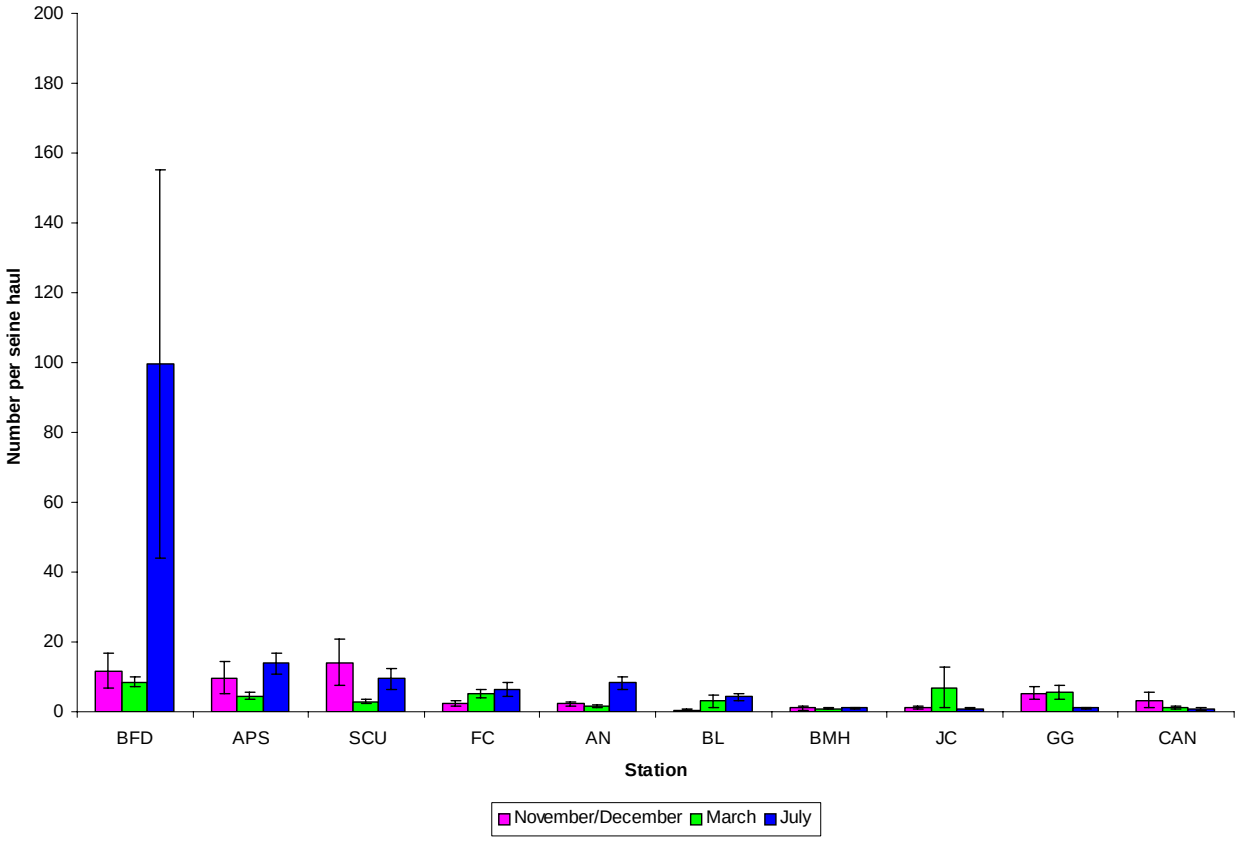

Figure 66. Combined native fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in November 2004, March 2005, and July/August 2005. Error bars represent +/- one standard error.

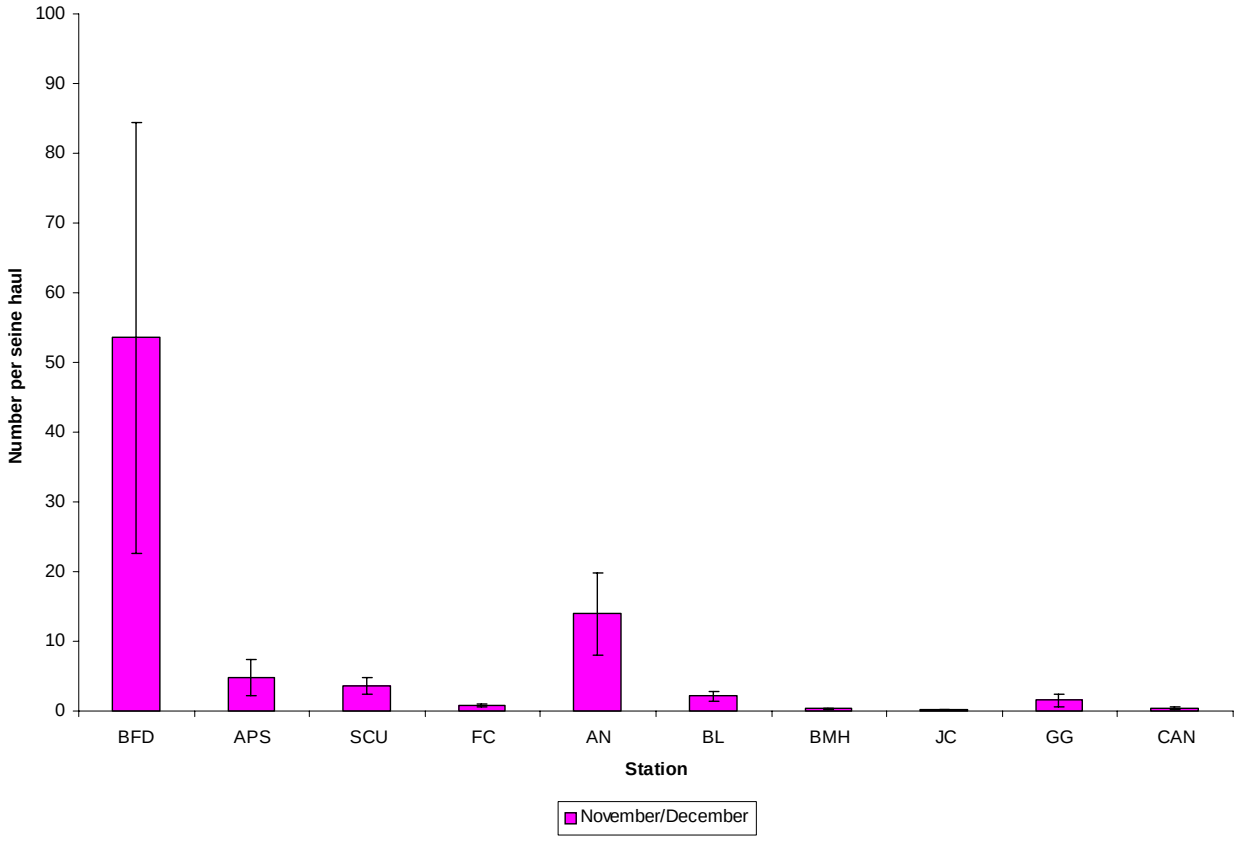

Figure 67. Combined native fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in November 2005. Error bars represent +/- one standard error.

stations in 2003–2004. We saw substantial variations during the same trip within reaches between years, but we could not compare those statistically (see Methods section) (Golden et al. 2004, Golden and Holden 2005). The overall native fish catch rates for each trip were not significantly different among years. We observed little difference in native fish catch rates between years during the March trips, but the November native fish catch rates in 2004 and 2005 were higher than the December 2002 and 2003 native fish catch rates. This trend was evident even when we only used stations sampled in all years to calculate the overall catch rate. Higher numbers of speckled dace in areas downstream of our Below Fruitland Diversion station appeared to be responsible for he increased overall native fish catch rate in November 2004 and 2005. During the July trips, the native fish catch rate was lower in 2005 than it had been in 2004 or 2003. However, when we examined the overall catch rate from stations sampled in all years, we did not see the same trend. Therefore, dropping the Upper San Juan and Lower Animas stations probably influenced the overall catch rate of native fishes in July 2005.

We found the highest catch rates for nonnative fishes between PNM Weir and Sand Island in all years (Figures 68–71). The stations below Mexican Hat had consistently lower catch rates of both native fishes and nonnative fishes. Overall, we found that the nonnative fish catch rate in November 2004 was higher than any of the other initial sampling trips and significantly higher than the nonnative fish catch rate during the December 2002 and 2003 trips ($p < 0.02$). When we compared the overall catch rates of nonnative fishes from the stations sampled in all years, the November 2004 catch rate was still the highest: however, it was not significantly higher than the other catch rates ($p = 0.08$). Removing the Upper San Juan and Lower Animas stations, along with the stations below Mexican Hat, eliminated all the stations with the lowest red shiner catch rates, which had the biggest influence on the overall nonnative catch rate. We found no other substantial trends or significant differences the overall nonnative fish catch rate.

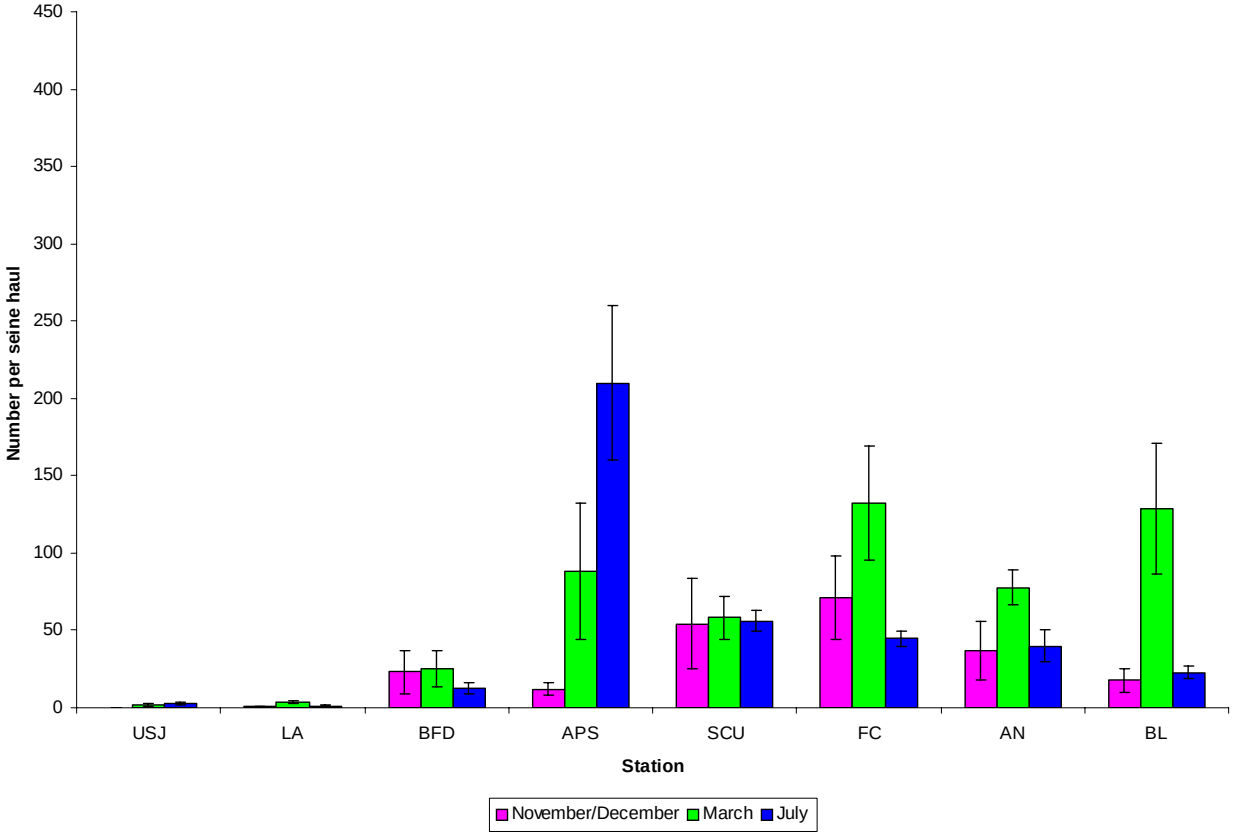

Figure 68. Combined nonnative fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in December 2002, March 2003, and July 2003. Error bars represent +/- one standard error.

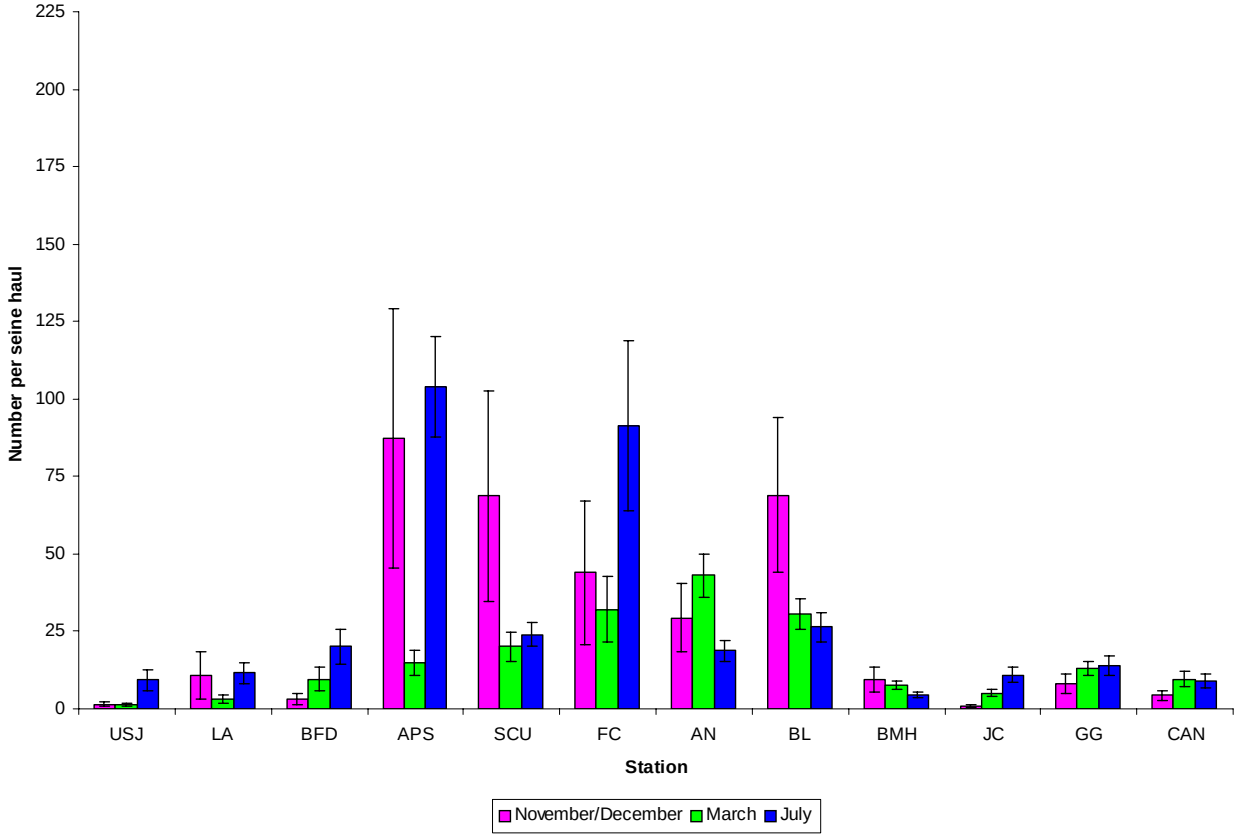

Figure 69. Combined nonnative fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in December 2003, March 2004, and July 2004. Error bars represent +/- one standard error.

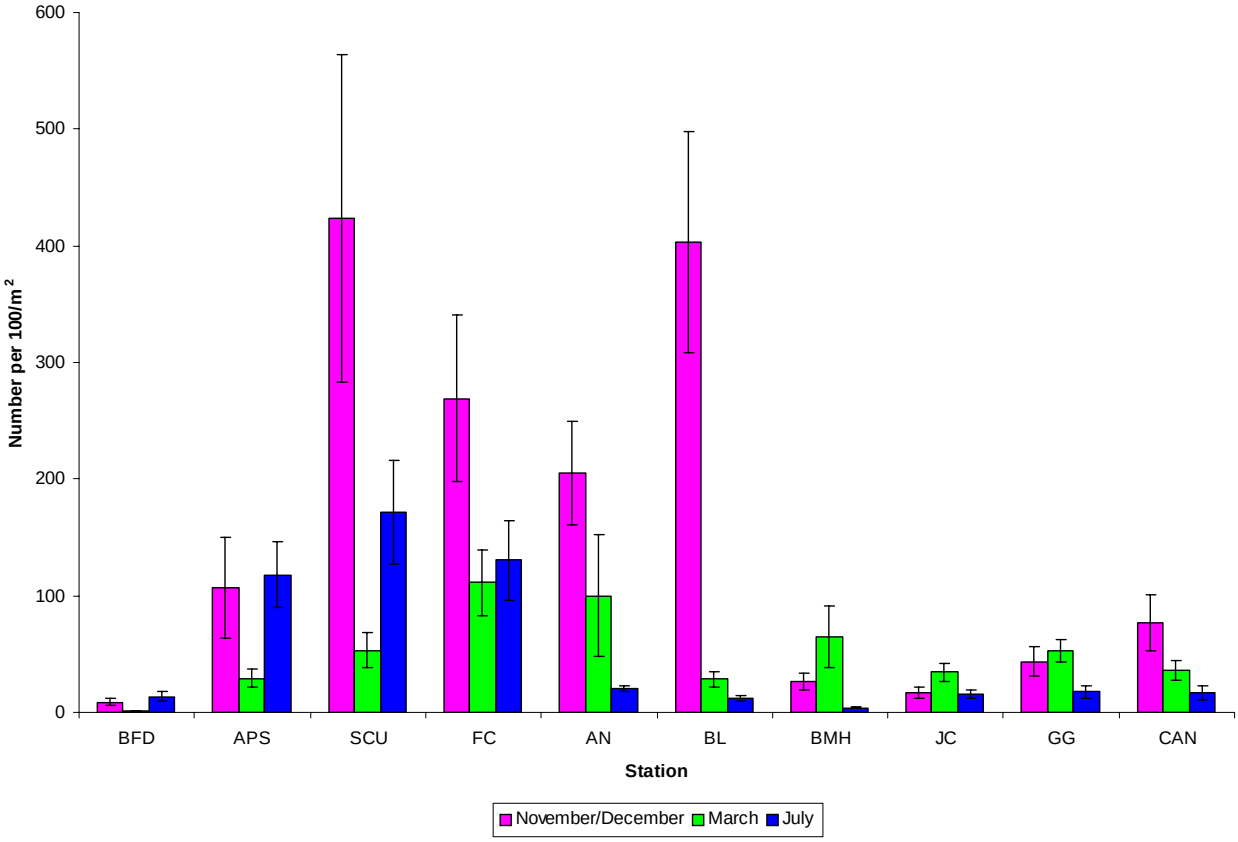

Figure 70. Combined nonnative fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in November 2004, March 2005, and July/August 2005. Error bars represent +/- one standard error.

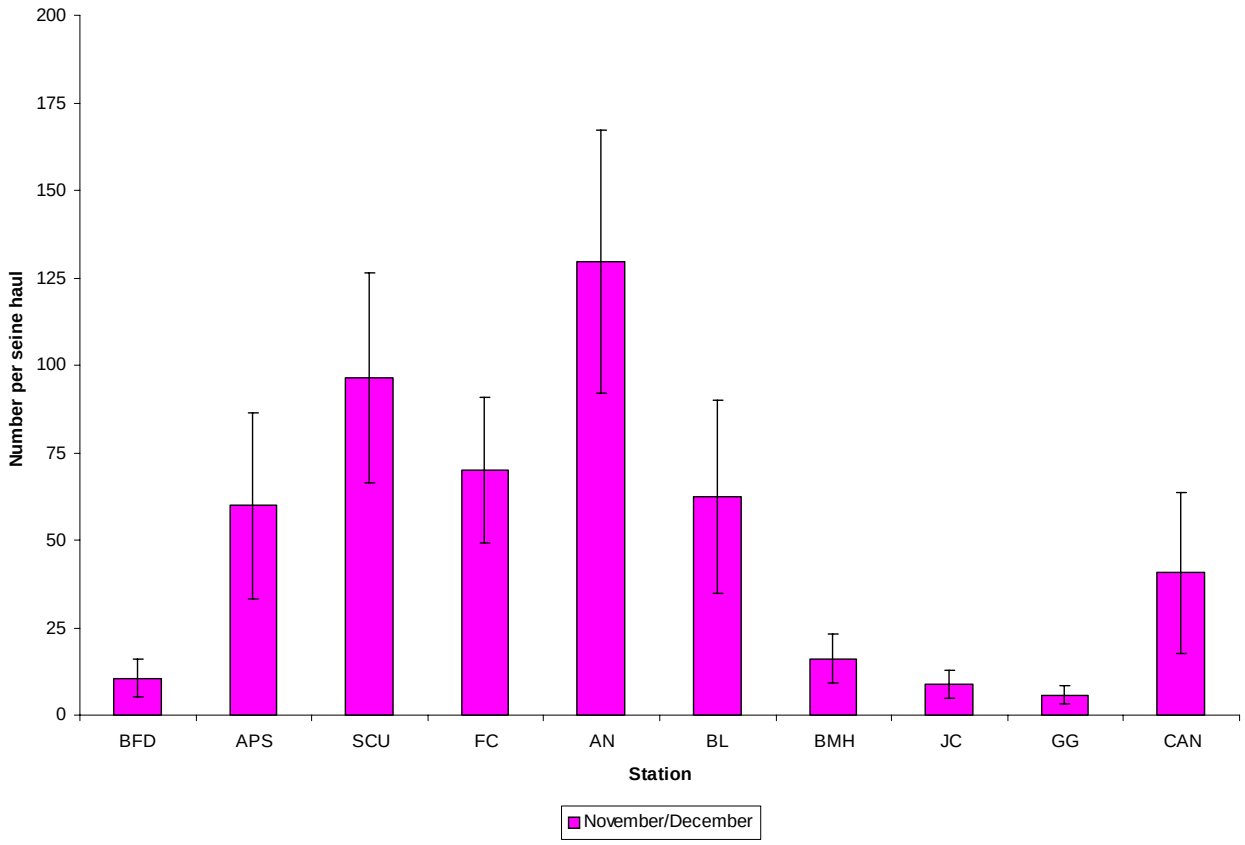

Figure 71. Combined nonnative fish catch rate (number of fish per seine haul with seine haul as the sample unit) at each station in November 2005. Error bars represent +/- one standard error.

Red shiner was the dominant nonnative fish species, and trends in the overall nonnative catch rate mirrored trends in red shiner abundance. Red shiner was most abundant from the APS Weir station downstream to the Bluff station, as was fathead minnow (*Pimephales promelas*), the second most abundant nonnative fish species. In November 2004 we saw higher red shiner numbers and catch rates for red shiner than any of the other initial monitoring trips. The red shiner catch rate in November 2004 was significantly higher than in December 2002 and 2003 ($p < 0.05$). However, as with the total nonnative catch rate, when we compared red shiner catch rates from stations sampled in all years, we found no significant differences ($p = 0.24$). We collected relatively high numbers of YOY largemouth bass (*Micropterus salmoides*) and YOY channel catfish in our July collections in all three study years. Largemouth bass were most numerous in stations upstream from Aneth, Utah, whereas channel catfish were most numerous in the stations below Mexican Hat.

Nonnative fishes were more numerous than native fishes on every sampling trip, but not in every station. Native fishes outnumbered nonnative fishes in the Upper San Juan station during all collections at that station. Native fishes also outnumbered nonnative fishes in several of the collections made in the Lower Animas and Below Fruitland Diversion stations. At all downstream stations nonnative fishes always outnumbered native fishes, primarily because of the increased number of red shiner and fathead minnow. With the exception of the July 2003 and July 2004 collections, the overall nonnative fish catch rate was significantly higher than the native fish catch rate in all collections (paired *t*-test using station as the sample unit, $p < 0.05$). We saw significant differences when we compared the nonnative fish and native fish catch rates from the stations sampled in all years ($p < 0.05$).

DISCUSSION

Retention

Despite the difficulties with making inferential comparisons of our data, examining the combined data from our project and other SJRIP research and monitoring projects does highlight a few key findings regarding the retention of stocked Colorado pikeminnow. First, the data suggest that we lost the majority of stocked YOY Colorado pikeminnow from our sampling efforts within 1 month after stocking. The low percentage of return for the number of stocked fish 4–5 months after stocking indicates that the bulk of stocked fish are lost to our sampling efforts. We found that scaled catch rates for initial sampling trips within the first 2 weeks after stocking (2004, 2005) were significantly higher than scaled catch rates for initial sampling trips conducted over 1 month after stocking, and a strong negative relationship existed between initial catch rates and the time we conducted the initial sampling trip after stocking. Additionally, we found that the high initial catch rates from 2004 and 2005 did not transfer into higher March and July catch rates, showing a fairly large loss of fish over the first 5 months after stocking.

Conversely, we found that scaled catch rates from initial sampling trips conducted more than 1 month after stocking (2002, 2003) showed little difference from the scaled catch rates 5 months after stocking, indicating little loss of fish between 1 and 5 months after stocking. Once we found an effective method for collecting larger Colorado pikeminnow, we found that our data also suggested that there is little loss/mortality between 5 and 9 months after stocking. For the most part, data from other SJRIP monitoring projects support these assertions. Therefore, in each year of the study, it appears that we lost the bulk of stocked fish in the first few weeks following stocking, but after this initial loss retention through July was constant, regardless of environmental conditions.

We assumed that the initial loss of fish was attributable to a combination of downstream drift and mortality, although it is possible that our ability to detect fish decreased with the amount of time elapsed since they were stocked. In accordance, our review of stocking programs and research examining post-release survival of stocked fish in North America and throughout the world has shown that the majority of stocked fishes, regardless of size, are lost within the first few days after release (Cresswell 1981, Wiley et al. 1993, Maynard et al. 1995, Cowx 1998, Brown and Laland 2001, Brown and Day 2002). The authors of these studies likewise attributed loss of fish to drift and mortality, and not a change in the detectability of the species. While the majority of these studies targeted trout and other game species, other research efforts to enhance and supplement Colorado pikeminnow and other native Colorado River fish species have also documented large amounts of downstream drift and dispersal, and little long-term success (Marsh and Langhorst 1988, Marsh and Brooks 1989, Hendrickson 1993, Masslich and Holden 1996, Burdick and Bonar 1997, Burdick 2003).

In the San Juan River, Dudley and Platania (2000) found that protolarval Colorado pikeminnow stocked below the Hogback Diversion (RM 159) could drift to Clay Hills Crossing (RM 2.9) in as little as 3 days. In follow-up monitoring of the 500,000 protolarval Colorado pikeminnow stocked for the drift study, the UDWR found none of these fish in three sampling trips from Hogback Diversion to Clay Hills Crossing (Trammell 2000). Jackson (2001) found four protolarval Colorado pikeminnow immediately after more than 100,000 fish were stocked below Cudei Diversion, but none were captured in subsequent monitoring. Trammell (2000) and Jackson (2001) concluded that massive transport of larvae to Lake Powell, variable flows altering nursery habitat, and predation were probably responsible for the poor retention of the larvae. Masslich and Holden (1996) summarized a number of studies showing that stocked Colorado pikeminnow drifted long distances downstream. Young-of-year Colorado pikeminnow (50–100 mm) were stocked in the Colorado River several times in the early 1980s. The fish generally dispersed from the stocking area within 30 days and were found up to 17 miles downstream within 6 days.

Despite this propensity for large-scale drift and mortality immediately after stocking, Trammel and Archer (2000) showed that stocking YOY Colorado pikeminnow in the San Juan River had some success at producing age-1 and age-2 Colorado pikeminnow in 1996 and 1997. The capture of several subadult fish in the early 2000s reinforced the idea that at least some of these fish will probably contribute to the adult population (Jackson 2003). The combined results of SJRIP-funded research from 2002–2005 showed that more-recent stocking efforts are also somewhat successful at producing age-1, age-2, and even age-3 Colorado pikeminnow. Therefore, while we are losing a large amount of stocked fish initially, some of the fish are recruiting into large size classes.

Our catch rate data and catch rate data from other SJRIP cooperators also suggest that the 2002 stocking effort appeared to be the least successful of the more recent stocking efforts. Many factors probably contributed to the success or failure of the various stocking efforts, including handling stress, water quality and habitat availability in the receiving waters, size of fish at stocking, predator and prey composition of the receiving waters, and hatchery-rearing techniques. Other authors have noted that these factors determined the success or failure of other stocking programs, including one for Colorado pikeminnow in Arizona (Hendrickson 1993, Margenau 1999, Wahl 1999). Of these factors, we feel that habitat availability probably had the largest influence on retention success of Colorado pikeminnow from the 2002 stocking effort.

Colorado pikeminnow have a preference for low-velocity habitats, particularly backwaters. We found Colorado pikeminnow in a significantly higher proportion of backwater habitats than expected, based on a random distribution, and Colorado pikeminnow catch rates were significantly higher in backwater habitats. Our data support the work of many other researchers in the San Juan River and elsewhere who have showed that YOY Colorado pikeminnow have a clear preference for backwater habitats (Haines and Tyus 1990, Tyus 1991, Tyus and Haines 1991, Haines and Modde 1996, Haines et al. 1998, Trammell and Chart 1999, Trammell and Archer 2000, Golden et al. 2004, Golden and Holden 2005). With such a clear preference for backwater habitats, changes in the amount of backwater habitat from year to year could impact the retention and survival of stocked YOY Colorado pikeminnow.

The amount of backwater habitat on the San Juan has fluctuated in the last 10 years, and we believe that the changes in habitat availability may be responsible for the poor success of the 2002 stocking effort. Trammel and Archer (2000) noted that nursery habitat was available and common in several sections of the San Juan River after stocking efforts in 1996 and 1997. However, habitat studies on the San Juan River have shown a decrease in both the number and area of backwaters from 1996 through 2003 (Bliesner and Lamarra 2004, Bliesner and Lamarra 2005). In fact, in 2002 and 2003 the area of backwater habitat available in the San Juan River was at its lowest point since habitat studies began in 1992. In addition, our data suggested that backwater habitats appeared to be extremely important in the period immediately following stocking. Since the data also indicate the initial period following stocking may be the defining

moment for YOY Colorado pikeminnow retention, the lack of backwater habitat present for Colorado pikeminnow stocked in autumn 2002 was probably a major factor in the poor initial retention and survival to age 1 that year.

While Bliesner and Lamarra (2005) found no increase in backwater abundance or area by autumn 2003, the number of backwaters had increased by 2004. We also saw an increase in area of backwater habitat we sampled throughout the course of the 2003–2004 study year (Golden and Holden 2005). Some of this may have been a sampling bias in our selection of sites. However, since we tried to sample all backwaters and other low-velocity habitat in our stations, we feel that the increase in the amount of backwater area sampled was indicative of an increase in the amount of backwater habitat. More recent data from habitat studies supports our assertion that backwater area and abundance increased between autumn 2003 and autumn 2004 (Bliesner and Lamarra 2005). A similar increase appears unlikely for 2005, because the number of backwaters appeared to remain steady between 2004 and 2005 (Bliesner 2006). Therefore, the increase in backwater habitat between 2003 and 2004, and shown in habitat mapping studies may help explain increases in initial retention after the 2004 stocking efforts vs. the 2002 stocking effort, it does not explain the increase in initial retention seen after the 2003 stocking effort.

While habitat mapping studies showed no increase in backwater habitat between 2002 and 2003, it is possible that the habitat changes happened at a smaller scale than can be detected by habitat mapping. The failure of our brush pile experiments illustrated the impact that small changes in discharge can have on the amount of backwater and other low-velocity habitat available when fish are stocked, at least in Geomorphic Reach 6. Average daily discharge surrounding the 2002 and 2004 stocking efforts was similar, but average daily discharge was about 200 cfs lower surrounding the 2003 stocking effort. The flow recommendations for the San Juan River would not suggest that the amount of backwater habitat would be significantly higher at 500 cfs (2003) than at 700 cfs (2002 and 2004) (Holden 1999), but it is possible that more low-velocity habitat was available during and immediately after the 2003 stocking. If more low-velocity habitat was indeed available, this could at least partially explain the increase in initial retention seen in 2003.

In addition to a lack of backwater habitat in 2002, stress from the stocking protocols used during that year may have also resulted in reduced survival. In 2002 Colorado pikeminnow were stocked in a traditional hatchery manner, where all the fish were transported in a large tank and dumped directly into the main channel of the river. Brown and Day (2001) cite other conservation biology literature as calling this “hard release.” Stress from harvest and transport of hatchery-reared fishes has been shown to impact the success of various stocking programs (Carmichael et al. 1984, Mather and Wahl 1989, Hanson and Margenau 1992, Margenau 1999, Wahl 1999). Transport stress negatively impacted the osmoregulatory balance of largemouth bass, causing a high rate of mortality (88%) in the 4 days following transport (Carmichael et al. 1984).

We saw a similar mortality rate (75–80%) within 4 days after transport for Colorado pikeminnow used in acclimation experiments in 2003. The DNFHTC personnel performed a necropsy on several specimens from the mortality event and determined that many of the internal organs had ruptured (Holden and Golden 2005), which could be a sign of osmoregulatory problems similar to those seen by Carmichael et al. (1984). We concluded that stress from being handled three times within 4 days and transported for over 10 hours was a major factor in the high mortality we saw in the first year of acclimation studies (Holden and Golden 2005). Similar stress-related mortality could have been a factor in the poor retention of 2002 stocked YOY Colorado pikeminnow. Carmichael et al. (1984) found that transporting fish at cooler temperatures and in saline water significantly decreased mortality, as did holding fish for 72 hours without food prior to transport. Mather and Wahl (1989) also showed that minimizing abrupt temperature changes, as well as the amount of handling and confinement, can help minimize stress-related mortality in stocked fishes. Since 2003 all Colorado pikeminnow leaving the DNFHTC have been allowed a 7-day rest between handling periods prior to transport, which appears to have alleviated the mortality we saw in 2003.

While hatchery handling protocols may have increased stress on YOY Colorado pikeminnow stocked in 2002 and 2003, it is also possible that the mortality we saw during our 2003 acclimation studies was an isolated incident. We found that scaled catch rates for March and July following the 2003 stocking effort, prior to the change in hatchery handling protocols, were similar to those following the 2004 stocking effort, after the change in hatchery handling protocols. In the absence of the other confounding factors (habitat, flow, water quality) that may have impacted retention in those years, this would indicate that hatchery handling protocols had no appreciable impact on the long-term retention of fish stocked in those years. We also attempted two studies designed to recreate the mortality event using the same handling techniques. We were never able to recreate the event (Holden and Golden 2005). Therefore, some specific combination of factors, including handling by hatchery personnel or our personnel, may have caused an isolated mortality event during 2003 acclimation studies. Other SJRIP cooperators stocking Colorado pikeminnow have also increased tempering times at the river from 30 minutes to 90 minutes in an attempt to reduce the handling stress surrounding stocking.

In addition to stress from hauling and handling, water quality differences between hatchery and transport tanks and the water in the receiving system can also have negative impacts on stocked fishes. Water temperatures in hauling trucks from the DNFHTC were generally at least 5 degrees warmer than the temperature of the San Juan River at the time of stocking. On November 3, 2005, temperature differences between hatchery truck water and the San Juan River were between 5.5 and 6.5 degrees Celsius (Ryden 2006). Many authors have noted the potential for abrupt temperature changes to reduce survival of hatchery-reared fishes (Berry 1988, Clapp et al. 1997, Wahl 1999). Abrupt temperature decreases of 15 degrees Celsius caused increased mortality in 14- and 40-day old Colorado pikeminnow (Berry 1988). The water at the DNFHTC is also considerably harder than the water in the San Juan River, which could result in

osmoregulatory problems for the stocked fish (Holden and Golden 2005). Temperature differences, water quality, handling and hauling stress, and fish condition factor can all act synergistically to reduce survival of stocked fish (Clapp et al. 1997). It is possible that the combination of different stressors combined to reduce the survival of the fish we attempted to acclimate in 2003 and that similar reductions in survival have happened in other years.

Water temperatures changes can also have sublethal impacts on survival and retention. Much of the literature on this topic concentrates on the negative impacts of stocking fish into warm water, but cold water can have negative impacts, too (Johnson 1982, Clapp et al. 1997, Margenau 1999, Smith and Hubert 2003). Smith and Hubert (2003) found no significant mortality to fingerling rainbow trout (*Oncoryhnchus mykiss*) from large, abrupt temperature changes, but they found disorientation and reduced evasive response in fishes exposed to abrupt temperature changes. Similar disorientation was observed during mortality experiments with Colorado pikeminnow exposed to the shortest tempering times in laboratory tests at DNFHTC and in our net pens (Holden and Golden 2005). Berry (1988) also noted decreased activity with abrupt decreases of 10 degrees Celsius and loss of equilibrium with abrupt decreases of 15 degrees Celsius. The decrease in activity may be a result of stress and diminished swimming performance. Several authors have noted a decrease in swimming ability of Colorado pikeminnow or other Colorado River Basin native fish species with decreasing temperatures (Berry and Pimentel 1985, Childs and Clarkson 1996, Ward et al. 2002). Cresswell (1981) also cites several studies showing that stocked trout have a higher propensity for downstream dispersal when stocked during colder water temperatures (5–7 degrees Celsius) than trout stocked during warmer temperatures (13–24 degrees Celsius).

As mentioned above, SJRIP cooperators have increased tempering times for stocked Colorado pikeminnow in an attempt to reduce any negative impacts of abrupt temperature and water quality changes. However, San Juan River water temperatures at the time of stocking have been below those shown to cause significant reductions in the swimming ability of young Colorado pikeminnow (Berry and Pimentel 1985, Childs and Clarkson 1996). The small differences in temperature at the time of stocking among years in our study do not appear to have influenced catch rates in those years. However, part of the initial loss of stocked YOY Colorado pikeminnow may be caused by disequilbrium and reduced swimming ability when introduced into the cold water temperatures of the San Juan River.

In addition to differences in habitat, discharge, and temperature, YOY Colorado pikeminnow were delivered at slightly different sizes every year. Other studies have noted that overwinter survival of wild Colorado pikeminnow, and other stocked and wild fishes, may be dependent on the presence of sufficient energy reserves (Kaeding and Osmundson 1988, Thompson et al. 1991, Margenau 1999, Wahl 1999). Hendrickson (1993) showed that stocked Colorado pikeminnow with lower condition factors dispersed further and faster from stocking sites. We found that the 5–7 mm differences in size between study years did not appear to impact the

initial retention or survival to age 1 of stocked YOY Colorado pikeminnow. Similarly, Converse et al. (1999) found no disproportionate overwinter mortality of smaller YOY Colorado pikeminnow when they examined 7 years of data on autumn and spring Colorado pikeminnow size from the Green River. Since the YOY Colorado pikeminnow stocked in the San Juan River have all been considerably larger than those noted to have reduced overwinter survival, they may be immune to the size-related overwinter mortality noted by others (Thompson et al. 1991). Therefore, we do not feel that the size variation in Colorado pikeminnow received from DNFHTC had any appreciable impact on initial retention or survival to age 1.

Increased size at stocking may play a role in increased return rates of Colorado pikeminnow stocked at average sizes near 200 mm TL over stocked YOY Colorado pikeminnow. The results of SJRIP-funded research from 2002–2005 show that initial return rates for Colorado pikeminnow stocked at sizes greater than 200 mm TL appear to be considerably higher than those for Colorado pikeminnow stocked at sizes between 40–50 mm standard length. This fits well with the general paradigm of stocking hatchery-reared fishes, which is that larger fish have higher post-release survival and/or recapture rates (Plosila 1977, Storck and Newman 1988, Koppleman et al. 1992, Wiley et al. 1993, Willis et al. 1995, Pope et al. 1996, Olson et al. 2000, Pratt and Fox 2003). Willis et al. (1995) found that recapture rates of red drum (*Sciaenops ocellatus*) released at 120 mm were nearly 4 times higher than red drum released at 60 mm. The difference in recapture rates was realized within 6 days after stocking and continued for at least 6 months following stocking. Similarly, fingerling red drum released at 200 mm were recaptured at a rate nearly 4 times higher than red drum released at 150 mm. Willis et al. (1995) also cited Yeager (1988) as finding that striped bass (*Morone saxatilis*) released at 150–250 mm were returned 100 times more often than striped bass released at 30–45 mm. Storck and Newman (1988) stocked different sizes of channel catfish concurrently into the same reservoir over 3 years. They found that survival was strongly related to size. Channel catfish between 200 and 250 mm TL survived much better than channel catfish stocked between 120–150 mm TL. They attributed the increased survival to decreased predation, and recommended that future stocking efforts use fish greater than 200 mm. Stocking efforts using smaller razorback sucker in Lake Mohave and elsewhere in the Lower Colorado River Basin have been unsuccessful, mainly because of predation by nonnative fishes (Marsh and Brooks 1989, Burdick 2003, Marsh et al. 2003, Marsh et al. 2005). Marsh et al. (2005) showed that survival of razorback sucker stocked into Lake Mohave increases with size and that the post-stocking survival of razorback sucker stocked at size greater than 350 mm is double that for fish stocked at 300 mm. Initial post-stocking survival and long-term survival of stocked muskellunge (*Esox masquinongy*) has also been shown to increase with the size of fish stocked (McKeown et al. 1999, Wahl 1999).

However, stocking fish at larger sizes is not always a better strategy (Wiley et al. 1993, Willett 1996, Naslund 1998, Margenaus 1999). Naslund (1998) found that brown trout (*Salmo trutta*) stocked as fry dispersed more quickly than brown trout stocked as age-1 and age-2 fish. However, long-term survival was considerably higher for trout stocked as fry or young

fingerlings (85 mm TL). Willett (1996) used food and temperature manipulations to rear silver perch (*Bidyanus bidyanus*) to two different sizes (35 mm and 50 mm) and stock them simultaneously. He found no significant difference in the survival of either size class, and found that the smaller size class grew more quickly. Wiley et al. (1993) showed that while planting larger trout close to the harvest increases angler harvest over stocking subcatchable trout, the survival of these larger fish is equally low in the absence of angler pressure. We found that the larger Colorado pikeminnow appeared to drift as far downstream as the YOY Colorado pikeminnow following stocking. Additionally, at least the first group of fish released from Mumma in November 2003 showed evidence of deformities, most likely from being reared in the hatchery for 12 additional months.

In determining what stocking size produces the best survival varies both between and within species, conflicting data on optimal stocking size even exist for the same species. Many researchers have attempted to identify the optimal stocking strategy for walleye (*Sander vitreus*) but their results have varied widely, illustrating the need for multiple years of data collection and experimentation. Different authors have noted that stocked sac fry, small fingerlings, or large fingerlings all survive and/or grow better after stocking (Heidinger et al. 1987, Fiedler 1992, Koppleman et al. 1992, McWilliams and Larscheid 1992, Mitzner 1992, Paragamian and Kingery 1992, Larscheid 1995,Olson et al. 2000, Pratt and Fox 2003).

The time scale with which success is judged also plays a role in what size class appears to be the best. Mckeown et al. (1999) showed significant changes in relative survival of stocked muskellunge between short-term estimates (30 days) and survival to adulthood (age 5). Since our data only span 2002–2005, we do not have data on the relative contributions of each size class to the adult population. McWilliams and Larscheid (1992) found that while the initial contribution of walleye fingerlings appeared higher than sac fry, walleye stocked as fingerlings had 2–16 times higher first year mortality than fingerlings originating from sac fry stockings. Similarly, Hopley et al. (1993) found that stocked coho salmon (*Oncorhynchus kisutch*) returning as sexually mature males at age 2 tended to be from juveniles that were larger at the time of release, but both males and females returning as age-3 fish were from juveniles that were smaller at the time of release.

The time scale with which success is judged may also exacerbate the apparent increase in success for Colorado pikeminnow stocked at larger sizes. Most of our comparisons of Colorado pikeminnow stocked at larger sizes and Colorado pikeminnow stocked as YOY fish were made using data from SJRIP autumn monitoring trips where the larger fish had been stocked 3–4 months prior to the trips, while the YOY fish of the same age were stocked 11–23 months prior to the trips. None of the age-1 Colorado pikeminnow stocked in November 2003 were collected as age-2 fish 11 months after they were stocked in autumn 2004, whereas 17 of the YOY Colorado pikeminnow stocked 23 months earlier (October 2002) were collected during those same efforts. Conversely, one Colorado pikeminnow stocked as an age-2 fish in June 2004 and

one Colorado pikeminnow stocked as a YOY fish in October 2002 were collected as age-3 fish during the 2005 SJRIP autumn monitoring. Taking into account the differences in the number of fish stocked, the return rate of the fish stocked at the larger, age-2 size was 172 times higher than fish stocked at the YOY size. Even though YOY Colorado pikeminnow stocked in 2002 had the worst survival rate of fish recently stocked, the differences in initial survival for YOY Colorado pikeminnow between 2002 and the other study years do not appear large enough to reconcile the 170-fold increase in return rate seen for fish stocked at the larger size. Returns of older fish (age-3+) appear to be low for all stocked Colorado pikeminnow, regardless of size at stocking, and to this point we only have 1 year of data from the most recent stocking efforts. Shorter term (3–4 month) return rates to age 1 and age 2 between larger and YOY Colorado pikeminnow have been closer to 30:1. Additional data collected during the 2006 and 2007 autumn monitoring should provide a better idea of how much higher the return rate is for Colorado pikeminnow stocked at larger sizes.

Another factor in determining the effectiveness of stocking larger fish is the increased in cost to rear fish to larger sizes (Mitzner 1992, Wiley et al. 1993, Larscheid 1995, Margenau 1999, Wahl 1999). While survival is increased for muskellunge stocked at larger sizes, Margenau (1999) showed that stocking of eggs, fry, fingerlings, or yearlings can each be the most cost-effective method for contributing to the adult population, depending on the environmental conditions of the receiving waters. The cost to raise YOY Colorado pikeminnow (~ 50 mm TL) is around $0.24/fish, whereas the cost to raise Colorado pikeminnow to larger sizes (> 150 mm TL) increases to at least $5.00/fish (Ulibarri 2006). Using these figures, it would cost $72,000 to raise 300,000 YOY Colorado pikeminnow. For that same amount, only 14,400 larger Colorado pikeminnow could be reared. Using data on return rates generated from the number of YOY Colorado pikeminnow stocked in 2002 surviving to age 3 vs. the return rate of larger, age-2 Colorado pikeminnow stocked in 2004 surviving to age 3 as an example we find that, even adjusted for cost, the larger Colorado pikeminnow appear to provide a better return. Only 0.0004 % of the total number of Colorado pikeminnow stocked as YOY fish in autumn 2002 were collected as age-3 fish, while 0.08% of the Colorado pikeminnow stocked as age-2 fish in June 2004 were collected as age-3 fish. Using these percentages we would expect that stocking 300,000 YOY Colorado pikeminnow would provide one or two age-3 Colorado pikeminnow, while stocking 14,400 age-2 Colorado pikeminnow would provide 11 or 12 age-3 Colorado pikeminnow. Similar comparisons of Colorado pikeminnow collected in autumn 2005 that were YOY Colorado pikeminnow stocked in 2003 and 2004 vs. age-1 and age-2 Colorado pikeminnow stocked in July 2005 showed returns to be between 4.6:1 and 1.6:1 in favor of the larger fish. While which size class will be more successful at producing adult fish it remains to be seen, the increased return rates and cost effectiveness of stocking the larger fish suggested by the initial data indicate that we should continue to stock large fish at some level.

Pilot Population Estimate

It is difficult to infer anything about population size from our catch rate data; however, the number of Colorado pikeminnow collected by all SJRIP-funded efforts appears relatively low. We can obtain some idea of how many fish should have remained in the river by examining the Augmentation Plan (Ryden 2003). Based on the Colorado pikeminnow survival rates in the Augmentation Plan and the number of fish stocked each year, we expected that a combined total of over 47,000 Colorado pikeminnow from the 2002-2004 stocking efforts should have been in the river when we performed our pilot population estimate in summer 2005. During the mark and recapture period we collected 409 individual Colorado pikeminnow. This suggests that our sampling efficiency for Colorado pikeminnow is extremely low or that the survival estimates in the plan may be inaccurate. If our sampling efficiency is low, then the Augmentation Plan may be on track. However, if survival rates for Colorado pikeminnow are lower than estimated in the Augmentation Plan, then SJRIP needs to make changes in order to meet the Recovery Goals. An accurate, precise population estimate would provide not only the answers to these questions, but also a comparable metric with which to judge the success of the different stocking efforts. Unfortunately, our first attempt at an estimate failed because our recapture rate was extremely low.

An explanation for our low recapture rate is that tags were lost, tagged fish died, and/or tagged fish behaved differently than untagged fish. Passive integrated transponder tags have been shown to be an effective tagging method for mark and recapture studies throughout the Colorado River Basin and elsewhere, so we feel that tag loss or failure in PIT tags should not have been a problem in our study. However, cooperators only marked 27% of the fish tagged with PIT tags. They marked the remaining 73% with VIE tags. No VIE-tagged fish were collected during sampling during the recapture period or during any SJRIP-funded research since the mark period. Haines and Modde (1996) and Haines et al. (1998) had success using VIE tags during their population estimates with YOY Colorado pikeminnow. They conducted field and laboratory experiments that showed comparatively low mortality (< 5%) and little tag loss with VIE tags (< 15%) vs. other methods (fin clips, tattoo ink). The recapture period in our pilot estimate was only 6–8 weeks after the mark period, and we would have expected that the VIE tags would still be plainly visible after this short amount of time. VIE tags in Colorado pikeminnow used in acclimation studies have been plainly visible after over 9 months, and Haines and Modde (1996) found VIE tags to be visible in 85% of marked Colorado pikeminnow after 142 days. We have seen retention and visibility of VIE tags for up to a year after marking woundfin on the Virgin River using similar protocols (Holden and Golden 2000, Golden and Holden 2004). Therefore, we do not believe that tag loss or tag-induced mortality was responsible for the low recapture rate observed in this study.

A more probable explanation for our low recapture rate is that Colorado pikeminnow were less susceptible to capture during the recapture period than they were during the mark period. Cooperators used different sampling gears and strategies during the mark period and the recapture period. We used block seining and electrofishing to collect Colorado pikeminnow during the mark period, but SJRIP cooperators used seining and raft-mounted electrofishing during the recapture period. We collected the bulk of Colorado pikeminnow that were VIE tagged using block seines, and these fish had an average length of 106 mm. They were already too large to be effectively collected with regular seines, but they would have had to grow an average of 44 mm between the mark and recapture period to enter the low end of size classes that are susceptible to raft-mounted electrofishing. Therefore, Colorado pikeminnow that we VIE tagged during the mark period probably had a much lower probability of being captured during the recapture period because block seining was not used as a collection method.

Not only did we use different gear types during the mark period, but we also sampled different sections of the river. During the mark period we used block seines to sample our nine discrete sampling stations, while NMFRO and UDWR used raft-mounted electrofishing to collect fish from Hogback Diversion to Shiprock and Mexican Hat to Clay Hills Crossing, respectively. During the recapture period, SJRIP cooperators seined multiple habitats in 1 of every 3 miles from the Animas confluence to Clay Hills Crossing and used raft-mounted electrofishing in 2 of every 3 miles (Propst et al. 2000b). Our data show that Colorado pikeminnow are often clumped together in optimal habitats. Because SJRIP cooperators only sampled portions of our stations during autumn monitoring, they may have had a lower probability of capturing marked fishes clumped in habitats found in their off miles. Obviously, we did not mark fish in the large sections of river between our stations during the mark period, which may have lowered the proportion of the population that received marks. Interestingly, both of the Colorado pikeminnow recaptured during the autumn monitoring were greater than 150 mm TL during both the mark and recapture period. Both of the recaptured fishes were also collected during raft-mounted electrofishing between Mexican Hat and Clay Hills Crossing. This indicates that recaptures are possible when the same methodology is used over large sections of river. The UDWR has had some success with preliminary Colorado pikeminnow population estimates in this section of the river, using data from multiple electrofishing passes during nonnative removal efforts (Jackson 2006). We feel that we could have even better success utilizing a combination of raft-mounted electrofishing and block seining throughout the river between the Animas confluence and Clay Hills Crossing.

Growth

The major difference in Colorado pikeminnow growth between study years appears related to variability in the flow and temperature regime in the river. After 1 year in the river, Colorado pikeminnow stocked as age-0 fish in autumn 2004 were significantly smaller (31–36 mm smaller) than Colorado pikeminnow stocked in autumn 2002 and autumn 2003. The most

obvious environmental difference between those years was the high runoff in late spring and early summer 2005. This runoff significantly depressed temperatures in May and June 2005 below those seen in May and June in 2003 and 2004, which were low-flow years. Colorado pikeminnow are not thought to grow at water temperatures below 13°C (Kaeding and Osmundson 1988, Trammell and Chart 1999). In 2003 and 2004 average daily water temperatures at Farmington reached 13°C for the first time in mid-April and were consistently higher than 13°C by early June. In 2005 average daily water temperatures at Farmington did not reach 13°C until June 21. The decreased growth of age-1 Colorado pikeminnow during spring and early summer 2005 appears to be the result of this difference in temperature. Since the 2005 flow year was similar to the 1996 and 1997 flow years, presumably temperatures were also reduced in those years. This would explain why Colorado pikeminnow from the 2004 stocking effort were similar in size after 1 year in the river to the Colorado pikeminnow stocked in 1996 and 1997. Similarly, the decreased May and June 2005 temperatures are probably responsible for the significantly decreased growth we observed in age-2 Colorado pikeminnow from the 2003 stocking efforts when compared with Colorado pikeminnow from the 2002 stocking effort.

The differences in growth between years with different flow and temperature characteristics appear to impact catch rates of Colorado pikeminnow during various SJRIP sampling efforts. Block seining seemed to be considerably more effective than seining for catching Colorado pikeminnow once they exceeded 100 mm TL, and it was possibly more effective for collecting smaller age-1 Colorado pikeminnow (< 150 mm) than raft-mounted electrofishing. Raft-mounted electrofishing seemed to be more effective at catching age 2 (> 200 mm) and older Colorado pikeminnow than both seining and block seining. Average total length of Colorado pikeminnow collected by electrofishing and block-seining in the same month (July) showed that the average size of Colorado pikeminnow collected by electrofishing was 77–91 mm larger than those collected by block seining. The bias of each gear type toward certain size classes of Colorado pikeminnow can influence the conclusions drawn about the retention success of different stocking efforts. For example, SJRIP projects using electrofishing may underestimate the abundance of age-1 Colorado pikeminnow in years with higher flow and depressed late spring and early summer temperatures, as we saw in 2005 and possibly in 1996.

The growth of Colorado pikeminnow on the San Juan River appears to be comparable to or higher than that seen in the Green and Colorado rivers. Osmundson et al. (1997) reported Colorado pikeminnow nearing age 2 to be to be 181 mm TL in the upper Colorado River. His average size fell in the range of average sizes seen for YOY Colorado pikeminnow stocked from 1996–2004 in their first autumn following stocking (165 mm–201mm TL). At the end of their second year in the river, Colorado pikeminnow from the 2002 stocking effort (308 mm TL) were larger than fish from the 1996, 1997, and 2003 stocking efforts (282–292 mm TL) (Ryden 2000b, Trammell and Archer 2000). Wild fish from the upper Colorado River were considerably smaller than this at a similar age (233 mm TL) (Osmundson et al. 1997). The one Colorado pikeminnow from the 2002 stocking effort collected during autumn 2005 large-bodied fish

monitoring was considerably larger (419 mm TL) than age-3 fish collected after the 1996 stocking effort (357 mm) and wild fish from the upper Colorado River (315 mm) (Osmundson 1997, Ryden 2000b). Therefore, growth of stocked Colorado pikeminnow in the San Juan River in the first year following stocking appears similar to that of wild Colorado pikeminnow from the upper Colorado River. However, growth after age 1 appears substantially higher for stocked Colorado pikeminnow in the San Juan River than for wild Colorado pikeminnow in the upper Colorado River.

One potential reason for the increased size of stocked Colorado pikeminnow is that they are stocked at a larger size than one would expect for wild Colorado pikeminnow of the same age. Wild Colorado pikeminnow YOY from the Green and Colorado rivers usually have an average total length of less than 45 mm in autumn (Tyus and Haines 1991, Haines et al. 1998, Converse et al. 1999, Trammel and Chart 1999, Trammel and Archer 2000). We measured the standard length of YOY Colorado pikeminnow during our study, but limited field data suggest that measurements of total length are at least 10 mm greater than measurements of standard length for YOY Colorado pikeminnow immediately after stocking efforts. Therefore, in most years Colorado pikeminnow received from DNFHTC are probably at least 10 mm larger than wild YOY Colorado pikeminnow found in the Green and Upper Colorado Rivers.

Stocking Protocol Changes and Studies

Data collected during all SJRIP-related research and monitoring indicates that a fairly low percentage of Colorado pikeminnow stocked as age-0 fish survive to age 1. Reviews of other stocking and reintroduction programs all show that the survival rate of hatchery-reared fish is low and the majority of stocked fish are lost within the first few days to weeks after stocking (Cresswell 1981, Wiley et al. 1993, Maynard et al. 1995, Cowx 1998, Brown and Laland 2001, Brown and Day 2002). Most authors would describe the success of an enhancement program as the number of fish that end up contributing to the population or to the creel (Leon 1986, Wiley et al. 1993, Banks 1994, Carmichael and Messmer 1995, Larscheid 1995, Cowx 1998, Fairchild and Howell 2004). Since only a low percentage of hatchery-reared fish appears to survive for very long after stocking, there are essentially two ways to increase the success of an enhancement program: (1) stock more fishes or (2) increase post-release survival of stocked fishes. The data presented in this report show the potential merit of both options.

If a constant proportion of stocked fish survive, then increasing the number of fish stocked should obviously increase the number of fishes that retain and survive. The 1996, 2003, and 2004 stocking efforts provide a good example of this. The SJRIP stocked 100,000, 176,000, and 280,000 YOY Colorado pikeminnow in those 3 years, respectively. Once we scaled the catch rates for the total number of fish stocked, we found little difference 4–5 months and 9 months after stocking among those years. Therefore, most of the increase in abundance of Colorado

pikeminnow we saw in 2003 and 2004 over 1996 was probably attributable to the increased numbers of fish stocked.

Stocking higher numbers of fishes is not necessarily the most cost-effective method for improving stocking success. Many authors have shown that hatchery-reared fishes have physical and behavioral deficiencies compared with wild fish (Wiley 1993, Brown and Laland 2001, Brown and Day 2002, Brown et al. 2003, Fairchild and Howell 2004, Braithewaite and Salvanes 2005). Most of these authors conclude that the best way to increase the success of stocking programs is to focus on increasing post-release survival (i.e., quality over quantity). We have already reviewed the potential benefits of stocking fish at different sizes and temperatures. In addition to these methods, research has also shown potential benefits to several other strategies for improving post-release survival of stocked fish including "soft release" tactics, environmental enrichment, predator avoidance training, forage training, and exercise training, among others.

As mentioned previously, YOY Colorado pikeminnow stocked en masse (hard release) in 2002 appeared to have the worst initial survival of recent stocking efforts. Since the 2002 stocking effort, stocking protocols for Colorado pikeminnow released into the San Juan River have been changed. The bulk of Colorado pikeminnow stocked in 2003 and all of the Colorado pikeminnow stocked in 2004 were stocked directly into low-velocity habitats, and some were held in these habitats for up to 7 days. Allowing fish any kind of acclimatization or rest period following release is termed "soft release" by Brown and Day (2002). These soft release strategies can also help reduce the impacts of stress from handling and stocking fishes, and ultimately increase post-release survival (Brown and Day 2002). Despite the fact that SJRIP habitat mapping showed no increase in backwater habitat between autumn 2002 and autumn 2003, we still found that scaled catch rates were substantially higher following the 2003 stocking effort than the 2002 stocking effort. Our acclimation and debris pile experiments both appeared to have failed in that year, which leaves changes in stocking protocol as the most logical explanation for the increased initial retention after the 2003 stocking effort. We feel that abandoning hard release protocols is at least partially responsible for the observed increase in catch rates we saw after the 2003 stocking effort.

Besides changes in stocking protocol, we also experimented with another soft release strategy, acclimation, from 2003-2005. The idea of using acclimation was the direct result of the poor retention seen after the 2002 stocking effort. The SJRIP cooperators stocked half the YOY Colorado pikeminnow available in 2002 at the upper end of critical habitat because of the propensity for YOY Colorado pikeminnow to drift, and because Recovery Goals for the San Juan are contingent on Colorado pikeminnow using the areas above the PNM Weir (Miller and Lamarra 2006). Our monitoring results after the 2002 stocking effort showed that not only did few fish retain above PNM Weir, but few fish retained throughout the entire river. Therefore, we

began acclimation studies in conjunction with the main stocking program, with the goals of improving both overall retention and retention above Hogback Diversion.

The mortality event, combined with tag failure, in 2003 made it impossible to judge any impact acclimation studies may have had on the increased catch rates seen after the 2003 stocking effort vs. the 2002 stocking effort. Additionally, the distribution of our data and wide confidence intervals prevent us from making meaningful inferences about how acclimation studies may be increasing overall catch rates in any of the years. However, we did note that while acclimated fish only comprised 10.5% of the fish stocked above our APS Weir to Hogback Diversion station, VIE-marked (acclimated) fish made up over 40% of the fish we collected in that station during our initial sampling trip and our sampling trip 5 months after stocking. This difference was not statistically significant, but we feel that the higher percentage of marked fish in that station was the result of fish that retained from the one "good" acclimation area we found there in 2004. Using two similar habitats in 2005, we were able to hold almost all 20,000 Colorado pikeminnow for the full 7 days. Again, we found a higher, but not significant, proportion of marked fish in the stations where we conducted acclimation studies than we expected based on the percentage of acclimated fish stocked in and above these stations. While the more recent March 2006 data were not ready for inclusion in this report, the results supported the data from November 2005, suggesting a higher proportion of marked fish in the upper stations.

In addition to the high proportion of marked fish we saw in our monitoring efforts, the scaled catch rates from the APS Weir to Hogback Diversion station appeared higher after the 2004 stocking efforts than after the 2003 stocking efforts. The combined catch rate of both our stations above Hogback Diversion also showed evidence of an increase, particularly 9 months after stocking. Again, these differences were not statistically significant but provide additional evidence that acclimation studies may be helping to increase retention of Colorado pikeminnow. The fact that acclimated fish were not found more than 64–73 miles downstream of the two acclimation sites, whereas non-acclimated fish were found 140–172 miles downstream of their respective stocking locations, also provides evidence that acclimated fish may be able to retain better than non-acclimated fish.

As noted previously, reintroductions of Colorado pikeminnow and other native Colorado River fishes have been plagued by downstream dispersal, and acclimation experiments have been suggested as a tool to decrease downstream dispersal by a number of other researchers (Marsh and Brooks 1989, Minckley et al. 1991, Ryden and Pfeifer 1996, Burdick 2003). Brown and Day (2002) evaluated stock-enhancement programs and promoted acclimation as a soft release strategy. They cited several studies showing that holding salmonids from 90 minutes to 7 days after stocking had a positive effect on angler return rate and/or post-release survival. Kenaston et al. (2001) cited Fast et al. (1991), who noted that acclimated spring chinook salmon (*Oncorhynchus tshawytscha)* had higher return rates than directly released fishes. Jonsson et al. (1994) found that acclimating brown trout to seawater for 1–2 months prior to release

significantly increased their recapture rate. Johnson et al. (1990) showed increased mortality in coho salmon smolts released directly into the river vs. those allowed to acclimate for 6 weeks after trucking. Olla et al. (1995) found that stressed coho and spring chinook salmon recovered their predator avoidance abilities within 24 hours. Brown and Day (2002) also cited studies showing that fish reared in outside ponds vs. raceways and tanks had better post-release survival. Similarly, Olsen et al. (2000) and McWilliams and Larscheid (1992) found that pond-reared walleye fingerlings had significantly better survival than raceway- or tank-reared walleye. Increased post-release survival has also been shown for pond-reared vs. tank-reared muskellunge (Margenau 1999, Mckeown et al. 1999, Wahl 1999).

Other authors have found mixed or neutral results when trying to increase survival of stocked fish using acclimation. Cresswell and Williams (1983) acclimated brown trout in cages at two receiving streams for 24 hours prior to release. One of the streams had low velocities. Follow-up monitoring in this low-velocity stream found that acclimated fish comprised a significantly greater proportion of fish than expected, and acclimated fish did not disperse as far as non-acclimated fish in this stream. The other stream had higher velocities and underwent several spate events following stocking. Cresswell and Williams (1983) found that abundance and dispersal distance of acclimated fish did not differ from non-acclimated fish in this stream. Tipping (1998) found no difference in return rates of steelhead (*Oncorhynchus mykiss*) smolts allowed to rest (acclimate) for 24 hours after trucking compared with those released directly into the river. Similar to Tipping (1998), Ward and Slaney (1990) and Kenaston et al. (2001) found no difference in the homing rate or survival of steelhead smolts acclimated for more than 30 days when compared with steelhead smolts released directly after transport. Several studies cited in Margenau (1999) showed no increased survival for fingerling muskellunge held in pens for 2–4 days before release over those released directly into lakes. Larscheid (1995) and Paragamian and Kingery (1992) found that walleye fingerlings reared in raceways survived better than those reared in nursery lakes.

Similar to the bulk of research we found on the impacts of acclimation on post-release survival on sport or commercial fish species, the acclimation studies of Colorado River fish also had mixed results. Mueller and Marsh (1998), Mueller and Foster (1999), and Mueller et al. (2003) attempted to determine differences in dispersal between acclimated and non-acclimated razorback sucker at several areas in the Colorado River Basin. No significant differences in dispersal of site-acclimated vs. non-acclimated fish were observed in any of the studies. However, in two of the studies it appeared that site-acclimated fish did not travel as far, or disperse as fast, as non-acclimated fish (Mueller and Marsh 1998, Mueller and Foster 1999). Additionally, in October 1982 Archer et al. (1985) held hatchery-reared Colorado pikeminnow in seven backwaters along the Colorado River with blocking nets for about 24 hours. Prior to removal of the nets, the backwaters were seined to estimate a baseline CPUE value. Backwaters were then sampled weekly to estimate retention. Hatchery-reared Colorado pikeminnow remained in the backwaters, but mean CPUE generally declined until no Colorado pikeminnow

were captured in the backwaters when sampling was terminated in early November. Fish were marked with coded-wire tags that required sacrificing the fish to determine the specific mark; no recaptured fish were sacrificed to identify the specific stocking sites.

Despite the mixed results from other acclimation studies, after 3 years of experimentation our acclimation studies appear to be achieving some level of success. In addition to acclimation, authors have noted the positive influence of other pre-release treatment strategies on the post-release survival of stocked fish (Wiley et al. 1993, Margenau 1999, McKeown et al. 1999, Wahl 1999, Brown and Day 2002, Mueller et al. 2003). Among these are environmental enrichment (simulating a more-natural rearing environment), exposure to live prey, predator avoidance training, and exercise training/conditioning (Olla and Davis 1989, Wiley et al. 1993, McWilliams and Larscheid 1992, McKeown et al. 1999, Wahl 1999, Olson et al. 2000, Brown and Laland 2001, Maynard et al. 2001, Brown and Day 2002, Brown et al. 2003, Fairchild and Howell 2004). While all these pre-release treatment strategies have potential applications for stocked Colorado pikeminnow, we feel the exercise conditioning may be the most germane given the propensity of stocked Colorado pikeminnow to drift.

Previous research has shown that exercise conditioning can increase the swimming ability and stamina of fish (Young and Cech 1993a, 1993b; Davison 1997; Moyle and Cech 2005). Ward and Hilwig (2004) tested flannelmouth sucker, bonytail (*Gila elegans*), razorback sucker, and spikedace (*Meda fulgida*) to compare the swimming performance of pond-reared, physically conditioned, and wild-captured, stream-dwelling fish. Subjecting pond-reared fishes to flowing water for even a nominal 10–14 days significantly increased fatigue velocities in all species tested, suggesting the utility of implementing exercise conditioning in native fishes. Leon (1986) showed that swimming performance of exercised-trained brook trout (*Salvelinus fontinalis*) fed to satiation and underfed was significantly higher than for unexercised brook trout fed to satiation. Davison (1997) reviewed literature on exercise conditioning and found that exercise training generally leads towards increased stamina and aerobic potential.

Exercise has been found to have other benefits as well. Young and Cech (1993a, b) found that cultured and wild YOY striped bass had increased growth and muscle development when held in raceways with water velocities of 1.2–2.5 body lengths per second for 60 days, compared with fish held in raceways with minimal flow. They also found that exercised fish had an improved stress response. Young and Cech (1993a, b) cite other research showing similar benefits from exercising Atlantic salmon (*Salmo salar*), coho salmon, brook trout, rainbow trout, chub (*Leuciscus cephalus*), and largemouth bass. Leon (1986) found that exercised brook trout fed to satiation grew significantly faster than unexercised brook trout fed to satiation. Davison (1997) indicated that exercise training at water speeds of less than 1.5 body lengths per second had a positive impact on growth. When Christiansen et al. (1992) stocked Arctic charr (*Salvelinus alpinus*) at low densities and subjected them to sustained exercise, the fish were able to obtain higher growth rates compared with fish that were not preconditioned to current.

Other researchers have found the ancillary benefits of exercise training to be variable. While Davison (1977) saw positive effects of exercise training on growth and stamina, the results on conversion efficiency, maximum swimming velocity, and muscle development were variable. Similarly, while exercise exercised Arctic char held at low densities showed increased growth, exercised Arctic charr held at high densities showed no increase in growth rate. Banks (1994) examined the growth and survival of chinook salmon raised at three different rearing densities in raceways with three different water flows (0.01 cms, 0.03, cms, and 0.04 cms) for 8–9 months over 4 different brood years. He found that water flow had no significant effect on growth or weight of these fish.

Similar to the research on soft release tactics, research on the influence of exercise on post-release survival of stocked fish has also shown variable results. Mueller et al. (2003) showed that hatchery-reared razorback sucker preconditioned to flow demonstrated significantly less downstream dispersal than fish reared in ponds. Maynard et al. (1995) performed a review of fish culture methods for increasing post-release survival and indicated that exercise training can significantly improve swimming ability and, in most cases, post-release survival. In studies with the largest increases in post-release survival for exercised vs. non-exercised fish, salmonids were exercised at high water velocities the same time each day for 2 weeks. Cresswell and Williams (1981) found trout conditioned to medium-velocity flows for 14 days had a significantly higher return rate. Cresswell and Williams (1983) also cited Miller (1954) as showing that hatchery - reared trout conditioned in a stream had a higher survival rate than non-conditioned fish. When Banks (1994) raised chinook salmon at three different rearing densities in raceways with three different water flows (0.01 cms, 0.03, cms, and 0.04 cms) for 8–9 months over four different brood years, he found that post-release survival and adult contribution was highest from raceways with the highest water flow (0.04 cms).

Other studies have indicated that exercise training may have no impact or even a negative impact on the post-release survival of stocked fish. Hendrickson and Brooks (1987) found that fingerling (50 mm–100 mm TL) Colorado pikeminnow conditioned to current (0.04 m/s) for 7 days dispersed downstream more rapidly than non current-conditioned fish. They attributed the faster dispersal to the smaller size (length and weight) of the conditioned Colorado pikeminnow. Evenson and Ewing (1993) exercised rainbow trout at water speeds of 0.1–0.8 m/s for an hour a day over the month prior to their release but found no increase in post-release survival over control fish. While Cresswell and Williams (1981) found trout conditioned for 14 days had higher return rates, trout conditioned for 8 hours or 2 days showed no increase in return rate. Horak (1972) rated exercised and non-exercised rainbow trout for stamina after they had been recaptured and found no evidence of increased survival for “high stamina” fish. Similarly, Lagasse et al. (1980) found that released higher-stamina coho salmon did not return at higher rates than other fish.

Exercise conditioning and other pre-release treatment options exist to try to improve the success of Colorado pikeminnow augmentation in the San Juan River. Research to date has shown that most methods to increase post-release survival have variable results and may be specific to species and even systems. Similar to our acclimation studies, experiments will have to be conducted to determine whether a given method will be successful at increasing survival of hatchery-reared Colorado pikeminnow in the San Juan River. However, the larger question of whether increasing the success of Colorado pikeminnow stocking efforts is necessary remains unanswered.

As demonstrated earlier, the number of fish collected in our mark-recapture effort was less than 1% of the number of fish predicted to be in the river using survival rates from the Augmentation Plan, which indicates a low level of detection by sampling or a lower survival rate of stocked fish than anticipated in the Augmentation Plan. The historical data also suggest problems with survival or detectability. While the 1996 stocking effort appeared to be the most successful, very few sub-adult and adult progeny of this stocking have been collected during SJRIP-related monitoring from 1999-2005 (Ryden 2000b; Trammel and Archer 2000; Ryden 2001; Jackson 2003; Ryden 2003b, 2003c; Davis 2004; Jackson 2004, 2005). This further suggests that either our collection methods are ineffective for Colorado pikeminnow age 3 and older or survival of Colorado pikeminnow past age 2 is poor. If the latter is true, then in order to meet the recovery goals we must identify and remove the factors reducing survival of fish past age 2 and/or increase the number of Colorado pikeminnow entering the age-2 year class.

Other Fish Data

One of the more-interesting ancillary findings of the YOY Colorado pikeminnow monitoring project was the collection of a half-dozen razorback sucker juveniles in 2004. We collected two juveniles in March 2004 that would have been spawned in 2003, and we collected four juveniles in July 2004 that had probably been spawned earlier that spring. All of these fish were collected in Reaches 1 and 2 between Mexican Hat and Clay Hills Crossing. During nonnative removal efforts, the UDWR also collected juvenile razorback sucker in 2004 (Jackson 2005). Interestingly, very few razorback sucker larvae (41) were collected in 2004 (Brandenburg et al. 2005), yet we collected our highest number of juveniles after spawning in 2004. Over 10 times as many larval razorback sucker were collected in 2003 (Brandenburg et al. 2004), which was a little more than 50% of what was collected in 2002 (Farrington et al. 2002). We did not sample the canyon section of the river in 2002 or 2003, so it is possible that more juveniles may have been present in those years. Perhaps the increase in backwater habitat from autumn 2003 through autumn 2004 played a role in allowing these fish to reach the juvenile life stage. However, if that was the case we would expect that additional juveniles would be found during sampling in 2005, but we did not find any.

The red shiner and fathead minnow domination of the small-bodied fish community mirror the results of small-bodied fish monitoring (Paroz et al. 2005). Because they sampled all meso-habitats and we concentrated on low-velocity habitats, we saw differences in the native fish community found in these studies. Small-bodied fish monitoring results have shown that speckled dace dominate the native fish community, whereas we have found that flannelmouth sucker abundance and catch rate is nearly equal to speckled dace during most of our sampling trips. However, speckled dace are common inhabitants of riffles, and we sample very few riffles in our study. As noted by others, native fish abundance is higher above the Hogback Diversion, but we saw an increasing trend in native fish abundance downstream from Mexican Hat between 2003 and 2005. While native fish catch rates varied considerably between years, we did not see any trends in native fish abundance between years. The higher catch rates we saw during initial sampling trips in 2004 and 2005 vs. 2002 and 2003 may have been related to warmer water temperatures that increased sampling efficiency. Similarly, we saw elevated catch rates of nonnative fishes in November 2004 and November 2005 vs. December 2002 and 2003.

CONCLUSIONS

1. The majority of stocked YOY Colorado pikeminnow appear to be lost from the system within 1 month after stocking.

Our results clearly show that the majority of Colorado pikeminnow stocked as age-0 fish are lost within the first few days to weeks after stocking (Figures 10-12). Whether this initial loss is from mortality, downstream drift, or just detectability is unclear, but we suspect drift is the major problem. After this initial loss, retention appears to remain steady through the autumn of the year following stocking. Therefore, any plans to increase survival to age 1 should be aimed at improving survival immediately following stocking.

2. Habitat availability, temperature at stocking, and behavioral deficiencies of hatchery-reared fishes probably act synergistically to influence initial retention.

Many factors appear to impact the retention of Colorado pikeminnow stocked as age-0 fish. As highlighted in the Discussion section, Colorado pikeminnow appear to prefer backwater habitats, which have varied in their abundance during the study period. Additionally, Colorado pikeminnow have been stocked at relatively cold temperatures, which resulted in little or no growth for the first 5 months after stocking (Figure 43 and Table 18) and possibly impaired swimming performance (see literature review in Discussion). Our data also indicate that when temperatures are colder, Colorado pikeminnow used habitat with cover in a higher proportion than expected based on the percentage of habitats with cover sampled (Figures 58 and 59). If low velocity and cover are needed, this further reduces the amount of optimum habitat for these fishes at the time of stocking and over their first winter in the river. The propensity of young

Colorado pikeminnow to drift, combined with potentially reduced habitat availability and swimming ability, may act in unison to cause the large loss of fishes immediately after stocking.

3. Handling protocols may influence post-release survival.

The mortality event we observed during acclimation studies in 2003 highlighted the influence of handling stress on the success of stocking programs (Golden and Holden 2005, Holden and Golden 2005). While our subsequent experiments failed to recreate the large-scale mortality we observed in November 2003, it seems apparent that stress from the compressed handling time frame, coupled with additional stress caused by the calcein dye procedure, was probably responsible for the mortality we saw in November 2004. Pitman and Gutreuter (1993) and Young and Cech (1993b) review how stress from harvest, transport, and stocking can result in mortality of hatchery-reared fish. They cite research showing how stress from handling and transport can result in decreased immune response and increased osmoregulatory problems, which can ultimately lead to sudden mortality. The new protocols of increasing the time between handling events at DNFHTC and by SJRIP cooperators in the field appear to help prevent the progression of stress-related physiological and biochemical problems, and assist in increasing initial post-release survival.

4. Colorado pikeminnow stocked at larger sizes may have a higher initial survival than Colorado pikeminnow stocked as YOY fish.

The limited recapture information we have for Colorado pikeminnow stocked at sizes averaging near 200 mm TL suggests that at least initial return rates of these fish may be considerably higher than Colorado pikeminnow stocked as YOY fish. Although the cost of rearing larger fish is higher, initial returns suggest that stocking these larger fish may actually be more cost effective. Until the larger fish and fish from the YOY Colorado pikeminnow stocking efforts begin to recruit into the adult population, it will remain difficult to determine which stocking strategy is most effective.

5. Stocked Colorado pikeminnow growth in the San Juan River may be dependent on the strength of the flow year, but it appears to be similar to or higher than growth of wild Colorado pikeminnow from other systems.

Growth of Colorado pikeminnow in the San Juan River was significantly impacted by the high flows in spring and early summer 2005 (Table 18; Figures 5, 7, 8, 43, 44). Spring flows appear to determine when temperatures exceed 13°C in the river, which may impact growth rates of Colorado pikeminnow. Also, our comparison of the average length of YOY Colorado pikeminnow stocked into the San Juan River with published values for average lengths of similarly aged wild Colorado pikeminnow showed larger fish (higher growth) for Colorado pikeminnow stocked into the San Juan River.

6. Soft release protocols may be helpful in increasing initial retention.

Other than finding higher initial catch rates with shorter intervals between stocking and sampling, the low retention for Colorado pikeminnow stocked in 2002 was the most obvious difference seen in catch rate data collected after the recent stocking efforts (Figure 11). The only major difference that we felt could have positively impacted initial retention between the 2002 and 2003 stocking efforts was the change in stocking protocols. Stocking fish directly into low-velocity habitats appears to positively impact retention.

When we were able to hold Colorado pikeminnow for the full 7 days in the proper habitats, our data indicated that acclimated fish were found in a higher proportion than we expected, based on the percentage of acclimated fish stocked and higher-appearing catch rates at acclimation study stations (Figures 13, 14, 39, 40, 42). Additionally, we saw some evidence that acclimated fish did not drift as far downstream and even witnessed some upstream movement of acclimated fish within 2 weeks after their release. Therefore, we feel that when the proper areas are used, acclimation of YOY Colorado pikeminnow can increase post-release survival and decrease the amount of downstream dispersal.

7. Directing efforts to increase retention above Hogback Diversion appear to have been successful.

After the 2002 stocking effort, we collected very few Colorado pikeminnow above the Hogback Diversion; no Colorado pikeminnow were collected above Hogback Diversion during large-bodied fish monitoring in autumn 2003 (Figures 13, 14, 42). In addition, 14 Colorado pikeminnow from the autumn 2003 stocking were collected during large-bodied fish monitoring in autumn 2004, and 11 Colorado pikeminnow from the autumn 2004 stocking effort were collected in autumn 2005. Therefore, we conclude that the combined impacts of stocking Colorado pikeminnow using soft release strategies, performing acclimation studies, and possibly increasing backwater habitat above Hogback Diversion appear to have substantially increased the initial retention and survival of Colorado pikeminnow to age 1 in Geomorphic Reach 6.

8. Catch per effort and abundance statistics do not appear to provide a tool to assess the true success of stocking efforts.

As highlighted in many areas of the report, the distribution of our data was heavily skewed to the left and provided us with no real way to meaningfully compare among trips and stations. In addition, catch rate and abundance statistics for all SJRIP-funded projects appear very susceptible to gear bias and changes caused by environmental conditions at the time of sampling, further adding to the difficulty of interpreting changes in catch rate among study years and sampling trips (Table 11, Figures 45–47). Additionally, the simultaneous impacts of changes in stocking protocols, changes in stocking numbers, and environmental stochasticity make it nearly

impossible to interpret what might be responsible for changes in catch rate among years. While it is apparent that SJRIP-funded projects have produced different catch rates and collected different numbers of Colorado pikeminnow in different years, it is very difficult to determine what those differences mean biologically. Therefore, our current evaluation of catch rate and abundance statistics from all SJRIP-related projects does little to help us judge the Augmentation Plan's progress toward achieving Recovery Goals.

RECOMMENDATIONS

Cowx (1998) contends that the majority of fish stocking programs are carried out without a clear objective or measurement of the potential or actual success of the endeavor. On the contrary, the SJRIP has a clear objective for stocking and attempted to measure the actual success of the recent and historical stocking efforts for Colorado pikeminnow in the San Juan River (Trammel 1999; Jackson 2000; Propst et al. 2000a; Ryden 2000a, 2000b;Trammel and Archer 2000; Ryden 2000a, 2000b; USFWS 2002; Ryden 2003a, 2003b, 2003c, 2004; Golden et al. 2004; Propst et al. 2004; Golden and Holden 2005; Paroz et al. 2005). We recommend the following actions to help measure the success and achieve the objectives of the Augmentation Plan.

1. Continue monitoring the fate of stocked Colorado pikeminnow with sampling specifically designed to collect Colorado pikeminnow.

We recommend the continuation of a study to monitor the fate of YOY Colorado pikeminnow stocked into the San Juan River with the following modifications:

(a) Eliminate the initial sampling trip after stocking.

The catch rates of Colorado pikeminnow in our initial trips after stocking were dictated by the proximity of that trip to the time of stocking. After the initial loss of fish, catch rates appear to remain steady into March. Therefore, we would recommend eliminating the initial sampling trip and using catch rates from the March sampling trip to judge the influence of environmental conditions and new stocking protocols/experiments on initial retention of stocked Colorado pikeminnow.

(b) Discontinue sampling below Clay Hills Crossing.

We collected two Colorado pikeminnow below the waterfalls, documenting that endangered fishes can survive in and utilize this area. However, we found few fish using this area, and the habitat is generally poor. Therefore, we do not see a need to continue data collection in this area.

(c) Devise a sampling methodology that will allow inferential comparison of retention between stocking efforts and evaluate the success of the Augmentation Plan at reaching Recovery Goals.

We believe that this report has highlighted the shortcomings the ability of our project, or any other SJRIP-funded projects, to provide the SJRIP with an accurate assessment of the success of each stocking effort or the success the Augmentation Plan has made towards achieving Recovery Goals. While there may be alternative methods to developing a statistically comparable metric to accomplish these goals, we recommend continuing to attempt a mark and recapture population estimate for juvenile Colorado pikeminnow in conjunction with the summer YOY Colorado pikeminnow monitoring trip, nonnative removal efforts, and SJRIP fall monitoring. We feel that enlarging our study area by eliminating our stations and randomly sampling habitat throughout the San Juan River from the confluence of the Animas River to Clay Hills Crossing will allow for a more accurate assessment of relative abundance and/or more precise population estimates. We feel that a population estimate that uses both block seining and raft-mounted electrofishing throughout the river from the confluence of the Animas River to Clay Hills Crossing for both the mark and recapture period would have the best chance at producing an accurate and precise estimate. The sampling for this estimate could be combined with other ongoing SJRIP-funded research (nonnative removal efforts, large-bodied fish monitoring).

2. Pursue habitat enhancement and restoration opportunities.

Clearly, the number and size of backwaters in the San Juan River is a limiting factor in the success of Colorado pikeminnow stocking efforts and for any future hope of establishing a self-sustaining population of Colorado pikeminnow. We recommend investigating small-scale habitat enhancements designed to enhance post-stocking retention of Colorado pikeminnow in Geomorphic Reach 6 (see Stamp et al. 2005 for examples), as well as initiating investigations of larger-scale habitat restoration, such as nonnative vegetation removal, throughout critical habitat.

3. Continue and increase the scope of acclimation efforts.

As we illustrated above, acclimation can substantially increase post-stocking survival of hatchery-reared fishes. Over the 3-year study period, we found that to properly acclimate Colorado pikeminnow, relatively large backwaters or extremely low-velocity side-channel habitats are necessary. Unfortunately, those habitats are limiting, particularly in Geomorphic Reach 6 where efforts have been directed thus far. Therefore, in order to proceed with larger-scale acclimation, we may have to utilize areas downstream from Hogback Diversion. Regardless of where the activities are performed, we recommend trying to acclimate at least 100,000 of the Colorado pikeminnow to be stocked in autumn 2006.

4. Continue to stock larger hatchery fish.

Initial data show that Colorado pikeminnow stocked at sizes averaging near 200 mm TL provide a better return than Colorado pikeminnow stocked between 50 and 60 mm TL. However, the contribution of this size of fish to the adult population remains to be seen. Nevertheless, we recommend continuing to stock some Colorado pikeminnow at larger sizes until the most cost-effective strategy can be devised.

5. Determine the need for increasing survival of stocked Colorado pikeminnow and move forward with additional pre-release strategies to improve retention.

As discussed previously, the current suite of research and monitoring projects provides us with little information on Colorado pikeminnow survival rates. Adopting mark and recapture population estimates as the primary sampling strategy with which to evaluate the success of YOY Colorado pikeminnow stocking efforts will allow us to determine whether survival rates of stocked fish are close enough to those outlined in the Augmentation Plan to meet Recovery Goals. If they are, then the SJRIP has no reason to increase initial retention over what we have achieved from 2003–2005. If they are not, then implementing additional pre-release strategies to improve initial retention may be a way to increase the number of fish reaching adulthood.

In the absence of data indicating that survival from the current stocking efforts will provide enough adult Colorado pikeminnow to meet recovery goals, we recommend pursuing additional variations in stocking protocol and pre-release training in an attempt to further increase post-release survival. Specifically, we recommend experimenting with different stocking times to alleviate the potential negative impacts of cold water temperatures on initial retention, as well as experimenting with exercise training to improve swimming performance and reduce recovery time from handling stress.

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LITERATURE CITED

Archer, D. L., L. R. Kaeding, B. D. Burdick, and C. W. McAda. 1985. A study of the endangered fishes of the upper Colorado River. Final report to the Northern Colorado Water Conservancy District, Cooperative Agreement No. 14-16-0006-82-959. U. S. Fish and Wildlife Service, Grand Junction, Colorado.

Banks, J.L. 1994. Raceway density and water flow as factors affecting spring chinook salmon (*Oncorhynchus tshawytscha*) during rearing and after release. Aquaculture 119: 201-217.

Berry, C.R., Jr. 1988. Effects of cold shock on Colorado squawfish larvae. Southwestern Naturalist 33: 193-197.

Berry, C.R. and R. Pimentel. 1985. Swimming performances of three rare Colorado River fishes. Transactions of the American Fisheries Society 114:397-402.

Bliesner, R. 2006. Keller-Bliesner Engineering. Personal communication with Mike Golden of BIO-WEST, Inc. regarding results of 2005 habitat studies. 3/14/06.

Bliesner, R. and V. Lamarra. 2004. Hydrology/Geomorphology/Habitat studies: 2003 Annual report. Prepared by Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 76 p.

Bliesner, R. And V. Lamarra. 2005. Hydrology/Geomorphology/Habitat studies: 2004 Annual report. Prepared by Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 70 p.

Braithewaite, V.A., and A.G.V. Salvanes. 2005. Environmental variability in the early rearing environment generates behaviourally flexible cod: implications for rehabilitating wild populations. Proceedings of the Royal Society, London Series B: 1-7.

Brandenburg, W.H., M.A. Farrington, and S.J. Gottleib. 2004. Razorback sucker larval fish survey in the San Juan River during 2003. Prepared by University of New Mexico, Museum of Southwestern Biology, Fishes Division for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 60p.

Brandenburg, W.H., M.A. Farrington, and S.J. Gottleib. 2005. Razorback sucker larval fish survey in the San Juan River during 2003. Prepared by University of New Mexico, Museum of Southwestern Biology, Fishes Division for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 99p.

Brown, C., T. Davison, and K. Laland. 2003. Environmental enrichment and prior experience of live prey improve foraging behaviour in hatchery-reared Altantic salmon. Journal of Fish Biology 63 (Suppl. A): 187-196.

Brown, C. And R.L. Day. 2002. The future of stock enhancements: Lessons for hatchery practice from conservation biology. Fish and Fisheries 3: 79-94.

Brown, C. and K. Laland. 2001. Social learning and life skills training for hatchery-reared fish: Review paper. Journal of Fish Biology 59: 471-493.

Burdick, B.D. 2003. Monitoring and evaluating various sizes of domestic-reared razorback sucker stocked in the Upper Colorado and Gunnison Rivers: 1995-2001. U.S. Fish and Wildlife Service, Colorado River Fishery Project, Recovery Program Project 50 Final Report, Grand Junction, Colorado.

Burdick, B.D. and R.B. Bonar. 1997. Experimental stocking of adult razorback sucker in the upper Colorado and Gunnison Rivers. U.S. Fish and Wildlife Service, Colorado River Fishery Project, Recovery Program Project 50, Grand Junction, Colorado.

Carmichael, G.J., J.R. Tomasso, B.A. Simko, and K.B. Davis. 1984. Characterization and alleviation of stress associated with hauling largemouth bass. Transactions of the American Fisheries Society 113: 778-785.

Carmichael, R.W and R.T. Messmer. 1995. Status of supplementing Chinook salmon natural production in the Imnaha River Basin. Pages 294-291 in H.L. Shcramm Jr. and R.G. Piper (editors) Uses and effects of cultures fishes in aquatic systems. American Fisheries Society Symposium 15. American Fisheries Society, Bethesda, MD.

Childs, M.R. and R.W. Clarkson. 1996. Temperature effects on swimming performance of larval and juvenile Colorado squawfish: implications for survival and species recovery. Transactions of the American Fisheries Society 125: 940-947.

Christiansen, J.S., Y.S. Svendsen, and M. Jobling. 1992. The combined effects of stocking density and sustained exercise on the behaviour, food intake, and growth of juvenile Arctic charr (Salvelinus Alpinus). Canadian Journal of Zoology 70:115-122.

Clapp, D.F. Y. Bhagwat, and D.H. Wahl. 1997. The effect of thermal stress on walleye fry and fingerling mortality. North American Journal of Fisheries Management 17: 429-437.

Converse, Y.K., L.D. Lentsch, and R.A. Valdez. 1999. Evaluation of size-dependent overwinter growth and mortality of age-0 Colorado pikeminnow. Utah Division of Wildlife Resources, Salt Lake City. 36 pages.

Cowx, I.A. 1998. Stocking strategies: issues and options for future enhancement programmes. Pages 3-13 in I.A. Cowx (editor) Stocking and introduction of fish. Fishing News Books, London, England.

Cresswell R.C. 1981. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters - a review. Journal of Fish Biology 18: 429-442.

Cresswell, R.C. and R. Williams. 1983. Post-stocking movements and recapture of hatchery trout released into flowing waters - effect of prior acclimation to flow. J. Fish. Biol. 23. 265 – 276.

Davis, J.E. 2004. Non-native species monitoring and control in the upper San Juan River, New Mexico. Draft Annual Report. Prepared by USFWS, Albuquerque, for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Davison, W. 1997. The effect of exercise training on teleost fish, a review of recent literature. Comparative Biochemistry and Physiology 117A: 67-75.

Dudley, R.K. and S.P. Platania. 2000. Downstream transport rates of passively drifting particles and larval Colorado pikeminnow in the San Juan River 1999. San Juan River Basin Recovery Implementation Program. USFWS, Albuquerque, NM. 33p.

Fairchild, E.A. and W.H. Howell. 2004. Factors affecting the post-release survival of cultured juvenile *Psuedopleuronectes americanus*. Journal of Fish Biology. 65 (Suppl. A): 69-87.

Fast, D., J. Hubble, M. Kohn, and B. Watson. 1991 Yakima River spring chinook enhancement study. Contract DE-AI79-83BP39461, Project 82-16, Final Report, prepared for Bonneville Poer Administration, Portland, OR.

Fielder, D.G. 1992. Evaluation of stocking walleye fry and fingerlings and factors affecting their success in lower Lake Oahe, South Dakota. North American Journal of Fisheries Management 12: 336-345.

Golden, M.E. and P.B. Holden. 2005. Retention, growth and habitat use of stocked Colorado pikeminnow in the San Juan River 2003-2004: Annual report. Prepared by BIO-WEST, Inc. for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. PR 874-2: 87 p.

Golden, M.E. and P.B. Holden. 2004. Summary of Lower Virgin River studies 1996-2002. Prepared for the Bureau of Reclamation, Lower Colorado Regional Office and the Southern Nevada Water Authority. 449-02.

Golden, M.E., P.B. Holden, and S.K. Dahle. 2004. Retention, growth and habitat use of stocked Colorado pikeminnow in the San Juan River 2002-2003: Draft Annual report. Prepared by BIO-WEST, Inc. for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. PR 874-1: 66 p.

Haines, G.B. and T. Modde. 1996. Evaluation of marking techniques to estimate population size and first-year survival of Colorado squawfish. North American Journal of Fisheries Management 16(4):905-912.

Haines, G.B., D.W. Beyers, and T. Modde. 1998. Estimation of winter survival, movement and dispersal of young Colorado squawfish in the Green River, Utah. Colorado River Recovery Program Project 36. Larval Fish Laboratory, Department of Fish and Wildlife, Fort Collins, CO. 46 pages.

Haines, G.B. and H. M. Tyus. 1990. Fish associations and environmental variables in age-0 Colorado squawfish habitats, Green River, Utah. Journal of Freshwater Ecology 5: 427-435.

Hansen, D.A., and T.L. Margenau. 1992. Movement, behavior, and survival of stocked muskellunge. North American Journal of Fisheries Management 12: 474-483.

Heidinger, R.C., J.H. Waddell, and B.L. Tetzlaff. 1987. Relative survival of walleye fry versus fingerlings in two Illinois reservoirs. Proceedings of the Annual Conference of Southeastern Association Fish and Wildlife Agencies 39(1985): 306-611

Hendrickson, D.A. 1993. Evaluation of the razorback sucker (*Xyrauchen texanus*) and Colorado squawfish (*Ptychochelius lucius*) reintroduction programs in central Arizona based on surveys of fish populations in the Salt and Verde Rivers from 1986 to 1990. Final Report. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix, AZ. 166p.

Hendrickson, D.A. and J.E. Brooks. 1987. Colorado River squawfish reintroduction studies. Proclamations of the Desert Fishes Council. 18: 207-208 (Abstract).

Holden, P.B. (Editor). 1999. Flow recommendations for the San Juan River. Prepared by the San Juan River Basin Recovery Implementation Program Biology Committee for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Holden, P.B. and M. E. Golden. 2005. Development of stocking protocols for Colorado Pikeminnow in the San Juan River or why did all of our fish die? Prepared by BIO-WEST, Inc. for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. PR-950-1.

Holden, P.B. and M.E. Golden. 2000. Lower Virgin River Endangered Fish Studies, 1998-2000: Evaluation of mechanical removal of red shiner (*Cyprinella lutrensis*), survival of stocked woundfin (*Plagopterus argentissimus*), and results of monitoring. Prepared for the Bureau of Reclamation, Lower Colorado Regional Office and the Southern Nevada Water Authority. PR 723-01.

Hopley, C.W., S.B. Mathews, A.E. Appleby, A Rankis, and K.L. Halliday. 1993. Effects of pond stocking rate on coho salmon survival at two lower Columbia River fish hatcheries. The Progressive Fish-Culturalist 55: 16-28.

Jackson, J.K. 2001. Evaluation of stocked Colorado pikeminnow into the San Juan River: 2000. Prepared by Utah Division of Wildlife Resources, Moab, Utah for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Jackson, J.K. 2003. Nonnative control in the lower San Juan River 2002, annual progress report. Prepared by Utah Division of Wildlife Resources, Moab, Utah for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 26 pp.

Jackson, J.K. 2004. Nonnative control in the lower San Juan River 2003, annual progress report. Prepared by Utah Division of Wildlife Resources, Moab, Utah for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Jackson, J.K. 2005. Nonnative control in the lower San Juan River 2004, annual progress report. Prepared by Utah Division of Wildlife Resources, Moab, Utah for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Jackson, J.K. 2006. Nonnative control in the lower San Juan River 2005, DRAFT interim progress report. Prepared by Utah Division of Wildlife Resources, Moab, Utah for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 37 p.

Johnson, L.D. 1982. Factors affecting short-term survival of stocked muskellunge fingerlings in Wisconsin. Wisconsin Department of Natural Resources. Technical Bulletin 17.

Johnson, S.L., M.F. Solazzi, and T.E. Nickelson. 1990. Effects of survival and homing of trucking yearling coho salmon to release sites. North American Journal of Fisheries Management 10: 427-433.

Jonsson, N., B. Jonsson, L.P. Hansen, P. Aass. 1994. Effects of seawater acclimatization and release sites on survival of hatchery-reared. Journal of Fish Biology 44: 973-981.

Kaeding, L.R. and D.B. Osmundson. 1988. Interaction of slow growth and increased early-life mortality: an hypothesis on the decline of Colorado squawfish in the upstream regions of its historic range. Environmental Biology of Fishes 22: 87-298.

Kenaston, K.R., R.B. Lindsay, and R.K. Schroeder. 2001. Effect of acclimation on the homing and survival of hatchery winter steelhead. North American Journal of Fisheries Management 21: 765-773.

Koppelman, J.B., K.P. Sullivan, and P.J. Jeffries. 1992. Survival of three sizes of genetically marked walleye stocked into two Missouri impoundments. North American Journal of Fisheries Management 12: 291-298.

Larscheid, J.G. 1995. Development of an optimal stocking regime for walleyes in east Okoboji Lake, IA. Pages 472-483 in H.L. Shcramm Jr. and R.G. Piper (editors) Uses and effects of cultures fishes in aquatic systems. American Fisheries Society Symposium 15. American Fisheries Society, Bethesda, MD.

Leach, G.C. 1926. Discussion in Symposium of Fish Culture. Transactions of the American Fisheries Society 56: 153-154.

Leon, K.A. 1986. Effect of exercise on feed consumption, growth, food conversion and stamina of brook trout. The Progressive Fish-Culturalist 48: 43-46.

Manly, B.F. 1997. Randomization, bootstrap, and Monte Carlo methods in biology. Chapman and Hall, New York, NY. 399 p.

Margenau, T.L. 1999. Muskellunge stocking strategies in Wisconsin: the first century and beyond. North American Journal of Fisheries Management 19: 223-229.

Marsh, P.C. and J.L Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of introduced razorback suckers. The Southwestern Naturalist 34:188-195.

Marsh, P.C. and D.R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21:59-67.

Marsh, P.C., B.R. Kesner, and C.A. Pacey. 2005. Repatriation as a management strategy to conserve critically imperiled fishes. North American Journal of Fisheries Management 25: 547-556.

Marsh, P.C., C.A. Pacey and B.R. Kesner. 2003. Decline of the razorback sucker in Lake Mohave, Colorado River, Arizona and Nevada. Transactions of the American Fisheries Society 132: 1251-1256.

Masslich, W. and P.B. Holden. 1996. Expanding the distribution of Colorado squawfish in the San Juan River: A discussion paper. BIO-WEST, Inc., Logan UT. PR 576-1. 35 p.

Mather, M. E. And D.H. Wahl. 1989. Comparative mortality of three esocids due to stocking stressors. Canadian Journal of Fisheries and Aquatic Sciences 46: 214-217.

Maynard, D.J., T.A. Flagg and C.V.W. Mahnken. 1995. A review of seminatural culture strategies for enhancing the postrelease survival of anadromous salmonids. Pages 307-314 in H.L. Shcramm Jr. and R.G. Piper (editors) Uses and effects of cultures fishes in aquatic systems. American Fisheries Society Symposium 15. American Fisheries Society, Bethesda, MD.

McKeown, P.E., J.L. Forney, and S.R. Mooradian. 1999. Effects of stocking size and rearing method on muskellunge survival in Chautauqua Lake, New York. North American Journal of Fisheries Management 19: 249-257.

McWilliams, R.H. and J.G. Larscheid. 1992. Assessment of walleye fry and fingerling stocking in the Okoboji Lakes, Iowa. North American Journal of Fisheries Management 12: 329-335.

Miller, R.B. 1954. Comparative survival of wild and hatchery reared cutthroat trout in a stream. Transactions of the American Fisheries Society 83: 120-130.

Minckley, W.L, P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Johnson. 1991. Management toward recovery of the razorback sucker. Pages 303-357 in Minckley and Deacon (editors) battle against extinction: Native fish management in the American west. University of Arizona Press, Tucson, AZ.

Mitzner, L. 1992. Evaluation of walleye fingerling and fry stocking in Rathbun Lake, Iowa. North American Journal of Fisheries Management 12: 321-328.

Moyle, P.B. and J.J. Cech, Jr. 2004. Fishes: an introduction to ichthyology. Fifth Edition. Prentice-Hall, NJ.

Mueller G, and D.K. Foster. 1999. A case for site acclimation in the reintroduction of the endangered razorback sucker (*Xyrauchen texanus*). Open File Report 99-110, Midcontinent Ecological Science Center, Fort Collins, CO.

Mueller G. and P.C. Marsh. 1998. Post-stocking dispersal, habitat use, and behavioral acclimation of juvenile razorback suckers (*Xyrauchen texanus*) in two Colorado River reservoirs. Open File Report 98-301, Midcontinent Ecological Science Center, Fort Collins, CO.

Mueller, G. A., P.C. Marsh, D. Foster, M. Ulibarri, and T. Burke. 2003. Factors influencing poststocking dispersal of razorback sucker. North American Journal of Fisheries Management. 23: 270-275.

Naslund, I. 1998. Survival and dispersal of hatchery-reared brown trout, Salmo trutta, released in small streams. Pages 59-76 in I.A. Cowx (editor) Stocking and introduction of fish. Fishing News Books, London, England.

Olla, B.L. and M. Davis. 1989. The role of learning and stress in predator avoidance of hatchery-reared coho salmon (*Oncorynchus kisutch*) juveniles. Aquaculture 76: 209-214.

Olla, B.L., M.W. Davis, and C.B. Schreck. 1995. Stress induced impairment of predator evasion and non-predator mortality in Pacific salmon. Aquaculture Research 26: 393-398.

Olson, M.H., T.E. Brooking, D.M. Green, A.J. VanDeValk, and L.G. Rudstam. 2000. Survival and growth of intensively reared large walleye fingerlings and intensively reared small fingerlings stocked concurrently in small lakes. North American Journal of Fisheries Management 20: 337-348.

Osmundson, D.B., R.J. Ryel, and T.E. Mourning. 1997. Growth and survival of Colorado squawfish in the upper Colorado River. Transactions of the American Fisheries Society 126: 687-698.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62.

Paragamian, V.L. and R. Kingery. 1992. A comparison of walleye fry and fingerling stockings in three rivers in Iowa. North American Journal of Fisheries Management 12: 313-320.

Paroz, Y.M., D.L. Propst, S.M. Carman, and R.D. Larson. 2005. Small-bodied fish monitoring San Juan River: September-October 2004. Prepared by New Mexico Department of Game and Fish for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 107 p.

Pitman, P.M. and S. Gutreuter. 1993. Initial poststocking survival of hatchery-reared fishes. North American Journal of Fisheries Management 13:151-159.

Plosila, D.S. 1977. Relationship of strain and size at stocking on survival of Lake trout in Adirondack lakes. New York Fish and Game Journal 24(1): 1-24.

Pope, K.L., M.K. Flammang, and D.W. Willis. 1996. Influence of size at stocking on survival of saugeye in a northern-latitude impoundment. Journal of Freshwater Ecology 11(4): 447-450.

Pratt, T.C., and M.G. Fox. 2003. Contribution and relative survival of age-0 walleyes stocked at two sizes in six eastern Ontario lakes. North American Journal of Fisheries Management 23: 997-1005.

Propst, D.L., S.P. Platania, D.W. Ryden, and R.L. Bliesner. 2000a. San Juan River Monitoring plan and protocols. San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Propst, D.L., A.L. Hobbes, and R.D. Larson. 2000b. Small-bodied fish monitoring San Juan River: 1998 and 1999. Prepared by New Mexico Department of Game and Fish for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 67 p.

Propst, D.L., Y.M. Paroz, S.M. Carman, and R.D. Larson. 2004. Small-bodied fish monitoring San Juan River: 2000-2003. Prepared by New Mexico Department of Game and Fish for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 102 p.

Rexstad, E., and K. Burnham. 1992. User's Guide for Interactive Program CAPTURE. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO. 29 p.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations.. Bulletin 191, Fisheries Research Board of Canada.

Ross, S. T., J.G. Knight, and S.D. Wilkins. 1992. Distribution and microhabitat dynamics of the threatened Bayou Darter, *Etheostoma rubrum*. Copeia 1992 (3): 658-671.

Ryden, D.W. 2000a. Adult fish community monitoring on the San Juan River 1991-1997. Final Report. U.S. Fish & Wildlife Service, Colorado River Fishery Project Grand Junction, CO.

Ryden, D.W., 2000b. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 1998 and 1999: Final Report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 46 p.

Ryden, D.W., 2001. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2000: Final Report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 70 p.

Ryden, D. 2003a. An augmentation plan for Colorado pikeminnow in the San Juan River. Final Report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D. W. 2003b. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 1999-2001 Integration report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 235 p.

Ryden, D.W. 2003c. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2002: Final report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 235 p.

Ryden, D.W. 2004. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2003. Interim Progress Report. U.S. Fish and Wildlife Service, Grand Junction, CO.

Ryden, D.W. 2006. Biologist, U.S. Fish and Wildlife Service. Personal communication with Mike Golden of BIO-WEST, Inc. regarding water temperature differences between hatchery trucks and the San Juan River. 4/25/2006.

Ryden, D.W. and F.K. Pfeifer. 1996. Monitoring of experimental stocked razorback sucker in the San Juan River. 1995 Annual Progress Report. US Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, CO.

Thompson, J.M., E.P. Bergersen, C.A.Carlson, and L.R. Kaeding. 1991. Role of size, condition, and lipid content in overwinter survival of age-0 Colorado squawfish. Transactions of the American Fisheries Society 120: 346-353.

Schofield, P.J. and S.T. Ross. 2003. Habitat selection of the channel darter, Percina (*Cottogaster copelandi*): a surrogate for the imperiled pearl darter, Percina aurora. Journal of Freshwater Ecology 18(2): 249-257.

Smith, M.A. and W.A. Hubert. 2003. Simulated thermal tempering versus sudden thermal temperature change ans short-term survival of fingerling rainbow trout. North American Journal of Aquaculture 65: 67-69.

Stamp, M., J. Grams, M. Golden, D. Olsen, and T. Allred. 2005. Feasibility evaluation of restoration options to improve habitat for young Colorado pikeminnow in the San Juan River. Draft report. Prepared by BIO-WEST, Inc for the for the San Juan River Basin Recovery Implementation Program, U.S. Bureau of Reclamation, Salt Lake City, UT. PR 947-1 under contract agreement 04-FG-40-2158.

Storck, T., and D. Newman. 1988. Effects of size at stocking on survival and harvest of channel catfish. North American Journal of Fisheries Management 8: 98-101.

Tipping, J.M. 1998. Return rates of transported steelhead smolts with and without a rest period before release. The Progressive Fish Culturalist 60: 284-287.

Trammell, M. 2000. Evaluation of reintroduction of young of year Colorado pikeminnow into the San Juan River: 1999 annual report. San Juan River Basin Recovery Implementation Program. US Fish and Wildlife Service, Albuquerque, NM. 17 p.

Trammell, M. and E. Archer. 2000. Evaluation of reintroduction of young of the year Colorado pikeminnow in the San Juan River 1996-1998. Pages 4-1 to 4-33, in Archer, E., T. A. Crowl, and M. Trammel (editors). Age-0 native species abundances and nursery habitat quality and availability in the San Juan River, New Mexico, Colorado, and Utah. Utah Division of Wildlife Resources, Salt Lake City, UT.

Trammell, M. and T. Chart. 1999. Aspinall studies : evaluation of nursery habitat availability and Colorado Pikeminnow young of year habitat use, in the Colorado River, Utah 1992-1996. Utah Division of Wildlife Resources, Moab Native Fishes Field Office, Project 44-A. 49 p.

Tyus, H.M. 1991. Movements and habitat use of young Colorado squawfish in the Green River, UT. Journal of Freshwater Ecology 6: 43-51.

Tyus, H.M. and G.B. Haines. 1991. Distribution, habitat use, and growth of age-0 Colorado squawfish in the Green River Basin, Colorado and Utah. Transactions of the American Fisheries Society. 120: 79-89.

Ulibarri, M. 2006. Center Director, Dexter National Fish Hatchery and Technology Center. Personal communication with Mike Golden of BIO-WEST, Inc. regarding rearing costs of Colorado pikeminnow. 4/21/06.

U.S. Fish and Wildlife Service. 2002. Colorado pikeminnow (Ptychocheilus lucius) recovery goals. Amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Region 6, Denver, CO.

Valdez, R.A., and B. Cowdell. 1996. Survival of age-0 Colorado squawfish in the Green river. Interim report - 1996. Prepared for the Utah Division of Wildlife Resources, Contract No. 90-2558, by BIO-WEST Inc., Logan, UT.

Wahl, D.H. 1999. An ecological context for evaluating the factors influencing muskellunge success. North American Journal of Fisheries Management 19: 238-248.

Ward, D.L. and K.D. Hilwig. 2004. Effects of holding environment and exercise conditioning on swimming performance of southwestern native fishes. North American Journal of Fisheries Management 24(3):1038-1087.

Ward, D.L., O.E. Maughan, and S.A. Bonar. 2002. Effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker. Transactions of the American Fisheries Society 131: 492-497.

Ward, B.R. and P.A. Slaney. 1990. Returns of pen-reared steelhead from riverine, estuarine, and marine releases. Transactions of the American Fisheries Society 119: 492-499.

Wiley, R.W., R.A. Whaley, J.B. Satake, and M. Fowden. 1993. An evaluation of the potential for training trout in hatcheries to increase poststocking survival in streams. North American Journal of Fisheries Management 13: 171-177.

Willett, D.J. 1996. Use of scale patterns to evaluate the stocking success of silver perch (*Bidyanus bidyanus* [Mitchell]), released at two different sizes. Marine and Freshwater Research 47: 757-61.

Willis, S.A., W.W. Falls, C.W. Dennis, D.E. Roberts, and P.G. Whitchurch. 1995. Assessment of season of release and size at release on recapture rates of hatchery-reared red drum. Pages 354-365 in H.L. Shcramm Jr. and R.G. Piper (editors) Uses and effects of cultures fishes in aquatic systems. American Fisheries Society Symposium 15. American Fisheries Society, Bethesda, MD.

Yeager, D.M. 1988. Evaluation of Phase I and Phase II hybrid striped bass in the Escambia River Florida. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 41(1978):41-17.

Young, P.S. and J.J. Cech. 1993a. Improved growth, swimming performance, and muscular development in exercise-conditioned young-of-the-year striped bass. Canadian Journal of Fisheries and Aquatic Sciences 50: 703-707.

Young, P.S. and J.J. Cech. 1993b. Effects of exercise conditioning on stress responses ans recovery in cultured and wild young-of-the-year striped bass, Morone saxatilis. Canadian Journal of Fisheries and Aquatic Sciences. 50: 2094-2099.

APPENDIX A: MAJOR HABITAT TYPES

Table 1. Individual habitat designations, their corresponding habitat type, and whether we considered them preferred habitat for analysis purposes.

Named habitat	Habitat type	Preferred habitat
Backwater	Backwater	Y
Backwater/debris pile	Debris	Y
Backwater/eddy	Backwater	Y
Backwater/pool	Backwater	Y
Backwater/run	Backwater	Y
Backwater/shoal	Backwater	Y
Backwatermouth	Backwater	Y
Debris pile	Debris	Y
Debris pile/pool	Debris	Y
Eddy	Eddy	N
Eddy/embayment	Backwater	Y
Eddy/pool	Eddy	N
Eddy/run	Eddy	N
Eddy/shoal	Eddy	N
Eddy/slackwater	Eddy	N
Embayment	Backwater	Y
Embayment/debris pile	Debris	Y
Irrigation return	Backwater	Y
Irrigation return/backwater	Backwater	Y
Irrigation return/debris pile	Debris	Y
Isolated pool	Backwater	Y
Pocket water	Slackwater	Y
Pool	Pool	N
Riffle	Riffle	N
Riffle/eddy	Riffle	N
Riffle/pool	Pool	N
Riffle/run	Riffle	N
Run	Run	N
Run/embayment	Backwater	Y
Run/pool	Run	N
Run/debris pile	Debris	Y
Run/side channel mouth	Run	N
Side channel mouth	Side channel mouth	N
Shoal	Shoal	N
Shoal run	Shoal	N
Shore eddy	Eddy	N
Shore pool	Pool	N
Shore run	Run	N
Slackwater	Slackwater	Y
Slackwater run	Slackwater	Y
Submerged backwater	Backwater	Y
Unknown	Unknown	N

APPENDIX B: OTHER FISH SPECIES COLLECTED

Table 1. Number of each species other than Colorado pikeminnow collected in each station during the December 2002 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	7	28	22	0	0	0	0	0	0	4	0	2	0	0	0	0	0	8	2
LA	0	13	0	0	0	0	0	0	3	0	2	1	0	0	0	0	0	15	0
BFD	27	318	54	0	0	2	2	2	5	5	4	5	0	0	0	0	1	859	0
APS	0	6	0	0	0	5	0	0	3	177	1	3	0	0	0	0	0	124	0
SCU	20	50	0	0	0	0	0	0	1	2,673	0	3	0	0	0	0	0	87	0
FC	3	17	1	0	0	0	0	1	13	2,701	0	7	0	0	0	0	0	1,418	0
AN	0	2	0	0	0	2	0	0	3	1,922	0	0	4	0	0	0	0	24	0
BL	0	3	0	0	0	1	0	0	1	822	0	1	1	0	0	0	0	4	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 2. Number of each species other than Colorado pikeminnow collected in each station during the March 2003 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	30	118	182	0	0	2	0	0	1	2	5	2	0	1	0	0	0	68	2
LA	184	98	61	0	0	11	0	1	1	1	1	12	0	1	1	0	0	92	1
BFD	111	315	746	0	0	5	0	0	0	480	8	2	2	1	0	0	0	895	2
APS*	22	264	39	0	0	5	0	0	0	2,918	13	2	0	0	1	0	0	1,370	0
SCU	0	63	13	0	0	0	0	0	0	2,110	1	0	1	0	0	0	0	860	0
FC	7	64	48	0	0	2	0	0	4	5,341	2	1	7	1	0	0	0	1,544	0
AN	5	68	70	0	0	2	0	0	3	4,684	3	0	60	1	0	0	0	451	0
BL	2	9	28	0	0	2	0	0	2	6,360	9	6	67	1	0	0	0	370	0

* reach from Hogback to Shiprock sampled
CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 3. Number of each species other than Colorado pikeminnow collected in each station during the July 2003 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN. ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	2,116	4,555	1,813	0	1,804	0	0	0	1	0	5	4	0	0	0	0	16	52	0
LA	3	16	137	0	239	0	0	0	9	0	0	14	0	0	0	0	26	7	0
BFD	349	1,590	2,429	0	1,699	0	0	0	7	0	2	47	0	0	1	0	226	252	0
APS	28	113	426	0	124	0	0	0	12	7,948	3	215	0	0	0	0	312	338	0
SCU	37	89	181	0	20	0	0	0	12	3,752	0	135	16	0	0	1	104	202	0
FC	121	149	678	0	20	1	0	1	24	3,072	11	8	60	0	0	1	22	230	0
AN	49	120	227	0	15	732	0	0	0	1,901	5	22	94	0	1	0	17	405	0
BL	2	89	138	0	6	3	0	0	2	1,199	1	18	73	0	0	0	8	278	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 4. Number of each species other than Colorado pikeminnow collected in each station during the December 2003 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	362	759	55	0	0	0	0	0	1	6	6	14	0	1	0	0	0	57	0
LA	0	8	18	0	0	0	0	0	0	0	2	4	0	0	0	0	0	339	0
BFD	25	72	137	0	0	1	0	0	2	7	26	24	0	0	0	0	0	141	0
APS	3	35	26	0	0	6	0	0	4	2,136	0	4	3	1	0	0	0	2,740	0
SCU	1	0	10	0	0	2	0	0	0	2,400	4	95	0	0	0	0	0	1,206	0
FC	1	0	2	1	0	0	0	0	1	1,527	1	0	1	0	0	0	1	138	0
AN	0	0	1	0	0	3	0	0	0	919	14	10	1	0	0	0	0	319	0
BL	0	1	0	0	0	2	1	0	1	2,246	13	166	1	0	1	0	0	534	0
BMH	0	4	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0
JC	0	1	0	0	0	0	0	0	0	16	0	0	2	0	0	0	0	2	0
GG	0	2	3	0	0	1	0	0	0	343	1	0	9	0	0	0	0	2	0
CAN	0	0	0	0	0	1	0	0	0	71	0	1	0	0	0	0	0	0	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 5. Number of each species other than Colorado pikeminnow collected in each station during the March 2004 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	79	164	220	0	0	0	0	0	0	10	5	1	0	0	0	0	0	55	0
LA	105	70	59	0	0	0	0	0	0	0	0	3	0	2	0	0	0	89	3
BFD	209	335	332	0	0	4	0	1	0	7	3	1	0	0	0	0	0	478	2
APS	34	178	379	0	0	8	0	0	8	390	4	35	0	7	0	0	0	356	0
SCU	7	40	51	0	0	3	0	0	1	1,250	8	1	0	0	1	0	0	403	0
FC	9	33	113	0	0	7	0	0	2	1,940	10	9	4	2	0	0	0	269	0
AN	0	20	25	0	0	14	0	0	2	2,095	21	11	71	3	1	0	0	538	0
BL	0	11	30	0	0	0	0	0	0	2,167	33	1	82	0	0	0	0	252	0
BMH	0	10	12	0	0	0	0	0	0	212	1	0	149	2	0	0	0	5	0
JC	1	4	1	0	0	0	0	0	0	126	0	1	83	3	0	0	0	0	0
GG	0	7	1	1	0	3	0	0	2	442	2	3	70	0	0	0	0	78	0
CAN	0	4	2	1	0	4	0	0	0	351	2	0	48	1	0	0	0	13	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 6. Number of each species other than Colorado pikeminnow collected in each station during the July 2004 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
USJ	173	2,271	215	0	0	1	1	0	7	3	0	0	0	0	0	0	169	141	4
LA	130	473	96	0	83	2	1	0	5	3	0	2	2	0	0	0	126	48	0
BFD	373	2,120	68	0	41	1	1	0	505	1	1	0	0	1	0	0	354	143	0
APS	21	760	73	1	0	1	2	0	1,687	1,506	0	33	2	2	0	0	219	830	0
SCU	11	454	15	1	0	4	0	0	685	511	0	22	16	0	2	0	53	134	0
FC	11	328	587	0	32	2	0	0	211	1,814	0	0	104	0	0	0	78	105	0
AN	6	165	248	0	0	18	0	0	5	194	4	0	322	0	0	0	2	7	0
BL	6	70	127	0	1	0	0	0	15	259	6	17	421	0	0	0	1	11	0
BMH	2	22	1	0	0	3	0	0	9	26	0	1	105	0	0	0	1	0	0
JC	0	14	30	0	0	37	0	0	3	76	0	1	215	0	0	0	4	3	0
GG	0	28	0	4	0	42	0	0	49	72	0	3	260	0	0	0	65	17	0
CAN	0	20	15	1	12	30	0	0	20	44	0	0	115	0	0	0	21	20	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 7. Number of each species other than Colorado pikeminnow collected in each station during the November 2004 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY. SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
BFD	55	92	50	0	0	0	0	0	2	27	34	23	0	0	0	0	7	391	0
APS	3	21	83	0	0	0	0	0	6	2,652	1	22	0	0	0	0	1	949	0
SCU	2	32	35	0	0	1	0	0	1	11,562	7	58	3	0	0	0	2	3,184	0
FC	5	13	22	0	0	0	0	0	3	8,315	8	8	1	0	0	0	0	1,352	0
AN	3	12	20	0	0	2	0	0	2	7,864	15	1	3	0	0	0	0	946	0
BL	1	9	1	0	0	0	0	0	2	15,844	0	12	20	0	0	0	0	650	0
BMH	16	8	4	0	0	2	0	0	1	957	0	4	24	0	0	0	0	12	0
JC	0	11	7	0	0	0	0	0	1	458	0	2	42	1	0	0	1	8	0
GG	2	13	0	0	0	3	0	0	1	1,020	0	1	3	0	0	0	1	18	0
CAN	5	12	5	0	0	1	0	0	0	2,426	0	0	23	0	0	0	3	31	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 8. Number of each species other than Colorado pikeminnow collected in each station during the March 2005 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
BFD	34	157	383	0	0	1	0	0	0	4	3	0	0	1	0	0	1	81	1
APS	14	53	176	0	0	2	0	0	1	1,218	1	0	0	4	0	0	0	538	0
SCU	14	40	101	0	0	0	0	0	3	3,124	0	0	0	0	0	0	0	440	0
FC	39	7	201	0	0	2	0	0	2	4,566	18	0	3	0	0	0	0	2,085	0
AN	1	7	43	0	0	1	0	0	0	5,749	0	0	7	0	0	0	0	429	0
BL	0	11	53	0	0	0	0	0	0	1,853	0	0	5	0	0	0	0	66	0
BMH	3	3	20	0	0	0	0	0	1	2,531	0	0	17	0	0	0	0	34	0
JC	5	1	4	0	0	0	0	0	0	1,478	1	0	13	0	0	0	0	34	0
GG	8	12	13	0	0	1	0	0	1	2,519	0	0	15	0	0	0	0	59	0
CAN	3	3	5	0	0	1	0	1	0	1,609	0	0	7	0	0	0	0	23	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 9. Number of each species other than Colorado pikeminnow collected in each station during the July 2005 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
BFD	91	272	324	0	1,850	1	0	0	5	3	0	6	0	1	0	0	33	308	2
APS	6	112	129	0	3	1	1	0	28	1,990	0	4	0	2	0	0	61	422	0
SCU	12	72	50	0	80	0	0	0	21	4,133	1	48	6	1	0	0	107	349	0
FC	51	42	54	0	0	0	0	0	22	3,497	1	0	20	0	0	0	30	104	0
AN	16	225	29	1	0	0	0	0	38	620	0	2	27	0	0	0	13	28	0
BL	10	121	8	1	0	0	0	0	5	364	0	12	35	0	0	0	2	11	0
BMH	6	21	10	0	0	0	0	0	41	84	0	5	55	0	0	0	6	1	0
JC	6	6	10	0	0	0	0	0	19	84	0	0	317	0	0	0	2	2	0
GG	0	4	0	0	0	14	0	0	210	324	0	0	204	1	0	0	13	1	0
CAN	1	3	0	0	0	2	0	0	22	43	0	0	136	0	0	0	4	0	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout

Table 10. Number of each species other than Colorado pikeminnow collected in each station during the November2005 monitoring trip.

Station	CAT DIS	CAT LAT	RHI OSC	XYR TEX	YOY SUC	AME MEL	CAT COM	CAT HYB	CYP CAR	CYP LUT	FUN ZEB	GAM AFF	ICT PUN	LEP CYA	LEP MAC	MIC PUN	MIC SAL	PIM PRO	SAL TRU
BFD	563	1,023	655	0	0	0	1	0	1	203	2	25	0	4	0	0	2	288	0
APS	9	34	6	0	0	0	0	0	2	2,873	0	19	0	1	0	0	17	204	0
SCU	3	33	13	0	0	0	0	0	3	5,380	5	44	1	2	1	0	1	449	0
FC	3	8	11	0	0	2	0	0	2	2,803	3	8	7	0	0	0	2	471	0
AN	79	31	280	0	0	20	0	0	6	2,659	16	40	7	1	0	0	0	1,790	0
BL	3	23	34	0	0	9	0	0	2	2,900	1	46	20	1	0	0	1	333	0
BMH	2	2	4	0	0	0	0	0	1	305	0	0	2	0	0	0	0	96	0
JC	0	0	2	0	0	0	0	0	0	208	0	1	0	0	0	0	0	9	0
GG	1	2	2	0	0	0	0	0	0	145	0	12	0	0	1	0	1	34	0
CAN	0	0	0	0	0	1	0	0	1	262	0	0	56	0	0	0	0	88	0

CATDIS = bluehead sucker
CATLAT = flannelmouth sucker
RHIOSC = speckled dace
XYRTEX = razorback sucker
YOYSUC = unidentified YOY suckers
AMEMEL = black bullhead
CATCOM = white sucker
CATHYB = sucker hybrid
CYPCAR = common carp
CYPLUT = red shiner
FUNZEB = plains killifish
GAMAFF = western mosquitofish
ICTPUN = channel catfish
LEPCYA = green sunfish
LEPMAC = bluegill sunfish
MICPUN = spotted bass
MICSAL = largemouth bass
PIMPRO = fathead minnow
SALTRU = brown trout