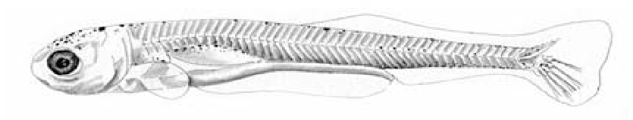
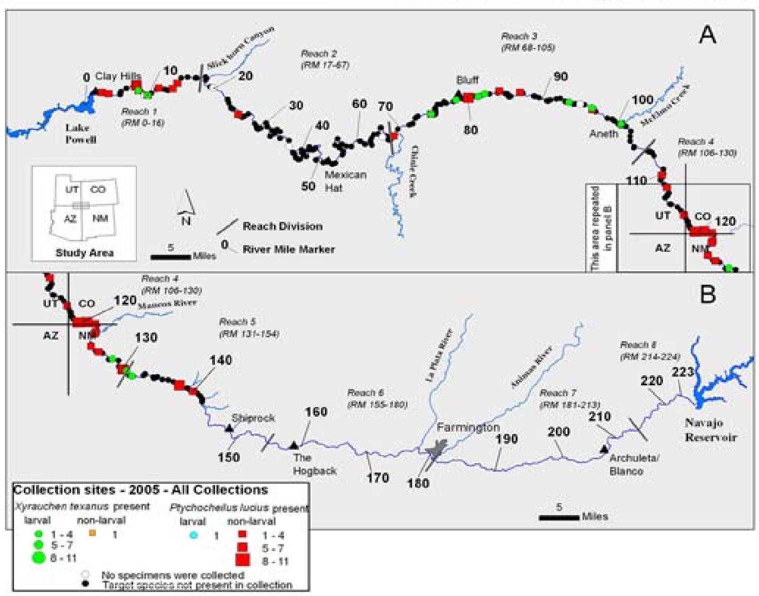
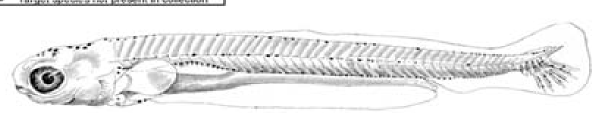
Colorado pikeminnow and razorback sucker larval fish survey in the San Juan River during 2005

FINAL REPORT



Colorado pikeminnow, *Ptychocheilus lucius*, larva





razorback sucker, *Xyrauchen texanus*, larva

illustrations by W.H. Brandenburg

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San Juan River Basin Recovery Implementation Program

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submitted to:

San Juan River Basin Biology Committee
under the authority of the
San Juan River Basin Recovery Implementation Program

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Executive Summary

1. There were 358 fish collections made at 264 unique sites between river miles 141.5 and 3.3 under the auspices of the 2005 larval Colorado pikeminnow and 2005 larval razorback surveys.

2. The 358 collections resulted in the collection of fish representing six families and 15 species with all but nine collections producing fish.

3. In 2005, the riverwide CPUE was 1054.8 fish per 100m^2 with a total of 109,364 specimens collected.

4. Non-native cyprinids accounted for 84.6% of the 2005 catch by number. Red shiner was the numerically dominant and most frequently encountered species occurring in 329 of the 349 collections that produced fish.

5. Native species accounted for 14.3% of the 2005 catch by number. Bluehead sucker was the numerically dominant species (n=7,395) while speckled dace was the most frequently encountered native species occurring in 202 of the 349 collections that produced fish.

6. Catostomids accounted for 9.6% of the 2005 catch by number with over twice as many bluehead sucker collected when compared to flannelmouth sucker (n=7,395 and 3,049 respectively). This ratio of bluehead sucker to flannelmouth sucker is nearly identical to what was seen in 2004.

7. The first larval catostomid was collected 20 April 2005 at river mile 100.5 (McElmo Creek).

8. A total of 92 age-1 Colorado pikeminnow were collected between April and July and it is assumed that these fish were stocked specimens. No larval Colorado pikeminnow were collected in 2005.

9. A total of 19 larval razorback suckers were collected from reaches 1, 3, 4 and 5. The first collection to produce larval razorback suckers was at river mile 78.7 on 14 May 2005. The last collection to produce larval razorback suckers was at river mile 93.5 on 3 August 2005.

10. Reach 3 produced more larval razorback suckers (n=11) that all other reaches combined and also produced the largest single collection of razorback larvae (n=4).

11. There was over twice as many larval razorback suckers collected in 2004 than in 2005 (n=41 and 19 respectively) and 2005 produced the third lowest total for razorback larvae since this project first documented spawning of razorback sucker in 1998. However, 2005 makes eight consecutive years of documented spawning by razorback sucker.

12. Back-calculated hatch dates for razorback sucker indicated hatching dates ranged from 26 April 2005 to 2 July 2005.

Introduction

Background Information

The primary focus of the 2005 San Juan River larval fish survey was on two federally endangered species, Colorado pikeminnow, *Ptychocheilus lucius*, and razorback sucker, *Xyrauchen texanus.*

Colorado pikeminnow, belonging to the family Cyprinidae, was listed by the U.S. Department of the Interior in 1974. It is endemic to the Colorado River Basin where it was once abundant and widespread (Tyus, 1991). This species now occupies only about 20% of its historic range (Tyus, 1990; Behnke and Benson 1983). The Green River sub-basin supports the majority of remaining Upper Basin individuals (Holden and Wick, 1982; Bestgen et al., 1998). Conversely, no Colorado pikeminnow have been reported in the Lower Basin since the 1960's (Minckley and Deacon, 1968; Minckley, 1973; Moyle, 1976).

A small population of this species occurs in the lowermost 225 river km (between Cudei Diversion Dam and the inlet of Lake Powell Reservoir) of the San Juan River. The decline of this and other native fishes in the San Juan River has been attributed to flow modifications and the resultant changes to the thermal regime, instream barriers, and non-native predation-competition for habitat and resources (Platania 1990, Ryden and Pfeifer 1994). Understanding the conditions necessary for spawning by Colorado pikeminnow and other native fishes was deemed necessary to stabilize and increase the population size of this species.

Much has been reported regarding the life-history and reproductive behavior of Colorado pikeminnow (Vanicek and Kramer, 1969). Studies in the Upper Colorado River Basin (Yampa and Green rivers) have demonstrated that this species spawns as spring runoff is receding and at water temperatures between 18^{o}C and 20^{o}C (Haynes et al., 1984; Nesler et al., 1988). Larval Colorado pikeminnow employ drift as a dispersal mechanism and are presumed to begin this passive movement approximately five days after hatching. The five-day time-frame corresponds with the swim-up period of this fish as reported by Hamman (1981, 1986).

This life-history phase (drifting larvae), the focus of several investigations in the Upper Colorado River Basin, has been investigated to provide information on spawning bar location, reproductive success, and the effects of various flow-regimes on reproduction. The collection of a juvenile (177 mm TL) Colorado pikeminnow in 1978 (Minckley and Carothers, 1979) and rediscovery of a reproducing population of Colorado pikeminnow in the San Juan River in 1987 (Meyer and Moretti, 1988; Platania and Bestgen, 1988; Platania et al., 1991) demonstrated a need for studies to ascertain information such as that obtained for this species in the Upper Colorado River Basin. Such studies would also provide comparable information on other members of the ichthyofaunal community.

In 1991, passive drift-netting for larval and young-of-year (YOY) fish was initiated in the San Juan River. The primary objectives of the passive drift-netting study were to 1) determine the temporal distribution of San Juan River ichthyoplankton in relation to the hydrograph, 2) provide comparative analysis of the reproductive success of San Juan River fishes, 3) attempt to characterize downstream movement of ichthyoplankton, and 4) attempt to validate the presumed spawning period of Colorado pikeminnow.

Passive drift-netting on the San Juan River at Mexican Hat was conducted by the Utah Division of Wildlife Resources (UDWR) during 1991-1994, samples at Four Corners were taken by New Mexico Department of Game and Fish (NMGF) during 1991-1994, and both sites were sampled by personnel of the Museum of Southwestern Biology, Division of Fishes at the University of New Mexico (UNM) during 1995-2001. Results from the 1991-1997 portion of the drift-net study were presented in a report by Platania et al. (2000) and will not be discussed in this report.

In 2000 a different passive sampling device, the Moore Egg Collector (Altenbach et al., 2000), was used, with similar results to drift-nets (2,138 specimens were collected). Between 1991-2000, only 20,901 specimens (and few Colorado pikeminnow) were collected in the passive sampling effort (Table 1). Meanwhile, the larval seining method had proven successful in larval razorback sucker fish surveys by UNM personnel between 1998-2000. The sampling protocol in 2001 included a combination of passive drift-netting and active sampling with larval seines.

Table 1. Summary of larval Colorado pikeminnow collected in the San Juan River (1993-2004) and back calculated dates of spawning.

Field Number	MSB Catalog Number	Number specimen	Total Length	Date Collected	Date Spawned	River Mile	Sample Method
MH72693-2	18098	1	9.2	26 Jul 93	08 Jul 93	53.0	drift netting
MH72793-2	18099	1	9.2	27 Jul 93	09 Jul 93	53.0	drift netting
JPS95-205	26187	1	9.2	02 Aug 95	15 Jul 95	53.0	drift netting
JPS95-207	26191	1	9.0	03 Aug 95	17 Jul 95	53.0	drift netting
WHB96-037	29717	1	8.6	02 Aug 96	18 Jul 96	128.0	drift netting
FC01-054	50194	1	8.5	01 Aug 01	17 Jul 01	128.0	drift netting
MAF04-046	53090	1	14.2	22 Jul 04	24 Jun 04	46.3	larval seine
MAF04-059	53130	1	18.1	26 Jul 04	25 Jun 04	17.0	larval seine
TOTAL		8					

After a decade of passive sampling, these methods (with the exception of occasional use of light-traps) were discontinued in 2002 in favor of active sampling with larval seines. In 2002, over four times as many specimens were collected (n=90,518) than in the previous ten years combined. The new sampling protocol was continued during 2003 and 2004 resulting in the collection of over 70,000 and 145,600 specimens respectively including documentation of reproduction of Colorado pikeminnow in 2004 (W.H. Brandenburg et al. 2004).

The second species of interest, razorback sucker, a member of the family Catostomidae, was listed as a federally endangered species in 1991. There are few historic San Juan River records of razorback sucker despite that this is one of three endemic Colorado River basin catostomids. Jordan (1891) conveyed anecdotal reports from the late 1800's of razorback sucker occurring in the Animas River as far upstream as Durango, Colorado. However, there were no specimens to substantiate this claim. The first verified record of razorback sucker in the San Juan River was in 1976 when two adult specimens were collected at an irrigation pond near Bluff, Utah (VTN Consolidated, Inc., and Museum of Northern Arizona, 1978). A 1987 U.S. Bureau of Reclamation document (U.S. Bureau of Reclamation, 1987), citing personal communication from the Utah Division of Wildlife resources, reported the 1981-1984 spring occurrence of razorback sucker in the San Juan River arm of Lake Powell. The most recent San Juan River drainage occurrence of razorback sucker was the April 1988 collection of a single adult tuberculate male in the San Juan River near Bluff, Utah (Roberts and Moretti, 1989).

The extreme rarity of razorback sucker in the San Juan River drainage necessitated the experimental stocking of a small number of individuals so that information on their habitat use, potential spawning areas, and survival and growth rates could be obtained. In 1994 personnel from the U.S. Fish and Wildlife Service Colorado River Fishery Project (CRFP; Grand Junction, Colorado) stocked the first series of razorback sucker (n=672) in the San Juan River. Those fish, whose mean length and mass at the time of stocking were about 400 mm TL and 710 g, respectively, were released between Hogback, New Mexico and Bluff, Utah. In 1995, numerous individuals from the 1994 stocking effort were recaptured including 13 tuberculate males with six of those individuals being ripe. Four razorback sucker recaptured in 1995 were determined to be female but, unlike the males, none were sexually mature. By 1996, a total of 939 razorback sucker, all of which were progeny of paired matings between San Juan River arm of Lake Powell adults, had been stocked in the San Juan River. In their 1995 report of activities, Ryden and Pfeifer (1996) suggested that the majority of experimentally stocked 1994 San Juan River razorback sucker would achieve sexual maturity by 1996 thereby providing the potential for spawning during 1997-1998. The success of the experimental stocking study resulted in the development of a full-scale augmentation program for razorback sucker in the San Juan River.

At the November 1996 San Juan River Basin Biology Committee integration meeting, it was suggested that the Colorado pikeminnow, larval fish drift study be expanded in an attempt to document spawning of razorback sucker. The UNM-NMGF larval fish drift study, which was designed to determine spawning period, identify approximate location of spawning sites, and assess the effects of annual hydrology (and temperature) on Colorado pikeminnow reproductive activities, was also successful in providing similar information for other members of the ichthyofaunal community (i.e., speckled dace, *Rhinichthys osculus*, and channel catfish, *Ictalurus punctatus*). However, because reproduction by razorback sucker (March-May) occurred considerably earlier than Colorado pikeminnow (June-July), separate investigations of spawning periodicity and magnitude were deemed necessary for each of the aforementioned species.

The most important difference between the established Colorado pikeminnow study and proposed razorback sucker study, besides temporal, was that the razorback sucker larval fish study was attempting to provide the first documentation of reproduction by stocked members of this species in the San Juan River. Sampling for larval razorback sucker was to be conducted with no assurance that the stocked population of adult razorback sucker would spawn in this system. Conversely, previous studies demonstrated that Colorado pikeminnow reproduction had and was still occurring in the San Juan River. This certainty allowed the Colorado pikeminnow larval fish sampling efforts to be different (i.e., monitoring) than those for razorback sucker (searching).

Numerous Upper Colorado River basin researchers identified light-traps as one of the most efficient means of collecting larval razorback sucker. The 1994-1995 National Park Service - San Juan River fish investigation employed light-traps near the San Juan River-Lake Powell confluence as a larval fish collecting technique. That study produced a large number of larval fish (ca. 25,000 per year) from a modest number of samples (n=20). Red shiner numerically dominated (>98%) the light-trap catch during both years but neither Colorado pikeminnow nor razorback sucker were collected. The success of Upper Basin researchers and potentially large number of fish that could be collected using this technique led to the selection of light-traps as the sampling device during the first year (calendar year 1997) of San Juan River larval razorback sucker study.

Numerous locations adjacent to U.S. Hwy 163 and Utah State Hwy 262 (which paralleled the San Juan River between Aneth and Bluff) that appeared suitable for sampling with light-traps were identified during March 1997. Light-traps were set nightly in low-velocity habitats between Aneth and Mexican Hat from late March through mid-June 1997. Traps were distributed at dusk and retrieved about four hours later with any fish taken in those samples preserved in the field. Sampling success during the 1997 razorback sucker larval fish study was poor. While there were over 200 light-trap sets, those sampling efforts produced only 297 fish. Of those, about

200 (66%) were larval suckers (either flannelmouth sucker, *Catostomus latipinnis*, or bluehead sucker, *Catostomus discobolus*). Larval razorback sucker were not present in the 1997 sampling survey.

While there were probably several variables that accounted for the poor light-trap catch rate, a principal factor was limited access to suitable habitats. Light-traps are most effective when set in habitats with little or no water velocity. Unfortunately, increased April-June flow in the San Juan River eliminated virtually all low velocity habitats identified in March 1997. Further reconnaissance from an automobile (April - May) of the snowmelt enhanced river failed to yield additional locations suitable for light-traps. One of the results of the 1997 study was the realization that being bound to specific collecting sites was an inefficient means of collecting the large number of larval fish necessary to document reproduction of a rare species.

In 1998 the razorback sucker larval fish sampling technique was modified to allow for collections over a larger portion of the San Juan River and capture of a considerably larger number of larval fish. An inflatable raft, which was used to travel on the river, provided the opportunity to sample habitats that were formerly either inaccessible or unobservable under the constraints of the 1997 sampling protocol. The primary collecting method was sampling low-velocity habitats with a fine mesh seine. The seining technique yielded more larval suckers in a single sample than were taken cumulatively in 1997 light-trap samples. Between 1998 and 2005 most aspects of the project remained the same other than an expansion of the study area as well as a temporal extension of the project (Table 2).

Table 2. Summary of larval and YOY razorback sucker collected in the San Juan River (1998-2004).

Year	Study Area	Project Dates	Effort m^2	Xyrtex	Sample Method
1998	127.5 - 53.0	17 Apr - 6 Jun	-	2	larval seine/ light trap
1999	127.5 - 2.9	5 Apr - 10 Jun	2,713.5	7	larval seine/ light trap
2000	127.5 - 2.9	4 Apr - 26 Jun	2,924.6	129	larval seine/ light trap
2001	141.5 - 2.9	10 Apr - 14 Jun	5,733.1	50	larval seine/ light trap
2002	141.5 - 2.9	15 Apr - 12 Sep	9,647.5	813	larval seine/ light trap
2003	141.5 - 2.9	15 Apr - 19 Sep	13,564.6	472	larval seine
2004	141.5 - 2.9	19 Apr - 14 Sep	11,820.3	42	larval seine
TOTAL				1,515	

Study Area

The San Juan River is a major tributary of the Colorado River and drains 99,200 km^2 in Colorado, New Mexico, Utah, and Arizona (Figure 1). From its origins in the San Juan Mountains of southwestern Colorado at elevations exceeding 4,250 m, the river flows westward for about 570 km before it confluences with the Colorado River. The major perennial tributaries to the San Juan River are (from upstream to downstream) Navajo, Piedra, Los Pinos, Animas, La Plata, and Mancos Rivers, as well as McElmo Creek. In addition there are numerous ephemeral arroyos and washes that contribute relatively little flow annually but input large sediment loads.

Navajo Reservoir, completed in 1963, impounds and isolates the upper 124 km of the San Juan River and regulates downstream discharge. The completion of Glen Canyon Dam in 1966 and subsequent filling of Lake Powell ultimately inundated the lower 87 km of the San Juan River by the early 1980s. The San Juan River is now a 359 km lotic system bounded by two reservoirs (Navajo Reservoir near its head and Lake Powell at its mouth).

The San Juan River is canyon-bound and restricted to a single channel between its confluence with Chinle Creek (ca. 20 km downstream of Bluff, Utah) and Lake Powell. The river is predominantly multi-channeled upstream of Chinle Creek with the highest density of secondary channels occurring between Bluff and the Hogback Diversion (ca. 13 km upstream of Shiprock, New Mexico). There is a general downstream reduction in channel stability in the section of river between Bluff and Shiprock. Below the confluence with the Animas River near Farmington, New Mexico, the channel is less stable and more subject to floods from it largest and unregulated tributary, the Animas River. Conversely, the regulated reach of river between Farmington, New Mexico and Navajo Dam is relatively stable with few secondary channels.

From Lake Powell to Navajo Dam, the mean gradient of the San Juan River is 1.67 m/km. Examined in 30 km increments, river gradient ranges from 1.24 to 2.41 m/km but locally (i.e., <30 km reaches) can be as high as 3.5 m/km. Between Shiprock and Bluff, San Juan River substrate is primarily sand mixed among some cobble. The proportion of sand is greatest in the downstream most reaches and declines along an upstream gradient. From Farmington to Navajo Dam, the San Juan River substrate is dominated by embedded cobble. Although less embedded, cobble is also the most common substrate between Shiprock and Farmington. Except in canyon-bound reaches, the river is bordered by nonnative salt cedar, *Tamarix chinensis*, and Russian olive, *Elaeagnus angustifolia*, and native cottonwood, *Populus fremontii*, and willow, *Salix* sp. Nonnative woody plants dominated nearly all sites and resulted in heavily stabilized banks. Cottonwood and willow accounted for less than 15% of the riparian vegetation.

The characteristic annual hydrographic pattern in the San Juan River is typical of rivers in the American Southwest with large flows during spring snowmelt, followed by low summer, autumn, and winter base flows. Summer and early autumn base flows are frequently punctuated by convective storm-induced flow spikes. Prior to closure of Navajo Dam, about 73% of the total annual San Juan River drainage discharge (based on USGS Gauge # 09379500; Bluff, Utah) occurred during spring runoff (1 March through 31 July). Mean daily peak discharge during spring runoff was 10,400 cfs (range = 3,810 to 33,800 cfs). Although flows resulting from summer and autumn storms contributed a comparatively small volume to total annual discharge, the magnitude of storm-induced flows exceeded the peak snowmelt discharge about 30% of the years, occasionally exceeding 40,000 cfs (mean daily discharge). Both the magnitude and frequency of these storm induced flow spikes are greater than those recorded in the Green or Colorado rivers.

Operation of Navajo Dam altered the annual discharge pattern of the San Juan River. The natural flow of the Animas River ameliorated some aspects of regulated discharge by augmenting spring discharge. Regulation resulted in reduced magnitude and increased duration of spring runoff in wet years and substantially reduced magnitude and duration of spring flow during dry years. Overall, flow regulation by operation of Navajo Dam has resulted in post-dam peak spring discharge averaging about 54% of pre-dam values. Conversely, post-dam base flow increased markedly over pre-dam base flows.

Since 1992, Navajo Dam has been operated to mimic a “natural” San Juan River hydrograph with the volume of release during spring linked to the amount of precipitation recorded during the preceding winter. Thus in years with high spring snowmelt, reservoir releases were “large”, and “small” in low runoff years. Base flows since 1992 were typically greater than

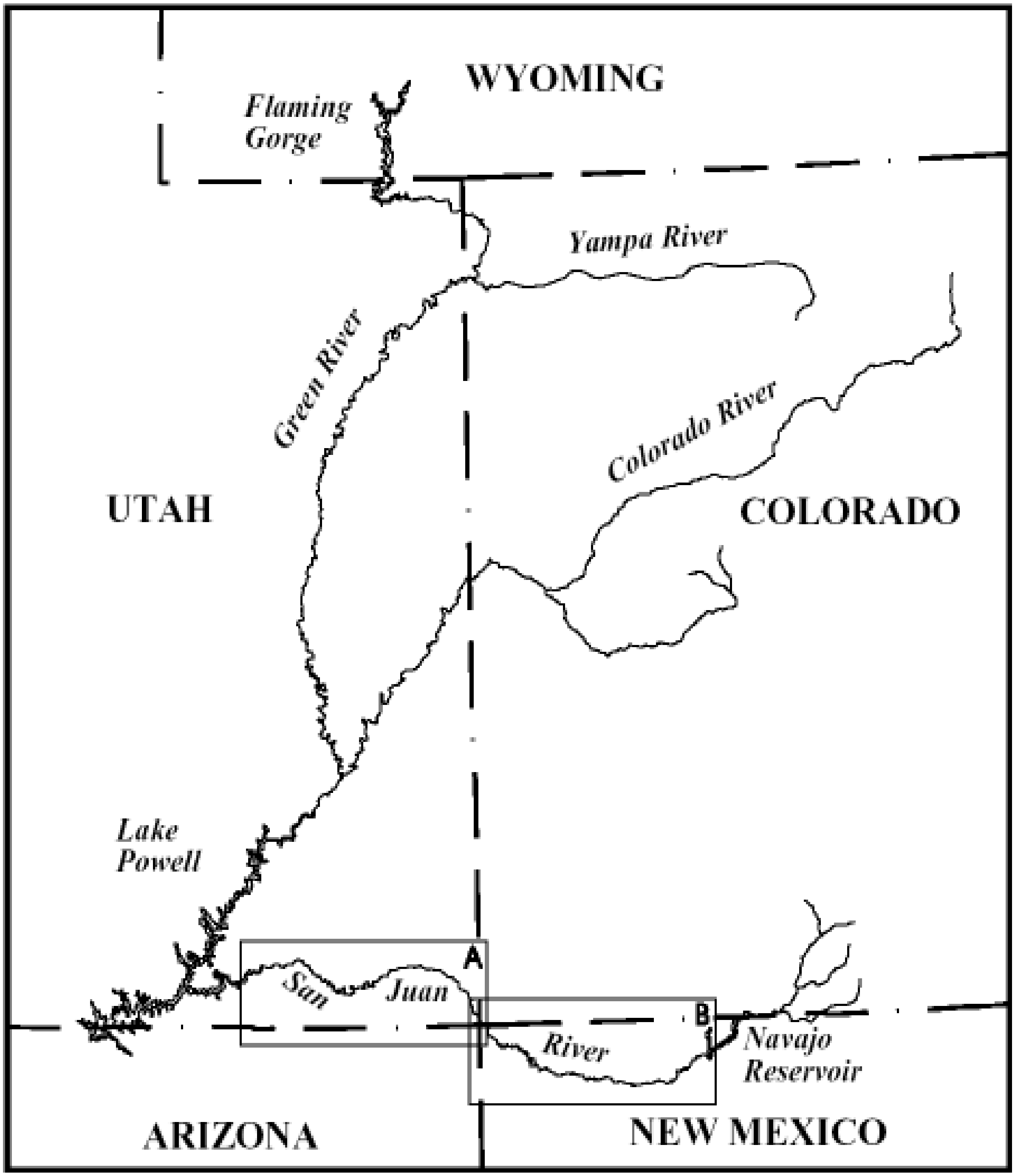


Figure 1. Location of the San Juan River within the Upper Colorado River Basin. The study area is outlined and labelled "A" and "B" with reference to subsequent maps in this report.

during pre-dam years but less than those between 1964-1991.

The primary study area for most investigations conducted under the auspices of the San Juan River Seven Year Research Program, including the present study, has been the mainstem San Juan River and its immediate vicinity between Navajo Dam and Lake Powell (Figure 2). There is considerable human activity within the floodplain of the San Juan River between Shiprock and Navajo Dam. Irrigated agriculture is practiced throughout this portion of the San Juan River Valley and adjacent uplands. Much of the river valley not devoted to agriculture (crop production and grazing) consists of small communities (e.g., Blanco and Kirtland) and several larger towns (e.g., Bloomfield and Farmington). The Animas River Valley is similarly developed. Small portions of the San Juan River valley and uplands from Shiprock to Bluff are farmed with dispersed livestock grazing as the primary land use. In the vicinity of Montezuma Creek and Aneth, petroleum extraction occurs in the floodplain and adjacent uplands. There are few human-caused modifications of the system from Bluff to Lake Powell.

A multivariate analysis of a suite of geomorphic features of the San Juan drainage was performed to segregate the river into distinct geomorphic reaches, enhance comparison between studies, and to provide a common reference for all research. This effort (Bliesner and Lamarra, 1999) resulted in the identification of eight reaches of the San Juan River between Lake Powell and Navajo Dam. A brief characterization of each reach (from downstream to upstream) follows.

Reach 1 (RM 0 to 16, Lake Powell confluence to near Slickhorn Canyon) has been greatly influenced by fluctuating reservoir levels of Lake Powell and its backwater effect. Fine sediment (sand and silt) has been deposited to a depth of about 12 m in the lowest end of this reach since the reservoir first filled in 1980. This deposition of suspended sediment into the delta-like environment of the river/reservoir transition makes it the lowest-gradient reach in the river. This portion of the river is canyon bound with an active sand bottom. Although an abundance of low-velocity habitat is present at certain flows, it is highly ephemeral, being influenced by both river flow and Lake Powell’s elevation.

Reach 2 (RM 17 to 67, near Slickhorn Canyon to confluence with Chinle Creek) is also canyon bound but is upstream of the influence of Lake Powell. The gradient in this reach is greater than in either adjacent reach and the fourth highest in the system. The channel is primarily bedrock confined and influenced by debris fans at ephemeral tributary mouths. Riffle-type habitat dominates, and the only major rapids in the San Juan River occur in this reach. Backwater abundance is low in this reach, usually occurring in association with debris fans.

Reach 3 (RM 68 to 105, Chinle Creek to Aneth, Utah) is characterized by higher sinuosity and lower gradient (second lowest) than the other reaches, a broad floodplain, multiple channels, high island count, and high percentage of sand substrate. While this reach has the second greatest density of backwater habitats after peak spring runoff, it is extremely vulnerable to change during summer and autumn storm events. After these storm events, this reach may have the second lowest density of backwaters of the eight reaches. The active channel distributes debris piles throughout the reach following spring runoff, leading to the nickname “Debris Field”.

Reach 4 (RM 106 to 130, Aneth, Utah, to below the Mixer) is a transitional zone between the upper cobble substrate-dominated reaches and the lower sand substrate-dominated reaches. Sinuosity is moderate compared with other reaches, as is gradient. Island area is higher than in Reach 3 but lower than in Reach 5, and the valley is narrower than in either adjacent reach. Backwater habitats are low overall in this reach (third lowest among reaches) and there is little clean cobble.

Reach 5 (RM 131 to 154, the Mixer to just below Hogback Diversion) is predominantly multi-channeled with the largest total wetted area and greatest secondary channel area of any of the reaches. Secondary channels in this section tend to be longer and more stable (but fewer) than in Reach 3. Riparian vegetation is more dense in this reach than in lower reaches but less dense than in upper reaches. Cobble and gravel are more common in channel banks than sand, and clean cobble areas are more abundant than in lower reaches. Backwaters and spawning bars in this reach are much less subject to perturbation during summer and fall storm events than are the lower reaches.

Reach 6 (RM 155 to 180, below Hogback Diversion to confluence with the Animas River) is predominantly a single channel, with 50% fewer secondary channels than Reaches 3, 4, or 5. Cobble and gravel are the dominant substrata with cobble bars containing clean interstitial spaces being most abundant in this reach. There are four diversion dams that may impede fish passage in this reach. Backwater habitat abundance is low in this reach, with only Reach 2 containing fewer of these habitats. The channel has been altered by dike construction in several areas to control lateral channel movement and over-bank flow.

Reach 7 (RM 181 to 213, Animas River confluence to between Blanco and Archuleta, New Mexico) is similar to Reach 6 in terms of channel morphology. The river channel is very stable, consisting primarily of embedded cobble substrate as a result of controlled releases from Navajo Dam. In addition, much of the river bank has been stabilized and/or diked to control lateral movement of the channel and over-bank flow. Water temperature is influenced by the hypolimnetic release from Navajo Dam and is colder during the summer and warmer in the winter than that of the river below the Animas confluence.

Reach 8 (RM 213 to 224, between Blanco and Archuleta and Navajo Dam) is the most directly influenced by Navajo Dam, which is situated at its uppermost end (RM 224). This reach is primarily a single channel, with only four to eight secondary channels, depending on the flow. Cobble is the dominant substrate type, and because lateral channel movement is less confined in this reach, some loose, clean cobble sources are available from channel banks. In the upper end of the reach, just below Navajo Dam, the channel has been heavily modified by excavation of material used in dam construction. In addition, the upper 10 km of this reach above Gobernador Canyon are essentially sediment free, resulting in the clearest water of any reach. Because of Navajo Dam's hypolimnetic release design, this area experiences much colder summer and warmer winter water temperatures. These cool, clear water conditions have allowed development of an intensively managed blue-ribbon trout fishery to the exclusion of most native species.

Objectives

This work was conducted as required by the San Juan River Basin Implementation Program Monitoring Plan and Protocol dated 31 March 2000. The objectives of this specific monitoring effort are identified in the aforementioned document (1a, 3a, and 3b) and listed below:

- Determine if Colorado pikeminnow reproduction occurred in the San Juan River and the relative level of any such effort.
- Determine the spawning periodicity of catostomids between mid-April and early September and examine potential correlations with temperature and discharge.
- Attempt to validate the presumed spawning period of San Juan River catostomids.
- Determine if reproduction by razorback sucker occurred in the San Juan River (upstream of Mexican Hat, Utah).
- Provide a comparative analysis of the reproductive effort of catostomids.
- Determine the relative annual reproductive success of razorback sucker (1a).
- Provide annual summaries of monitoring results (3a).
- Provide detailed analysis of data collected to determine progress towards endangered species recovery in three years and thence every five years (3b).

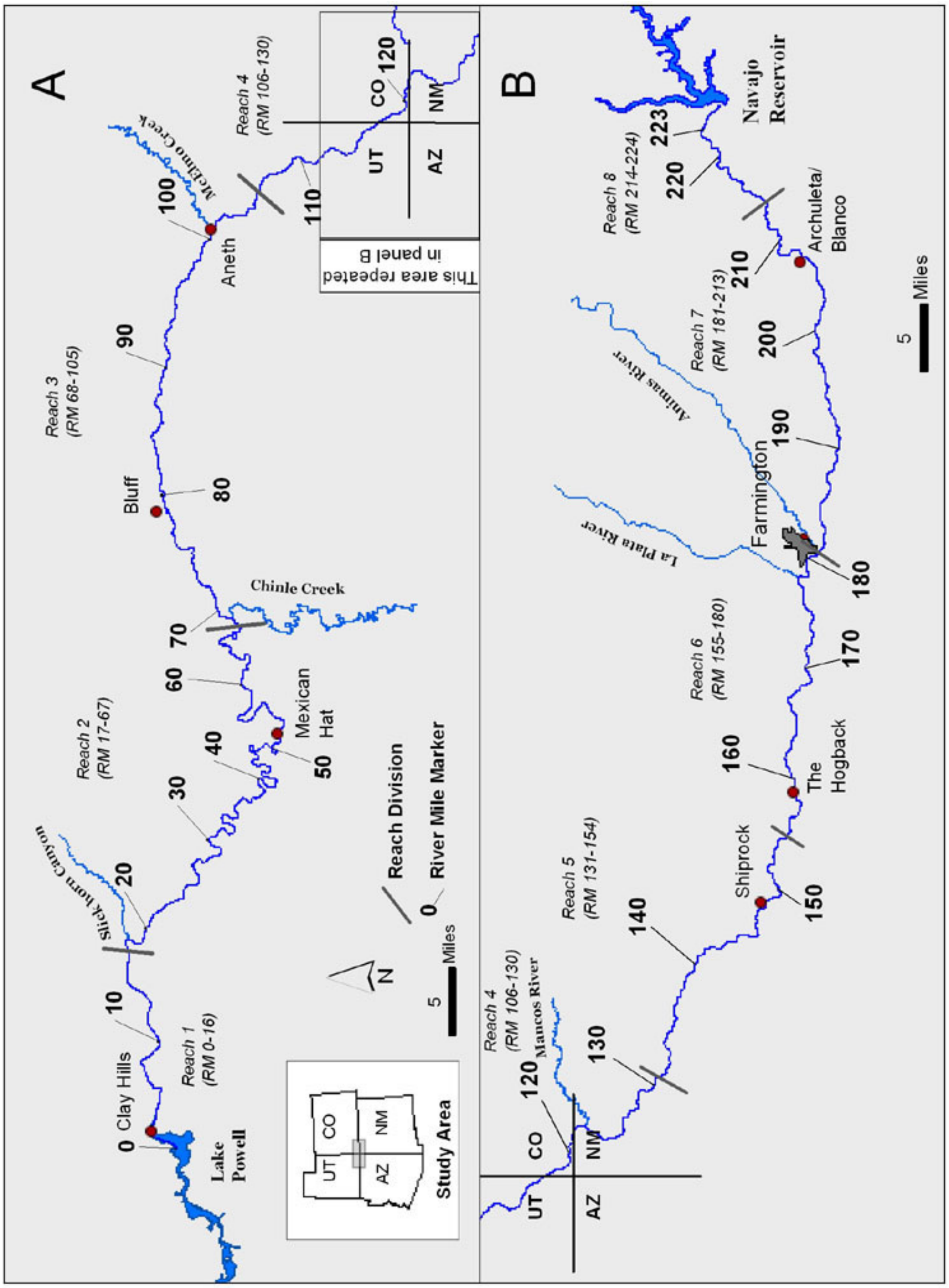


Figure 2. Map of the San Juan River study area.

Methods

Access to the river and collection localities was gained through the use a 16' inflatable raft that transported both personnel and collecting gear. There was not a predetermined number of collections per river mile nor geomorphic reach for this study. Instead, an effort was made to collect in as many suitable larval fish habitats as possible within the river reach being sampled. Previous San Juan River investigations have clearly demonstrated that larval fish most frequently occur and are most abundant in low velocity habitats such as pools and backwaters. Sampling of the entire study area is done during single uninterrupted trips which allow for meaningful between reach comparisons.

Collecting efforts for larval fish concentrated on low velocity habitats using small mesh seines (1 m x 1 m x 0.8 mm). Several seine hauls (between 3 and 12) were run through an individual collecting site depending on the size of the habitat. For each seine collection, the length of each seine haul was determined in addition to the number of seine hauls per site. Meso-habitat type, length, maximum depth, substrate, and turbidity (using a secchi disk) were recorded in the field data sheet for the particular collecting site (Appendix III). Water quality measurements (dissolved oxygen, conductivity, salinity, and temperature) were also obtained using a multi-parameter YSI-85 water quality meter (Appendix IV). A minimum of one digital photograph was recorded at each collection site.

River mile was determined to tenth of a mile using the 2003 standardized aerial maps produced for the San Juan River Basin Recovery Implementation Program and used to designate the location of collecting sites. In addition, geographic coordinates were determined at each site with a Garmin Navigation Geographic Positioning System (GPS) unit and were recorded in Universal Transverse Mercator (UTM) Zone 12 (NAD27). In instances where coordinates could not be obtained due to poor GPS satellite signal, coordinates were determined in the lab using a Geographic Information System based on the recorded river mile.

All retained specimens were placed in plastic bags (Whirl-Paks) containing a solution of 10% formalin and a tag inscribed with unique alpha-numeric code that was also recorded on the field data sheet. Samples were returned to the laboratory where they were sorted, specimens identified to species, enumerated, measured (minimum and maximum size [mm standard length] for each species at each site), transferred to 70% ethyl alcohol, and catalogued in the Division of Fishes of the Museum of Southwestern Biology (MSB) at the University of New Mexico (UNM). Scientific and common names of fishes used in this report follow Nelson et al. (2006) while six letter codes for species are those adopted by the San Juan River Basin Biology Committee (Table 3). Common names, arranged in phylogenetic order, are presented in the tables in this report. For Colorado pikeminnow and razorback sucker, a measure of total length (TL) was recorded for each individual in addition to standard length (SL) [Appendix I, II]. This was done in an effort to provide a higher degree of consistency and comparability with information presented from the San Juan River Basin and Upper Colorado River Basin programs. Throughout this report, lengths of YOY razorback sucker are presented as TL.

Specimens were identified to species by MSB personnel with expertise in San Juan River Basin larval fish identification. The term young-of-year (YOY) can include both larval and juvenile fish. It refers to any fish, regardless of developmental stage, between hatching or parturition and the date (1 January) that they reach age 1 (i.e., YOY = age 0 fish). Larval fish is a specific developmental (morphogenetic) period between the time of hatching and when larval fish transform to juvenile fish. We have chosen to follow larval fish terminology as defined by Snyder (1981). There are three distinct sequential larval developmental stages: protolarvae, mesolarvae, and metalarvae. Fish in any of these developmental stages are referred to as larvae or larval fish. Juvenile fish are those that have progressed beyond the metalarvae stage

Table 3. Scientific and common names and species codes of fish collected from the San Juan River. Asterisk (*) indicates species collected in previous years, but absent from 2005 samples.

Scientific Name	Common Name	Code
Order Cypriniformes		
Family Cyprinidae	carps and minnows	
Cyprinella lutrensis	red shiner	(CYPLUT)
Cyprinus carpio	common carp	(CYPCAR)
*Gila robusta**	roundtail chub	(GILROB)
Pimephales promelas	fathead minnow	(PIMPRO)
Ptychocheilus lucius	Colorado pikeminnow	(PTYLUC)
Rhinichthys osculus	specked dace	(RHIOSC)
Family Catostomidae	suckers	
Catostomus (Pantosteus) discobolus	bluehead sucker	(CATDIS)
Catostomus latipinnis	flannelmouth sucker	(CATLAT)
Xyrauchen texanus	razorback sucker	(XYRTEX)
Order Siluriformes		
Family Ictaluridae	catfishes	
Ameiurus melas	black bullhead	(AMEMEL)
Ictalurus punctatus	channel catfish	(ICTPUN)
Order Salmoniformes		
Family Salmonidae	trouts	
*Oncorhynchus nerka**	kokanee salmon	(ONCNER)
Order Atheriniformes		
Family Fundulidae	killifishes	
Fundulus zebrinus	plains killifish	(FUNZEB)
Family Poeciliidae	livebearers	
Gambusia affinis	western mosquitofish	(GAMAFF)
Order Perciformes		
Family Centrarchidae	sunfishes	
Lepomis cyanellus	green sunfish	(LEPCYA)
Lepomis macrochirus	bluegill	(LEPMAC)
Micropterus salmoides	largemouth bass	(MICSAL)

and no longer retain traits characteristic of larval fishes. Juveniles were classified as individuals that 1) had completely absorbed their fin folds, 2) had developed the full adult complement of rays and spines, and 3) had developed segmentation in at least a few of the rays. Specimens whose species-specific identity was questionable were forwarded to Darrel E. Snyder (Larval Fish Laboratory, Colorado State University) for review.

We determined differences in mean CPUE by species among years using a one-way Analysis of Variance (ANOVA). A Poisson Distribution provided the best fit to the raw data. A variety of transformations (e.g., logarithmic, reciprocal, square root) were run on the mean CPUE data. It was determined that a square-root transformation as described in Freeman and Tukey (1950) yielded the best variance-stabilizing qualities while also producing a relatively normal distribution. Pair-wise comparisons between years (2002 – 2005; N=6 comparisons) were made for each species and significance (i.e., $p<0.05$) was determined using the Tukey-Kramer HSD test. Finally, a nonparametric Analysis of Variance (i.e., Kruskal–Wallis test) was also run for the various data sets to compare results to the parametric analyses.

An electronic copy of the 2005 fish collection data was formatted and submitted for inclusion in the San Juan River integrated database being developed at UNM.

This study was annually initiated prior to spring runoff and completed near the end of the summer season (late September). Daily mean discharge during the study period was acquired from U.S. Geological Survey Gauge (# 09379500) near Bluff, Utah. Temperature data (mean, max, min) was supplied by Keller-Bliesner Engineering and taken at Mexican Hat, Utah (Figure 3)

Results

2005 Survey

Riverwide

High precipitation during the winter and early spring of 2005 created high spring runoff in the San Juan River and a brief reprieve from years of drought conditions in the Southwest. Runoff flows peaked at approximately 12,000 cfs, with eight consecutive days (23-30 May) above 10,000 cfs. (Figure 4). The lowest recorded flow during this study was 402 cfs on 4 August 2005.

Between 19 April and 14 September a total of six trips were conducted between Cudei, NM (river mile 141.5) and Clayhills, UT (river mile 2.9) [Figure 5]. A total of 358 samples were taken producing 109,364 specimens (Table 4). Red shiner was the dominant and most frequently encountered species accounting for 72.9% of the total catch and occurring in 329 samples. Fathead minnow was the second most abundant species accounting for 11.0% of the total catch. Combined, non-native fish species constituted nearly 86% of all fish collected in 2005. The most abundant native species collected was bluehead sucker followed by speckled dace, flannelmouth sucker, Colorado pikeminnow and razorback sucker. Larval catostomids were first collected during the first trip at McElmo Creek and collected during all subsequent trips. Larval non-native cyprinids were first collected during the second trip and also collected in all subsequent trips. Larval speckled dace were first collected during trip 3, with their numbers peaking during trip 4. No larval Colorado pikeminnow were collected in 2005. All Colorado pikeminnow collected in the 2005 survey were age-1 fish and presumed to be stocked fish. Larval razorback suckers were first collected during trip 2 and were present in trips 3, 4 and 5. A total of nineteen larval razorbacks were collected from reaches 1, 3, 4 and 5. This total was the third lowest total for larval razorbacks in the San Juan River since spawning was first documented (for this study) in 1998. However, 2005 makes eight consecutive years of documented

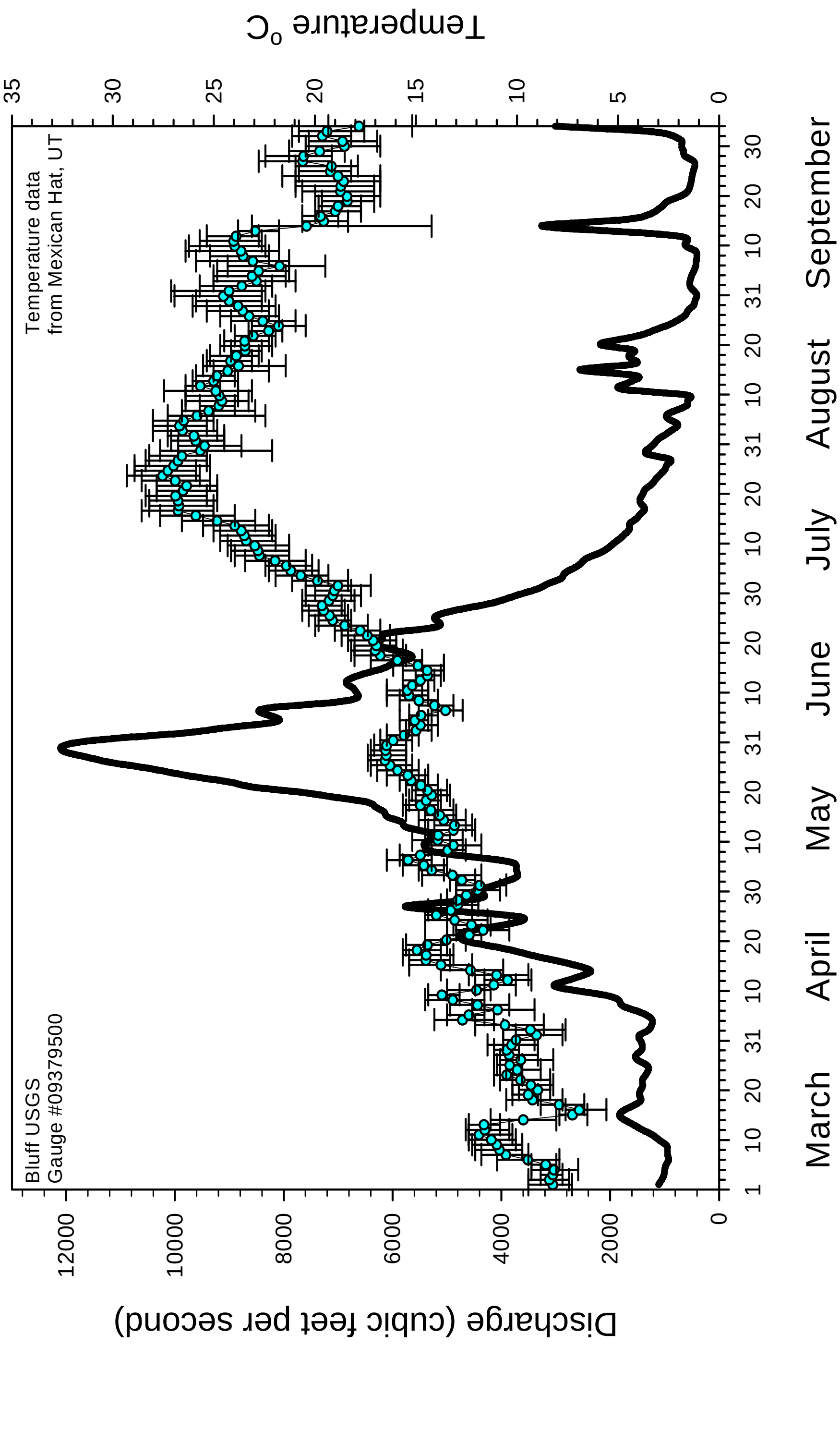


Figure 3. Hydrograph of the San Juan River at Bluff gauge, Utah and temperature data (daily max, min, and average shown) taken at Mexican Hat, Utah during the 2005 sampling period.

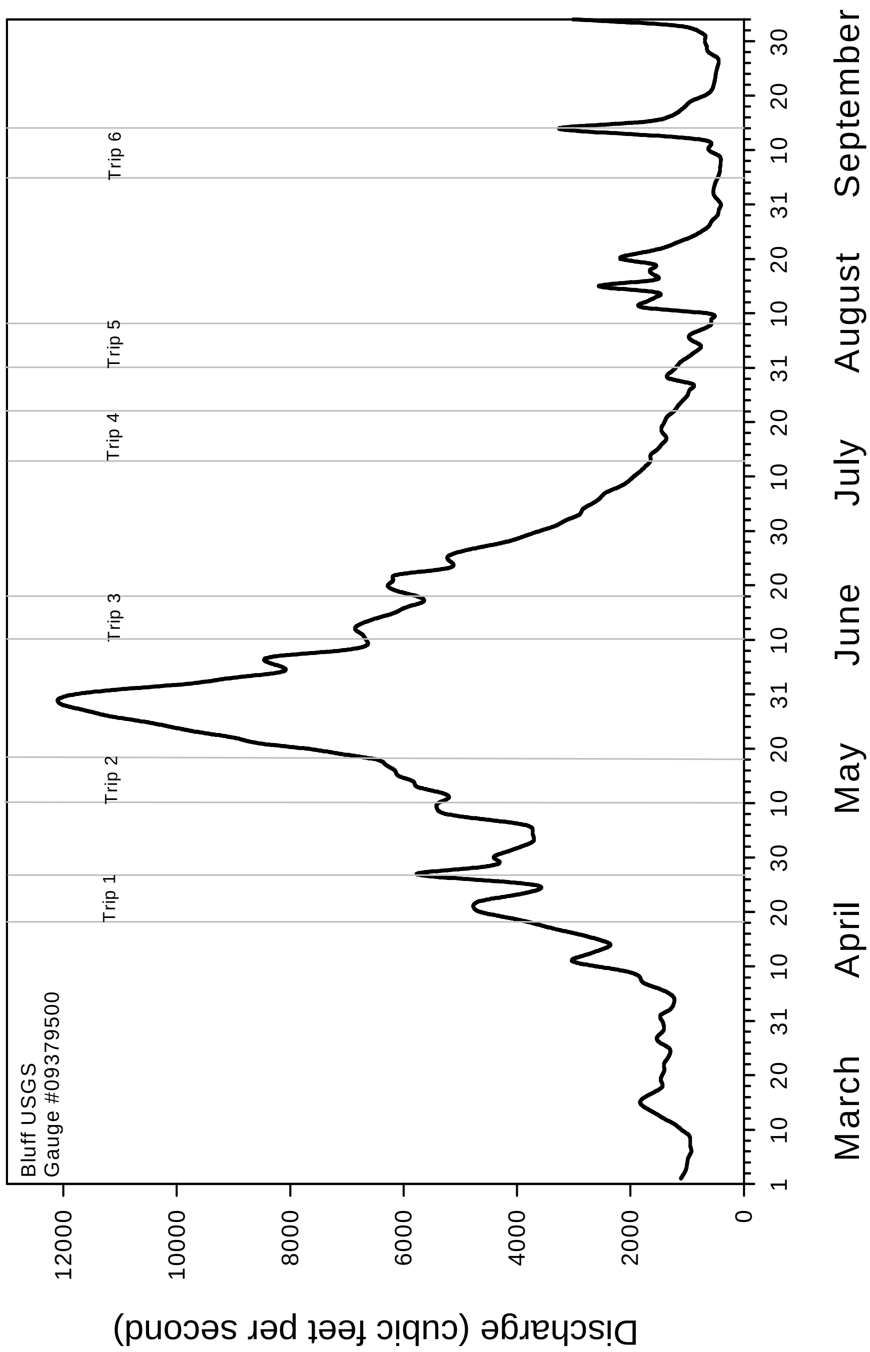


Figure 4. Hydrograph of the San Juan River at Bluff gauge, Utah during the 2005 sampling period.

Table 4. Summary of 2005 San Juan River larval Colorado pikeminnow and razorback sucker seining collections. (19 April-14 September) Effort = 10,368.6m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	79,756	72.9	769.2	329	91.9
common carp	I	820	0.7	7.9	36	10.1
roundtail chub	N	-	-	-	-	-
fathead minnow	I	12,016	11.0	115.9	230	64.2
Colorado pikeminnow	N	92	0.1	0.9	37	10.3
speckled dace	N	5,035	4.6	48.6	202	56.4
SUCKERS						
flannelmouth sucker	N	3,049	2.8	29.4	170	47.5
bluehead sucker	N	7,395	6.8	71.3	152	42.5
razorback sucker	N	19	*	0.2	13	3.6
BULLHEAD CATFISHES						
black bullhead	I	7	*	0.1	4	1.1
channel catfish	I	542	0.5	5.2	67	18.7
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	36	*	0.3	20	5.6
LIVEBEARERS						
western mosquitofish	I	572	0.5	5.5	91	25.4
SUNFISHES						
green sunfish	I	7	*	0.1	4	1.1
bluegill	I	1	*	*	1	0.3
largemouth bass	I	17	*	0.2	14	3.9
TOTAL		109,364		1,054.8		

1 N = native; I = introduced
2 CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
3 Frequency and % frequency of occurrence are based on n=358 samples.

* Value is less than 0.05

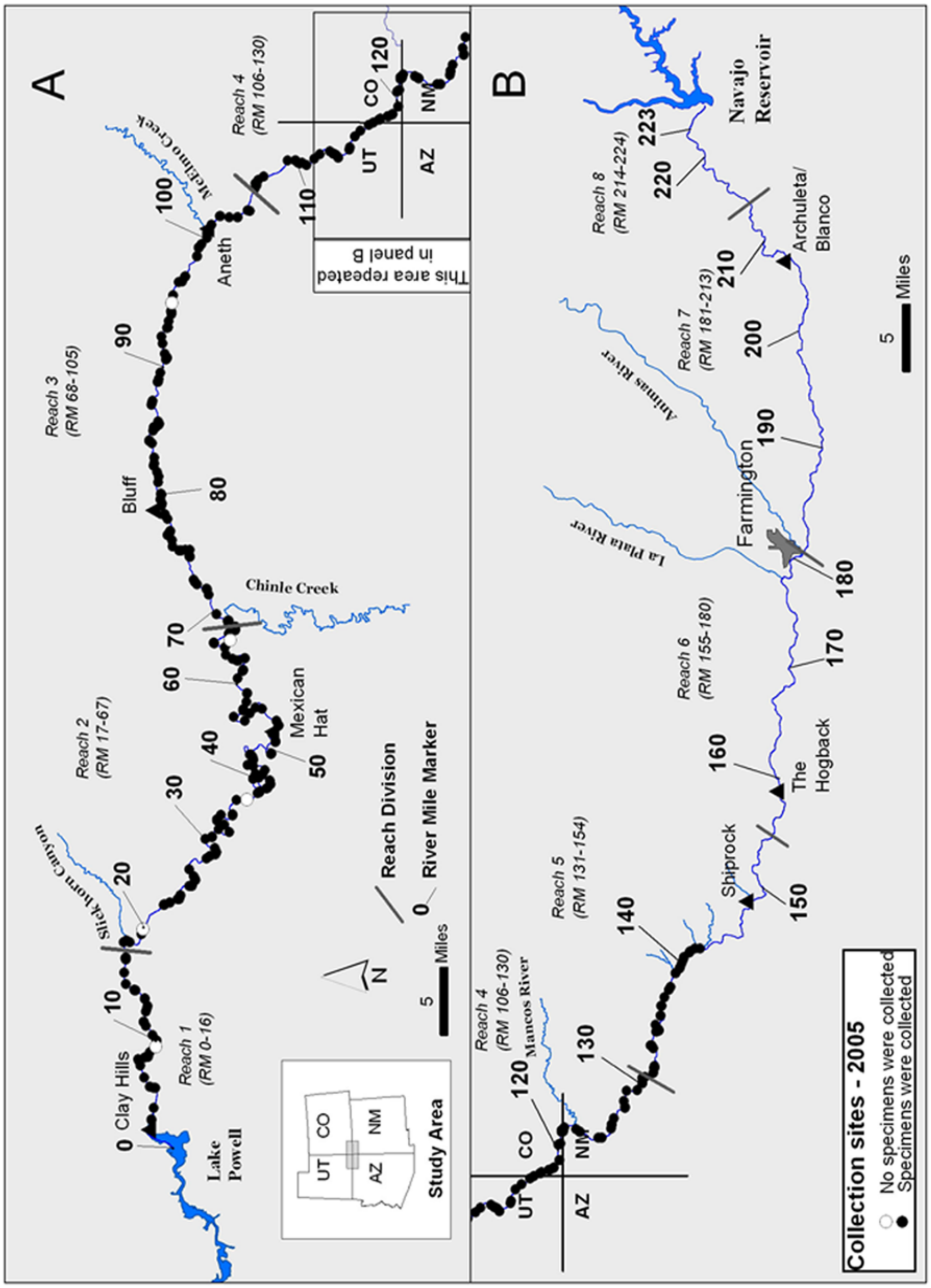


Figure 5. Map of all localities sampled during the 2005 San Juan River larval ichthyofaunal survey (19 April - 14 September 2005, Cudei to Clay Hills Crossing RM 141.5- 2.9).

spawning by razorback sucker and was one of only two years in which larvae were collected from reach 5.

Trip analysis

Trip 1 (April). The first 2005 collecting effort took place between 19 and 25 April 2005. A total of 60 samples were taken producing 4,491 specimens (Table 5). Non-native adult cyprinids accounted for 94.0% of the catch and were primarily comprised of red shiner, *Cyprinella lutrensis*, (n= 3,742). Native cyprinids comprised 2.1% of the catch in the first trip (5.8 fish per 100 m^2). Similar to the non-native cyprinids, none of the native cyprinids collected in the April trip were larval specimens. Trip 1 produced the largest number of Colorado pikeminnow collected during any single trip in 2005 (n=44) and also had the highest CPUE of any trip (2.7 fish per 100 m^2, (Figure 6). All of these specimens are presumed to be fish that had been stocked in the San Juan River in October 2004 under the auspices of the Colorado pikeminnow augmentation program. Adult speckled dace were collected in low numbers in trip 1. Catostomids comprised 3.3% of the total catch in trip 1 and had a CPUE of 8.9 fish per 100 m^2. A total of 147 flannelmouth sucker were collected in trip 1. The majority of flannelmouth sucker collected in trip 1 were larval specimens. Larval flannelmouth sucker were first collected at river mile 100.5, (McElmo Creek) on 20 April 2005 and were collected in subsequent sites downstream. No larval razorback sucker were collected in the first trip.

Trip 2 (May). A total of 60 collections were taken between 10 and 17 May 2005. Adult non-native cyprinids were numerically dominant and constituted 81.5% of the entire catch for trip 2 (Table 6). Red shiner accounted for 91.6% of the non-native cyprinids collected in trip 2 (n=4,225) and had the highest CPUE of trip 2 (248.4 fish per 100 m^2). Native cyprinids accounted for 1.0% of the entire catch in trip 2. None of the native cyprinids collected in trip 2 were larval individuals. Twenty-three Colorado pikeminnow were collected during this trip, all represented by stocked specimens. The majority of Colorado pikeminnow were collected in reaches 5 and 4. There was over a six fold increase in the number of larval catostomids collected in trip 2 compared to trip 1. Flannelmouth sucker accounted for 98.7% of the catostomids collected in this trip. A few larval flannelmouth sucker were collected in reach 4 and the upper portions of reach 3. Flannelmouth sucker numbers increased downstream of McElmo Creek. The first larval bluehead sucker and razorback sucker were collected in trip 2 (Figure 7). Both were collected on 14 May 2005. Razorback sucker larvae were first collected at river mile 78.7 and bluehead sucker larvae at river mile 74.4. A total of 4 razorback sucker larvae were collected in trip 2.

Trip 3 (June). The third trip occurred between 10 and 17 June 2005 with a total of 8,995 fish collected among 60 sites. Red shiner accounted for 56.2% of the fish collected and had the highest CPUE of trip 3 (313.7 fish per 100 m^2). Collections documented spawning of both native and non-native cyprinids in June 2005. The first larval fathead minnow were collected 10 June 2005 at river mile 141.1. The first larval red shiner and speckled dace were both collected two days later at McElmo Creek, river mile 100.5. The first cyprinid larvae, both native and non-native, were documented on the descending limb of the hydrograph in 2005 (Figure 9). Fifteen Colorado pikeminnow were collected throughout the study area, all of which were stocked individuals (Figure 8). Catostomids comprised 25.8% of the total catch during trip 3 (Table 7). Flannelmouth sucker for the third consecutive month in 2005 was the dominate catostomid taxa comprising 74.8% of the total catostomid catch. Flannelmouth larvae were collected throughout the study area in June and had the second highest CPUE of any species collected (107.6 fish per 100 m^2). Larval bluehead sucker comprised 24.8% of the catostomid catch in trip 3. Trip 3

Table 5. Summary of 2005 San Juan River trip 1 larval Colorado pikeminnow and razorback sucker seining collections (19-25 April 2005). Effort =1,654.2m^2

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	3,742	83.3	226.2	54	90.0
common carp	I	-	-	-	-	-
roundtail chub	N	-	-	-	-	-
fathead minnow	I	480	10.7	29.0	36	60.0
Colorado pikeminnow	N	44	1.0	2.7	15	25.0
speckled dace	N	51	1.1	3.1	18	30.0
SUCKERS						
flannelmouth sucker	N	147	3.3	8.9	23	38.3
bluehead sucker	N	-	-	-	-	-
razorback sucker	N	-	-	-	-	-
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	11	0.2	0.7	5	8.3
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	13	0.3	0.8	6	10.0
LIVEBEARERS						
western mosquitofish	I	3	0.1	0.2	1	1.7
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	-	-	-	-	-
TOTAL		4,491		271.6		

1 N = native; I = introduced
2 CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
3 Frequency and % frequency of occurrence are based on n=60 samples.

* Value is less than 0.05

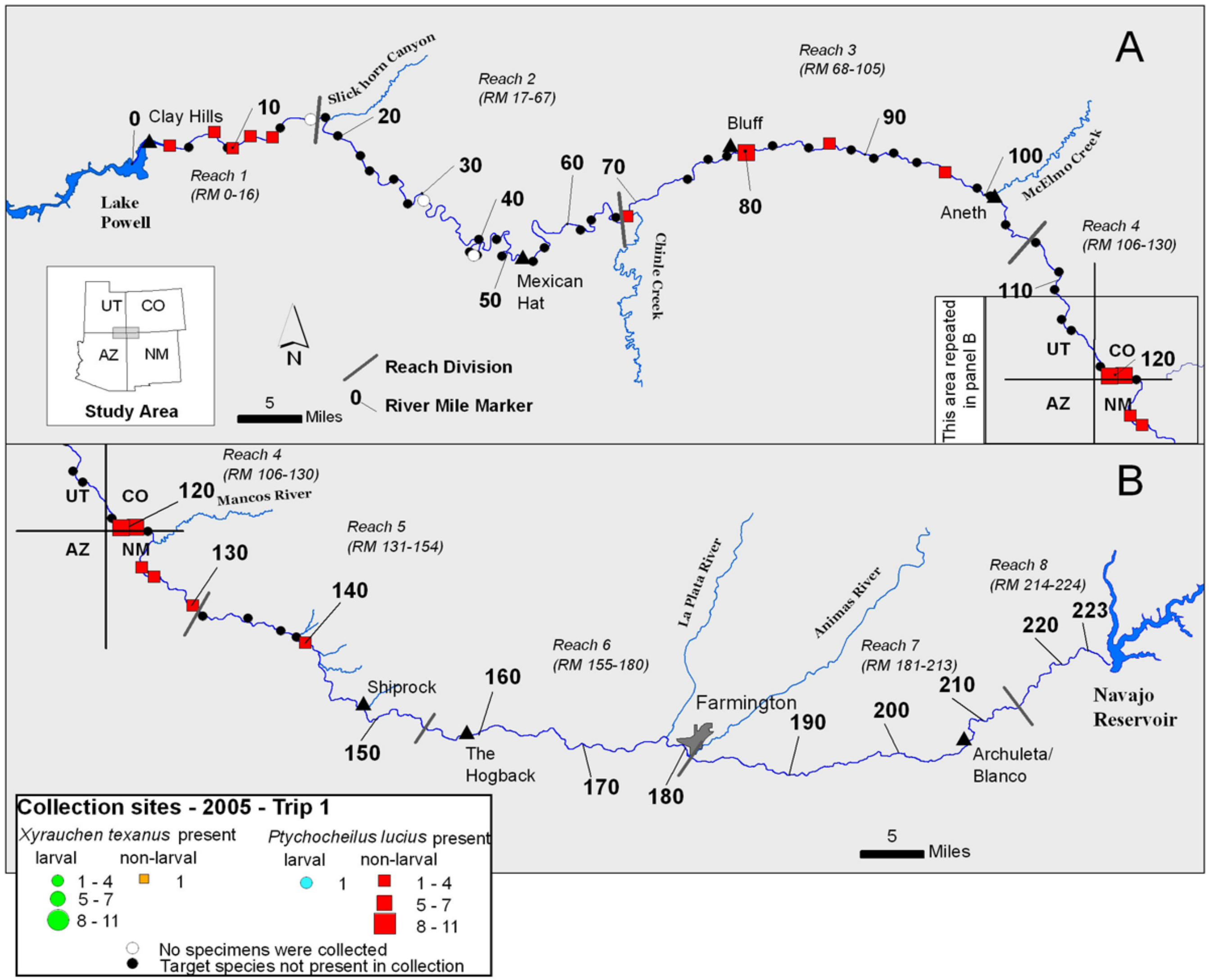


Figure 6. Map of localities sampled during trip 1 of the 2005 San Juan River larval ichthyofaunal survey (19-25 April 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

Table 6. Summary of 2005 San Juan River trip 2 larval Colorado pikeminnow and razorback sucker seining collections (10-17 May 2005). Effort = 1,700.9m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	4,225	74.7	248.4	52	86.7
common carp	I	2	*	0.1	2	3.3
roundtail chub	N	-	-	-	-	-
fathead minnow	I	383	6.8	22.5	30	50.0
Colorado pikeminnow	N	23	0.4	1.3	11	18.3
speckled dace	N	32	0.6	1.9	14	23.3
SUCKERS						
flannelmouth sucker	N	964	17.0	56.7	35	58.3
bluehead sucker	N	9	0.2	0.5	8	13.3
razorback sucker	N	4	0.1	0.2	3	5.0
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	10	0.2	0.6	8	13.3
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	3	0.1	0.2	3	5.0
LIVEBEARERS						
western mosquitofish	I	1	*	0.1	1	1.7
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	-	-	-	-	-
TOTAL		5,656		332.5		

1 N = native; I = introduced
2 CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
3 Frequency and % frequency of occurrence are based on n=60 samples.

* Value is less than 0.05

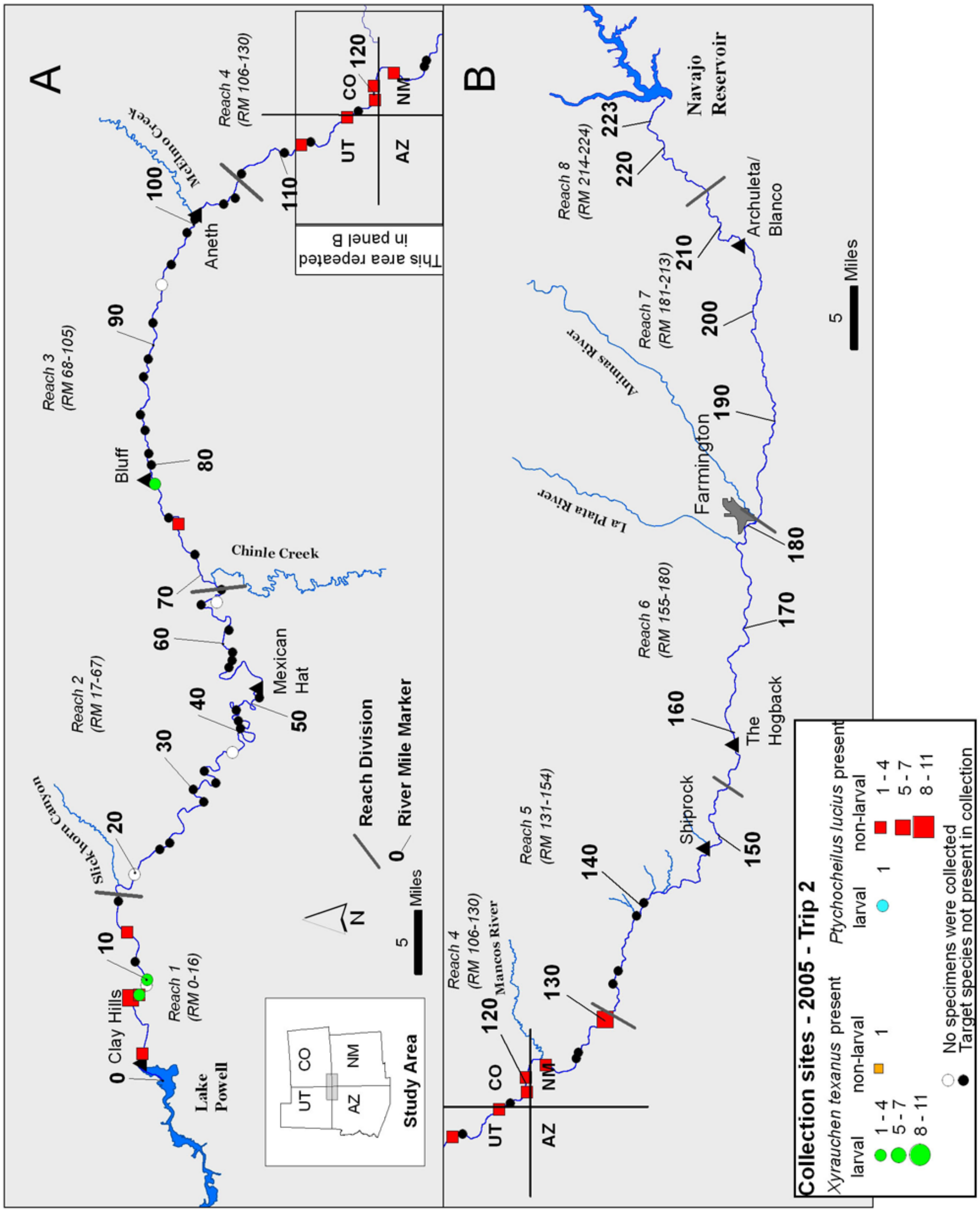


Figure 7. Map of localities sampled during trip 2 of the 2005 San Juan River larval ichthyofaunal survey (10-17 May 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

Table 7. Summary of 2005 San Juan River trip 3 larval Colorado pikeminnow and razorback sucker seining collections (10-17 June 2005). Effort = 1612.9m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	5,059	56.2	313.7	53	88.3
common carp	I	780	8.7	48.4	10	16.7
roundtail chub	N	-	-	-	-	-
fathead minnow	I	736	8.2	45.6	33	55.0
Colorado pikeminnow	N	15	0.2	0.9	6	10.0
speckled dace	N	32	0.4	2.0	16	26.7
SUCKERS						
flannelmouth sucker	N	1,735	19.3	107.6	51	85.0
bluehead sucker	N	576	6.4	35.7	42	70.0
razorback sucker	N	9	0.1	0.6	5	8.3
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	2	*	0.1	2	3.3
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	2	*	0.1	2	3.3
LIVEBEARERS						
western mosquitofish	I	47	0.5	2.9	10	16.7
SUNFISHES						
green sunfish	I	1	*	0.1	1	1.7
bluegill	I	1	*	0.1	1	1.7
largemouth bass	I	-	-	-	-	-
TOTAL		8,995		557.7		

1 N = native; I = introduced
2 CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
3 Frequency and % frequency of occurrence are based on n=60 samples.

* Value is less than 0.05

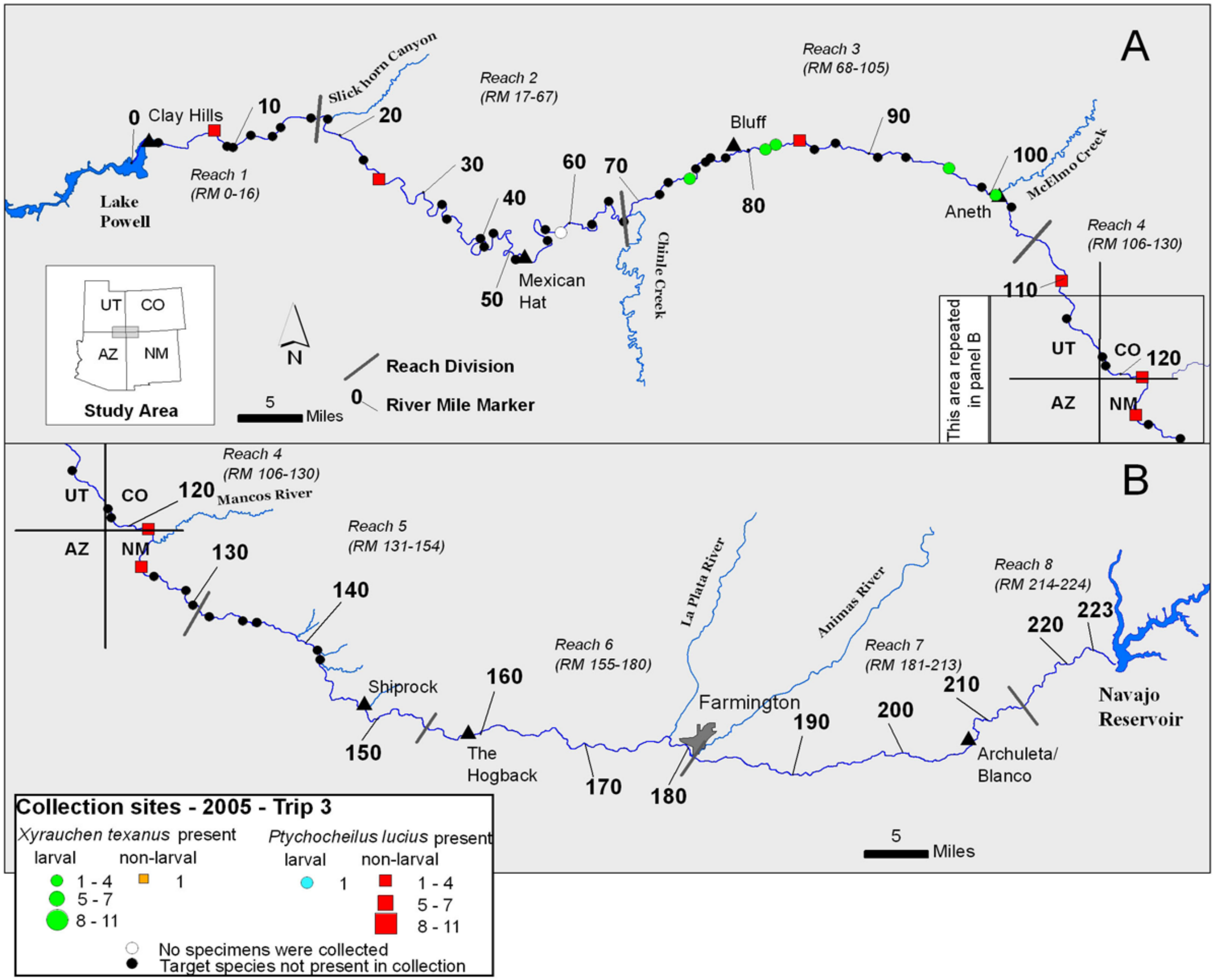


Figure 8. Map of localities sampled during trip 3 of the 2005 San Juan River larval ichthyofaunal survey (10-17 June 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

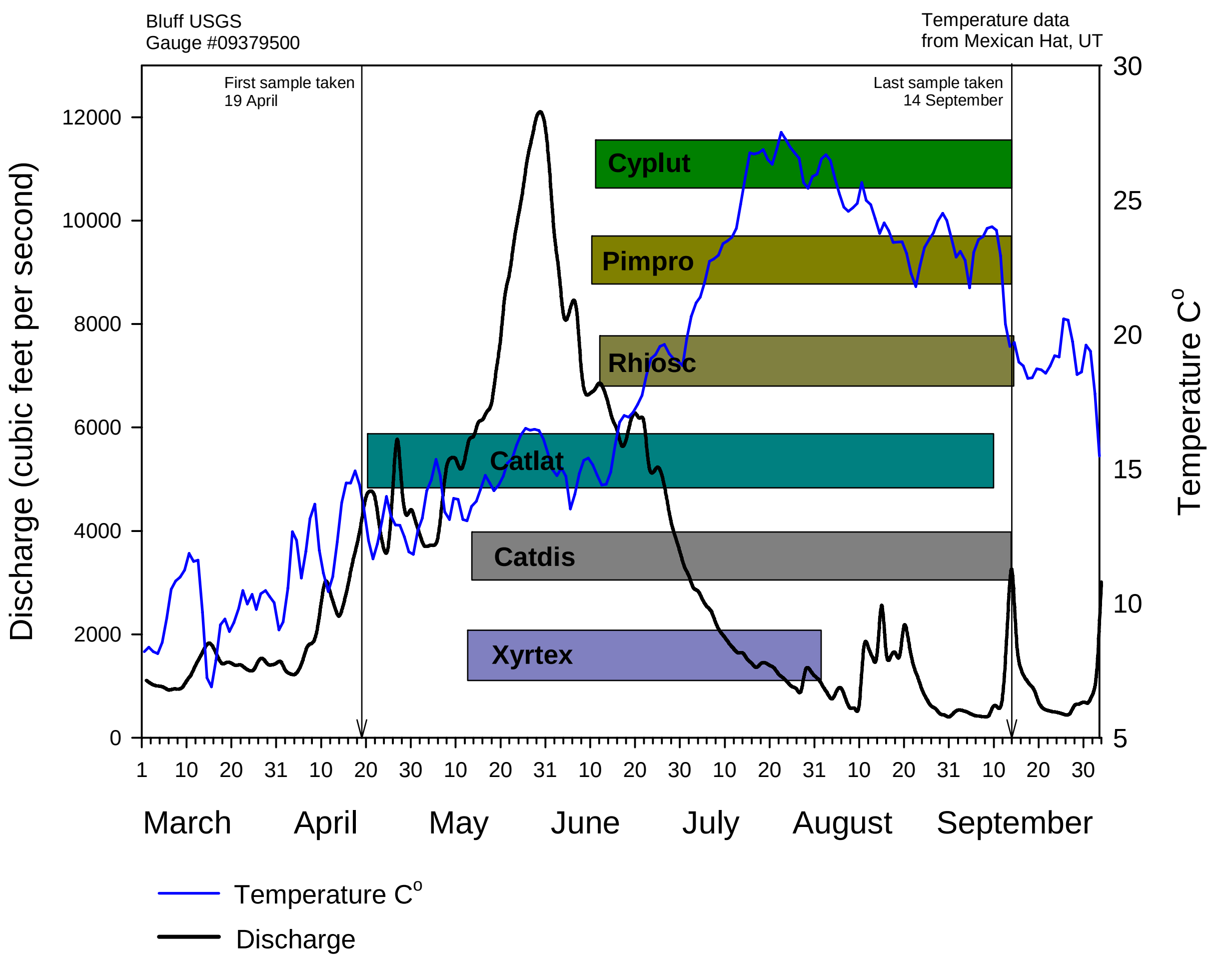


Figure 9. Occurrence of larval and young-of-year fishes in the San Juan River during 2005 (19 April - 14 September) plotted against temperature and discharge. Colored bars represent the period between date of first and last collection of larvae or young-of-year for each species.

Table 8. Summary of 2005 San Juan River trip 4 larval Colorado pikeminnow and razorback sucker seining collections (13-22 July 2005). Effort = 1,881.1m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	10,166	57.9	540.4	53	88.3
common carp	I	13	0.1	0.7	8	13.3
roundtail chub	N	-	-	-	-	-
fathead minnow	I	445	2.5	23.7	28	46.7
Colorado pikeminnow	N	10	0.1	0.5	4	6.7
speckled dace	N	2,418	13.8	128.5	52	86.7
SUCKERS						
flannelmouth sucker	N	135	0.8	7.2	28	46.7
bluehead sucker	N	4,294	24.4	228.3	53	88.3
razorback sucker	N	5	*	0.3	3	5.0
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	-	-	-	-	-
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	-	-	-	-	-
LIVEBEARERS						
western mosquitofish	I	69	0.4	3.7	12	20.0
SUNFISHES						
green sunfish	I	5	*	0.3	1	1.7
bluegill	I	-	-	-	-	-
largemouth bass	I	7	*	0.4	5	8.3
TOTAL		17,567		933.9		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=60 samples.

* Value is less than 0.05

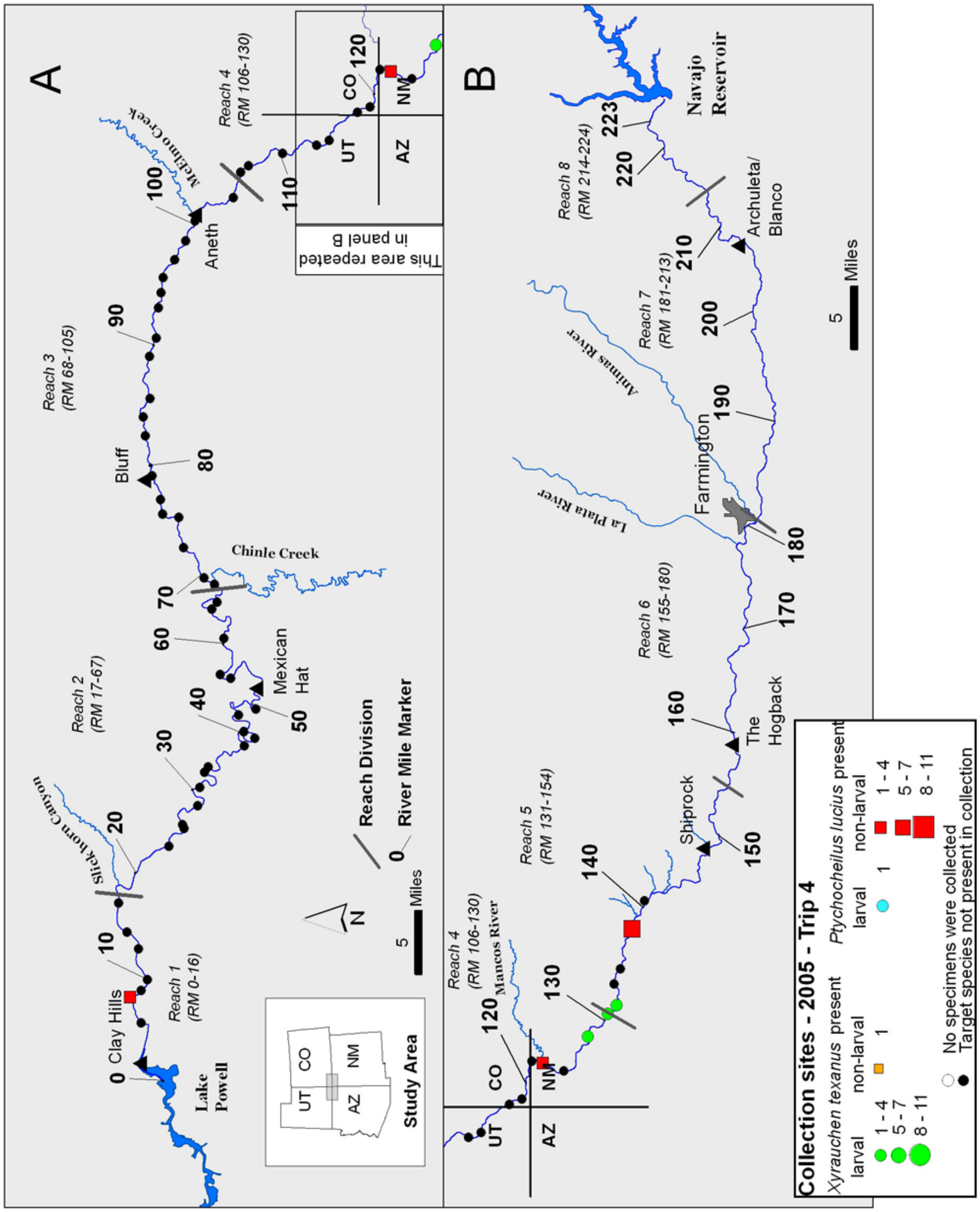


Figure 10. Map of localities sampled during trip 4 of the 2005 San Juan River larval ichthyofaunal survey (13-22 July 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

produced the largest number of larval razorback sucker in 2005 (n=9) all of which were collected in reach 3.

Trip 4 (July). Trip 4 was conducted between 13 and 22 July 2005. A total of 60 samples were taken yielding 17,567 specimens (Table 8). Trip 4 produced the second highest number of fish in 2005. Red shiner comprised 57.9% of the total catch in July and virtually all red shiner collected were larval specimens. Red shiner had the highest CPUE in trip 4 (540.4 fish per 100 m^2). Native cyprinids comprised 13.9% of the total catch in trip 4. Speckled dace comprised 99.6% of the native cyprinid catch and virtually all of these specimens were larval individuals and collected throughout the study area. Trip 4 was the lowest CPUE for Colorado pikeminnow (0.5 fish per 100 m^2) and was the last trip in which this species was collected. Reaches 5 and 4 produced 90.0% of Colorado pikeminnow collected in trip 4 (Figure 10). Catostomids accounted for 25.2% of the entire catch in trip 4. A shift was observed between larval numbers of flannelmouth sucker and bluehead sucker. In contrast to to trip 3, the cpue of bluehead suckers exceeded that of flannelmouth sucker in trip 4, with bluehead sucker making up 96.4% of the catostomid catch and having the second highest (228.3 fish per 100 m^2) for the trip. Greater numbers of bluehead sucker were collected in the upper reaches of the study area. Razorback sucker accounted for less than .05% of the total catch in trip 4 (n=5). This is the second year since 2002 that larval razorback sucker have been collected in July.

Trip 5 (August). Trip 5 began on 31 July and terminated at Clay Hills Crossing on 8 August 2005. A total of 65 collections produced 63,084 specimens, the largest number of larval fish collected in any one trip in 2005 (Table 9). The large number of larval fish collected in trip 5 represents the peak in spawning of non-native red shiner. Larval red shiner comprised 77.2% of the total catch in trip 5 and had the greatest CPUE of any other species (2,352.2 fish per 100 m^2) [Figure 13]. The second highest CPUE was that of larval fathead minnow (425.4 fish per 100 m^2). Combined, non-native cyprinids comprised 91.4% of the total catch in trip 5. For the second trip in a row bluehead sucker was the most abundant catostomid species collected representing 97.7% of the total catostomid catch. Similar to the previous month greater numbers of bluehead sucker were collected in the upper reaches of the study area. Collection of flannelmouth sucker was greatly reduced in trip 5. Flannelmouth sucker that were collected were larger juvenile fish (approximately 30 – 50 mm SL). A single larval razorback sucker (metalarva) was collected in trip 5 at river mile 99.6 (Figure 11). This is the first year we have captured razorback larvae in August since we began running six trips a year in 2002. The August trip also documented the spawning of channel catfish (n=475). Channel catfish larvae were collected throughout reaches 3 and 2.

Trip 6 (September). Trip 6 was conducted between 6 and 14 September 2005. A total of 9,571 specimens were collected in 53 separate samples representing (22.2 % decrease in CPUE numbers) over a ten-fold decrease from the prior month (Table 10). Non-native cyprinids (red shiner and fathead minnow) comprised 93.2% of the total catch in trip 6. Speckled dace accounted for 3.1% of the total catch and had the third highest CPUE (20.7 fish per 100 m^2). No Colorado pikeminnow were collected in trip 6. Catostomids accounted for 0.5% of the total catch in trip six. No razorback sucker were collected in September (Figure 12).

Reach analysis

Reach 1. Reach 1 had the lowest total specimen number and the lowest CPUE of any of the reaches. A total of 47 collections yielding 9,556 specimens were collected from reach 1, giving reach 1 the second lowest overall CPUE (593.8 fish per 100m^2) of any of the reaches. Similar patterns of both catch and CPUE were observed in both 2003 and 2004. Non-native cyprinids dominated the catch with red shiner accounting for 93.6 percent of the catch in reach 1

Table 9. Summary of 2005 San Juan River trip 5 larval Colorado pikeminnow and razorback sucker seining collections (31 July-8 August 2005). Effort = 2,094.5m.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	48,701	77.2	2,325.2	64	98.5
common carp	I	24	*	1.1	14	22.0
roundtail chub	N	-	-	-	-	-
fathead minnow	I	8,911	14.1	425.4	57	87.7
Colorado pikeminnow	N	-	-	-	-	-
speckled dace	N	2,207	3.5	105.4	61	93.8
SUCKERS						
flannelmouth sucker	N	57	0.1	2.7	27	41.5
bluehead sucker	N	2,474	3.9	118.1	37	56.9
razorback sucker	N	1	*	*	1	1.5
BULLHEAD CATFISHES						
black bullhead	I	7	*	0.3	3	4.6
channel catfish	I	475	0.8	22.7	31	47.7
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	7	*	0.3	4	6.2
LIVEBEARERS						
western mosquitofish	I	210	0.3	10.0	33	50.8
SUNFISHES						
green sunfish	I	1	*	*	1	1.5
bluegill	I	-	-	-	-	-
largemouth bass	I	9	*	0.4	7	10.8
TOTAL		63,084		3,011.9		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=65 samples.

* Value is less than 0.05

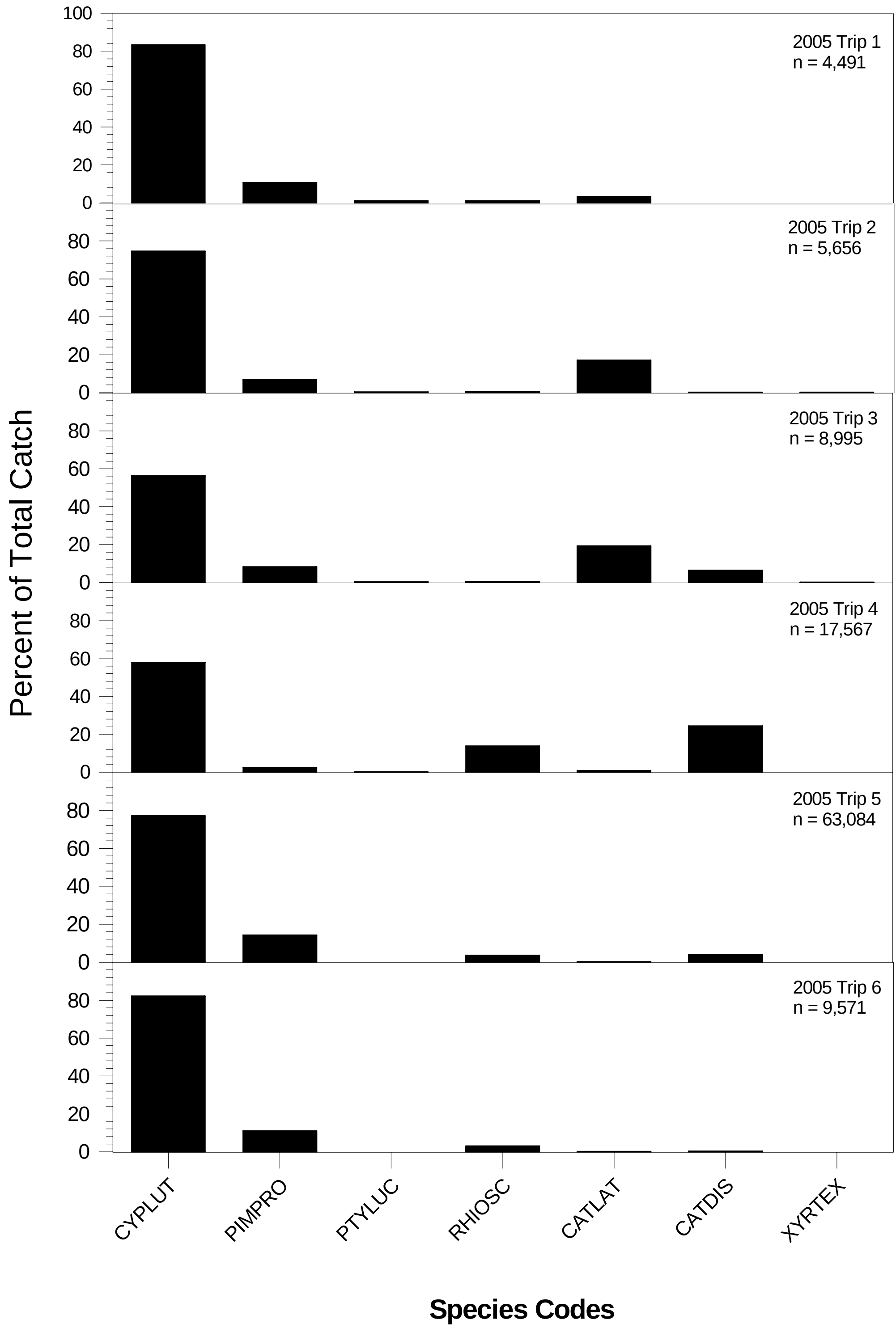


Figure 11. Ichthyofaunal composition of the most abundant species from 2005 sampling efforts by trip.

Table 10. Summary of 2005 San Juan River trip 6 larval Colorado pikeminnow and razorback sucker seining collections (6-14 September 2005). Effort = 1,425.0m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	7,863	82.2	551.8	52	98.1
common carp	I	1	*	0.1	1	1.9
roundtail chub	N	-	-	-	-	-
fathead minnow	I	1,061	11.1	74.5	45	84.9
Colorado pikeminnow	N	-	-	-	-	-
speckled dace	N	295	3.1	20.7	40	75.5
SUCKERS						
flannelmouth sucker	N	11	0.1	0.8	5	9.4
bluehead sucker	N	42	0.4	2.9	11	20.8
razorback sucker	N	-	-	-	-	-
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	44	0.5	3.1	20	37.7
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	11	0.1	0.8	4	7.5
LIVEBEARERS						
western mosquitofish	I	242	2.5	17.0	33	62.3
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	1	*	0.1	1	1.9
TOTAL		9,571		671.6		

1 N = native; I = introduced
2 CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
3 Frequency and % frequency of occurrence are based on n=53 samples.

* Value is less than 0.05

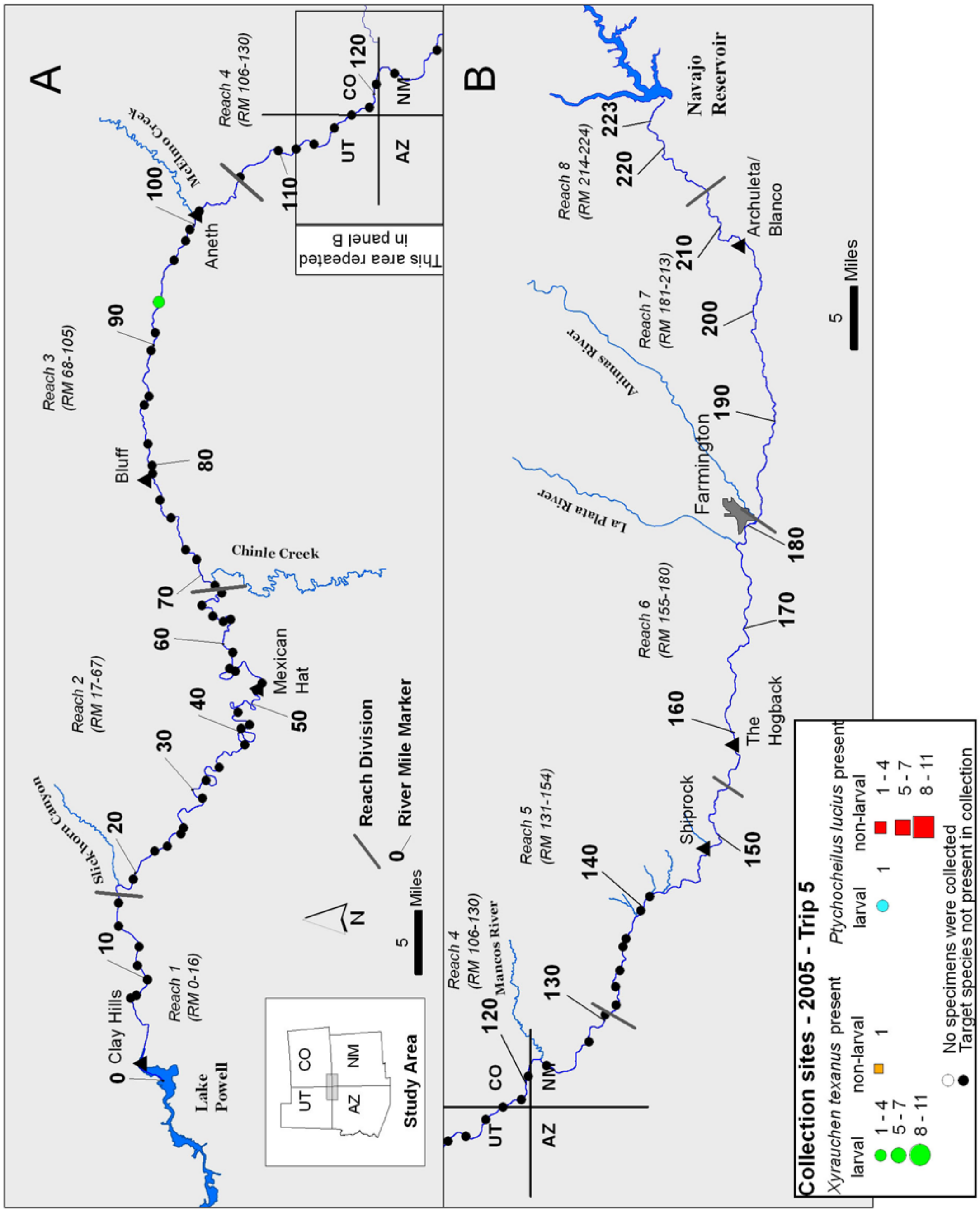


Figure 12. Map of localities sampled during trip 5 of the 2005 San Juan River larval ichthyofaunal survey (31 July - 8 August 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

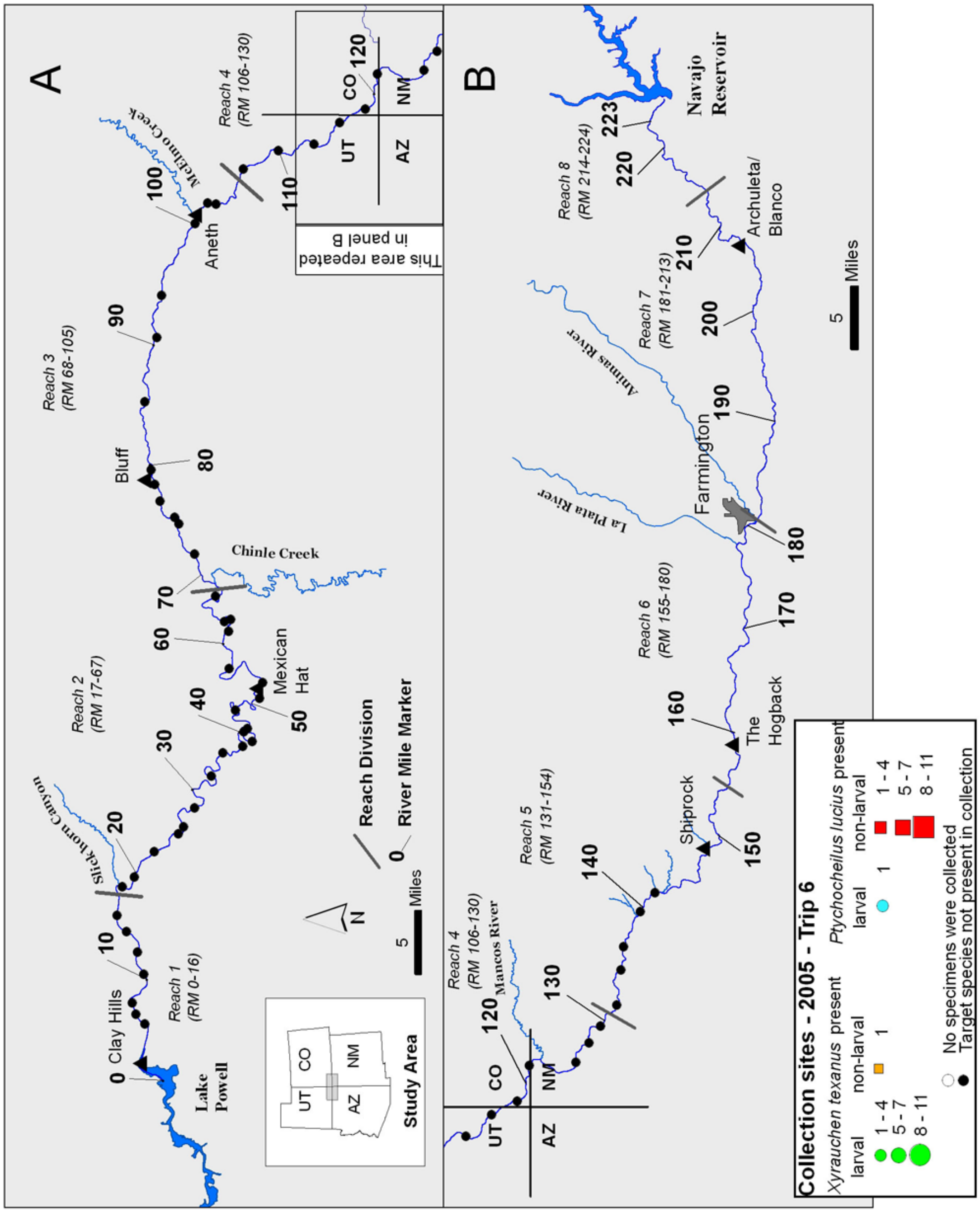


Figure 13. Map of localities sampled during trip 6 of the 2005 San Juan River larval ichthyofaunal survey (6-14 September 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

Table 11. Summary of 2005 San Juan River reach 1 larval Colorado pikeminnow and razorback sucker seining collections. Effort = 1,609.3m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	8,942	93.6	555.6	45	95.7
common carp	I	8	0.1	0.5	4	8.5
roundtail chub	N	-	-	-	-	-
fathead minnow	I	181	1.9	11.2	24	51.1
Colorado pikeminnow	N	24	0.3	1.5	11	23.4
speckled dace	N	44	0.5	2.7	18	38.3
SUCKERS						
flannelmouth sucker	N	177	1.9	11.0	17	36.2
bluehead sucker	N	75	0.8	4.7	14	29.8
razorback sucker	N	3	*	0.2	2	4.3
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	20	0.2	1.2	10	21.3
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	-	-	-	-	-
LIVEBEARERS						
western mosquitofish	I	73	0.8	4.5	14	29.8
SUNFISHES						
green sunfish	I	7	0.1	0.4	3	6.4
bluegill	I	1	*	0.1	1	2.1
largemouth bass	I	1	*	0.1	1	2.1
TOTAL		9,556		593.8		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=47 samples.

* Value is less than 0.05

(Table 11). This is the highest percent of total for any species in any reach for the 2005 survey. Over forty percent of non-native cyprinids (n=3,795) collected in reach 1 were taken during trip 4. Native fishes constituted 3.5% of the reach 1 catch with flannelmouth sucker being the dominant and most frequently encountered native fish, however no flannelmouth sucker were collected in reach 1 after trip 3 in 2005. Reach 1 was the least productive reach (both numerically and for CPUE) of any of the reaches for speckled dace and bluehead sucker. A total of 24 juvenile Colorado pikeminnow were taken from reach 1. Three larval razorback sucker werecollected between river miles 10 and 8.8. All larval razorback suckers taken were collected during trip 2.

Reach 2. A total of 113 collections were made in reach 2 in 2005 producing 15,351 specimens (Table 12). Reach 2 had the lowest CPUE (586.2 fish per 100m^2) of any of the reaches in 2005, however the 2005 CPUE for reach 2 was more than double the 2004 CPUE (283.3 fish per 100m^2). While non-native cyprinids made up 82.5% of the reach 2 catch, both red shiner and fathead minnow had a lower percent frequency of occurrence (85.8% and 43.4% respectively) in this reach than any other reach in 2005. Fathead minnow had the second highest CPUE during trip 6 (74.5 fish per 100m^2). Native fish accounted for 15.6% of the catch with speckled dace being the most frequently encountered native species (55.8% frequency of occurrence) and bluehead sucker being the numerically dominant native species (n=1,084). For both of these species, trip 4 was the most productive trip in 2005. A total of three juvenile Colorado pikeminnow were collected. All three specimens came from a single sample on 16 June, 2005 (trip 3) at river mile 24.5, making this reach the least productive for Colorado pikeminnow. Reach 2 was the only reach to produce no larval razorback sucker in 2005.

Reach 3. Reach 3 produced the largest number of specimens of any reach in 2005 (n=36,397), yet had the third highest CPUE of the five reaches (1,114.9 fish per 100m^2) [Table 13]. This same pattern was observed in 2004. Non-native cyprinids made up 83.7% of the catch, with red shiner accounting for 92.2% of all non-native cyprinids and occurring in 93 of the 100 collections taken. Native species made up 15% of the catch with roughly equal numbers of speckled dace, flannelmouth and bluehead suckers collected from this reach. As in 2004, this reach was the first to produce larval catostomids. Larval flannelmouth suckers were encountered at river mile 100.5 (McElmo Creek) on 20 April, 2005 (trip 1) and were collected in every other subsequent trip. Reach 3 had a greater CPUE for flannelmouth sucker than any other reach (59.4 fish per 100m^2) [Figure 19]. Larval bluehead suckers were first collected during trip 2, and were also collected in every other subsequent trip. This reach was the most productive of the reaches for larval razorback suckers and had the highest CPUE of any reach (0.3 fish per 100m^2) [Figure 21]. Eleven of the 19 razorbacks collected in 2005 were collected in three of the six trips conducted. A total of 16 juvenile Colorado pikeminnow were collected in reach 3. More channel catfish (both larval and young-of-year) were collected from this reach than all other reaches combined.

Reach 4. A total of 66 collections were made in reach 4 producing 31,747 specimens in 2005 (Table 14). This reach was the second most productive reach both numerically and with regards to CPUE (1,603.2 fish per 100 m^2). Red shiner had their lowest percent of total in this reach (65.1%) [Figure 14] while both fathead minnow and common carp had their highest percent of total in this reach (16.4% and 2.0% respectively). Over three times as many common carp were collected from this reach than all other reaches combined. Native species made up 16.1% of the catch making this reach the most productive reach for overall native species collected. Speckled dace had the highest CPUE of native cyprinids of any reach in reach 4 (97.6 fish per 100m^2) [Figure 18]. However, flannelmouth sucker accounted for only 0.6% of the catch making this reach the least productive for that species. This reach was the most productive reach for speckled dace and the second most productive reach for bluehead sucker with numbers of both of these species peaking during trips 4 and 5. This reach was also the most pro-

Table 12. Summary of 2005 San Juan River reach 2 larval Colorado pikeminnow and razorback sucker seining collections. Effort = 2,618.9m².

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	10,779	70.2	411.6	97	85.8
common carp	I	25	0.2	1.0	15	13.3
roundtail chub	N	-	-	-	-	-
fathead minnow	I	1,859	12.1	71.0	49	43.4
Colorado pikeminnow	N	3	*	0.1	1	0.9
speckled dace	N	679	4.4	25.9	63	55.8
SUCKERS						
flannelmouth sucker	N	626	4.1	23.9	39	34.5
bluehead sucker	N	1,084	7.1	41.4	30	26.5
razorback sucker	N	-	-	-	-	-
BULLHEAD CATFISHES						
black bullhead	I	6	*	0.2	2	1.8
channel catfish	I	218	1.4	8.3	38	33.6
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	3	*	0.1	1	0.9
LIVEBEARERS						
western mosquitofish	I	64	0.4	2.4	19	16.8
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	5	*	0.2	4	3.5
TOTAL		15,351		586.2		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m² (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=113 samples.

* Value is less than 0.05

Table 13. Summary of 2005 San Juan River reach 3 larval Colorado pikeminnow and razorback sucker seining collections. Effort = 3,264.7m².

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	28,086	77.2	860.3	93	93.0
common carp	I	145	0.4	4.4	7	7.0
roundtail chub	N	-	-	-	-	-
fathead minnow	I	2,233	6.1	68.4	68	68.0
Colorado pikeminnow	N	16	*	0.5	6	6.0
speckled dace	N	1,848	5.1	56.6	59	59.0
SUCKERS						
flannelmouth sucker	N	1,938	5.3	59.4	68	68.0
bluehead sucker	N	1,656	4.5	50.7	54	54.0
razorback sucker	N	11	*	0.3	8	8.0
BULLHEAD CATFISHES						
black bullhead	I	1	*	*	1	1.0
channel catfish	I	299	0.8	9.2	16	16.0
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	10	*	0.3	6	6.0
LIVEBEARERS						
western mosquitofish	I	151	0.4	4.6	29	29.0
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	3	*	0.1	3	3.0
TOTAL		36,397		1,114.9		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m² (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=100 samples.

* Value is less than 0.05

Table 14. Summary of 2005 San Juan River reach 4 larval Colorado pikeminnow and razorback sucker seining collections. Effort = 1,980.2m².

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	20,675	65.1	1,044.1	63	95.5
common carp	I	636	2.0	32.1	6	9.1
roundtail chub	N	-	-	-	-	-
fathead minnow	I	5,219	16.4	263.6	60	90.9
Colorado pikeminnow	N	40	0.1	2.0	15	22.7
speckled dace	N	1,933	6.1	97.6	41	62.1
SUCKERS						
flannelmouth sucker	N	190	0.6	9.6	27	40.9
bluehead sucker	N	2,963	9.3	149.6	31	47.0
razorback sucker	N	4	*	0.2	2	3.0
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	5	*	0.3	2	3.0
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	13	*	0.7	8	12.1
LIVEBEARERS						
western mosquitofish	I	67	0.2	3.4	12	18.2
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	2	*	0.1	2	3.0
TOTAL		31,747		1,603.2		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m² (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=66 samples.

* Value is less than 0.05

Table 15. Summary of 2005 San Juan River reach 5 larval Colorado pikeminnow and razorback sucker seining collections. Effort = 895.5m^2.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT OF TOTAL	CPUE[2]	FREQUENCY OF OCCURRENCE[3]	% FREQUENCY OF OCCURRENCE[3]
CARPS AND MINNOWS						
red shiner	I	11,274	69.1	1,259.0	30	93.8
common carp	I	6	*	0.7	3	9.4
roundtail chub	N	-	-	-	-	-
fathead minnow	I	2,524	15.5	281.9	28	87.5
Colorado pikeminnow	N	9	0.1	1.0	3	9.4
speckled dace	N	531	3.3	59.3	20	62.5
SUCKERS						
flannelmouth sucker	N	118	0.7	13.2	18	56.3
bluehead sucker	N	1,617	9.9	180.6	22	68.8
razorback sucker	N	1	*	0.1	1	3.1
BULLHEAD CATFISHES						
black bullhead	I	-	-	-	-	-
channel catfish	I	-	-	-	-	-
TROUT						
kokanee salmon	I	-	-	-	-	-
KILLIFISHES						
plains killifish	I	10	0.1	1.1	4	12.5
LIVEBEARERS						
western mosquitofish	I	217	1.3	24.2	16	50.0
SUNFISHES						
green sunfish	I	-	-	-	-	-
bluegill	I	-	-	-	-	-
largemouth bass	I	6	*	0.7	3	9.4
TOTAL		16,313		1,821.7		

[1] N = native; I = introduced
[2] CPUE = catch per unit effort; value based on catch per 100 m^2 (surface area) sampled
[3] Frequency and % frequency of occurrence are based on n=32 samples.

* Value is less than 0.05

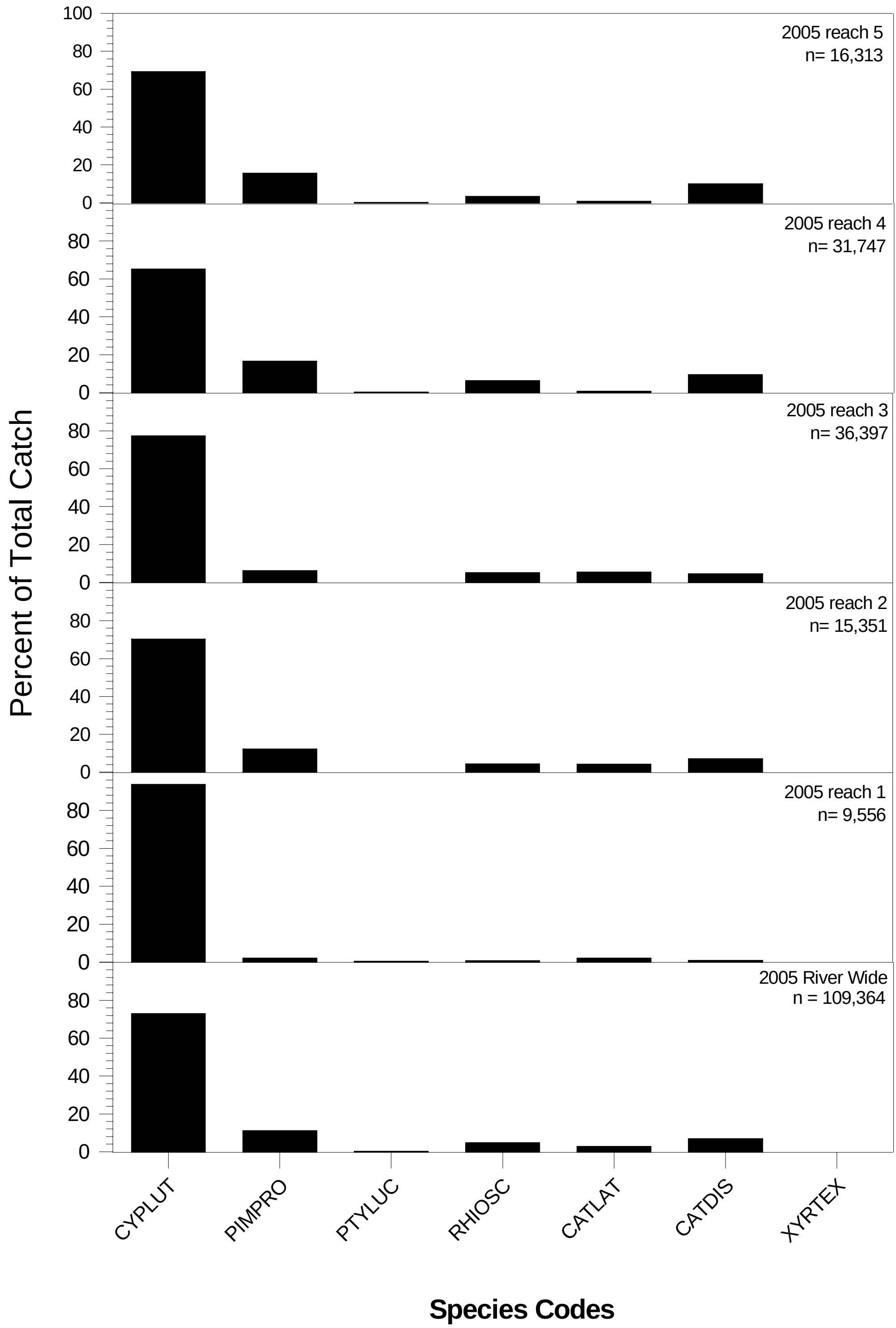


Figure 14. Ichthyofaunal composition of the most abundant species from 2005 sampling efforts by reach.

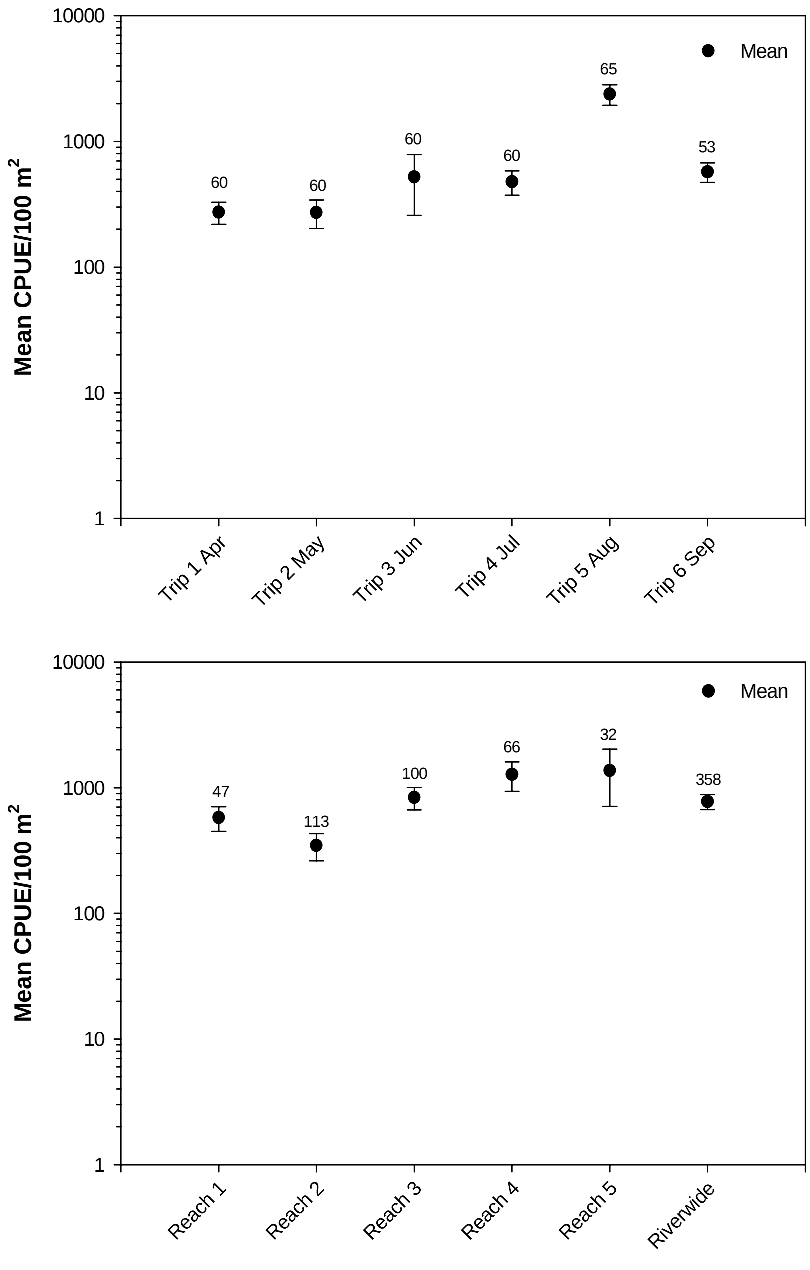
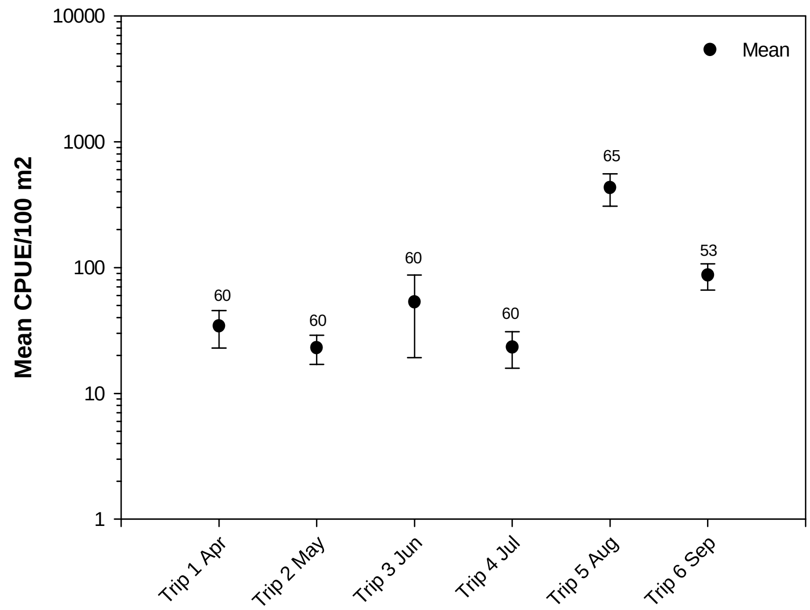


Figure 15. Mean CPUE / 100 m^2 (±1 SE) for red shiner, *Cyprinella lutrensis* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.



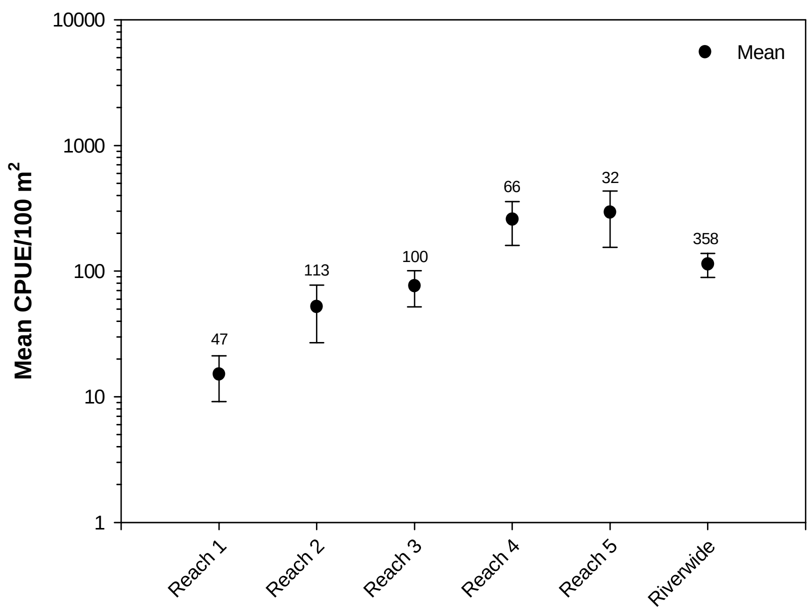


Figure 16. Mean CPUE / 100 m^2 (±1 SE) for fathead minnow, *Pimephales promelas* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.

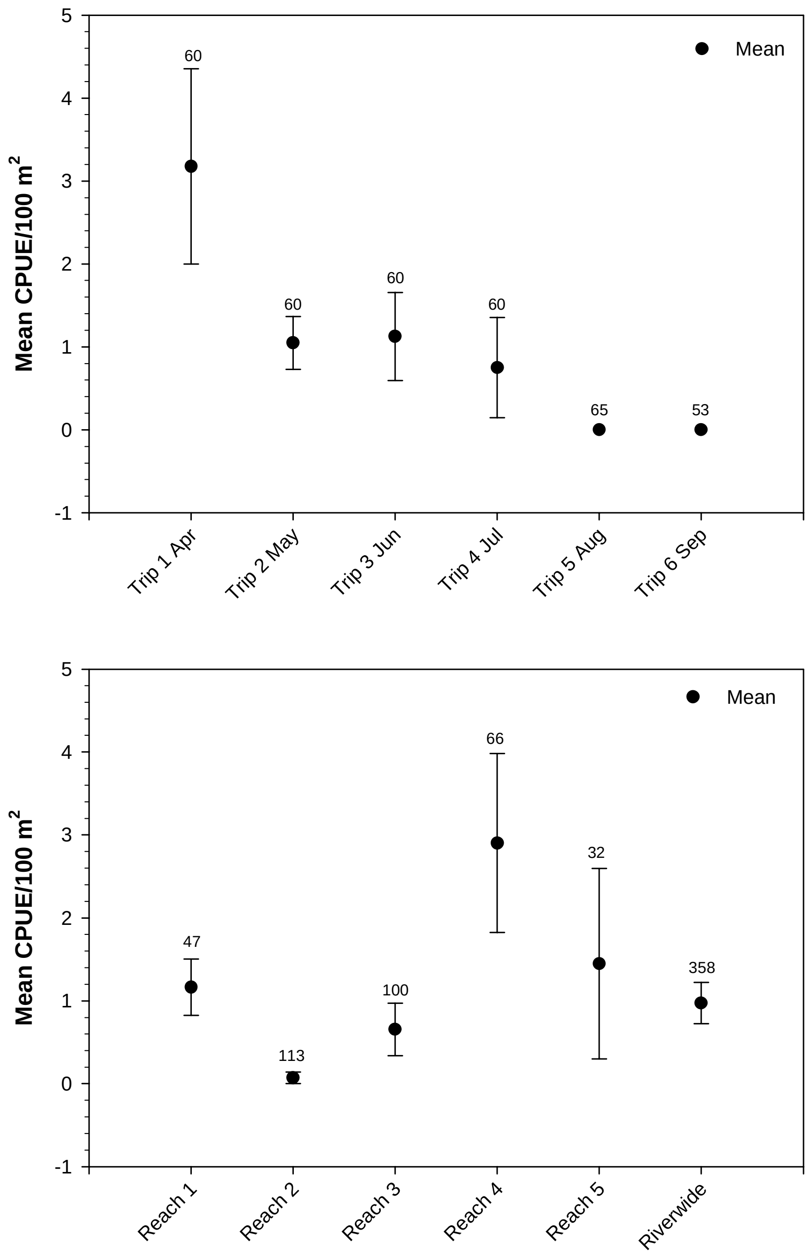
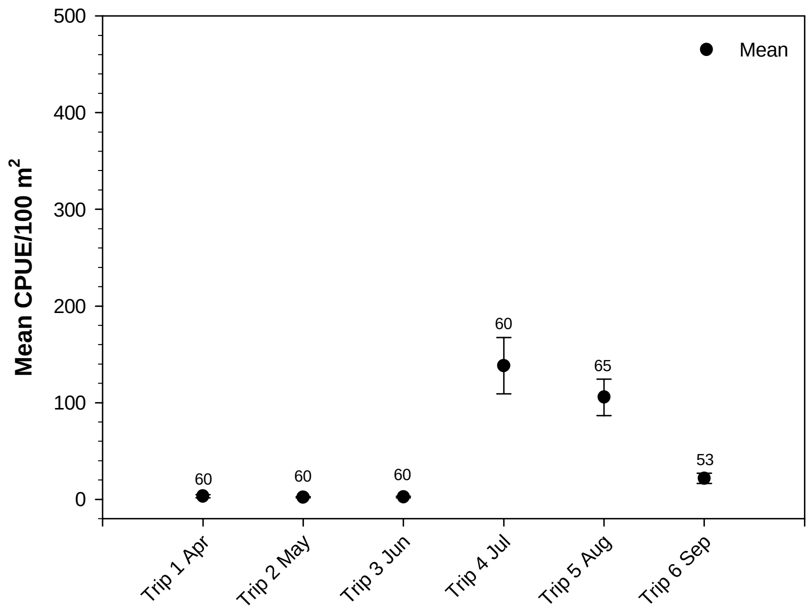


Figure 17. Mean CPUE / 100 m^2 (±1 SE) for Colorado pikeminnow, *Ptychocheilus lucius* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.



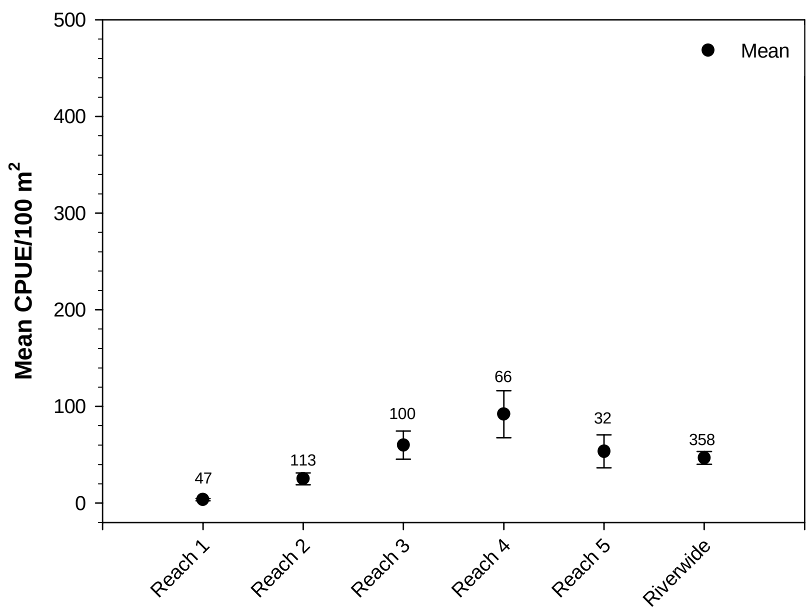


Figure 18. Mean CPUE / 100 m^2 (±1 SE) for speckled dace, *Rhinichthys osculus* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.

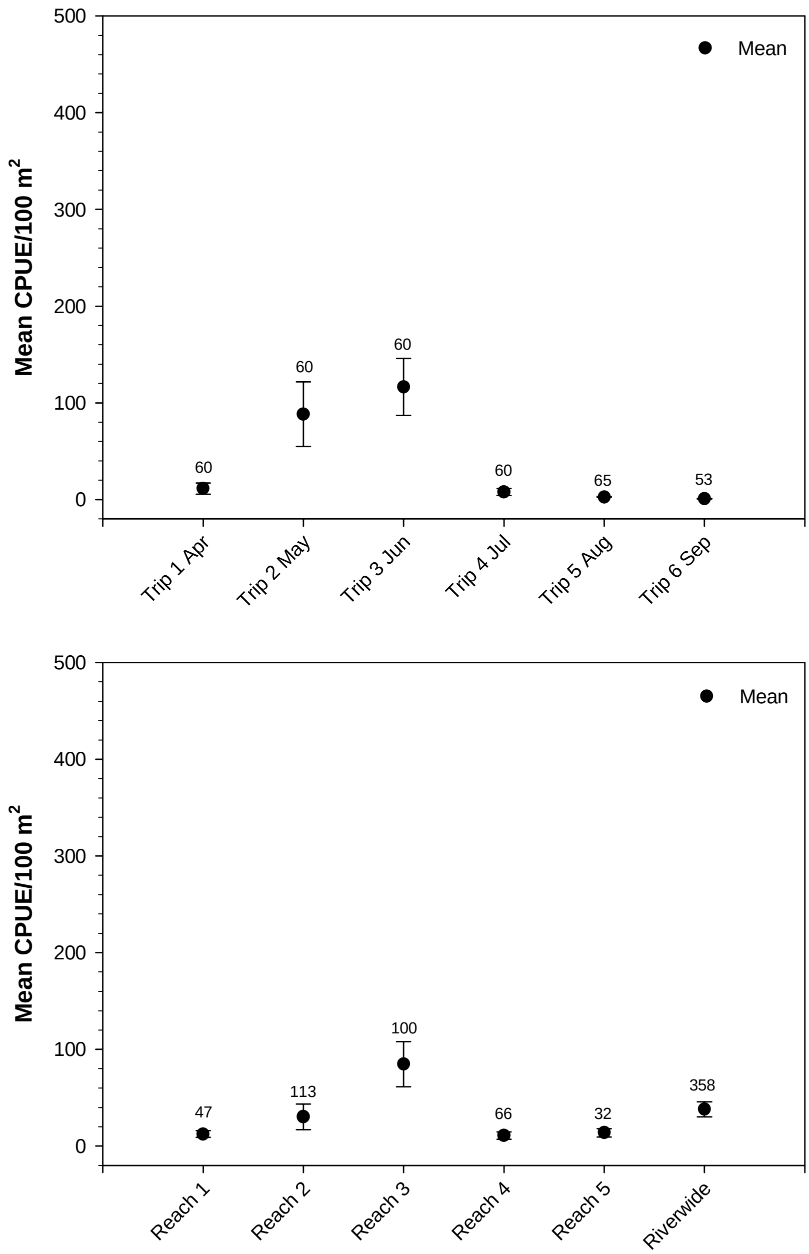


Figure 19. Mean CPUE / 100 m² (+1 SE) for flannelmouth sucker, *Catostomus latipinnis* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.

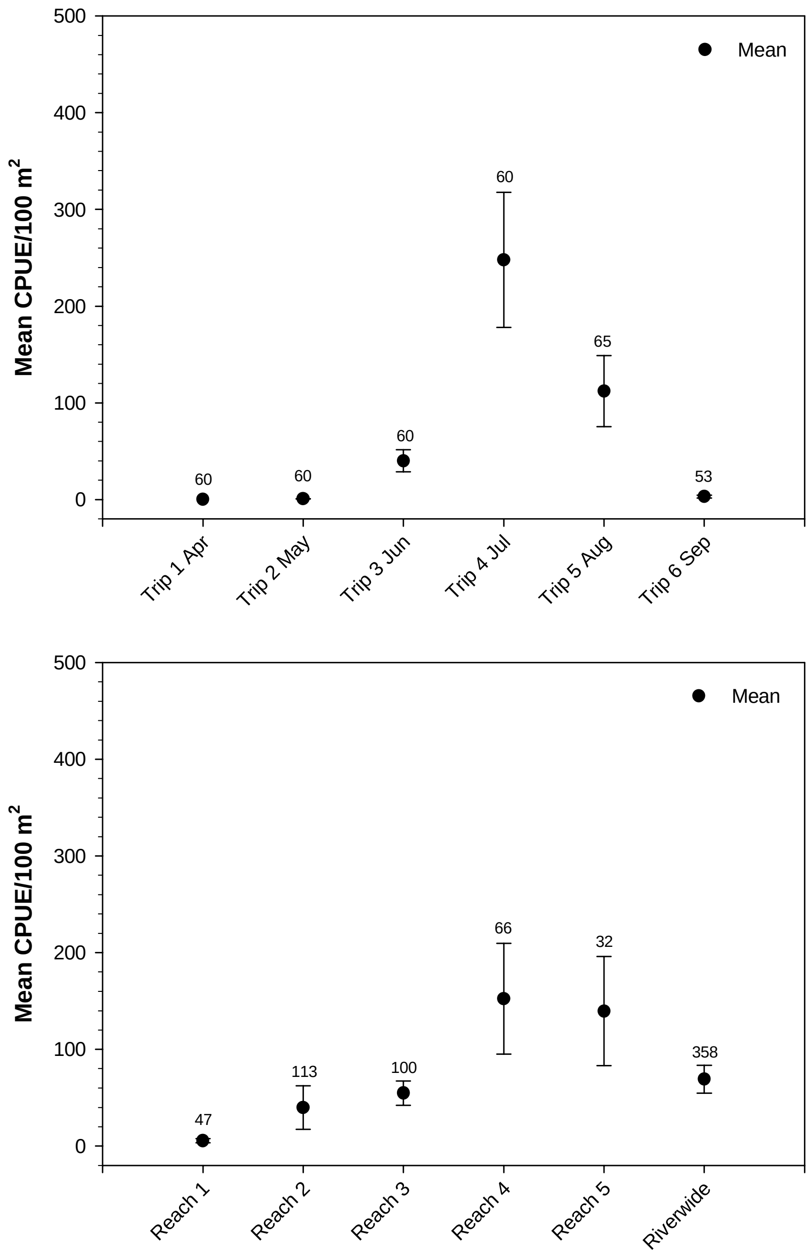


Figure 20. Mean CPUE / 100 m^2 ($\pm$1 SE) for bluehead sucker, *Catostomus discobolus* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.

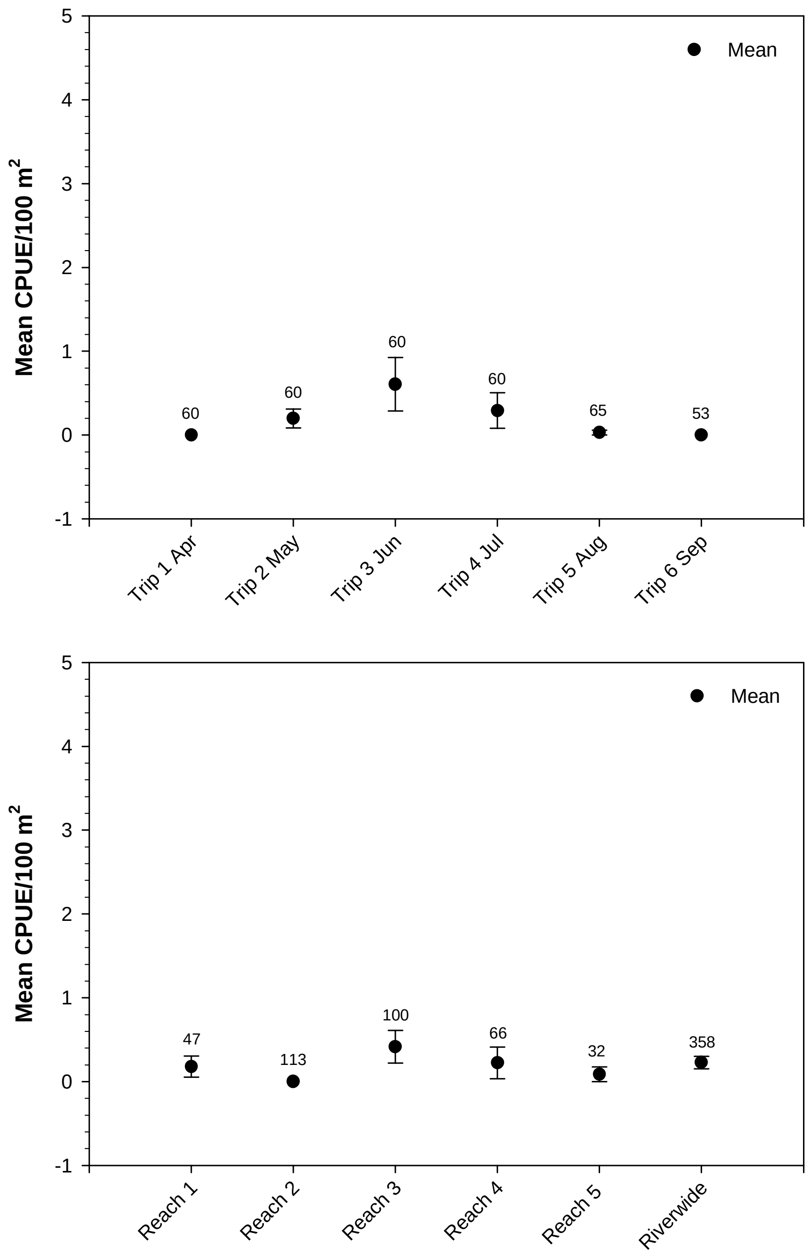


Figure 21. Mean CPUE / 100 m^2 ($\pm$1 SE) for razorback sucker, *Xyrauchen texanus* by trip, reach, and riverwide for 2005. Sample size reported above SE bars.

ductive for juvenile Colorado pikeminnow yielding 40 of the 92 specimens with a CPUE of 2.0 fish per 100m^2 (Figure 17). Four larval razorback suckers were collected in two samples during trip 4. The collection of these fish was spatial close with less than 3 river miles separating the two collections that produced larval razorback suckers.

Reach 5. Reach 5 had the highest overall CPUE (1,821.7) of any of the reaches in 2005 with 32 samples producing 16,313 specimens (Table 15). Individually, both red shiner and fathead minnow recorded their highest CPUE in this reach as well (1,259.0 and 281.9 fish per 100m^2 respectively) [Figures 15 and 16]. Numerically, this reach was the second lowest for both speckled dace and flannelmouth suckers with these two species combined accounting for only 4.0% of the catch. Conversely, this reach was best reach for bluehead sucker with regards to CPUE (180.6 fish per 100m^2) [Figure 20]. Nearly 10% of all fish collected from this reach were bluehead sucker. Of the 1,617 bluehead sucker collected, 1,359 of those were taken during trip 5. Nine juvenile Colorado pikeminnow were collected along with a single larval razorback sucker. Larval razorback sucker were last collected from this reach in 2002.

2005 Colorado pikeminnow

A total of 92 Colorado pikeminnow were collected in 2005. All of these fish were age-1 fish and presumed to be stocked fish. No larval Colorado pikeminnow were collected in 2005. The first Colorado pikeminnow was collected on 19 April 2005 at river mile 140.0 and the last was collected on 21 July 2005 at river mile 8.1 (Steer Gulch). Colorado pikeminnow were collected from all five reaches sampled, with reach 4 producing more fish (n=40) than any of the other reaches.

2005 razorback sucker

A total of 19 larval razorback suckers were collected in 2005. This number is less than half of the number of larval razorback suckers collected in 2004 (n=41). This total was also the third lowest total for larval razorback sucker collected from the San Juan River since spawning was first documented (for this study) in 1998. The first larval razorback sucker was collected on 14 May 2005 at river mile 78.7 with the last collected on 3 August 2005 at river mile 93.5. Thirteen collections contained razorback sucker larvae, with the single largest collection yielding four individuals. Reach 3 produced 11 of the 19 individuals collected and reach 2 was the only reach in which razorback larvae were not collected. Larval specimens ranged in development from yolked protolarvae to the late metalarvae stage (Appendix I). Larval razorback suckers were more spatial distributed in 2005 than in 2004, and 2005 was one of only 2 years in which larvae were collected from reach 5 (Figure 22).

A back-calculated hatching date was generated for each individual razorback sucker larvae collected in 2005. Hatching dates were calculated by subtracting the average length of larvae at hatching (8.0 mm TL) from the length at time of capture (Bestgen et al. 2002). This length was then divided by 0.3 mm, which was the average daily growth rate of wild larvae observed by Muth et al. (1998). The result was the estimated number of days since hatching which was then converted to hours. This value was then subtracted from the hour of collection (rounded up or down) in an effort to obtain a more precise date of hatching. For the nineteen larvae collected in 2005 hatching dates ranged from 26 April to 2 July 2005 (Figure 23). While the calculations used to generate these dates are as precise as possible, the data are presented to provide a temporal frame of reference for the occurrence of hatching razorback larvae in the San Juan River. Hatching occurred between the ascending and descending limb of spring runoff. Flows during

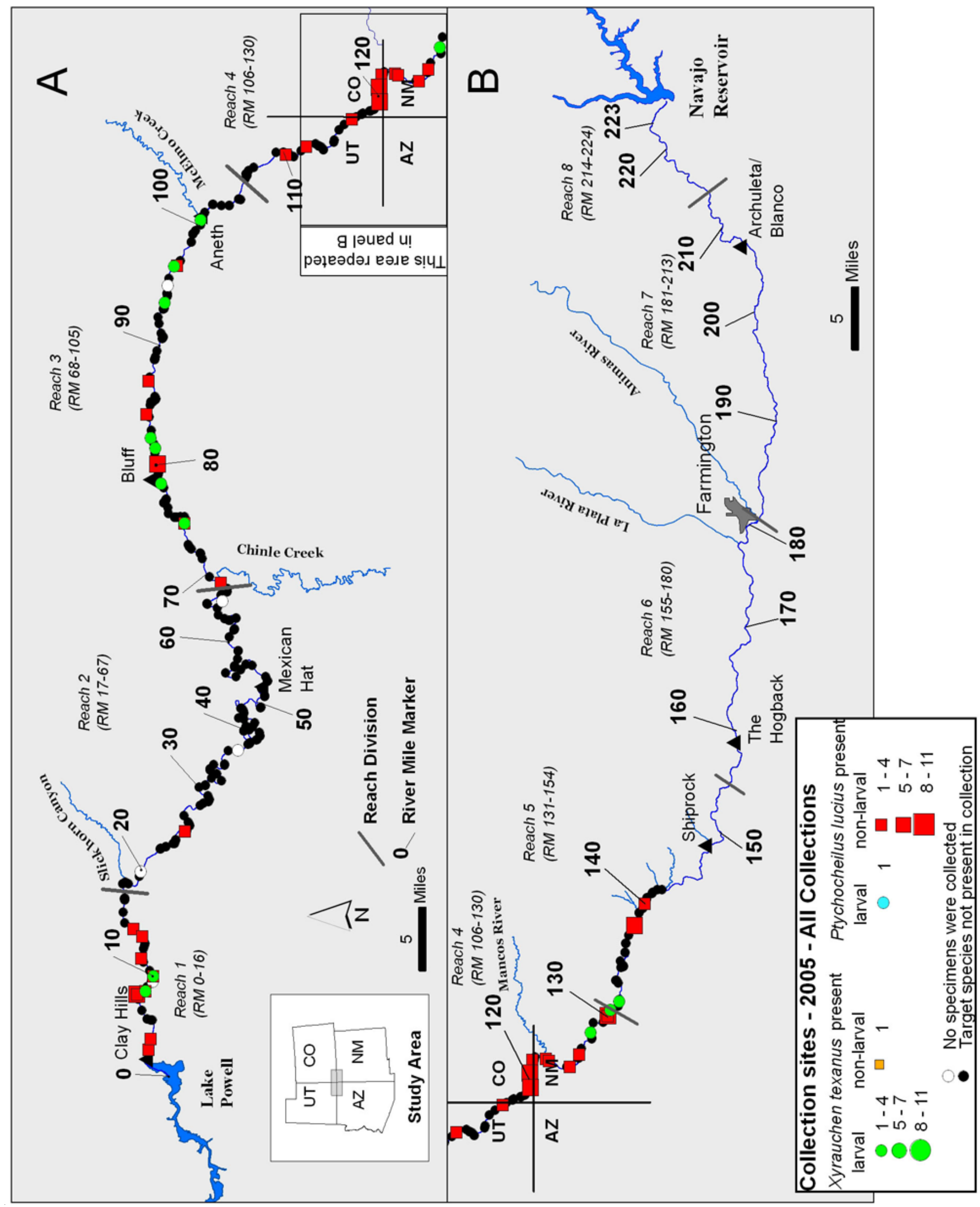


Figure 22. Map of localities sampled during the 2005 San Juan River larval ichthyofaunal survey (19 April - 14 September 2005, Cudei to Clay Hills Crossing; RM 141.5-2.9).

this period ranged from 2,840 and 12,100 cfs (average CFS, 6,455). The average temperature during this window of hatching was 15.6 °C.

For several reasons, a further effort to back-calculated time of fertilization (i.e. spawning) was not made. A review of the literature revealed several good, but often conflicting studies. For example, Marsh (1985) reported total egg mortality at 10° C and reduced hatching at 15° C while Bozek et al. (1990) reported little or no effect on hatching success at 15° C, with nearly 60% of the larvae hatching at 10° C and total egg mortality at 8° C. Additionally, experimental design (naturally ripened versus hormonally induced maturation, acclimation temperature gradients, and the use of formaldehyde to control fungus) varies greatly among researchers. Finally, temperature variation in the San Juan River make it very difficult to accurately predict temperature-dependent times of incubation.

2002- 2005 mean CPUE

In addition to providing mean CPUE data between trips and reaches, further effort was made to provide a comparative analysis of mean CPUE by species among years. In order to maintain consistency with trip and reach analyses, the three native catostomid species, the two native cyprinid species, and the two most abundant non-native cyprinid species were analyzed. Only data between 2002 and 2005 were plotted. Prior to 2002, larval seining was only conducted between the months of April and June. Sampling protocols changed in 2002 to include six months (April-September) of collecting and use of a larval seine as the sole means of collecting. It should also be mentioned that the data used to generate mean CPUE graphs include juvenile, adult and larvae collected during larval surveys. However, with the exception of Colorado pikeminnow, over 90% of all specimens collected regardless of year or species were larval specimens. In some cases, over 99% of a particular species (usually catostomids) were represented by larval specimens. In short, it is the collection of larval and young-of-year fish that are driving the cross-year mean CPUE data. While both ANOVA and Kruskal-Wallis were used to analyze data, data transforms enabled use of parametric analysis in all cases. Additionally, the significance values between parametric and nonparametric techniques were nearly identical and so only the parametric analysis will be presented.

While there was a difference among annual red shiner CPUE data during the study period ($F=3.22$, $p<0.05$) [Figure 24], the only pair-wise difference ($p<0.05$) was between 2003 and 2005. There were significant differences ($p<0.05$) between annual catch rates of fathead minnow for two comparisons (2002 vs. 2003 and 2004 vs. 2005) and the overall ANOVA was highly significant ($F=11.68$, $p<0.001$) [Figure 25]. No Colorado pikeminnow were collected in 2002 so that data set was removed when running pair-wise comparisons between years. There was no significant difference between yearly mean CPUE ($F= 0.662$, $p=0.5160$) for Colorado pikeminnow [Figure 26]. Nearly all Colorado pikeminnow collected were presumably stocked individuals with the exception of two larval Colorado pikeminnow collected in 2004. According to a pair-wise comparison of mean CPUE for speckled dace, 2003 was the only year which was significantly different ($p<0.05$) from the other years; ANOVA detected an overall difference among years ($F=3.99$, $p<0.01$) [Figure 27]. Larval flannelmouth sucker and bluehead sucker exhibited few significant changes between years in pair-wise comparisons. Flannelmouth sucker showed significant pair-wise differences ($p<0.05$) in 2002 compared to the other years as mean CPUE was higher in that year (Figures 28). Bluehead sucker showed a significant difference ($p<0.05$) in 2003 when mean CPUE was lower compared to the other three years; results from ANOVA were highly significant ($F=6.77$, $p<0.001$) [Figure 29]. However, larval razorback sucker seem to show the most dramatic change in mean CPUE between years within the catostomid family with

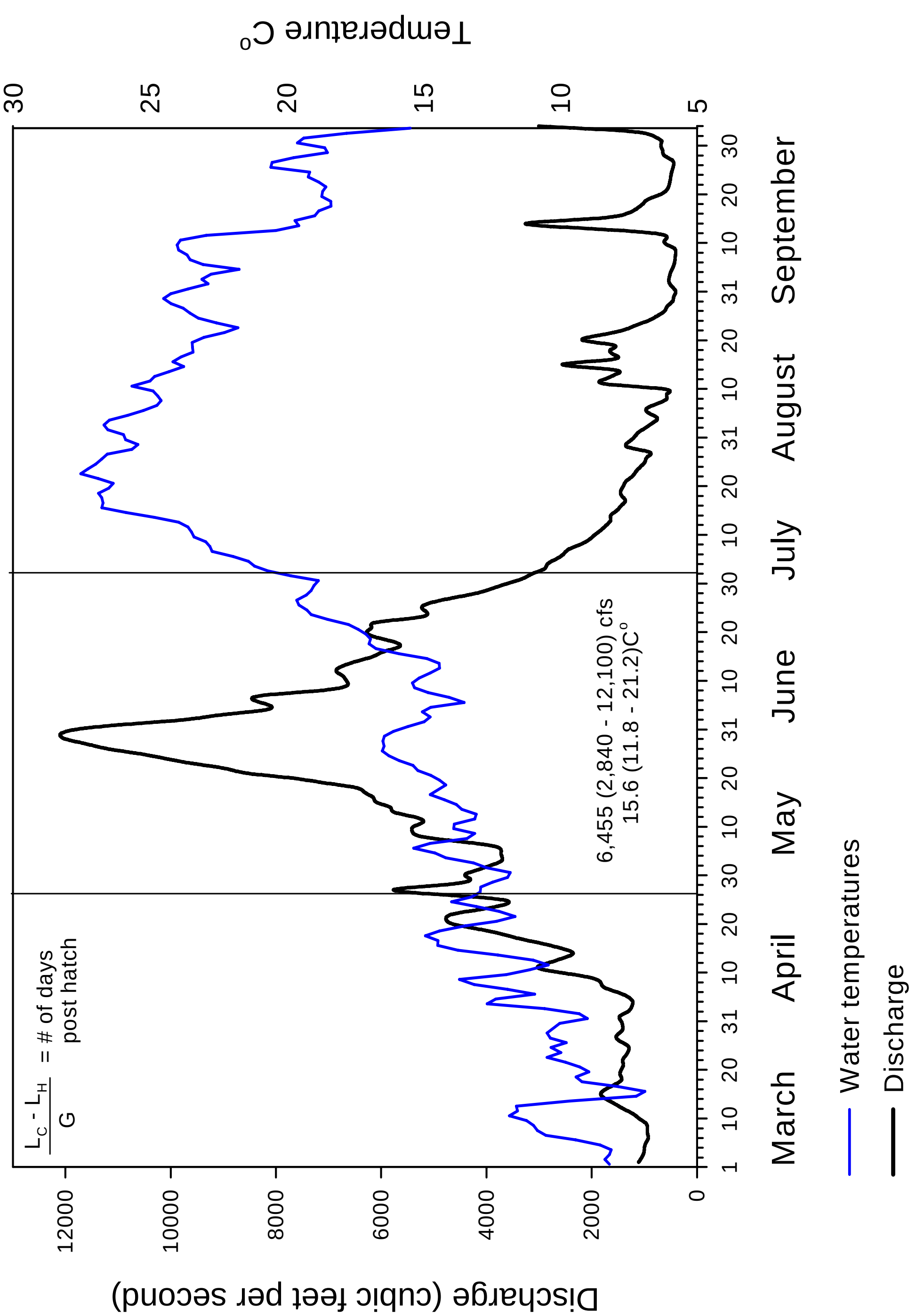


Figure 23. Back-calculated hatching dates for razorback sucker collected in 2005. Hatching dates are within the two vertical lines.

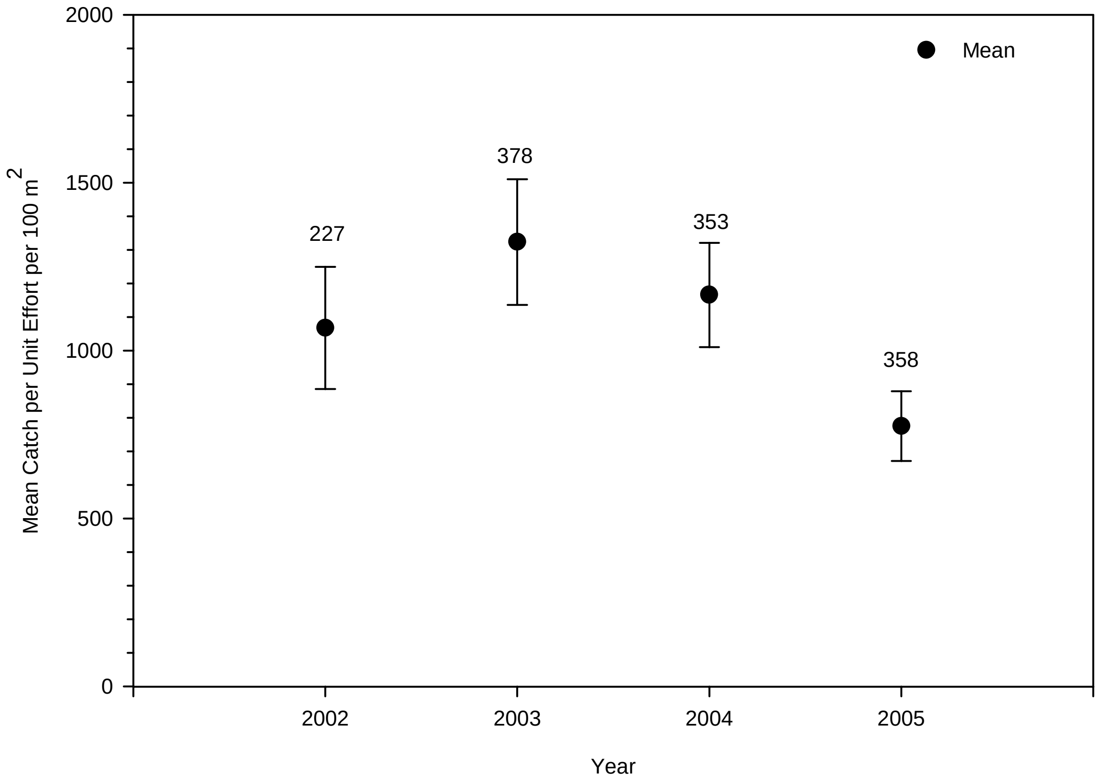


Figure 24. Mean CPUE / 100 m^2 (±1 SE) for red shiner by year (2002 - 2005). Sample size reported above SE bars.

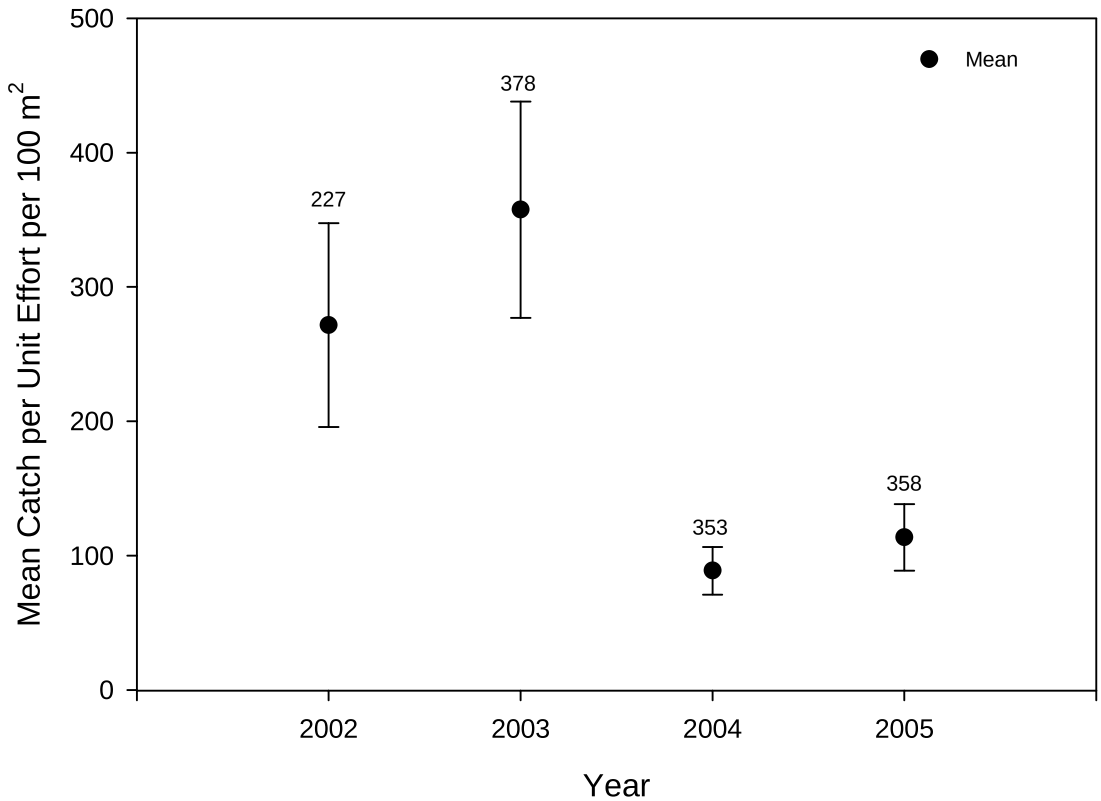


Figure 25. Mean CPUE / 100 m^2 (+1 SE) for fathead minnow by year (2002 - 2005). Sample size reported above SE bars.

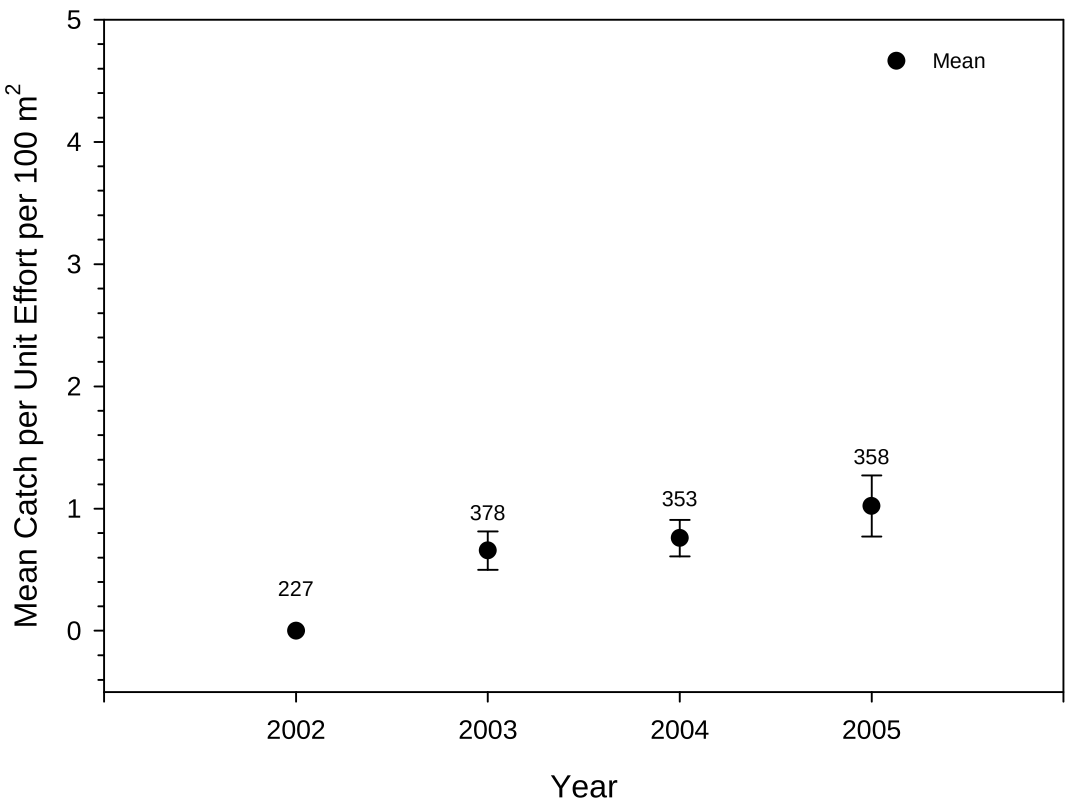


Figure 26. Mean CPUE / 100 m^2 (±1 SE) for Colorado pikeminnow by year (2002 - 2005). Sample size reported above SE bars.

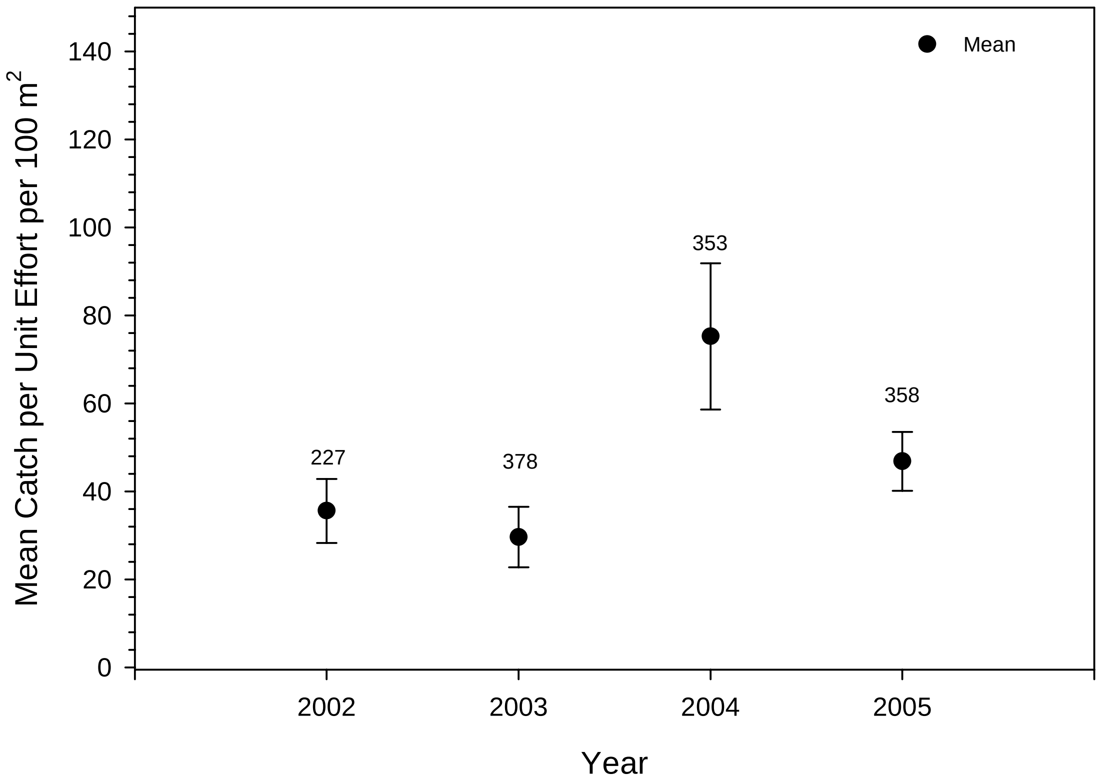


Figure 27. Mean CPUE / 100 m^2 (±1 SE) for speckled dace by year (2002 - 2005). Sample size reported above SE bars.

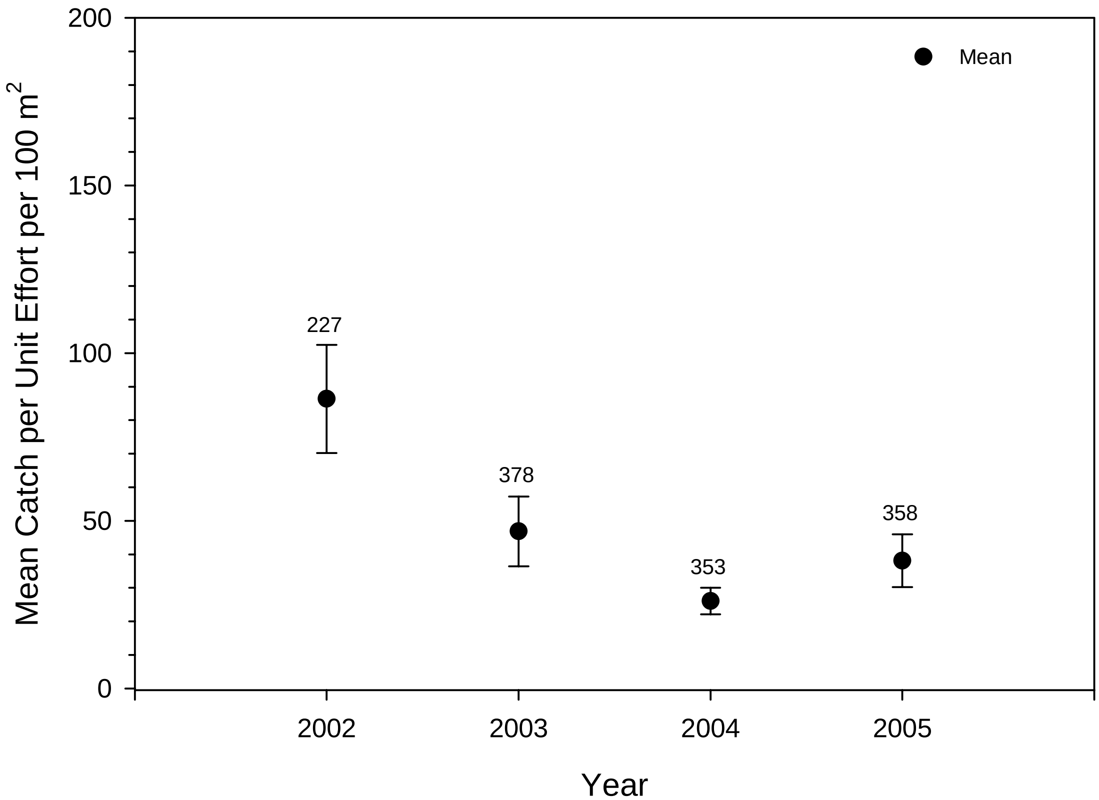


Figure 28. Mean CPUE / 100 m^2 (±1 SE) for flannelmouth sucker by year (2002 - 2005). Sample size reported above SE bars.

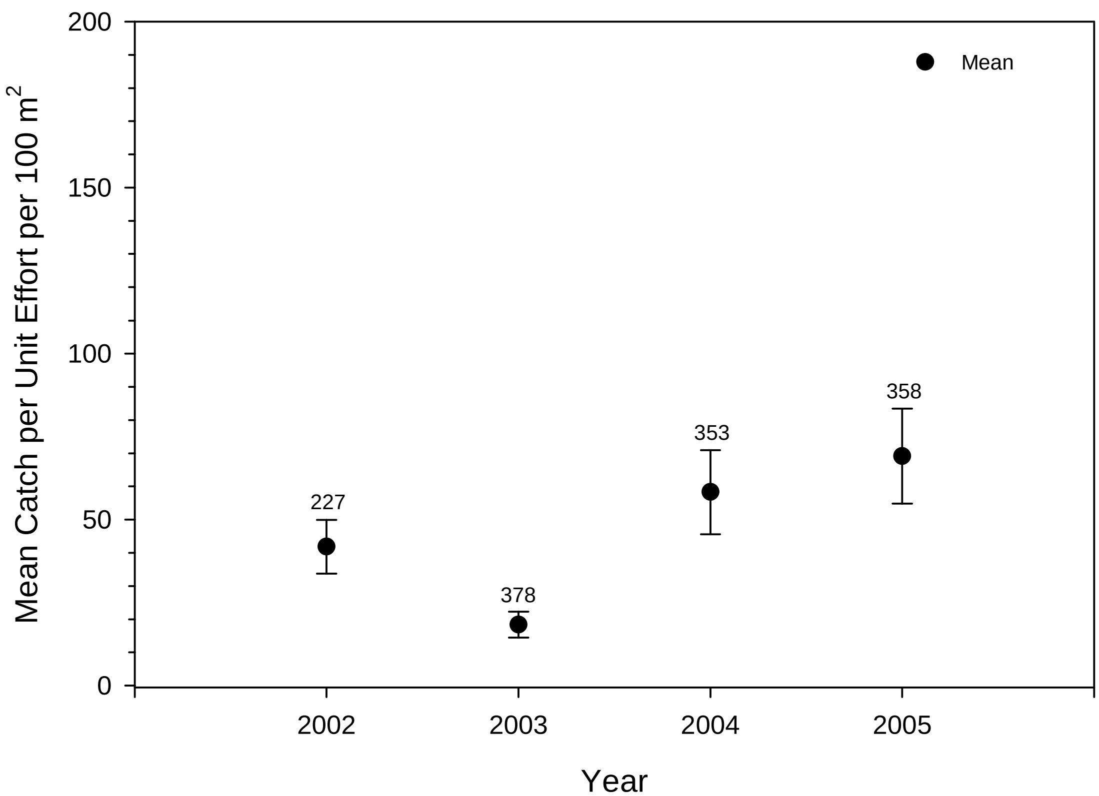


Figure 29. Mean CPUE / 100 m^2 ($\pm$1 SE) for bluehead sucker by year (2002 - 2005). Sample size reported above SE bars.

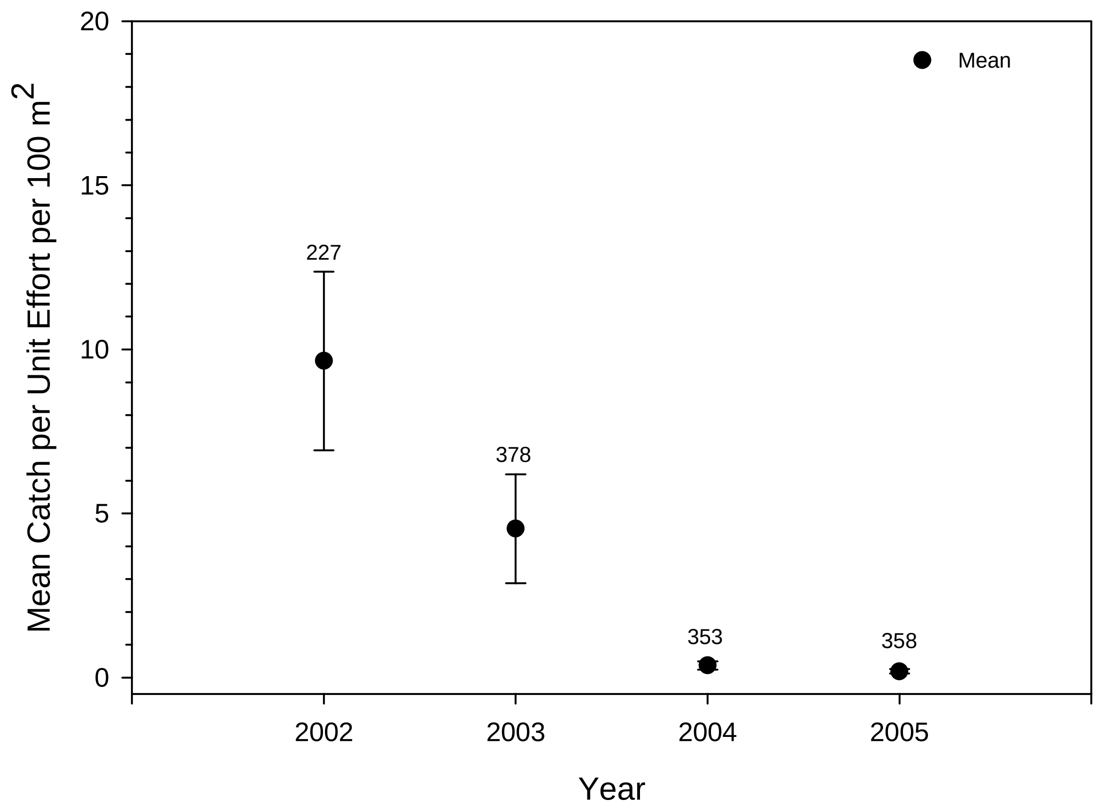


Figure 30. Mean CPUE / 100 m^2 ($\pm$1 SE) for razorback sucker by year (2002 - 2005). Sample size reported above SE bars.

significant difference between all years except 2004 vs. 2005; results from ANOVA yielded the highest F-value of any species-specific comparison (*F=25.18, p<0.001)* [Figure 30].

There are substantial mortality rates within early life stages of fishes caused from both abiotic and biotic factors (Jennings and Philipp 1994, Harvey 1991). For the years of 2002 - 2005 abiotic conditions between years and within years were not accounted for within these mean CPUE graphs. It is difficult to read treads from these graphs because of these reasons and they should not be viewed as a direct correlation to adult populations.

Acknowledgments

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Literature Cited

Altenbach, C. S., R. K. Dudley, and S. P. Platania. 2000. A new device for collecting drifting semibuoyant fish eggs. *Transactions of the American Fisheries Society* 129(1): 296-300.

Behnke, R. J.. and D. E. Benson. 1983 Endangered and threatened fishes of the upper Colorado River basin. Colorado State University, Cooperative Extension Service. Bulletin 503A, Fort Collins.

Bestgen, K. R., R. T. Muth, and M. A. Trammell. 1998. Downstream transport of Colorado squawfish larvae in the Green River drainage: temporal and spatial variation in abundance and relationships with juvenile recruitment. Unpublished report to the Colorado River Recovery Implementation Program: Project Number 32. 63 pp.

Bestgen, K. R., G. B. Haines, R. Brunson, T. Chart, M. Trammell, R. T. Muth, G Birchell, K. Chrisopherson, and J. M. Bundy. 2002. Status of wild razorback sucker in the Green River Basin, Utah and Colorado, determined from basinwide monitoring and other sampling programs. Unpublished report to the Colorado River Recovery Implementation Program: Project Number 126. 63 pp.

Bliesner, R. and V. Lamarra. 1999. Chapter 2. Geomorphology, hydrology, and habitat of the San Juan River. Pages 2-1 to 2-30 *In*: P. B. Holden, editor. Flow recommendations for the San Juan River. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, New Mexico.

Bozek, M. A., L. J. Paulson, and G. R. Wilde. 1990. Effects of ambient Lake Mohave temperatures on development, oxygen consumption, and hatching success of the razorback sucker. *Environmental Biology of Fishes* 27: 255-263

Brandenburg, W. H., M. A. Farrington, and S. J. Gottlieb. 2004. Colorado pikeminnow and razorback sucker larval fish survey in the San Juan River during 2004. Unpublished report San Juan River Basin Recovery Implementation Program. 100 pp.

Freeman and Tukey. 1950 Transformations related to the angular and squareroot. Ann. Math. Statist. 21: 607 - 611.

Hamman, R. L. 1981. Spawning and culture of Colorado squawfish in raceways. *Progressive Fish Culturist* 43: 173-177.

Hamman, R. L. 1986. Induced spawning of hatchery-reared Colorado squawfish. *Progressive Fish Culturist* 48: 72-74.

Harvey, B. C. 1991. Interaction of abiotic and biotic factors influences larval fish survival in an Oklahoma stream. *Canadian Journal of Fisheries and Aquatic Science*. 48: 1476-1480.

Haynes, C. M., T. A. Lytle, E. J. Wick, and R. T. Muth. 1984. Larval Colorado squawfish (*Ptychocheilus lucius*) in the Upper Colorado River Basin, Colorado. *The Southwestern Naturalist* 29:21-33.

Holden, P. B., and E. J. Wick. 1982. Life history and prospects for recovery of Colorado squawfish. pp. 98-108. *In*: W. H. Miller, H. M. Tyus, and C. A. Carlson, (eds.) Fishes of the upper Colorado River system: Present and future, Bethesda, MD: Western Division, American Fisheries Society.

Jennings, M. J., and D. P. Philipp. 1994. Biotic and abiotic factors affecting survival of early life history intervals of a stream-dwelling sunfish. *Environmental Biology of Fishes*. 39: 153-159.

Jordan, D. S. 1891. Reports of explorations in Colorado and Utah during the summer of 1889, with an account of the fish found in each of the river basins examined. Bulletin of the U.S. Fish Commission 89:1-40.

Marsh, P. C. 1985. Effects of incubation temperature on survival of embryos of native Colorado River fishes. *Southwestern Naturalist*. 30: 129-140.

Meyer, C. W., and M. A. Moretti. 1988. Fisheries survey of the San Juan River, Utah, 1987. Final Report for Utah Division of Wildlife Resource-U.S. Bureau of Reclamation Cooperative Agreement 7FC-40-05050. Salt Lake City, UT.

Minckley, C. O., and S. W. Carothers. 1979. Recent collections of the Colorado squawfish and razorback sucker from the San Juan and Colorado rivers in New Mexico and Arizona. *The Southwestern Naturalist* 24:686-687.

Minckley, W. L., and J. E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species". *Science* 159:1424-1433.

Minckley, W. L. 1973. Fishes of Arizona. Phoenix: Arizona Game and Fish Department.

Moyle, P. B. 1976. Inland fishes of California. Berkeley: University of California Press.

Muth, R. T., G. B. Haines, S. M. Meismer, E. J. Wick, T. E. Chart, D. E. Snyder, and J. M. Bundy. 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado, 1992 - 1996. Final Report of Colorado State University Larval Fish Laboratory to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Nelson, J. S. 2006 Fishes of the World. Fourth Edition. John Wiley and Sons, Inc., Hoboken, New Jersey.

Nesler, T. P., R. T. Muth, and A. F. Wasowicz. 1988. Evidence for baseline flow spikes as spawning cues for Colorado squawfish in the Yampa River, Colorado. *American Fisheries Society Symposium* 5: 68-79.

Platania, S. P., and K. R. Bestgen. 1988. Survey of the fishes of the lower San Juan River, New Mexico, Final Report for U.S. Bureau of Reclamation Contract 516.6-74-23. New Mexico Game and Fish Department, Santa Fe, NM.

Platania, S. P., K. R. Bestgen, and M. A. Moretti, D. L. Propst, and J. E. Brooks. 1991. Status of Colorado squawfish and razorback sucker in the San Juan River, Colorado, New Mexico, and Utah. *The Southwestern Naturalist* 36:147-150.

Platania, S. P., R. K. Dudley, and S. L. Maruca. 2000. Drift of fishes in the San Juan River 1991-1997, Final Report for San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, New Mexico.

Roberts, B. and M. Moretti. 1989. Fisheries survey of the San Juan River, Utah 1998. Report to the Utah Division of Wildlife Resources, (Cooperative Agreement 7-FC-40-05050), Salt Lake City, Utah. 40 pp.

Ryden, D. W., and F. K. Pfeifer. 1994. An experimental stocking plan for razorback sucker in the San Juan River. U. S. Fish and Wildlife Service, Grand Junction, CO. 26 pp.

Ryden, D. W. and F. K. Pfeifer. 1996 . Adult fish community monitoring on the San Juan River: 1995 Annual Progress Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 46 pp.

Snyder, D. E. 1981. Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River system in Colorado. U.S. Bureau of Land Management, Biological Sciences Series 3, Denver, CO. 81 pp.

Tyus, H. M. 1990. Potamodromy and reproduction of Colorado squawfish in the Green River basin, Colorado and Utah. *Transactions of the American Fisheries Society* 119:1035-1047.

Tyus, H. M. 1991. Ecology and management of Colorado squawfish. pp. 379-402. *In*: W. L. Minckley and J. E. Deacon, (eds.) Battle Against Extinction: Native Fish Management in the American Southwest, University of Arizona Press, Tucson, AZ.

U.S. Bureau of Reclamation. 1987. San Juan River rare and endangered fish study: river miles 16.2- (-) 2.0; 1987 field season. U.S. Bureau of Reclamation, Durango Projects Office, Durango, Colorado. 24 pp.

U.S. Department of the Interior. 1974. Taking, possession, transportation, sale, purchase, barter, exportation, and importation of wildlife. Federal Register 39[3] Part III:1158-1185.

Vanicek, C. D., and R. H. Kramer. 1969. Life history of the Colorado squawfish, *Ptychocheilus lucius*, and the Colorado chub, *Gila robusta*, in the Green River in Dinosaur National Monument, 1964-1966. *Transactions of the American Fisheries Society* 98:193-208.

VTN Consolidated, Inc., and Museum of Northern Arizona. 1978. Fish, wildlife, and habitat assessment; San Juan River, New Mexico and Utah. Gallup-Navajo Indian water supply project.VTN Consolidated, Inc., Irvine, California. 241 pp.

Appendix I. Summary of larval razorback sucker collected in the San Juan River.

Field Number	MSB Catalog Number	Number of Specimens	Total Length	Larval Stage	Date Collected	River Mile	Sampling Method
1998	**TOTAL**	**2**					
WHB98-143	42207	1	12.7	mesolarva	21 May 1998	88.8	larval fish seine
WHB98-147	42218	1	12.1	mesolarva	22 May 1998	80.2	larval fish seine
1999	**TOTAL**	**7**					
WHB99-075	44201	1	11.2	mesolarva/yolk	04 May 1999	82.5	larval fish seine
WHB99-105	44254	1	14.1	mesolarva	12-13 May 1999	96.2	light-trap
WHB99-106	44257	1	10.2	mesolarva	12-13 May 1999	96.2	light-trap
WHB99-112	44269	1	11.2	protolarva/yolk	13 May 1999	82.5	larval fish seine
WHB99-167	44421	1	17.9	mesolarva	14 June 1999	16.5	larval fish seine
WHB99-169	44428	1	20.7	metalarva	14 June 1999	13.1	larval fish seine
WHB99-170	44435	1	13.8	mesolarva	14 June 1999	11.5	larval fish seine
2000	**TOTAL**	**129**					
WHB00-104	47770	1	10.4	mesolarva	09 May 2000	104.6	larval fish seine
WHB00-108	47779	2	10.6 - 11.3	mesolarvae	10 May 2000	99.7	larval fish seine
WHB00-109	47784	1	10.9	mesolarva	10 May 2000	99.4	larval fish seine
WHB00-115	47805	5	10.4 - 11.3	mesolarvae/yolk	10 May 2000	89.2	larval fish seine
WHB00-116	47808	1	11.1	mesolarva	10 May 2000	88.8	larval fish seine
WHB00-118	47814	3	10.5 - 10.8	mesolarvae	11 May 2000	85.6	larval fish seine
WHB00-119	47819	5	10.6 - 11.8	mesolarvae	11 May 2000	84.1	larval fish seine
WHB00-121	47824	1	10.6	mesolarva	11 May 2000	82.3	larval fish seine
WHB00-122	47829	6	10.4 - 13.2	mesolarvae	11 May 2000	79.4	larval fish seine
WHB00-130	47855	1	15.2	mesolarva	23 May 2000	69.5	larval fish seine
WHB00-133	47864	1	10.0	mesolarva	23 May 2000	59.8	larval fish seine
WHB00-139	47878	1	14.9	mesolarva	24 May 2000	40.5	larval fish seine
WHB00-143	47882	2	9.3 - 18.6	mesolarvae	25 May 2000	23.3	larval fish seine
WHB00-149	47896	1	16.1	mesolarva	26 May 2000	15.4	larval fish seine
WHB00-150	47902	1	17.6	mesolarva	26 May 2000	14.0	larval fish seine
WHB00-152	47910	6	15.3 - 17.9	mesolarvae	26 May 2000	13.0	larval fish seine
WHB00-154	47918	1	12.2	mesolarva	26 May 2000	10.0	larval fish seine
WHB00-155	47924	2	13.6 - 16.4	mesolarvae	26 May 2000	8.8	larval fish seine
WHB00-156	47930	86	9.4 - 18.1	meso - metalarvae	26 May 2000	8.1	larval fish seine
WHB00-158	47937	1	16.4	mesolarva	01 June 2000	124.8	larval fish seine
WHB00-168	47978	1	12.0	mesolarva	02 June 2000	104.5	larval fish seine
2001	**TOTAL**	**50**					
WHB01-123	48806	2	15.5 - 16.0	mesolarvae	16 May 2001	62.1	larval fish seine
WHB01-133	48832	1	13.8	mesolarva	17 May 2001	21.1	light-trap
WHB01-134	48834	1	13.5	mesolarva	17 May 2001	21.0	light-trap
WHB01-137	48843	1	11.3	mesolarva	18 May 2001	16.5	larval fish seine
WHB01-138	48846	1	15.5	mesolarva	18 May 2001	16.4	larval fish seine
WHB01-145	48873	11	10.1 - 14.8	mesolarvae	18 May 2001	9.5	larval fish seine
WHB01-146	48879	4	11.7 - 14.8	mesolarvae	18 May 2001	8.5	larval fish seine
WHB01-157	48918	1	14.3	mesolarva	30 May 2001	124.8	larval fish seine
WHB01-172	48978	1	17.5	metalarva	31 May 2001	89.2	larval fish seine
WHB01-173	48984	1	13.0	mesolarva	31 May 2001	88.8	larval fish seine
WHB01-175	48992	1	19.4	metalarva	1 June 2001	80.2	larval fish seine
WHB01-200	49078	4	22.0 - 26.3	metalarvae	14 June 2001	13.0	larval fish seine
WHB01-201	49082	1	17.2	metalarva	14 June 2001	11.9	larval fish seine
WHB01-203	49096	4	16.0 - 18.5	meso - metalarvae	14 June 2001	10.0	larval fish seine
WHB01-205	49108	16	16.1 - 28.8	metalarvae/juvenile	14 June 2001	8.1	larval fish seine
TOTAL (1998-2001)		**188**					

Appendix I. Summary of larval razorback sucker collected in the San Juan River (continued).

Field Number	MSB Catalog Number	Number of Specimens	Total Length	Larval Stage	Date Collected	River Mile	Sampling Method
2002 TOTAL		**812**					
WHB02-028		2	10.2- 11.0	protolarvae	29 April 2002	76.1	larval fish seine
WHB02-029		1	10.8	protolarva	29 April 2002	75.5	larval fish seine
WHB02-032		1	10.8	protolarva	29 April 2002	68.3	larval fish seine
WHB02-033		18	10.2- 11.5	proto - mesolarvae/yolk	29 April 2002	66.8	larval fish seine
WHB02-037		2	11.0- 11.1	mesolarvae	30 April 2002	58.2	larval fish seine
WHB02-039		1	10.5	mesolarva	30 April 2002	54.5	larval fish seine
WHB02-040		6	10.5- 12.8	proto - mesolarvae	30 April 2002	52.3	larval fish seine
WHB02-043		27	9.7- 12.3	proto - mesolarvae/yolk	1 May 2002	43.0	larval fish seine
WHB02-046		1	12.9	mesolarva	1 May 2002	25.0	larval fish seine
WHB02-047		12	10.9- 11.9	proto - mesolarvae	1 May 2002	23.5	larval fish seine
WHB02-048		91	10.0- 13.8	proto - mesolarvae/yolk	1 May 2002	21.2	larval fish seine
WHB02-051		1	10.7	mesolarva	2 May 2002	12.9	larval fish seine
WHB02-052		18	10.7- 13.3	mesolarvae	2 May 2002	11.6	larval fish seine
WHB02-053		2	11.3- 13.2	mesolarvae	2 May 2002	9.2	larval fish seine
WHB02-054		89	10.1- 13.9	mesolarvae	2 May 2002	8.7	larval fish seine
WHB02-055		24	10.1- 14.1	mesolarvae	2 May 2002	5.2	larval fish seine
WHB02-064		2	12.1- 13.7	mesolarvae	16 May 2002	129.1	larval fish seine
WHB02-066		3	12.4- 13.9	mesolarvae	16 May 2002	124.8	larval fish seine
WHB02-067		7	12.5- 15.5	mesolarvae	16 May 2002	122.6	larval fish seine
WHB02-070		5	11.0- 12.6	mesolarvae	16 May 2002	116.2	light-trap
WHB02-073		3	13.0- 13.6	mesolarvae	17 May 2002	110.1	larval fish seine
WHB02-078		5	13.5- 14.6	mesolarvae	17 May 2002	97.1	light-trap
WHB02-079		39	12.8- 18.3	meso - metalarvae	18 May 2002	95.8	larval fish seine
WHB02-080		1	18.7	metalarva	18 May 2002	93.7	larval fish seine
WHB02-081		36	12.6- 19.8	meso - metalarvae	18 May 2002	93.0	larval fish seine
WHB02-082		1	15.3	mesolarva	18 May 2002	88.8	larval fish seine
WHB02-083		2	13.4- 17.6	meso - metalarvae	18 May 2002	87.8	larval fish seine
WHB02-084		1	11.0	mesolarva	18 May 2002	85.8	larval fish seine
WHB02-085		3	13.4- 18.8	meso - metalarvae	18 May 2002	82.8	larval fish seine
WHB02-086		21	11.5- 18.8	meso - metalarvae	18 May 2002	78.9	light-trap
WHB02-087		4	11.9- 21.5	meso - metalarvae	19 May 2002	77.2	larval fish seine
WHB02-088		14	15.5- 26.4	meso - metalarvae	29 May 2002	75.7	larval fish seine
WHB02-090		4	17.8- 30.7	metalarvae - juvenile	29 May 2002	71.9	larval fish seine
WHB02-091		51	14.9- 26.8	meso - metalarvae	29 May 2002	71.3	larval fish seine
WHB02-093		19	16.8- 29.7	mesolarvae - juvenile	29 May 2002	60.6	larval fish seine
WHB02-094		1	20.3	metalarva	30 May 2002	58.2	larval fish seine
WHB02-096		71	12.4- 26.6	meso - metalarvae	30 May 2002	52.5	larval fish seine
WHB02-097		4	14.8- 24.3	meso - metalarvae	30 May 2002	50.7	larval fish seine
WHB02-098		1	20.6	metalarva	30 May 2002	48.0	larval fish seine
WHB02-100		11	10.9- 26.5	meso - metalarvae	30 May 2002	41.7	larval fish seine
WHB02-101		2	20.1- 26.7	metalarvae	31 May 2002	38.9	larval fish seine
WHB02-104		2	18.6- 21.0	metalarvae	31 May 2002	29.0	larval fish seine
WHB02-105		7	17.4- 29.7	meso - metalarvae	31 May 2002	25.2	larval fish seine
WHB02-106		50	14.5- 33.4	mesolarvae - juvenile	31 May 2002	23.4	larval fish seine
WHB02-107		1	33.3	juvenile	31 May 2002	17.6	larval fish seine
WHB02-109		1	14.6	mesolarva	1 June 2002	11.5	larval fish seine
WHB02-110		3	20.8- 25.3	metalarvae	1 June 2002	9.6	larval fish seine
WHB02-111		13	12.6- 35.4	mesolarvae - juvenile	1 June 2002	7.3	larval fish seine
WHB02-112		4	14.7- 24.3	meso - metalarvae	1 June 2002	2.8	larval fish seine
WHB02-118		1	35.8	juvenile	11 June 2002	134.5	larval fish seine
WHB02-121		1	33.1	juvenile	11 June 2002	128.1	larval fish seine
WHB02-126		2	29.4- 35.3	metalarvae - juvenile	12 June 2002	116.2	larval fish seine
WHB02-128		1	30.9	juvenile	12 June 2002	109.8	larval fish seine
WHB02-130		2	37.2- 49.0	juvenile	12 June 2002	103.2	larval fish seine
WHB02-133		3	32.4- 43.4	juvenile	13 June 2002	94.0	larval fish seine
WHB02-134		23	29.7- 55.2	metalarvae - juvenile	13 June 2002	93.0	larval fish seine
WHB02-135		48	20.4- 50.8	metalarvae - juvenile	13 June 2002	91.6	larval fish seine
WHB02-137		2	37.0- 38.1	juvenile	13 June 2002	84.6	larval fish seine

Appendix I. Summary of larval razorback sucker collected in the San Juan River (continued).

Field Number	MSB Catalog Number	Number of Specimens	Total Length	Larval Stage	Date Collected	River Mile	Sampling Method
2002 (cont.)							
WHB02-138		14	31.7 - 40.3	juvenile	13 June 2002	82.6	larval fish seine
WHB02-139		4	33.9 - 52.0	juvenile	13 June 2002	79.7	larval fish seine
WHB02-140		8	18.1 - 46.7	mesolarvae - juvenile	13 June 2002	77.1	larval fish seine
WHB02-141		1	53.1	juvenile	27 June 2002	75.4	larval fish seine
WHB02-142		2	35.6 - 49.3	juvenile	27 June 2002	74.9	larval fish seine
WHB02-146		1	51.1	juvenile	28 June 2002	68.7	larval fish seine
WHB02-148		2	59.5 - 62.4	juvenile	28 June 2002	62.3	larval fish seine
WHB02-149		8	41.8 - 54.4	juvenile	28 June 2002	61.3	larval fish seine
WHB02-150		1	39.8	juvenile	28 June 2002	60.2	larval fish seine
2003	**TOTAL**	**472**					
WHB03-096		6	12.6 - 15.8	mesolarvae	16 May 2003	97	larval fish seine
WHB03-099		33	9.5 - 14.6	proto - mesolarvae	17 May 2003	94.2	larval fish seine
WHB03-104		7	9.8 - 12.4	proto - mesolarvae	17 May 2003	85.6	larval fish seine
WHB03-105		19	10.1 - 14.5	proto - mesolarvae	17 May 2003	84.2	larval fish seine
WHB03-107		8	10.0 - 12.0	proto - mesolarvae	17 May 2003	80.2	light-trap
WHB03-108		7	9.9 - 14.1	proto - mesolarvae	18 May 2003	79.3	larval fish seine
WHB03-109		6	10.7 - 14.1	mesolarvae	18 May 2003	77.1	larval fish seine
MAF03-007		11	9.1 - 14.3	mesolarvae	18 May 2003	73.8	larval fish seine
MAF03-008		2	12.7 - 12.8	mesolarvae	18 May 2003	72.5	larval fish seine
MAF03-014		1	12.1	mesolarva	19 May 2003	57.9	larval fish seine
MAF03-016		31	10.2 - 13.9	mesolarvae	19 May 2003	50.9	larval fish seine
MAF03-017		3	11.2 - 11.8	mesolarvae	19 May 2003	48.3	larval fish seine
MAF03-021		1	12	mesolarva	20 May 2003	40.4	larval fish seine
MAF03-026		1	11.7	mesolarva	20 May 2003	24.5	larval fish seine
MAF03-027		5	10.2 - 13.2	mesolarvae	21 May 2003	23.8	light-trap
MAF03-029		4	10.1 - 13.6	mesolarvae	21 May 2003	21	larval fish seine
MAF03-031		34	10.6 - 19.2	meso - metalarva	21 May 2003	17.7	larval fish seine
MAF03-033		5	9.5 - 18.0	mesolarvae	22 May 2003	13.1	larval fish seine
MAF03-034		19	13 - 17.8	mesolarvae	22 May 2003	11.4	larval fish seine
MAF03-035		11	10.3 - 19.0	proto - mesolarvae	22 May 2003	9.6	larval fish seine
MAF03-036		99	10.2 - 22.1	meso - metalarvae	22 May 2003	8.1	larval fish seine
MAF03-037		50	10 - 21.1	meso - metalarvae	22 May 2003	6.9	larval fish seine
WHB03-141		16	18.3 - 23.7	meso - metalarvae	13 June 2003	90.1	larval fish seine
WHB03-142		1	33.1	juvenile	13 June 2003	88.1	larval fish seine
WHB03-145		81	15.4 - 29.4	mesolarvae - juvenile	13 June 2003	84.1	larval fish seine
WHB03-151		3	22.8 - 35.3	metalarva - juvenile	14 June 2003	75.1	larval fish seine
WHB03-168		1	26.0	juvenile	16 June 2003	33.5	larval fish seine
WHB03-169		1	26.7	juvenile	16 June 2003	28.8	larval fish seine
WHB03-178		3	26.9 - 36.1	juvenile	17 June 2003	15.4	larval fish seine
WHB03-180		2	30.2 - 37.3	juvenile	17 June 2003	12.3	larval fish seine
WHB03-183		1	22.4	mesolarvae	18 June 2003	3.3	larval fish seine
2004	**TOTAL**	**42**					
WHB04-092	52479	1	10.5	mesolarvae	15 May 2004	77.1	larval fish seine
WHB04-103	52504	7	10.2- 13.5	mesolarvae	16 May 2004	57.9	larval fish seine
WHB04-108	52514	1	10.6	flexion mesolarvae	17 May 2004	43.4	larval fish seine
WHB04-112	52527	1	9.2	protolarvae	17 May 2004	33.6	larval fish seine
WHB04-114	52533	2	10.1- 10.5	proto - mesolarvae	18 May 2004	26.4	larval fish seine
WHB04-120	52546	1	10.3	preflexion mesolarvae	18 May 2004	14.7	larval fish seine
WHB04-130	52579	1	10	preflexion mesolarvae	9 Jun 2004	130.1	larval fish seine
WHB04-132	52592	1	9.1	protolarvae	9 Jun 2004	126	larval fish seine
WHB)4-133	52597	1	9.1	protolarvae	9 Jun 2004	124.8	larval fish seine
WHB04-134	52604	1	9.9	flexion mesolarvae	9 Jun 2004	122.5	larval fish seine

Appendix I. Summary of larval razorback sucker collected in the San Juan River (continued).

Field Number	MSB Catalog Number	Number of Specimens	Total Length	Larval Stage	Date Collected	River Mile	Sampling Method
WHB04-138	52626	3	10.3 -11.5	mesolarvae	10 Jun 2004	110.3	larval fish seine
WHB04-139	52648	1	9	protolarva	10 Jun 2004	106.7	larval fish seine
WHB04-148	52684	11	9.4 -16.3	meso - metalarvae	11 Jun 2004	89.1	larval fish seine
WHB04-159	52736	2	8.7- 9.1	protolarvae	12 Jun 2004	69.9	larval fish seine
WHB04-165	52756	1	9.8	preflexion mesolarva	13 Jun 2004	52.9	larval fish seine
WHB04-182	52798	6	11.3- 25.9	meso - metalarvae	15 Jun 2004	8.1	larval fish seine
2005	**TOTAL**	**19**					
WHB05-090		1	10.8	protolarvae	14 May 2005	78.7	larval fish seine
WHB05-116		2	11.5- 11.9	proto - mesolarvae	17 May 2005	10.0	larval fish seine
WHB05-118		1	11.0	protolarva	17 May 2005	8.7	larval fish seine
WHB05-138		1	20.4	metalarva	12 Jun 2005	100.5	larval fish seine
WHB05-140		4	14.1- 18.6	meso - metalarvae	12 Jun 2005	96.4	larval fish seine
WHB05-146		1	12.3	mesolarva	12 Jun 2005	82.4	larval fish seine
WHB05-147		1	13.2	mesolarva	12 Jun 2005	81.6	larval fish seine
WHB05-153		2	14.4- 22.0	meso - metalarvae	13 Jun 2005	74.4	larval fish seine
MAF05-005		1	12.3	mesolarva	14 Jun 2005	131.8	larval fish seine
MAF05-006		1	11.7	protolarva	14 Jun 2005	130.8	larval fish seine
MAF05-007		3	11.5- 11.9	protolarvae	14 Jun 2005	128.1	larval fish seine
MAF05-083		1	25.3	metalarva	3 Aug 2005	93.5	larval fish seine

TOTAL 1,533

Appendix II. Summary of larval Colorado pikeminnow collected in the San Juan River.

Field Number	MSB Catalog Number	Number of Specimens	Total Length	Larval Stage	Date Collected	River Mile	Sampling Method
2004	**TOTAL**	**2**					
MAF04-046	53090	1	14.2	metalarva	22 July 2004	46.3	larval seine
MAF04-059	53130	1	17.0	metalarva	24 July 2004	17.0	larval seine
TOTAL		**2**					

Appendix III. Detailed sampling and fish identification protocol.

1. Determination and access to sampling sites

   a. Suitable habitats for larval fish, including areas of low velocity (pools, backwaters, and secondary channels) were identified by field personnel while floating the river.
   b. Access to the habitats was gained via 16' inflatable raft.
   c. River Mile was determined to tenth of a mile using the standardized map set 2003 aerial photos produced for the San Juan River Basin Recovery Implementation Program.
   d. Geographic coordinates were determined at each site with a Garmin Navigation Geographic Positioning System (GPS) Instrument and were recorded in Universal Transverse Mercator (UTM) Zone 12 NAD27 CONUS. In instances where coordinates could not be obtained due to poor GPS satellite signal, coordinates were determined in the lab using a Geographic Information System based on the recorded river mile.

2. Collection of larval fish samples via seine and associated data recorded

   a. Small-mesh seines (1m x 1m x 0.8 mm) were drawn through the sampling site.
   b. The number of seine hauls per site was recorded along with the length of each seine haul. This information was used to calculate effort (area sampled) using the equation:

$$\Sigma \, haul\ lengths\ (m) \bullet seine\ width\ (m) = effort\ (m^2)$$

   c. Ecological data about each site were recorded, including meso-habitat type, length of habitat area, maximum depth, and substrate. A secchi disk was used to determine water clarity. Figure 16 illustrates data recorded at seining sites in the field.

4. Retention, identification, and permanent deposition of specimens

   a. Retained specimens at each site were placed in WhirlPak bags containing a solution of 10% formalin and a tag inscribed with a unique alpha-numeric code that was also recorded on the field data sheet.
   b. Samples were returned to the Division of Fishes, Museum of Southwestern Biology (MSB), University of New Mexico. The specimens were removed from the field bags, debris and silt was removed and they were transferred to glass museum jars containing a solution of 5% buffered formalin. Specimens from each site were sorted and identified to species, then the species series were enumerated, and measured for minimum and maximum size (mm SL) of that sample.
   c. Specimens were identified to species by MSB personnel with expertise in San Juan River Basin larval fish identification. Identifications were made using a polarized, underlit stereo microscope. Specimens whose species-specific identity was questionable were forwarded to Darrel E. Snyder (Larval Fish Laboratory, Colorado State University) for review.
   d. Specimens identified as razorback sucker were further examined for determination of developmental stage and minimum and maximum size (mm TL).
   e. All collections were transferred through a series of 35%, 50%, and ultimately 70% ethanol, catalogued, labeled, and placed on shelves in the in the collection archives of the MSB.

Appendix III. Detailed sampling and fish identification protocol (continued).

Field No.: WHB05 - 145

Date: 12 Jun 2005 / Sample: 2 bags Acc. No.: 2005 - IV : 18

State/Country: Utah / USA Locality: San Juan River @ RM 84.1 "Recapture Creek"

County: San Juan Co. Drainage: San Juan Quad.:

Coordinate System: Nad 27 N/S: 4127367 E/W: 635528 Zone: 12

Shore Description: sand bank, few salt cedar Air Temp.: 24 °C

Water Description: backwater

Substrate: Silt & mud Water Depth: .22 m

Aquatic Vegetation/Cover: none

Water Temp.: 20.6 °C Velocity (est.): Ø m/s Width (est.): 8 m

Secchi Depth: 18 cm D.O.: 7.12 mg/l Conductivity: 323.9/3525 µS Salinity: 0.2 ppt pH:

Method of Capture: larval seine / 1m x 1m

No. Hauls: 5 Area: 46.7 m^2 Shocking Sec.: Volts: Amps:

Distance from Shore (est.): m Depth of Capture: .05 - .48 m

Collected by: WHBrandenburg & LERenfro

Time: (start) 1503 h (stop) 1532 h Notes taken by: WHBrandenburg

Orig. Preservative: 10% formalin Photographs: ~~0856 & 0857~~ 0857 0858

Released fishes (Yes) / No (list separately):

76 *Ptychocheilus lucius* n=3 50, 60 & 75 mm SL (see following page)

At the downstream portion of Recapture Creek (which is not flowing) are two long backwaters. The smaller of the two has a tenuous connection to the main channel and is almost an isolated pool. Only larval catostomids were collected here in the two hauls made and very few fish were collected. The larger of the two backwaters had a much better connection to the main channel. Hauls were run towards the back portion of it and lots of fish were collected. Adult *Cyprinella lutrensis* were by far the dominate taxa. While larval catostomid were captured their numbers were still low. Three *Ptychocheilus lucius* were collected in the last haul where water temperatures were warmest. All three specimens were very healthy in appearance.

Figure 31. Field sheet used to record seine collection data at a sampling site during the razorback sucker survey in the San Juan River in 2001.

Appendix III. Detailed sampling and fish identification protocol (continued).

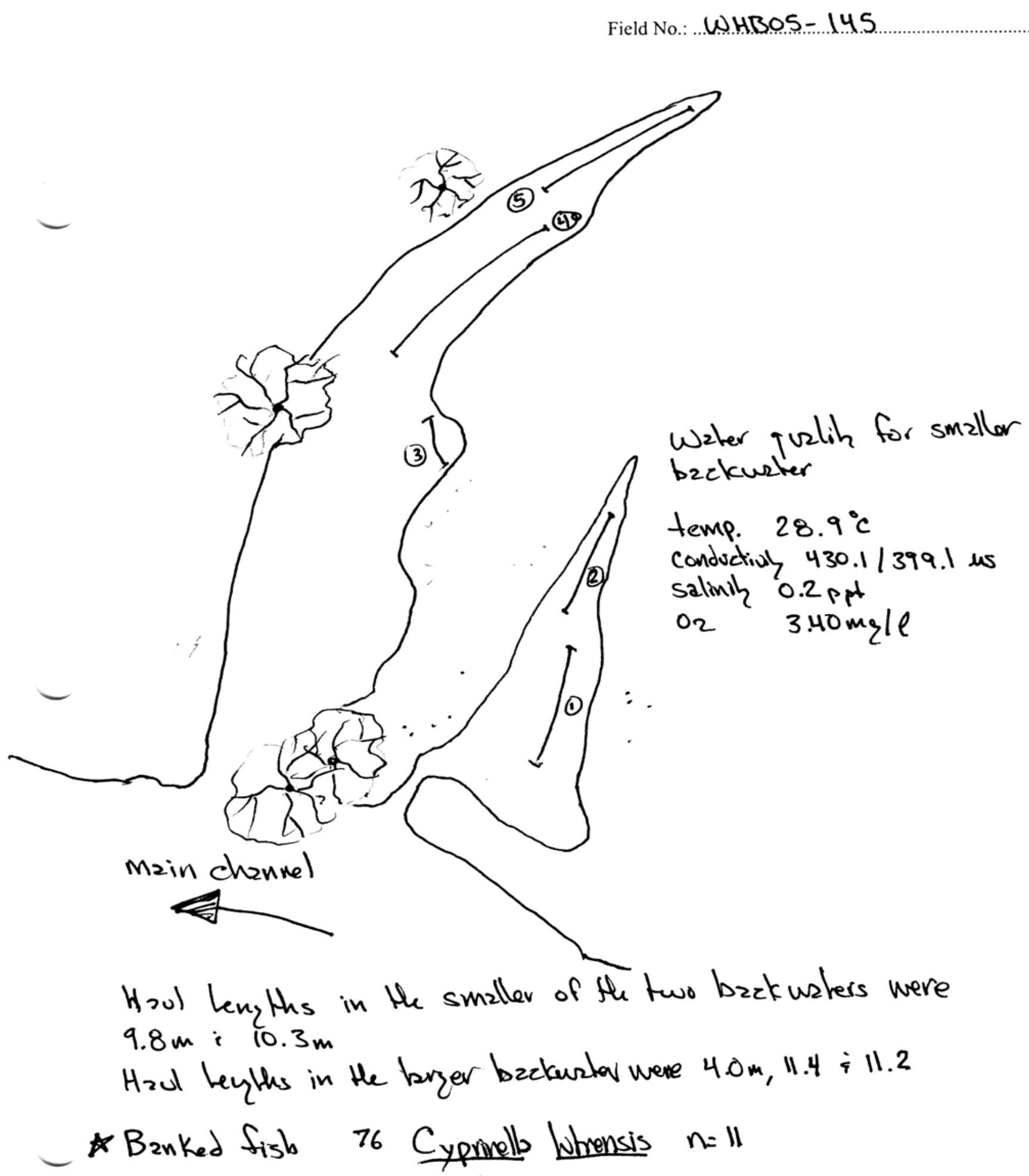

Figure 32. Field sheet used to record seine collection data at a sampling site during the razorback sucker survey in the San Juan River in 2001.

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004.

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
WHB05-001	19-Apr-2005	140.0	5.88	11.00	0.2	309
WHB05-002	19-Apr-2005	139.1	7.07	11.80	0.2	343
WHB05-003	19-Apr-2005	137.9	6.57	11.10	0.2	274
WHB05-004	19-Apr-2005	135.2	5.36	13.20	0.2	327
WHB05-005	19-Apr-2005	131.4	6.78	12.20	0.2	282
WHB05-006	19-Apr-2005	130.1	6.69	15.90	0.2	313
WHB05-007	19-Apr-2005	126.0	5.65	14.60	0.2	307
WHB05-008	19-Apr-2005	124.8	6.21	19.90	0.2	386
WHB05-009	19-Apr-2005		7.04	13.40	0.1	156
WHB05-010	20-Apr-2005	120.4	5.90	12.00	0.2	265
WHB05-011	20-Apr-2005	119.5	6.47	10.70	0.2	272
WHB05-012	20-Apr-2005	118.3	7.40	10.50	0.2	269
WHB05-013	20-Apr-2005	114.6	6.88	6.88	0.2	272
WHB05-014	20-Apr-2005	113.7	6.40	11.60	0.2	3000
WHB05-015	20-Apr-2005	110.6	6.60	13.10	0.2	290
WHB05-016	20-Apr-2005	109.4	7.23	12.00	0.2	281
WHB05-017	20-Apr-2005	106.5	6.73	14.80	0.2	305
WHB05-018	20-Apr-2005	103.4	5.83	16.50	0.2	346
WHB05-019	20-Apr-2005	100.5	6.05	16.90	1.4	2213
WHB05-020	21-Apr-2005	99.3	7.45	9.90	0.2	323
WHB05-021	21-Apr-2005	96.6	4.42	14.10	0.2	336
WHB05-022	21-Apr-2005	94.2	7.44	11.30	0.2	314
WHB05-023	21-Apr-2005	92.2	6.11	14.60	0.2	320
WHB05-024	21-Apr-2005	90.7	6.17	16.10	0.2	361
WHB05-025	21-Apr-2005	88.8	7.07	20.00	0.2	377
WHB05-026	21-Apr-2005	86.8	6.65	12.90	0.2	326
WHB05-027	21-Apr-2005	85.2	6.78	15.10	0.2	339
WHB05-028	21-Apr-2005	82.3	6.62	14.30	0.2	341
WHB05-029	22-Apr-2005	80.3	7.11	10.40	0.2	300
WHB05-030	22-Apr-2005	78.7	3.38	11.60	0.2	309
WHB05-031	22-Apr-2005	77.0	6.86	14.10	0.2	355
WHB05-032	22-Apr-2005	74.4	5.42	14.70	0.2	327
WHB05-033	22-Apr-2005	68.6	7.42	13.40	0.2	261
WHB05-034	22-Apr-2005	67.3	6.33	14.00	0.2	324
WHB05-035	22-Apr-2005	63.3	7.53	13.10	0.2	317
WHB05-036	22-Apr-2005	61.1	7.12	12.90	0.2	317
WHB05-037	23-Apr-2005	54.0	7.44	11.50	0.2	311
WHB05-038	23-Apr-2005	52.7	7.51	12.30	0.2	318
WHB05-039	23-Apr-2005	49.5	7.66	12.30	0.2	317
WHB05-040	23-Apr-2005	46.0	7.50	12.70	0.2	320
WHB05-041	23-Apr-2005	41.8	7.28	13.50	0.2	325
WHB05-042	23-Apr-2005	41.6	3.49	23.60	0.1	201
WHB05-043	23-Apr-2005	41.5	5.68	22.30	0.2	418
WHB05-044	23-Apr-2005	40.3	7.67	13.90	0.2	329
WHB05-045	24-Apr-2005	30.5	6.84	14.20	0.2	347
WHB05-046	24-Apr-2005	26.4	6.67	14.30	0.2	348

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
WHB05-047	24-Apr-2005	23.8	6.31	14.20	0.2	647
WHB05-048	24-Apr-2005	23.2	6.74	14.30	0.2	306
WHB05-049	24-Apr-2005	22.0	6.55	14.50	0.2	350
WHB05-050	24-Apr-2005	19.7	6.32	15.70	0.2	358
WHB05-051	24-Apr-2005	17.5	6.50	15.10	0.2	355
WHB05-052	24-Apr-2005	16.4	6.50	15.20	0.2	358
WHB05-053	24-Apr-2005	13.4	5.87	16.60	0.2	355
WHB05-054	25-Apr-2005	13.0	5.44	13.00	0.2	249
WHB05-055	25-Apr-2005	11.4	6.31	13.30	0.2	345
WHB05-056	25-Apr-2005	10.0	6.41	12.50	0.2	329
WHB05-057	25-Apr-2005	9.6	7.00	13.10	0.2	340
WHB05-058	25-Apr-2005	8.1	6.21	14.80	0.2	338
WHB05-059	25-Apr-2005	5.6	6.19	14.90	0.2	283
WHB05-060	25-Apr-2005	4.2	6.44	17.50	0.2	375
WHB05-061	10-May-2005	140.3	7.61	13.6	0.2	284
WHB05-062	10-May-2005	139.1	6.48	17.3	0.3	297
WHB05-063	11-May-2005	134.5	7.47	10.6	0.2	265
WHB05-064	11-May-2005	133.5	7.02	11.1	0.2	268
WHB05-065	11-May-2005	130.1	6.33	13.2	0.2	302
WHB05-066	11-May-2005	126.5	6.12	12.3	0.2	274
WHB05-067	11-May-2005	126.0	7.07	12.6	0.2	281
WHB05-068	11-May-2005	123.2	6.95	13.0	0.2	284
WHB05-069	11-May-2005	120.4	6.63	14.9	0.2	311
WHB05-070	11-May-2005	119.5	7.00	14.0	0.2	299
WHB05-071	11-May-2005	117.9	7.20	12.9	0.2	285
WHB05-072	12-May-2005	116.9	7.68	10.1	0.2	258
WHB05-073	12-May-2005	112.9	7.52	10.7	0.2	261
WHB05-074	12-May-2005	112.1	7.36	12.1	0.2	271
WHB05-075	12-May-2005	110.5	7.36	13.1	0.2	278
WHB05-076	12-May-2005	106.6	7.42	12.4	0.2	271
WHB05-077	12-May-2005	104.4	7.42	12.4	0.2	271
WHB05-078	12-May-2005	103.3	6.57	13.0	0.2	277
WHB05-079	12-May-2005	100.5	5.90	20.9	1.1	193
WHB05-080	13-May-2005	99.3	7.99	12.4	0.2	299
WHB05-081	13-May-2005	96.6	7.60	13.6	0.2	296
WHB05-082	13-May-2005	94.8	6.92	11.9	0.2	283
WHB05-083	13-May-2005	91.7	7.91	15.4	0.2	308
WHB05-084	13-May-2005	88.8	6.10	21.0	0.2	356
WHB05-085	13-May-2005	87.1	7.32	13.8	0.2	297
WHB05-086	13-May-2005	84.1	4.56	27.7	0.8	1692
WHB05-087	13-May-2005	82.8	-	22.8	0.3	678
WHB05-088	13-May-2005	81.3	7.23	14.6	0.2	304
WHB05-089	14-May-2005	80.2	-	11.9	0.2	290
WHB05-090	14-May-2005	78.7	6.57	12.7	0.2	296
WHB05-091	14-May-2005	75.6	7.09	14.3	0.2	307
WHB05-092	14-May-2005	74.4	7.01	15.0	0.2	362

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
WHB05-093	14-May-2005	71.5	7.14	15.2	0.2	315
WHB05-094	14-May-2005	68.0	6.20	16.1	0.2	352
WHB05-095	14-May-2005	67.7	6.95	14.7	0.2	308
WHB05-096	14-May-2005	65.2	6.84	15.3	0.2	312
WHB05-097	15-May-2005	61.2	6.58	13.0	0.2	298
WHB05-098	15-May-2005	59.0	6.54	13.3	0.2	312
WHB05-099	15-May-2005	58.7	6.61	13.4	0.2	303
WHB05-100	15-May-2005	57.9	7.30	17.1	0.4	792
WHB05-101	15-May-2005	50.9	7.14	14.7	0.2	308
WHB05-102	15-May-2005	46.3	7.06	16.0	0.2	322
WHB05-103	15-May-2005	44.5	7.18	15.2	0.2	311
WHB05-104	15-May-2005	41.1	6.59	17.0	0.2	328
WHB05-105	15-May-2005	37.8	4.79	15.8	0.2	317
WHB05-106	16-May-2005	33.7	7.08	14.6	0.2	309
WHB05-107	16-May-2005	32.1	6.67	14.8	0.2	311
WHB05-108	16-May-2005	30.0	6.91	15.0	0.2	312
WHB05-109	16-May-2005	28.6	6.55	16.5	0.2	323
WHB05-110	16-May-2005	23.2	6.59	17.2	0.2	329
WHB05-111	16-May-2005	22.0	6.48	17.0	0.2	320
WHB05-112	16-May-2005	19.7	6.10	17.8	0.2	321
WHB05-113	16-May-2005	16.4	6.06	17.4	0.2	322
WHB05-114	16-May-2005	13.9	4.64	17.8	0.2	327
WHB05-115	17-May-2005	11.5	4.87	15.2	0.2	314
WHB05-116	17-May-2005	10.0	6.57	14.1	0.2	324
WHB05-117	17-May-2005	9.6	5.89	15.6	0.2	345
WHB05-118	17-May-2005	8.7	7.27	15.4	0.2	313
WHB05-119	17-May-2005	8.1	5.97	18.8	0.2	367
WHB05-120	17-May-2005	3.4	5.97	17.0	0.2	324
WHB05-121	10-Jun-2005	141.8	7.09	14.0	0.2	255
WHB05-122	10-Jun-2005	140.4	4.81	24.7	0.3	626
WHB05-123	10-Jun-2005	135.9	7.69	14.2	0.1	236
WHB05-124	10-Jun-2005	135.9	7.27	17.7	0.2	269
WHB05-125	10-Jun-2005	134.8	6.97	20.0	0.2	288
WHB05-126	10-Jun-2005	131.9	7.47	13.1	0.1	229
WHB05-127	10-Jun-2005	130.1	6.01	20.6	0.2	303
WHB05-128	11-Jun-2005	128.8	5.87	13.9	0.2	258
WHB05-129	11-Jun-2005	126	4.61	12.7	0.2	247
WHB05-130	11-Jun-2005	124.8	6.64	13.7	0.2	244
WHB05-131	11-Jun-2005	121.5	5.67	17.9	0.2	313
WHB05-132	11-Jun-2005	118.3	6.25	13.7	0.2	263
WHB05-133	11-Jun-2005	121.5	5.99	22.7	0.2	338
WHB05-134	11-Jun-2005	117.5	7.17	18.3	0.2	277
WHB05-135	11-Jun-2005	113.7	5.18	19.5	0.2	346
WHB05-136	11-Jun-2005	110.3	6.54	15.1	0.2	273
WHB05-137	12-Jun-2005	102.1	7.53	11.7	0.2	245
WHB05-138	12-Jun-2005	100.5	6.58	16.1	0.8	1256

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
WHB05-139	12-Jun-2005	99.2	5.42	15.4	0.6	897
WHB05-140	12-Jun-2005	96.4	3.54	19.6	0.7	1230
WHB05-141	12-Jun-2005	92.9	7.35	13.3	0.2	267
WHB05-142	12-Jun-2005	90.5	6.90	18.4	0.2	298
WHB05-143	12-Jun-2005	87.6	7.36	19.1	0.2	312
WHB05-144	12-Jun-2005	85.4	6.41	15.8	0.2	287
WHB05-145	12-Jun-2005	84.1	7.12	20.6	0.2	324
WHB05-146	12-Jun-2005	82.4	6.49	17.4	0.2	300
WHB05-147	12-Jun-2005	81.6	6.14	19.0	0.2	315
WHB05-148	13-Jun-2005	78.2	6.21	16.5	0.2	333
WHB05-149	13-Jun-2005	77.1	7.06	13.9	0.2	283
WHB05-150	13-Jun-2005	77.1	3.96	16.1	0.2	317
WHB05-151	13-Jun-2005	76.6	6.31	18.7	0.2	323
WHB05-152	13-Jun-2005	75.4	5.67	21.9	0.2	354
WHB05-153	13-Jun-2005	74.1	5.71	22.5	0.3	589
WHB05-154	13-Jun-2005	72.8	6.83	16.0	0.2	303
WHB05-155	13-Jun-2005	70.4	6.36	17.3	0.2	317
WHB05-156	14-Jun-2005	68.1	-	14.4	0.2	289
WHB05-157	14-Jun-2005	65	6.22	15.1	0.2	295
WHB05-158	14-Jun-2005	63	6.68	15.2	0.2	246
WHB05-159	14-Jun-2005	59	7.18	15.5	0.1	232
WHB05-160	14-Jun-2005	57.9	5.27	24.0	1.4	2628
WHB05-161	14-Jun-2005	54.7	5.54	21.0	0.2	348
WHB05-162	14-Jun-2005	50.9	4.10	32.0	0.2	571
WHB05-163	14-Jun-2005	50.9	6.70	17.4	0.2	309
WHB05-164	15-Jun-2005	45.1	6.63	16.2	0.2	301
WHB05-165	15-Jun-2005	43.5	6.70	16.5	0.2	305
WHB05-166	15-Jun-2005	40	4.90	18.3	0.2	338
WHB05-167	15-Jun-2005	40	6.10	17.1	0.2	309
WHB05-168	15-Jun-2005	35.4	6.20	17.3	0.2	310
WHB05-169	15-Jun-2005	33.7	6.02	18.0	0.2	305
WHB05-170	16-Jun-2005	24.5	6.28	17.5	0.2	319
WHB05-171	16-Jun-2005	21.7	6.40	18.4	0.2	328
WHB05-172	16-Jun-2005	17.3	4.50	23.9	0.2	482
WHB05-173	16-Jun-2005	16.4	6.72	18.2	0.2	324
WHB05-174	17-Jun-2005	13.8	6.33	17.8	0.2	314
WHB05-175	17-Jun-2005	13.1	4.82	18.5	0.2	246
WHB05-176	17-Jun-2005	11.5	6.21	18.0	0.2	320
WHB05-177	17-Jun-2005	10	5.69	18.0	0.2	328
WHB05-178	17-Jun-2005	9.6	4.97	19.9	0.2	349
WHB05-179	17-Jun-2005	8.1	6.10	21.8	0.2	360
WHB05-180	17-Jun-2005	3.3	5.83	21.1	0.2	346
MAF05-001	13-Jul-2005	140.5	5.63	30.0	0.2	492.0
MAF05-002	13-Jul-2005	138.1	6.23	28.8	0.2	482.0
MAF05-003	13-Jul-2005	135.4	5.40	27.2	0.2	471.0
MAF05-004	13-Jul-2005	133.7	5.50	27.3	0.2	475.0

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
MAF05-005	14-Jul-2005	131.8	5.52	21.5	0.2	428.9
MAF05-006	14-Jul-2005	130.8	5.83	23.1	0.2	440.0
MAF05-007	14-Jul-2005	128.1	4.89	23.7	0.3	608.0
MAF05-008	14-Jul-2005	124.6	5.19	27.3	0.2	483.0
MAF05-009	14-Jul-2005	122.8	5.06	29.5	0.2	504.0
MAF05-010	14-Jul-2005	121.8	5.16	29.5	0.2	496.0
MAF05-011	14-Jul-2005	119.0	7.14	33.6	0.2	912.0
MAF05-012	14-Jul-2005	117.8	3.91	32.1	0.2	535.0
MAF05-013	15-Jul-2005	114.6	5.40	21.4	0.2	433.0
MAF05-014	15-Jul-2005	113.5	4.16	22.2	0.2	439.0
MAF05-015	15-Jul-2005	110.4	5.83	23.1	0.2	454.0
MAF05-016	15-Jul-2005	107.3	5.44	23.8	0.2	456.0
MAF05-017	15-Jul-2005	106.6	5.20	24.9	0.2	494.0
MAF05-018	15-Jul-2005	104.3	5.44	-	0.2	488.0
MAF05-019	15-Jul-2005	100.4	4.09	31.5	0.2	535.0
MAF05-020	15-Jul-2005	98.6	4.14	35.4	0.3	799.0
MAF05-021	15-Jul-2005	97.0	5.03	30.0	0.2	544.0
MAF05-022	16-Jul-2005	95.2	4.91	23.1	0.2	477.0
MAF05-023	16-Jul-2005	94.2	4.81	23.4	0.3	530.0
MAF05-024	16-Jul-2005	93.0	5.33	23.5	0.2	486.0
MAF05-025	16-Jul-2005	90.5	5.67	27.2	0.2	516.0
MAF05-026	16-Jul-2005	89.1	5.19	28.2	0.2	526.0
MAF05-027	16-Jul-2005	85.5	5.83	27.2	0.2	511.0
MAF05-028	16-Jul-2005	83.9	4.65	27.5	0.2	518.0
MAF05-029	17-Jul-2005	82.6	4.93	23.9	0.2	494.0
MAF05-030	17-Jul-2005	79.3	4.76	25.1	0.2	499.0
MAF05-031	17-Jul-2005	77.4	4.39	26.4	0.2	509.0
MAF05-032	17-Jul-2005	76.5	5.06	28.8	0.2	536.0
MAF05-033	17-Jul-2005	74.9	5.82	28.8	0.2	550.0
MAF05-034	17-Jul-2005	72.5	5.08	32.9	0.2	584.0
MAF05-035	18-Jul-2005	69.7	5.37	23.8	0.2	488.0
MAF05-036	18-Jul-2005	69.1	5.58	24.8	0.2	490.0
MAF05-037	18-Jul-2005	66.6	5.46	25.1	0.2	495.0
MAF05-038	18-Jul-2005	-	5.52	25.2	0.2	501.0
MAF05-039	18-Jul-2005	-	5.16	26.4	0.2	504.0
MAF05-040	19-Jul-2005	57.2	5.41	24.7	0.2	506.0
MAF05-041	19-Jul-2005	56.1	5.08	24.6	0.2	506.0
MAF05-042	19-Jul-2005	49.4	5.41	27.2	0.2	526.0
MAF05-043	19-Jul-2005	46.0	5.20	27.5	0.2	535.0
MAF05-044	19-Jul-2005	42.7	5.15	28.7	0.2	546.0
MAF05-045	19-Jul-2005	41.6	5.03	30.0	0.2	558.0
MAF05-046	20-Jul-2005	38.8	4.13	24.8	0.2	504.0
MAF05-047	20-Jul-2005	34.1	5.78	25.6	0.2	509.0
MAF05-048	20-Jul-2005	33.6	5.44	26.8	0.2	525.0
MAF05-049	20-Jul-2005	30.6	5.63	26.8	0.2	515.0
MAF05-050	20-Jul-2005	28.2	5.42	27.5	0.2	522.0

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
MAF05-051	20-Jul-2005	25.4	5.05	27.8	0.2	530.0
MAF05-052	20-Jul-2005	25.1	-	28.3	0.2	530.0
MAF05-053	20-Jul-2005	23.0	5.59	28.5	0.2	536.0
MAF05-054	21-Jul-2005	16.3	5.02	26.5	0.2	515.0
MAF05-055	21-Jul-2005	13.9	4.94	25.1	0.2	508.0
MAF05-056	21-Jul-2005	12.4	4.45	26.8	0.2	523.0
MAF05-057	21-Jul-2005	10.0	4.38	26.6	0.2	470.0
MAF05-058	21-Jul-2005	9.2	5.08	30.6	0.2	569.0
MAF05-059	21-Jul-2005	8.0	4.38	26.9	0.3	587.0
MAF05-060	22-Jul-2005	6.0	5.35	25.3	0.2	324.0
MAF05-061	31-Jul-2005	140.8	6.99	27.2	0.3	616.0
MAF05-062	31-Jul-2005	139.6	5.95	26.7	0.3	595.0
MAF05-063	31-Jul-2005	137.3	5.11	29.4	0.3	604.0
MAF05-064	1-Aug-2005	136.5	5.51	21.8	0.2	559.0
MAF05-065	1-Aug-2005	134.7	4.76	20.9	0.3	566.0
MAF05-066	1-Aug-2005	133.3	5.25	23.8	0.3	687.0
MAF05-067	1-Aug-2005	131.8	5.25	25.8	0.3	604.0
MAF05-068	1-Aug-2005	130.3	6.13	26.0	0.3	610.0
MAF05-069	1-Aug-2005	127.9	7.77	28.0	0.3	542.0
MAF05-070	1-Aug-2005	123.2	8.51	31.9	0.3	628.0
MAF05-071	1-Aug-2005	120.6	7.43	28.6	0.3	628.0
MAF05-072	2-Aug-2005	118.8	5.99	22.9	0.3	582.0
MAF05-073	2-Aug-2005	117.3	6.07	23.7	0.3	587.0
MAF05-074	2-Aug-2005	115.5	6.08	24.4	0.3	588.0
MAF05-075	2-Aug-2005	113.2	6.21	30.3	0.4	345.0
MAF05-076	2-Aug-2005	111.7	6.70	28.6	0.4	801.0
MAF05-077	2-Aug-2005	110.1	7.02	27.9	0.3	628.0
MAF05-078	2-Aug-2005	106.1	6.45	27.7	0.3	631.0
MAF05-079	2-Aug-2005	101.4	-	27.1	0.3	628.0
MAF05-080	3-Aug-2005	99.6	4.12	22.0	0.3	663.0
MAF05-081	3-Aug-2005	98.6	5.38	21.7	0.3	660.0
MAF05-082	3-Aug-2005	96.9	4.75	23.6	0.3	659.0
MAF05-083	3-Aug-2005	93.5	5.76	25.1	0.3	670.0
MAF05-084	3-Aug-2005	90.9	5.75	24.5	0.3	663.0
MAF05-085	3-Aug-2005	89.4	5.44	25.8	0.3	677.0
MAF05-086	3-Aug-2005	85.7	7.30	34.1	1.5	333.0
MAF05-087	3-Aug-2005	84.4	4.63	28.5	0.3	717.0
MAF05-088	4-Aug-2005	81.9	6.23	29.9	0.3	-
MAF05-089	4-Aug-2005	80.0	4.58	22.8	0.4	718.0
MAF05-090	4-Aug-2005	79.5	5.69	22.4	0.4	683.0
MAF05-091	4-Aug-2005	77.3	4.10	21.8	0.2	168.0
MAF05-092	4-Aug-2005	75.5	4.35	25.7	0.3	719.0
MAF05-093	4-Aug-2005	72.3	4.80	24.6	0.4	718.0
MAF05-094	4-Aug-2005	71.1	4.57	27.3	0.3	721.0
MAF05-095	4-Aug-2005	69.0	4.45	26.7	0.4	751.0
MAF05-096	4-Aug-2005	67.7	0.72	26.5	0.4	767.0

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (°C)	Salinity (ppt)	Conductivity (ms)
MAF05-097	4-Aug-2005	65.0	5.12	26.1	0.4	753.0
MAF05-098	5-Aug-2005	63.8	5.28	22.8	0.4	702.0
MAF05-099	5-Aug-2005	63.3	4.50	22.8	0.4	709.0
MAF05-100	5-Aug-2005	62.0	4.45	22.0	0.4	825.0
MAF05-101	5-Aug-2005	59.0	4.80	25.0	0.4	774.0
MAF05-102	5-Aug-2005	57.9	5.26	24.3	2.1	3825.0
MAF05-103	5-Aug-2005	55.3	4.38	26.8	0.4	782.0
MAF05-104	5-Aug-2005	52.4	4.50	26.5	0.4	725.0
MAF05-105	5-Aug-2005	51.7	4.59	28.4	0.4	824.0
MAF05-106	5-Aug-2005	46.2	4.81	26.7	0.4	797.0
MAF05-107	6-Aug-2005	43.8	5.08	23.3	0.4	714.0
MAF05-108	6-Aug-2005	43.0	5.32	23.4	0.4	714.0
MAF05-109	6-Aug-2005	38.8	5.41	23.5	0.4	716.0
MAF05-110	6-Aug-2005	35.4	5.62	24.7	0.4	736.0
MAF05-111	6-Aug-2005	31.1	5.46	26.0	0.4	753.0
MAF05-112	6-Aug-2005	28.8	4.79	25.9	0.4	754.0
MAF05-113	6-Aug-2005	25.1	5.16	26.1	0.4	758.0
MAF05-114	6-Aug-2005	24.7	5.21	25.8	0.4	752.0
MAF05-115	7-Aug-2005	23.0	4.54	23.6	0.4	726.0
MAF05-116	7-Aug-2005	22.0	4.33	20.6	0.4	814.0
MAF05-117	7-Aug-2005	19.3	4.50	26.4	0.4	769.0
MAF05-118	7-Aug-2005	16.3	3.70	29.6	0.3	834.0
MAF05-119	7-Aug-2005	14.1	3.66	28.1	0.4	797.0
MAF05-120	7-Aug-2005	12.3	5.00	31.9	0.4	851.0
MAF05-121	7-Aug-2005	11.2	4.03	36.4	0.4	1011.0
MAF05-122	7-Aug-2005	10.0	4.48	22.5	0.1	184.0
MAF05-123	7-Aug-2005	10.0	4.90	27.6	0.3	762.0
MAF05-124	8-Aug-2005	8.5	1.98	23.5	0.4	703.0
MAF05-125	8-Aug-2005	8.0	1.99	23.5	0.3	592.0
MAF05-126	6-Sep-2005	141.5	5.10	21.6	0.3	509.0
MAF05-127	6-Sep-2005	139.6	7.74	22.7	0.3	602.0
MAF05-128	7-Sep-2005	136.5	6.65	18.8	0.3	516.0
MAF05-129	7-Sep-2005	134.8	4.24	19.1	0.3	543.0
MAF05-130	7-Sep-2005	131.8	7.09	20.8	0.3	534.0
MAF05-131	7-Sep-2005	129.8	4.62	21.5	0.3	546.0
MAF05-132	7-Sep-2005	127.7	7.02	22.7	0.3	560.0
MAF05-133	7-Sep-2005	125.7	5.32	28.1	0.3	670.0
MAF05-134	7-Sep-2005	121.6	7.12	25.2	0.3	598.0
MAF05-135	7-Sep-2005	118.2	7.12	25.0	0.3	608.0
MAF05-136	8-Sep-2005	116.2	5.26	19.6	0.4	659.0
MAF05-137	8-Sep-2005	113.2	5.84	21.7	0.3	569.0
MAF05-138	8-Sep-2005	110.2	6.17	23.4	0.3	592.0
MAF05-139	8-Sep-2005	106.8	6.18	22.9	0.3	549.0
MAF05-140	8-Sep-2005	102.9	6.16	22.4	0.3	574.0
MAF05-141	8-Sep-2005	102.2	5.85	22.6	0.3	575.0
MAF05-142	8-Sep-2005	100.3	6.18	22.6	0.7	1265.0

Appendix IV. Water quality data for individual collection localities in the San Juan River, 2004 (continued).

Field Number	Date	RM	Dissolved Oxygen (mg/l)	Water Temp (^{o}C)	Salinity (ppt)	Conductivity (ms)
MAF05-143	9-Sep-2005	94.2	6.11	21.7	0.4	680.0
MAF05-144	9-Sep-2005	90.5	5.17	26.6	0.4	821.0
MAF05-145	9-Sep-2005	84.2	5.62	23.5	0.4	712.0
MAF05-146	10-Sep-2005	79.9	5.43	17.8	0.3	508.0
MAF05-147	10-Sep-2005	78.7	5.58	18.3	0.3	514.0
MAF05-148	10-Sep-2005	77.3	5.10	18.3	0.3	573.0
MAF05-149	10-Sep-2005	75.1	5.16	20.0	0.3	595.0
MAF05-150	10-Sep-2005	74.4	4.06	20.8	0.3	609.0
MAF05-151	10-Sep-2005	71.6	0.91	21.1	0.3	624.0
MAF05-152	10-Sep-2005	67.1	4.76	22.0	0.3	649.0
MAF05-153	11-Sep-2005	63	4.57	18.6	0.5	947.0
MAF05-154	11-Sep-2005	62.5	4.28	20.3	0.3	950.0
MAF05-155	11-Sep-2005	61.2	4.50	19.7	0.5	965.0
MAF05-156	11-Sep-2005	57.9	5.06	21.8	0.9	1664.0
MAF05-157	11-Sep-2005	52.4	2.85	23.1	0.6	1014.0
MAF05-158	11-Sep-2005	50.9	4.52	21.1	0.5	999.0
MAF05-159	11-Sep-2005	46.3	5.05	21.4	0.5	1010.0
MAF05-160	12-Sep-2005	43.5	5.08	18.1	0.5	884.0
MAF05-161	12-Sep-2005	42.5	5.79	18.4	0.5	873.0
MAF05-162	12-Sep-2005	41.2	4.06	21.1	0.6	1031.0
MAF05-163	12-Sep-2005	38.7	1.26	28.2	0.5	1168.0
MAF05-164	12-Sep-2005	36.7	2.55	20.5	0.5	939.0
MAF05-165	12-Sep-2005	32.9	5.05	21.0	0.5	820.0
MAF05-166	12-Sep-2005	28.8	5.89	20.3	0.5	955.0
MAF05-167	12-Sep-2005	25.2	5.51	20.4	0.5	970.0
MAF05-168	13-Sep-2005	24.4	5.85	18.0	0.4	664.0
MAF05-169	13-Sep-2005	21.9	5.26	18.2	0.4	669.0
MAF05-170	13-Sep-2005	19.8	4.88	19.0	0.4	683.0
MAF05-171	13-Sep-2005	18.3	5.38	19.5	0.4	690.0
MAF05-172	13-Sep-2005	15.4	5.77	21.4	0.4	718.0
MAF05-173	13-Sep-2005	13.9	4.97	21.1	0.4	719.0
MAF05-174	13-Sep-2005	12	5.38	20.4	0.4	718.0
MAF05-175	13-Sep-2005	10.4	1.05	26.9	0.5	1040.0
MAF05-176	13-Sep-2005	7.6	6.18	17.8	0.4	657.0
MAF05-177	14-Sep-2005	6.9	3.24	19.5	0.4	702.0
MAF05-178	14-Sep-2005	5.7	2.71	19.1	0.4	737.0