ADULT FISH COMMUNITY MONITORING ON THE SAN JUAN RIVER, 1991-1997

Final Report

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EXECUTIVE SUMMARY

The San Juan River is historic habitat for seven native fish species including three rare fish species: the Colorado pikeminnow (Ptychocheilus lucius), razorback sucker (Xyrauchen texanus), and roundtail chub (Gila robusta).

Jeopardy opinions issued by the U. S. Fish and Wildlife Service (Service) during consultations on the Animas-La Plata (ALP) and Navajo Indian Irrigation Projects (NIIP) under Section 7 of the Endangered Species Act led to the initiation of a seven-year research period on the fish community of the San Juan River, beginning in 1991. The goal of this research period was to study the effects of test flows from Navajo Reservoir (upstream of Farmington, New Mexico {NM}) on the fish community and instream habitats in the San Juan River for the purpose of developing long-term flow recommendations for the permanent reoperation of Navajo Dam. As part of these seven-year studies, the Service's Colorado River Fishery Project (CRFP) office in Grand junction, Colorado (CO) was given the lead responsibility for monitoring the response of the main channel adult fish community to test flows. The main objective of these test flows was to mimic, in shape, duration, and time (but not magnitude) a "natural" pre-Navajo Dam hydrograph and observe the effects this natural hydrograph had on the San Juan River fish community.

Between 1991 and 1997 the CRFP office conducted a total of 26 electrofishing and numerous radiotelemetry trips in the San Juan River between the Animas River confluence (river mile {RM} 180.0; Reach 6) at Farmington, NM and Clay Hills Landing (RM 2.9; Reach 1) just upstream of Lake Powell in Utah (UT). Between 1991 and 1997, a total of 242,163 fish representing 26 species and three hybrid sucker forms were collected. Of the 26 species, 7 were native and 19 were introduced (nonnative) species. The three hybrid sucker forms included one native X native sucker hybrid and two native X nonnative sucker hybrids. Six species accounted for 99.1% of all fish collected during adult fish community monitoring (adult monitoring) trips. Three of these were native species (flannelmouth sucker, bluehead sucker, and speckled dace) and three were nonnative species (channel catfish {Ictalurus punctatus}, common carp {Cyprinus carpio}, and red shiner {Cyprinella lutrensis}).

The three most common nonnative species did not show a quantifiable negative response to test flows from Navajo Reservoir in main channel habitats. In fact, between 1993 and 1997 numbers of channel catfish and common carp increased in adult monitoring collections. It appears that with the amount of water presently available in the San Juan River, that populations of these three common nonnative fish species can probably not be reduced or eliminated using flows from Navajo Reservoir alone. A drop in catch per unit of effort (CPUE; i.e., the number of fish per hour of electrofishing) observed for channel catfish and common carp in October 1997 versus previous trips may be linked to mechanical removal efforts that began on adult monitoring trips in October 1996 and took place on all subsequent trips. Notable among collections of nonnative fish species were the first scientifically-documented collections of a grass carp (Ctenopharyngodon idella), and of white sucker (Catostomus commersoni) X flannelmouth sucker and white sucker X bluehead sucker hybrids from the mainstem San Juan River. Also notable among nonnative fish collections were the walleye, striped bass, and threadfin shad that invaded the lower San Juan River starting in the spring of

1995 when the waterfall at RM 0.0 became inundated by a rising Lake Powell. Walleye were collected as far upstream as RM 108.3 and striped bass as far upstream as RM 91.2. The upstream limit of threadfin shad distribution appears to be Government Rapid at RM 20.2.

Both flannelmouth sucker and bluehead sucker showed declining CPUE between 1991 and 1997 in the core sampling area (RM 158.6-53.0). Declines in flannelmouth sucker CPUE were much more dramatic than those for bluehead sucker. However, during the same time period, the average condition factor of these two fish species increased. In addition, CPUE for both of these species increased in Reach 6 (RM 180.0-158.6) collections. The declines in flannelmouth sucker and bluehead sucker populations may be cyclical fluctuations in these populations.

There does not appear to be a resident, reproducing population of roundtail chub in the San Juan River. The individual roundtail chub collected in the San Juan River during the seven-year research period appear to be originating from upstream tributaries, namely the Animas, La Plata, and Mancos River drainages, that support populations of roundtail chub.

Between 1991 and 1993, no wild razorback sucker were collected in the San Juan River. Razorback sucker that were experimentally-stocked between 1994 and 1997 appear to be surviving and growing in the San Juan River.

Adult monitoring has also proven to be efficient in monitoring juvenile Colorado pikeminnow that were experimentally-stocked by the Utah Division of Wildlife Resources in 1996 and 1997. Thirty-nine of these fish ranging from 44-235 mm total length (TL) were recaptured in 1997. Thirty-eight of these recaptured juvenile Colorado pikeminnow were in the 125-235 mm TL range. Six of which were implanted with PIT tags. The sampling regime presently in place for adult monitoring studies appears to be efficient for monitoring stocked juvenile Colorado pikeminnow greater than 100 mm TL.

Between 1991 and 1995, 19 wild Colorado pikeminnow, 17 adults (519-945 mm TL) and two large juveniles (363 and 432 mm TL) were collected via electrofishing. All of these Colorado pikeminnow were captured downstream of Cudei Diversion (RM 142.0). Of the 19 Colorado pikeminnow collected, 16 (all adults) were collected in the section of the San Juan River between Cudei Diversion and the Four Corner's bridge (RM 142.0-199.2). Thirteen wild, adult Colorado pikeminnow were implanted (tagged) with radio transmitters (tags). All 16 Colorado pikeminnow captured and tagged between RM 142.0 and 119.2 remained in a 33-mile section of river from RM 142.0-109.0. This area of the San Juan River seems to have properties that make it a "preferred" reach for adult Colorado pikeminnow. Adult Colorado pikeminnow appear to have very small home ranges which they occupy throughout most of the year, moving only during pre-spawning (mid-May through June) and spawning (July through mid-August) periods. Only one adult Colorado pikeminnow demonstrated migratory behavior. This individual, a large female fish, moved upstream from her home range downstream of Bluff, Utah apparently to spawn in the summer of 1994.

Of the 13 radio-tagged Colorado pikeminnow, 11 were contacted in area of the San Juan River known as the Mixer (RM 133.4-129.8) during presumed spawning periods. Seven individual adult Colorado pikeminnow were contacted in or at the mouth of the Mancos River (RM 122.6) during pre-spawn periods, a behavior dubbed "staging." Two fish tracked in multiple years used the Mancos during two separate pre-spawn periods. Two fish tracked in multiple years, including one of the fish contacted in the Mancos in two separate years moved to the Mixer during two separate spawning seasons. There appears to be a seasonally-repeated behavior among San Juan River Colorado pikeminnow of staging at the Mancos River, then moving to the Mixer to spawn.

Using a Schnabel population estimate, the number of Colorado pikeminnow between RM 136.6 and 119.2 for the period between June 1991 and October 1995 was estimated at 19 fish (based on 15 sampling trips). Ninety-five percent confidence intervals place the range of this population at 10-42 Colorado pikeminnow. Petersen index population estimates for the same time period and group of river miles place the Colorado pikeminnow population between 9 and 20 fish (based on the 14 sampling intervals).

Five major instream diversion structures in the San Juan River between RM 178.5 and 142.0 impede fish movements to varying degrees. Of these diversions, the San Juan Generating Station (PNM) Weir is probably the greatest barrier to native fish movements. However, the PNM Weir also appears to be inhibiting the upstream spread of channel catfish.

Walleye and striped bass invaded the San Juan River from Lake Powell in 1995 when rising lake levels inundated the waterfall at RM 0.0. These species have been documented to prey upon native flannelmouth sucker. The presence of these aggressive lacustrine predators coupled with the already large numbers of nonnative fish species that compete with and prey upon native species, complicates recovery efforts for endangered fishes in the San Juan River.

Both endangered Colorado pikeminnow and razorback sucker have been collected within the San Juan River of Lake Powell and the lake influence zone in the San Juan River. Both of these species have been documented moving upstream from Lake Powell into the San Juan River when the waterfall at RM 0.0 was not present. So, while the waterfall protected native fishes in the San Juan River from predatory lacustrine fishes, it also kept rare fish species in Lake Powell from communicating with riverine populations.

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INTRODUCTION

Water development and introduction of nonnative (i.e., introduced) species of fish have had a profound effect on certain members of the native fish fauna of the San Juan River. Three native species, the Colorado pikeminnow (formerly known as Colorado squawfish; Nelson et al. 1998), razorback sucker, and roundtail chub have become rare throughout their native range.[1] The Colorado pikeminnow and razorback sucker are listed as Endangered under the Endangered Species Act (ESA; United States Department of the Interior 1974, 1991). All three species are protected by the states of New Mexico (NM) and Utah (UT). Historical collections (summarized in Platania 1990) documented Colorado pikeminnow, razorback sucker, and roundtail chub as members of the San Juan River fish community. For the purposes of this report, these three species will be referred to as "rare fish." Other native species such as the flannelmouth sucker, bluehead sucker, speckled dace, and mottled sculpin, however, are still common in the San Juan River.

In 1994, Critical Habitat was designated for both Colorado pikeminnow and razorback sucker in the San Juan River (USFWS 1994). Critical Habitat for Colorado pikeminnow extends from the State Route 371 Bridge in Farmington, NM downstream to Neskahai Canyon in the San Juan River arm of Lake Powell, while Critical Habitat for razorback sucker extends from the Hogback Diversion, NM downstream to Neskahai Canyon.

The adult monitoring study was one of a number of studies begun in 1991 as part of a seven-year, multi-agency research program. This seven-year research program was initiated as a result of the 1991 Section-7 Consultation on the Animas-La Plata Project near Durango, Colorado (CO). The purpose of the seven-year research program was to obtain basic information about the San Juan River, its fish community (with special emphasis on the two endangered fish species: Colorado pikeminnow and razorback sucker), and its hydrologic processes, for the purpose of making flow recommendations for the reoperation of Navajo Reservoir, upstream of Farmington, NM, at the end of the seven years (i.e., 1998). The seven-year research program was incorporated into the San Juan River Basin Recovery Implementation Program (SJRIP) upon its formation in 1992, and the research being done originally for the purpose of making flow recommendations became additionally guided by the San Juan River Long Range Plan (LRP), which was completed in 1995. This plan outlines in detail the proposed recovery effort for the two endangered fishes in the San Juan River. The adult monitoring study provided research information needed to address many of the various goals, objectives, and milestones in the LRP. As a part of this seven-year research project, the U.S. Fish and Wildlife Service's (USFWS) Colorado River Fishery Project (CRFP) office in Grand Junction, Colorado was given the primary responsibility for conducting the adult fish community monitoring study ("adult monitoring" for short) which sampled adult and juvenile fishes in the river's main channel habitats.

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[1] Scientific and common names for all fishes collected during our study are listed in Table 11, page 26. Only common names for these fishes are used in the text.

Objectives

The objectives of the adult fish community monitoring study were as follows:

1. Increase abundance and distribution data on the native and nonnative fish community in the San Juan River to examine changes in this assemblage that may be associated with test flows from Navajo Reservoir. Special emphasis was placed on obtaining data on three rare fish species (Colorado pikeminnow, razorback sucker, and roundtail chub).
2. Determine habitat use and needs and monitor population trends of rare fish species (Colorado pikeminnow, razorback sucker, and roundtail chub).
3. Locate potential spawning areas of rare fish species.
4. Determine the extent to which current instream diversion structures (dams, weirs, etc.) impede movement of San Juan River fishes, with emphasis on rare fish species.
5. Monitor the upstream movement of lacustrine predatory fish species and rare fish species from Lake Powell. Determine potential negative impacts of lacustrine predatory fish species on the native fish community in the San Juan River.

This report represents a summary of the data collected on adult monitoring trips between 1991 and 1997 and examines the data under items 1 through 5 above. Each objective is represented by a single chapter in this report. Information has been synthesized across years to discuss data trends and patterns. The data collected on adult monitoring trips overlaps, ties in with, and is supported by numerous other studies. Many of the conclusions drawn in this report and based on our data include supporting data presented from other researchers and agencies. The source reports for these pieces of information are cited in the text. The author wishes to thank the other authors and agencies for letting us use and interpret their data in support of our study objectives.

SAN JUAN RIVER STUDY AREA DESCRIPTION

The San Juan River is a major tributary of the Colorado River and drains 99,200 km^2 in Colorado, Utah, Arizona, and New Mexico (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 to the Colorado River. The major perennial tributaries to the San Juan River are the Navajo, Piedra, Los Pinos, Animas, La Plata, and Mancos rivers, and McElmo Creek. In addition there are numerous ephemeral arroyos and washes contributing little total flow but large sediment loads.

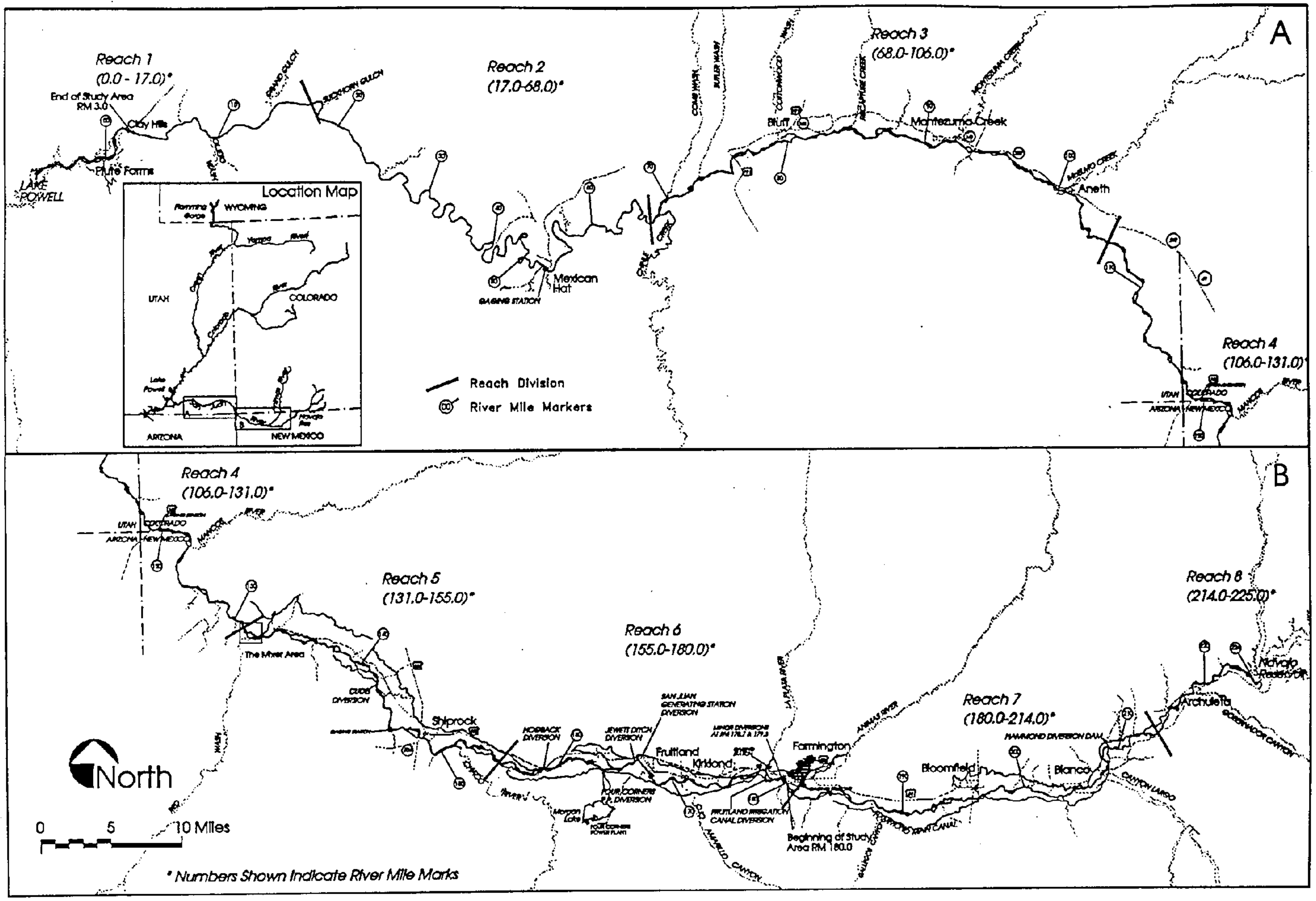


Figure 1. Map of the San Juan River between Lake Powell and Navajo Reservoir, including the locations of major towns, drainages, diversion structures, gaging stations, and river reach designations.

Navajo Reservoir, completed in 1963, impounds the San Juan River, isolating the upper 124 km of river and partially regulating downstream flows. The completion of Glen Canyon Dam and subsequent filling of Lake Powell in the early 1980's inundated the lower 87 km of the river, leaving about 359 km of river between the two reservoirs.

From Navajo Dam to Lake Powell, the mean gradient of the San Juan River is 1.67 m/km. Locally, the gradient can be as high as 3.5 m/km, but taken in 30 km increments, the range is from 1.24 to 2.41 m/km. Between the confluence of the San Juan River with Lake Powell and the confluence with Chinle Creek about 20 km downstream of Bluff, UT, the river is canyon-bound and restricted to a single channel. Upstream of Chinle Creek the river is multi-channeled to varying degrees with the highest density of secondary channels occurring between the Hogback Diversion about 13 km east of Shiprock and Bluff, Utah. The reach of river between Navajo Dam and Farmington, NM is relatively stable with predominantly embedded cobble substrate and few secondary channels. Below the confluence with the Animas River, the channel is less stable and more subject to floods from the unregulated Animas River. Between Farmington and Shiprock cobble substrate still dominates, although it is less embedded. Between Shiprock and Bluff the cobble substrate becomes mixed with sand to an increasing degree with distance downstream, resulting in decreasing channel stability.

Except in canyon-bound reaches, nonnative woody plants--salt cedar (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*)–dominate the river’s borders, with native cottonwoods (*Populus fremontii* and *P. angustifolia*) and willows (*Salix amygdaloides* and *S. exiqua*) accounting for less than 15% of the riparian vegetation. With the advent of higher flows in the 1990's there appears to be generation of new stands of cottonwood and willow taking place, although it is still too early to tell if this will represent a significant, let alone permanent, improvement.

Discharge of the San Juan River is typical of rivers in the American Southwest. The characteristic annual pattern is one of large flows during spring snowmelt, followed by low summer, autumn, and winter base flows. Base flows are frequently punctuated by convective storm-induced flow spikes during summer and early autumn. Prior to closure of Navajo Dam about 73% of the total annual discharge (based on USGS Bluff, UT gage) of the drainage occurred during spring runoff (1 March through 31 July). The median daily peak discharge during spring runoff was 10,400 cubic feet per second ({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 in the basin, 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 magnitude and frequency of these storm-induced flow spikes are greater than those seen in the Green or Colorado rivers.

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

Since 1992, Navajo Dam has been operated to mimic a “natural” hydrograph with the volume of release during spring linked to the amount of precipitation 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 during pre-dam years but less than post-dam years.

The primary study area for most studies conducted under the auspices of the San Juan River Seven Year Research Program, including the adult monitoring study, was the mainstem San Juan River and its immediate vicinity between Navajo Dam and Lake Powell. Between Navajo Dam and Shiprock there is considerable human activity within the floodplain of the San Juan River. Irrigated agriculture is practiced throughout this portion of the valley and much of the immediate uplands. Much of the river valley that is 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 valley of the Animas River, the San Juan's largest tributary in the study area, is similarly developed. Downstream of Shiprock to Bluff small portions of the river valley (and uplands) are farmed, however, dispersed livestock grazing is the primary land use. In the vicinity of Montezuma Creek and Aneth, petroleum extraction occurs within the floodplain and the adjacent uplands. Between Bluff and the confluence with Lake Powell, there are few human-caused modifications of the system.

Adult Monitoring Study Area

To enhance comparisons among studies and to provide a common reference for all research, a multivariate analysis of a variety of geomorphic features of the San Juan River drainage was performed to segregate the river into distinct geomorphic reaches. This effort (Bliesner and Lamarra 2000) identified eight geomorphic reaches between Navajo Dam and Lake Powell. However, as is typical of tailwaters below large dams in the Upper Colorado River Basin (UCRB), the river immediately downstream of Navajo Dam (i.e., Reaches 7 and 8) is too clear and cold to support populations of endangered fish (Holden and Wick 1982, Bestgen and Williams 1994, Ryden and Ahlm 1996). These cold waters extend some 44 miles downstream to Farmington, NM. Therefore the adult monitoring study area begins at the Animas-San Juan River confluence in Farmington, NM (river mile {RM} 180.0) and ends 177 RM downstream at Clay Hills Landing, just upstream of Lake Powell. Following is a brief description of each geomorphic reach within the adult monitoring study area.

Reach 6 (RM 180.0 to 155.0, Animas River confluence to below Hogback Diversion, NM) is predominately a single channel, with 50% fewer secondary channels than Reaches 3, 4, or 5. Cobble and gravel substrates dominate, and cobble bars with clean interstitial space are more abundant in this reach than in any other. Backwater habitat abundance is low in this reach, with only Reach 2 having less. The channel has been altered by dike construction in several area to control lateral channel movement and over-bank flow.

Several instream diversion structures, located between Navajo Dam and the Colorado state line, may be impediments to fish passage (Figure 1). Of these diversion structures, the majority (four major and three minor) are located in Reach 6. The four major diversion structures are Fruitland Diversion at RM

178.5, San Juan Generating Station Diversion at RM 166.6, Four Corners Generating Station Diversion at RM 163.3, and Hogback Diversion at RM 158.6. Three minor diversion structures are located at RM 179.3, 178.7, and 166.4.

Reach 5 (RM 155.0 to 131.0, just below Hogback Diversion to the “Mixer”, New Mexico) is predominantly multi-channeled with the largest total wetted area (TWA) and largest secondary channel area of any of the reaches. Secondary channels tend to be longer and more stable than in Reach 3 but fewer in number overall. 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. This is the lowermost reach containing an instream diversion structure (Cudei Diversion), at RM 142.0. Backwaters and spawning bars in this reach are much less subject to perturbation during summer and fall storm events than the lower reaches.

In this section of the river (i.e., the border of Reaches 4 and 5) is an area of the river known as the "Mixer." The Mixer extends from RM 133.4 to RM 129.8. The river channel in these 3.6 miles has been relatively stable over the historic record with little variation in the degree of channel braiding. However, certain areas are locally dynamic. The habitat is complex with numerous channels always present. The locally dynamic areas contribute to this complexity.

Reach 4 (RM 131.0 to 106.0, below the Mixer to Aneth {New Mexico, Colorado, and Utah}) is a transitional reach between the upper cobble-dominated reaches and the lower sand-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 habitat abundance is low overall in this reach (third lowest among reaches) and there is little clean cobble.

Reach 3 (RM 106.0 to 68.0, Aneth to Chinle Creek confluence {UT}) 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. This reach has the second highest density of backwater habitats after spring peak flows, but is extremely vulnerable to change during summer and autumn storm events, after which this reach may have the second lowest density of backwaters. Following spring runoff, debris piles are deposited throughout the active channel in this reach, leading to the nickname “The Debris Fields”.

Reach 2 (RM 68.0 to 17.0, Chinle Creek confluence to near Slickhorn Canyon {UT}) is also canyon bound but is located above the influence of Lake Powell. The gradient in this reach is higher than in either adjacent reach and the fourth highest in the system. The channel is primarily bedrock confined and is influenced by debris fans at ephemeral tributary mouths. Riffle-type habitat dominates, and the major rapids in the San Juan River occur in this reach. Backwater abundance is low in this reach, occurring mostly in association with the debris fans

Reach 1 (RM 17.0 to 0.0, near Slickhorn Canyon to Piute Farms Marina in Lake Powell {UT}) has been heavily influenced by the 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 the reach since the reservoir first filled in 1980. This deposition of suspended sediment into the delta-like environment of the river/reservoir transition has created the lowest-gradient reach in the river. This reach is canyon bound with an active sand substrate. Although there is an abundance of low velocity habitat at certain flows, it is highly ephemeral, being influenced by both river flow and the elevation of Lake Powell.

As Lake Powell filled to capacity, approximately 14 RM of the lower San Juan River was inundated. This enabled fish to travel freely between Lake Powell and riverine habitats (Platania et al. 1991, Ryden and Ahlm 1996). In the late 1980's the water level in Lake Powell receded, leaving the lower 14 miles of river to wander through immense sediment deposits just upstream of the lake. The accumulated sediments greatly decreased the gradient of this reach of the San Juan River. The sediment accumulation also caused the river channel to shift from its historic bed and flow over a sandstone outcrop as it entered Lake Powell, creating a waterfall ($\geq$ 10 meters [m] high at some lake levels) that was impassable by fish. This feature was present for about six years. In spring 1995, lake levels rose high enough to inundate the waterfall, once again allowing unimpeded movement of fish species between Lake Powell and the San Juan River.

CHAPTER 1: ABUNDANCE AND DISTRIBUTION OF SAN JUAN RIVER FISH SPECIES

< Objective 1: Increase abundance and distribution data on the native and nonnative fish community in the San Juan River to examine changes in this assemblage that may be associated with test flows from Navajo Reservoir. Special emphasis was placed on obtaining data on three rare fish species (Colorado pikeminnow, razorback sucker, and roundtail chub).

METHODS

Electrofishing was the primary method used to sample main channel fishes. Summaries of the dates, RM, and flows during adult monitoring trips between 1991-1997 are presented in Table 1 and Figure 2. A variety of electrofishing boats were used on different sampling trips (Table 2), but sampling techniques remained constant among trips. Two types of sampling trips took place during adult monitoring studies, standardized electrofishing trips and rare fish "hunts."

All standardized electrofishing trips had the following sampling protocol. Electrofishing proceeded downstream in a continuous fashion from put-in to take-out. One or two netters stood on an elevated platform above the anodes and collected fish as they were drawn into the electrical field. The raft operator maneuvered the boat via oars, monitored the Variable Voltage Pulsator (VVP), and made adjustments to current, voltage, amperage, frequency, and pulse width when necessary. Rafts were oriented perpendicular to the shoreline with the anode nearest the shoreline. On trips with only two electrofishing rafts, one raft shocked along each shoreline of the river, breaking off into large secondary channels, when they were accessible. When three boats were used, the third boat worked in tandem with one of the shoreline boats. In narrow areas of river, all three boats worked abreast of one another, covering the entire channel. When one of the shoreline boats entered a secondary channel, the third electrofishing boat shocked the main-channel shoreline until the first boat reentered the main channel. The third electrofishing boat would also shock along mid-channel features such as debris piles, cobble bars, and island shorelines where they were present.

The study area was divided into five-mile sections. The first four RM of each section were called non-designated (ND) miles and the fifth mile was called a designated mile (DM). Sampling technique was the same for DM and ND miles. Electrofishing crews began at the upstream end of each mile and collected all the fish they could net as they shocked downstream. All non-rare fish collected in ND miles were enumerated by species and age class. All non-rare fish collected in DM's were weighed in grams (g), measured for total length (TL) and standard length (SL) in millimeters (mm), and had sex and reproductive status noted (if possible to determine). Notes were kept on all visible lesions, parasites, and abnormalities for fish health studies (see Hart and Major 1995, Hart et al. 1996 and 1997 for results). Between May 1991 and October 1996 all fish collected and enumerated were returned alive to the river. Between May 1992 and July 1996, channel catfish and common carp were

Table 1. Summary of dates, in chronological order, and RM sampled on adult fish community monitoring trips in the San Juan River, New Mexico, Colorado, and Utah, 1991-1997.

Sampling Dates	River Miles (RM) Sampled	Number of Electrofishing Rafts	Mean trip flow at Shiprock gage (09368000) in CFS and (cubic meters/second)
1991			
05/05/91-05/15/91	147.9- 53.0	2	3,732 (105.5)
06/06/91-06/13/91	158.6- 76.4	2	2,823 (79.8)
10/15/91-10/24/91	158.6- 76.4	3	621 (17.5)
1992			
05/11/92-05/20/92	180.0- 53.0	3	5,670 (160.3)
06/25/92-07/03/92	158.6- 76.4	3	2,625 (74.2)
10/06/92-10/15/92	158.6- 53.0	3	670 (18.9)
1993			
04/13/93-04/17/93	136.6-119.2	3	5,798 (164.0)
05/11/93-05/14/93	136.6-119.2	2	4,848 (137.1)
07/19/93-07/25/93	180.0-158.6 and 53.0- 2.9	2	817 (23.1)
10/01/93-10/09/93	158.6- 53.0	3	787 (22.3)
1994			
04/12/94-04/15/94	136.6-119.2	3	539 (15.2)
05/10/94-05/18/94	158.6- 53.0	4	4,863 (137.5)
08/10/94-08/12/94	178.5-166.6	2	450 (12.7)
10/02/94-10/11/94	158.6- 53.0	3	1,070 (30.3)
1995			
05/08/95-05/16/95	158.6- 53.0	4	5,694 (161.0)
07/31/95-08/04/95	53.0- 2.9	1	1,646 (46.6)
10/03/95-10/12/95	158.6- 53.0	3	988 (27.9)
1996			
04/16/96-04/19/96	180.0-158.6 and 136.6-119.2	5	439 (12.4)
05/13/96-05/21/96	158.6- 53.0	4	3,171 (89.7)
06/17/96-06/21/96	53.0- 2.9	2	2,710 (76.7)
07/22/96-07/23/96	178.5-158.6	2	442 (12.5)
10/14/96-10/25/96	180.0- 53.0	3	1,040 (29.4)
1997			
04/28/97-05/07/97	180.0- 53.0	3	1,935 (54.7)
07/01/97-07/02/97	180.0-158.6	2	4,740 (134.1)
08/11/97-08/15/97	53.0- 2.9	2	2,276 (64.3)
09/29/97-10/09/97	180.0- 53.0	3	1,491 (42.2)

Table 2. Types of electrofishing boats used during adult fish community monitoring trips on the San Juan River in New Mexico, Colorado, and Utah 1991-1997.

Type	Power	Agency	Number of Positives (Front)	Number of Negatives (Back)	Generator and VVP	Year
18 ft. Havasu raft	25 hp. motor	UDWR Moab, Utah	2 11-inch spheres	multiple cable droppers	Honda 6500 watt generator/ Coffelt VVP-15	1991
18 ft. aluminum jonboat	80 hp. jetshoe motor	USBR Durango, Colorado	2 11-inch spheres	bottom of boat	Honda 6500 watt generator Coffelt VVP-15	1991
16 ft. Avon raft	Oars	BIA/NIIP Farmington, New Mexico	2 9-inch spheres	single cable dropper	Honda 5000 watt generator/ Coffelt VVP-15	1992
14 ft. Avon raft	Oars	NMGF Navajo Dam, New Mexico	1 9-inch sphere	2 "witches brooms" w/ multiple droppers	Smith Root 5.0 GPPW Electrofisher w/ 5000 watt generator	1991-1996
14 ft. Avon raft	Oars	USFWS Dexter and Albuquerque, New Mexico	1 9-inch sphere	1 9-inch sphere	Smith Root 5.0 GPPW Electrofisher w/ 5000 watt generator	1991-1997
16 ft. Avon raft	Oars	USFWS Grand Junction, Colorado	1 11-inch sphere	1 "witches broom" w/ 7 droppers	Honda EB 5000X generator/ Coffelt VVP-15	1991-1997
14 ft. Avon raft	Oars	NMGF Santa Fe, New Mexico	1 9-inch sphere	1 9-inch sphere	Smith Root 5.0 GPPW Electrofisher w/ 5000 watt generator	1994-1997

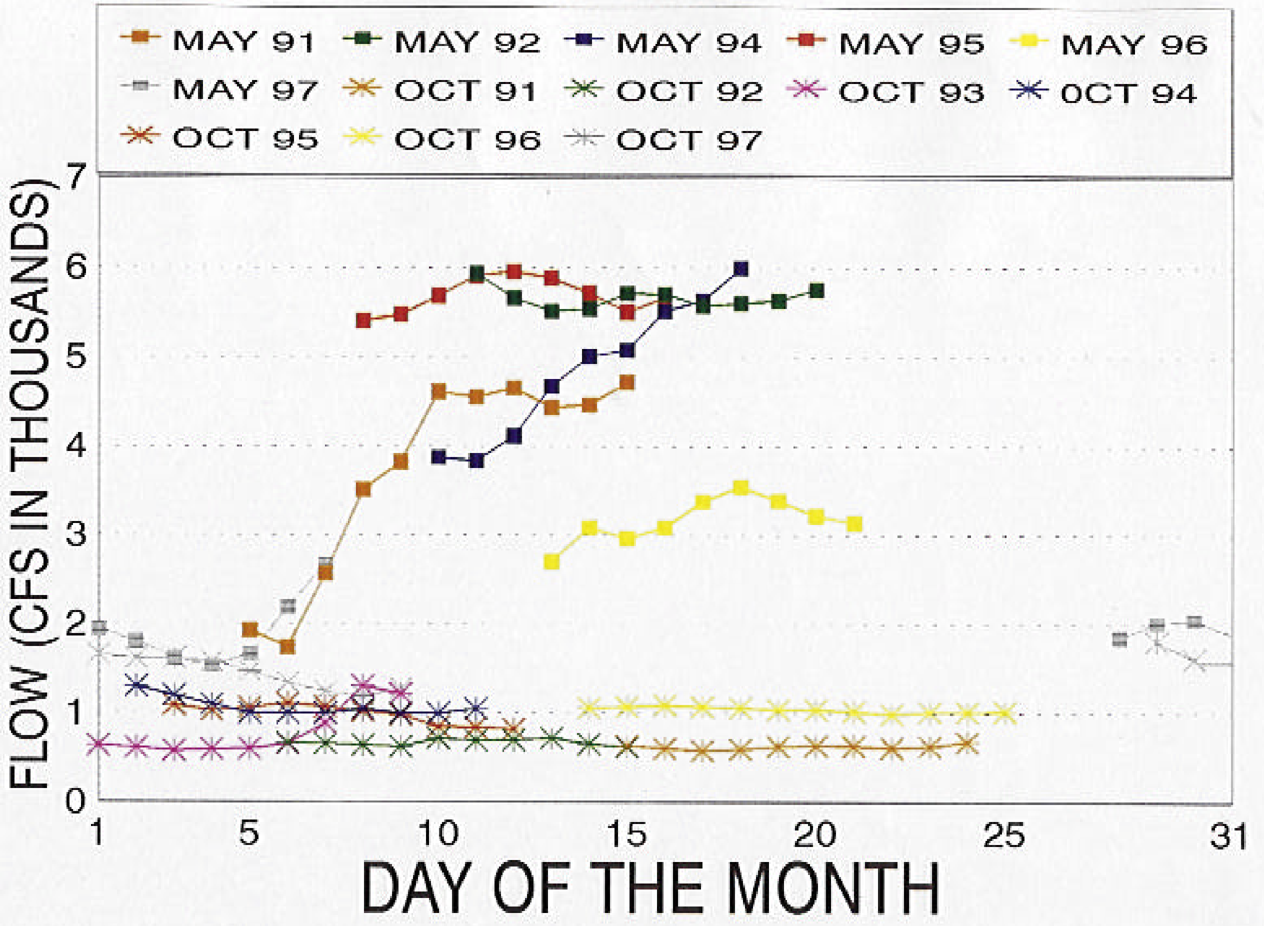


Figure 2. A comparison of flows and day of the month during May and October adult fish community monitoring trips, 1991-1997. Flow data is taken from the Shiprock, New Mexico USGS gage (09368000).

FLOY-tagged before release for another study (see Brooks and Williams 1993, Brooks et al. 1994, Buntjer and Brooks 1995 and 1996, and Brooks et al. 2000 for results). Beginning in October 1996, all nonnative fish species collected on adult monitoring trips were removed from the river, again in support of another study (Brooks et al. 2000). Native fishes continued to be returned alive to the river.

All captured specimens of rare fish (Colorado pikeminnow, razorback sucker, and roundtail chub) were anesthetized using MS-222 (200 mg/L of water), weighed, measured, and PIT-tagged. Large Colorado pikeminnow (> 500 mm TL) were surgically-implanted with radio transmitters ("tags"). In addition, between May 1992 and October 1994, tissue samples were taken from all Colorado pikeminnow larger than 200 mm TL using standardized non-lethal, aseptic techniques. Tissue samples were frozen in liquid nitrogen immediately upon collection and later sent to the appropriate laboratories for genetic or contaminants analysis (Williamson et al. 1997, Simpson and Lusk 1999).

During rare fish hunts, shoreline electrofishing, such as that described above was performed between RM 136.6 and 119.2, however, only rare fish species were collected. The primary purpose of these rare fish hunts was to capture adult rare fish to be surgically-implanted with radio tags for habitat-use and spawning site studies (Miller 1994a and 1995, Ryden and Pfeifer 1995a and 1996a, Ryden and Ahlm 1996). All rare fish collected during rare fish hunts were weighed, measured, and PIT-tagged before radio tag implantation.

Electrofishing data from standardized electrofishing trips were summarized as total (juvenile + adult fish) catch per unit effort (CPUE) per raft. The total number of fish collected by all rafts electrofishing in a given reach combined was divided by the total number of hours (hr) shocked by all rafts in that reach combined to determine the number of fish collected per hr of electrofishing. Frequency of occurrence for each species was based on the number of collections in which a species occurred. A collection was one electrofishing sample (usually one RM of electrofishing) or one trammel net set.

Between 1991 and 1993, only total number of fish by species was recorded on data sheets for ND miles. Relative abundance of various life stages of fish species collected on DM's was then extrapolated to the total catch of a species per reach to determine the relative abundance of young-of-the-year (YOY), juvenile, and adult fish per species collected on 1991 to 1993 standardized electrofishing trips. Beginning in 1994, a new data sheet was used that allowed investigators to quickly categorize fish caught in ND miles into the three basic life stages (YOY, juvenile, and adult) as well. This information in combination with length and weight information obtained on DM's provided a more reliable look at population size-structures. Life stage breakdowns were taken from data sheets used by the USFWS's CRFP office in research done on the Colorado and Gunnison Rivers since the early 1980's. Mean TL was used to determine population size-structure trends for the four most common large-bodied fish species (flannelmouth sucker, bluehead sucker, channel catfish, and common carp) by reach, by trip, and by year.

Although electrofishing cannot accurately sample small species (e.g., red shiner and speckled dace), these fish were included in the analysis of fish community composition because of the relatively high number of specimens collected. Actual numbers of these smaller species in the main channel are without a doubt much higher than indicated in our collection data.

Trammel nets (one-inch mesh) were used on a limited basis during all sampling trips between 1991 and 1997. Because of the need to cover a minimum number of RM each day, trammel nets were set only for short periods in any one area. Nets were set across the mouths of backwaters, low-velocity discharge side channels, or mouths of tributaries (e.g., the Mancos River confluence). After a net was in place, an electrofishing boat or ground personnel started at the top of the backwater or side channel and drove fish to the net by shocking, dragging a second net downstream towards the first net, or walking in and agitating the water. This enabled field crews to quickly sample the backwater and eliminated long-duration net sets. All fish collected in trammel nets were enumerated by species before being returned to (natives) or removed from (nonnatives) the river. Very low numbers of fish were collected in trammel net sets. Because of this, trammel net data were not analyzed as separate data for determining the makeup of the San Juan River fish community. Instead trammel net data were lumped with electrofishing data to determine the total number of fish collected each year (total catch). Trammel net data were not used in CPUE calculations, however.

When the adult monitoring study began in 1991, data was being collected and analyzed using a different set of study reaches (see Ryden and Pfeifer 1993). In 1995, the system of geomorphic reaches was adopted for data analysis by all research elements in the SJRIP in order to make data more readily comparable between studies. However, the RM being sampled on adult monitoring trips remained the same, to allow for comparisons with data from previous years. In other words, May and October sampling trips all took place in the core sampling area (RM 158.6-53.0; Table 1). Thus, sampling on these trips included only the very lowest portion of Reach 6 (RM 158.6-155.0), the entirety of Reaches 5, 4, and 3, and the top 15 RM of Reach 2 (RM 68.0-53.0). This discrepancy in areas of geomorphic reaches sampled tends to complicate data analysis somewhat. Therefore, data in this report is analyzed either by whole geomorphic reaches only (i.e., Reaches 5, 4, and 3 for May and October trips) or more often by common sampled area between trips (i.e., trips from RM 180.0-158.6 {referred to as “Reach 6"}, May and October trips from RM 158.6-53.0 {referred to as the “core sampling area”}, June trips from RM 158.6-76.4 {referred to as “June trips”, and summer trips from RM 53.0-2.9 {referred to as the “lower river”}).

When a section of the river was sampled in more than one time period, or month, over numerous years (e.g., May 1991-1997 and October 1991-1997 trips in the core sampling area), trends in CPUE between trips were often observed that were either ambiguous or, sometimes, directly contrary to one another. In these cases, sampling speeds (i.e., miles fished per hr of electrofishing {mph}) and river flows (CFS) were examined to determine which month would yield the most representative trend information for the four common, large-bodied fish species (flannelmouth sucker, bluehead sucker, channel catfish, and common carp). In order to standardize comparisons between trip flows and CPUE, riverwide, flow data from the Shiprock USGS gage (09368000) was used. Sampling speeds and trip flows were analyzed by generating descriptive statistics and performing a one-way analysis of variance (ANOVA), with a post-hoc Scheffe pairwise multiple comparison test (ANOVA/Scheffe), comparing data between trips in a particular month or season over all years sampled (e.g., October 1991-1997 in the core sampling area) and between months (e.g., May 1991-1997 vs. October 1991-1997 in the core sampling area) for all years combined. Since ANOVA/Scheffe tests on sampling speed and flows were performed on real, known values, the alpha value for determining significance between comparisons was set at $p < 0.05$.

Variations in sampling speeds and flows were then analyzed to determine if they negatively influenced CPUE of the four common large-bodied fish species. A linear regression analysis was performed to determine whether sampling speeds and flows negatively influenced total CPUE of the four common large-bodied fish species in common sampled areas of the river between months. Since CPUE data represented only a sample of a population and not a known number (i.e., population parameter), the alpha value for determining significance between comparisons was set at $p < 0.10$. This higher alpha value was used in order to help avoid making a Type II Error (i.e., failing to statistically detect a change in CPUE values when there was indeed a change).

Data from all fish collected were partitioned by species and, where appropriate, by life stage (young-of-the-year {YOY}, juvenile, and adult), and analyzed by common sampled areas or whole geomorphic reaches. CPUE was calculated for the four common large-bodied fishes and compared by whole geomorphic reaches or common sampled areas between years within the same month and between months across all years. For all analyses on CPUE data, non-normally distributed data sets were first analyzed using nonparametric Kruskal-Wallis (for relationships between three or more data points) or Mann-Whitney U tests (for relationships between two data points) to determine if statistically significant differences in values existed between years. Again, since CPUE data represented a sample of a population and not a known number (i.e., population parameter), significance was determined at $p < 0.10$. If statistically significant differences between years were detected, CPUE data was ranked (to obtain a more normal distribution) and analyzed using an ANOVA/Scheffe, to identify which years were statistically different from one another. If CPUE data was normally distributed, an ANOVA/Scheffe, was performed on the unranked data.

In order to help detect more long-term trends in relative abundance of the four common, large-bodied fish species, CPUE from our study was compared to that reported from DM’s by Platania (1990). Unfortunately, discrepancies existed in areas sampled and sampling methods both between our study and Platania’s study and between the Utah and New Mexico portions of the San Juan River in Platania’s study (see Platania 1990 for discussion). Due to these discrepancies, CPUE for these four fish species between the two studies was only comparable in the section of the river between Shiprock (RM 147.9) and Four Corners (RM 119.2) bridges on October trips.

Lengths and weights obtained from fish measured at DM’s were used to examine changes in mean TL, total and mean biomass (weight {WT} in g or kg), and condition factor ($\{K\} = [WT\ (\text{in g}) \times 10^5]/[TL\ (\text{in mm})]^3$) for the four most common large-bodied fish species by geomorphic reach and year. As with flow data, since TL and WT were both known (i.e., set) values the alpha value for determining significance between comparisons was set at $p < 0.05$. Therefore, differences between years in a given month and between months, all years combined, were tested for using an ANOVA/Scheffe, to identify where significant differences were present. However, like CPUE data, since the values for TL and WT were being extrapolated to represent an entire population in which unknown values existed, significance level was set at $p < 0.10$.

Independent analyses of adult monitoring data sets by Keith Lawrence (Ecosystems Research Institute, Logan, UT) and Mike Buntjer (USFWS, Albuquerque, NM) examined the relationship of CPUE and K of flannelmouth sucker, bluehead sucker, channel catfish, and common carp to test flows from Navajo Reservoir between 1991 and 1997 (Lawrence 1999). These analyses were only performed for fish collected in the core sampling area (RM 158.6-53.0) on May and October trips. Lawrence analyzed data for flannelmouth sucker and bluehead sucker, while Buntjer analyzed data for channel catfish and common carp.

Lawrence performed linear regression analyses to determine the influence of flows on total CPUE for flannelmouth sucker and bluehead sucker in the core sampling area on May and October trips. When significant negative flow effects were detected, Lawrence performed an analysis of covariance (ANCOVA) to determine whether there were actual differences between annual flannelmouth sucker and bluehead sucker CPUE values considering the negative linear relationships between flow and CPUE. Lawrence also compared average juvenile and adult condition factor for flannelmouth sucker and bluehead sucker collected in DM’s to flows to look for trends in condition factor correlated to river flows. Buntjer calculated Pearson correlation coefficients to determine the effect of flows on total CPUE for channel catfish and common carp in the core sampling area on May and October trips. Buntjer looked for trends between average adult channel catfish and common carp condition factor and the number of YOY channel catfish and common carp in main and secondary channel seining collections that same fall.

RESULTS

Overview

A total of 23 standardized electrofishing trips were performed between 1991 and 1997 (Table 1). During these trips Reach 6 (RM 180.0-158.6) was sampled 8 times, the core sampling area (RM 158.6-53.0) was sampled 13 times, a subsection of the core sampling area (RM 158.6-76.4) was sampled twice on June trips, and the lower river (RM 53.0-2.9), was sampled 4 times, always during summer months (Table 1). The June sampling trips (RM 158.6-76.4) were discontinued after 1992, due to concerns that electrofishing might adversely effect Colorado pikeminnow spawning activities in this area of the river.

Unless otherwise stated, the following analyses represent only data collected on standardized electrofishing trips and refers to total (juvenile + adult) CPUE data.

Sampling Speed and Flows vs. CPUE

Sampling speeds (in mph) varied not only between months (all trips in a given month combined), but between trips in a given month across years. Trips that sampled Reach 6 took place during three months; May (April and May trips were grouped), July, and October (Table 1). Sampling speeds on May trips were not significantly different from those on July and October trips (Table 3-a). However, sampling speeds for July trips were significantly faster than those for October trips (Tables 3-a, 4). Of the three months sampled, sampling

Table 3-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds, grouped by months across years, in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 5.856, r^2 = 0.038, p = 0.003*

Scheffe matrix:	May	July	October
May	1.000		
July	0.125	1.000	
October	0.228	0.004*	1.000

Table 3-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for May trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 30.099, r^2 = 0.332, p = 0.000*

Scheffe matrix:	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.013*	0.000*	1.000

Table 3-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for July trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 29.363, r^2 = 0.338, p = 0.000*

Scheffe matrix:	1993	1996	1997
1993	1.000		
1996	0.000*	1.000	
1997	0.018*	0.000*	1.000

Table 3-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for October trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7.222, r^2 = 0.116, p = 0.010*

Scheffe matrix:	1996	1997
1996	1.000	
1997	0.010*	1.000

Table 4. Summary statistics for electrofishing trips used in performing one-way ANOVA's and linear regression analyses for determining the effects of sampling speed and flows on CPUE.

					Mean Total CPUE (fish per hour)			
Year	Trip	RM Sampled	Mean MPH	Mean Flow (in CFS) at Shiprock	Catlat	Catdis	Ictpun	Cypcar
'May' Trips, RM 180.0-158.6:								
1992	May	180.0-158.6	3.50	6,030	47.46	22.76	2.40	5.98
1996	April	180.0-158.6	2.46	576	64.01	63.72	2.81	28.23
1997	May	180.0-158.6	3.07	1,850	57.15	59.04	10.68	19.18
July Trips, RM 180.0-158.6:								
1993	July	180.0-158.6	3.22	999	67.29	35.32	0.78	17.96
1996	July	180.0-158.6	2.53	442	83.27	42.40	6.06	11.54
1997	July	180.0-158.6	3.63	4,740	104.99	62.65	7.90	10.08
October Trips, RM 180.0-158.6:								
1996	Oct.	180.0-158.6	2.54	1,065	108.40	80.15	25.85	17.25
1997	Oct.	180.0-158.6	2.90	1,810	98.00	114.45	5.27	15.90
May Trips, RM 158.6-53.0:								
1991	May	147.9-53.0	3.35	3,732	64.03	10.06	12.17	18.30
1992	May	158.6-53.0	3.56	5,670	89.18	15.97	11.76	8.22
1994	May	158.6-53.0	3.22	4,863	95.60	8.07	5.88	4.01
1995	May	158.6-53.0	3.28	5,694	64.15	5.54	9.74	5.43
1996	May	158.6-53.0	2.77	3,171	86.93	12.79	12.14	13.69
1997	May	158.6-53.0	2.63	1,935	45.45	9.56	26.83	23.96
October Trips, RM 158.6-53.0:								
1991	Oct.	158.6-76.4	2.57	621	125.10	23.82	23.84	19.79
1992	Oct.	158.6-53.0	2.44	670	154.18	28.46	39.58	13.77
1993	Oct.	158.6-53.0	2.70	787	93.14	18.43	12.34	9.48
1994	Oct.	158.6-53.0	2.38	1,070	95.14	13.88	16.54	6.01
1995	Oct.	158.6-53.0	2.39	988	83.99	16.25	26.60	11.28
1996	Oct.	158.6-53.0	2.50	1,040	66.63	12.05	30.29	18.91
1997	Oct.	158.6-53.0	2.64	1,491	54.31	11.86	22.84	14.62
June Trips, RM 158.6-76.4:								
1991	June	158.6-76.4	2.63	2,824	86.12	18.38	14.70	28.39
1992	June	158.6-76.4	2.55	2,656	146.03	35.19	18.67	15.90
Summer Trips, RM 53.0-2.9:								
1993	July	53.0-2.9	2.32	744	36.50	0.82	4.39	1.94
1995	Aug.	53.0-2.9	2.22	1,630	44.92	2.16	31.24	14.60
1996	June	53.0-2.9	2.54	2,710	42.27	0.79	17.27	4.45
1997	Aug.	53.0-2.9	2.48	2,276	19.34	0.58	2.65	6.18

speeds on October trips were the least variable, followed by July, then May. The mean sampling speed on October trips was 2.75 mph (standard error {SE} = 0.069, coefficient of variation {CV} = 0.190), for July the mean was 3.134 mph (SE = 0.072, CV = 0.248), and for May the mean was 2.95 mph (SE = 0.067, CV = 0.252). When sampling speeds on trips in Reach 6 were compared across years within a given month (e.g., May 1993, 1996, and 1997) differences in sampling speeds were significantly different in all cases (Tables 3-b - 3-d).

Trips that sampled the core sampling area took place in May (1991-1992 and 1994-1997) and October (1991-1997). Sampling speeds on May trips in the core sampling area were significantly faster than those on October trips (Tables 4, 5-a, Figure 3). Sampling speeds on October trips in the core sampling area were also less variable than on than on May trips in this river section (Figure 3). The mean sampling speed on October trips was 2.52 mph (SE = 0.012, CV = 0.209) while the mean sampling speed for May trips was 2.94 mph (SE = 0.022, CV = 0.294). Sampling speeds for May and October trips, when compared across years, were both highly variable. Significant differences were present in 10 of 15 (66.7 % of) comparisons for May sampling speeds between years (Table 5-b). Fewer significant differences, 10 of 21 (47.6%), were present in comparisons for October sampling speeds between years (Table 5-c).

Sampling speeds on June trips were not significantly different between the two years (Table 6-a). Mean sampling speed on June trips was 2.57 mph (SE = 0.053, CV = 0.360).

Significant differences in sampling speeds existed in half of the comparisons for summer trips between years, with 1996 being the most unlike (i.e., faster than) other years (Tables 4, 7-a). Mean sampling speed on summer trips was 2.41 mph (SE = 0.027, CV = 0.211).

Linear regression analysis indicated a negative influence of sampling speed on CPUE for all four common large-bodied fish species. In other words, the faster the sampling speed, the less fish were caught. These negative correlations were evident in 13 of 20 (65.0%) relationships examined (Table 8). These 13 negative correlations were divided almost equally among species -- three each for flannelmouth sucker, bluehead sucker, and channel catfish and four for common carp (Table 8). However, none of the 13 negative correlations for sampling speed versus CPUE were statistically significant (Table 8).

Unlike sampling speeds, no significant differences were found in trip flows between months (Table 9-a). Of the three months sampled, flows on October trips were the least variable, followed by May, then July. The mean flow on October trips was 1,313 CFS (SE = 248.350, CV = 0.328), for May the mean was 2,819 CFS (SE = 1647.247, CV = 1.012), and for July the mean was 2,060 CFS (SE = 855.308, CV = 1.017). When trip flows in Reach 6 were compared across years within a given month (e.g., May 1993, 1996, and 1997) significant different were present in less than half of the comparisons (Tables 9-b - 9-d). May trips in Reach 6 showed no significant differences in flows between any of the three years (Table 9-b).

May trip flows in the core sampling area were significantly higher than those on October trips (Tables 4, 10-a, Figure 2). October trip flows in the core sampling area were also less variable than on May trips (Figure 2). The mean flow on October trips CFS (SE = 36.625, CV = 0.322) while mean May flow was 4,149 CFS (SE = 197.296, CV = 0.362). Trip flows for both May and October, when compared between years, were highly variable. Significant

Table 5-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds, grouped by months across years, in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 651.596, r^2 = 0.149, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 5-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 48.282, r^2 = 0.123, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.200	1.000				
1994	0.948	0.000*	1.000			
1995	0.990	0.001*	0.999	1.000		
1996	0.000*	0.000*	0.000*	0.000*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.925	1.000

Table 5-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 18.590, r^2 = 0.053, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.320	1.000					
1993	0.186	0.000*	1.000				
1994	0.007*	0.913	0.000*	1.000			
1995	0.013*	0.960	0.000*	1.000	1.000		
1996	0.918	0.927	0.001*	0.175	0.262	1.000	
1997	0.536	0.000*	0.996	0.000*	0.000*	0.018*	1.000

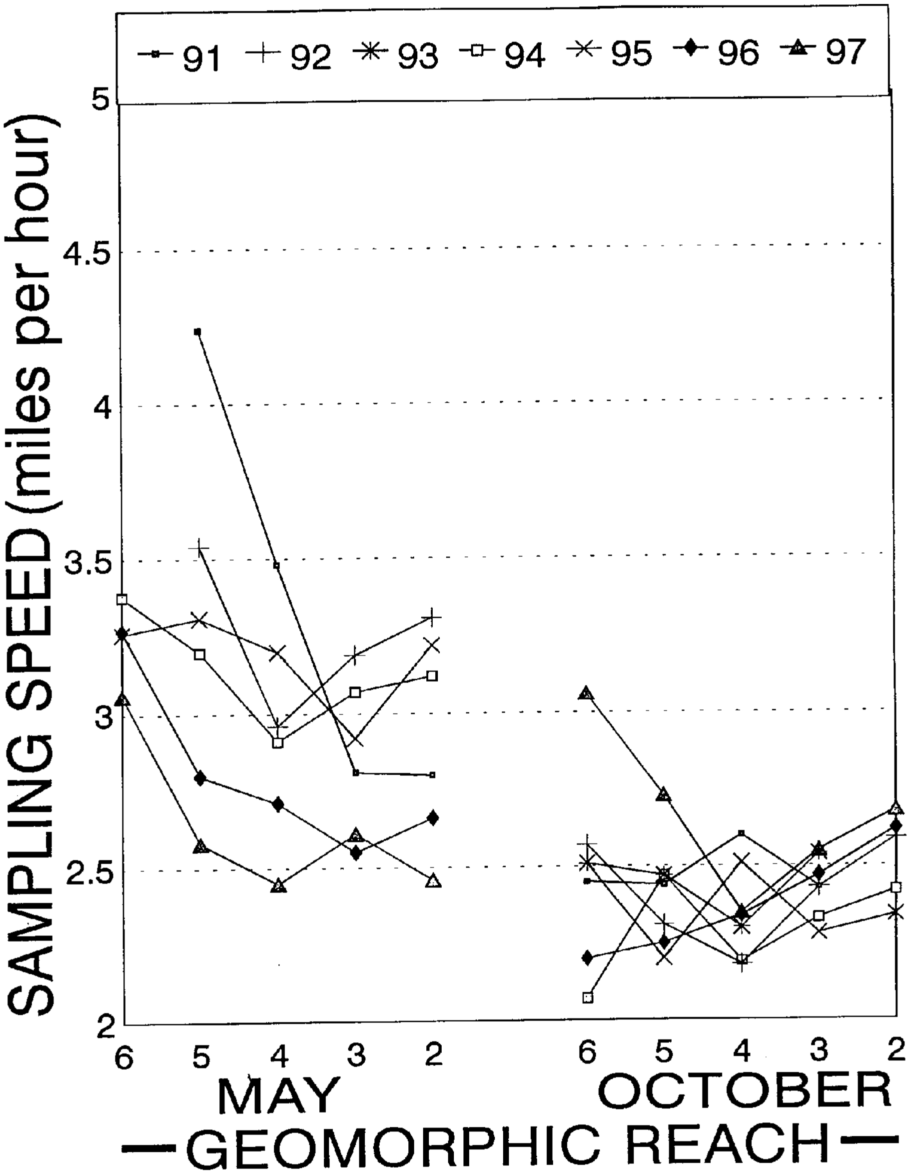


Figure 3. Comparison of sampling speeds in miles per hour by geomorphic reach between May and October adult fish community monitoring trips, 1991-1997.

Table 6-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for June sampling trips, RM 158.6-76.4 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.504, r^2 = 0.002, p = 0.478

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.478	1.000

Table 6-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for June sampling trips, RM 158.6-76.4 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.670, r^2 = 0.043, p = 0.426

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.426	1.000

Table 7-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling speeds for summer sampling trips, RM 53.0-2.9 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 6.681, r^2 = 0.054, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.747	1.000		
1996	0.017*	0.003*	1.000	
1997	0.136	0.027*	0.867	1.000

Table 7-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for summer sampling trips, RM 53.0-2.9 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 96.036, r^2 = 0.947, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.000*	0.000*	1.000	
1997	0.000*	0.001*	0.024*	1.000

Table 8. Pearson correlation coefficients (r-values) and significance values (p-values) obtained by performing linear regression analyses of CPUE (fish per hour of electrofishing) of the four common large-bodied fish species against mean flow (CFS) and mean sampling speed (miles per hour {MPH}) in commonly sampled areas of the San Juan River across years.

Species	Is CPUE negatively correlated with...		Is relationship statistically significant?		r-values		p-values	
	Flow	MPH	Flow	MPH	Flow	MPH	Flow	MPH
April/May Trips (RM 180.0-158.6); 1992, 1996, 1997:								
Catlat	Yes	Yes	No	No	-0.980	-0.980	0.127	0.126
Catdis	Yes	Yes	Yes	No	-0.993	-0.868	0.077	0.330
Ictpun	Yes	No	No	No	-0.336	0.056	0.782	0.965
Cypcar	Yes	Yes	No	No	-0.982	-0.979	0.122	0.132
July Trips (RM 180.0-158.6); 1993, 1996, 1997:								
Catlat	No	No	No	No	0.848	0.446	0.335	0.706
Catdis	No	No	No	No	0.932	0.604	0.237	0.587
Ictpun	No	No	No	No	0.610	0.105	0.583	0.993
Cypcar	Yes	Yes	No	No	-0.547	-0.029	0.631	0.981

* NOTE: No statistical tests could be done for RM 180.0-158.6 on October trips because there were only two data points (1996 and 1997).

May Trips (RM 158.6-53.0); 1991-1992, 1994-1997:								
Catlat	No	No	No	No	0.537	0.415	0.272	0.413
Catdis	Yes	No	No	No	-0.037	0.144	0.944	0.785
Ictpun	Yes	Yes	Yes	No	-0.774	-0.659	0.071	0.154
Cypcar	Yes	Yes	Yes	No	-0.893	-0.608	0.017	0.200
October Trips (RM 158.6-53.0); 1991-1997:								
Catlat	Yes	Yes	Yes	No	-0.841	-0.254	0.018	0.583
Catdis	Yes	Yes	Yes	No	-0.834	-0.061	0.020	0.897
Ictpun	Yes	Yes	No	No	-0.206	-0.435	0.658	0.329
Cypcar	Yes	No	No	No	-0.156	0.252	0.738	0.585

* NOTE: No statistical tests could be done for RM 158.6-53.0 on June/July trips because there were only two data points (1991 and 1992).

Summer Trips (RM 53.0-2.9); 1993, 1995-1997:								
Catlat	Yes	Yes	No	No	-0.143	-0.418	0.857	0.582
Catdis	Yes	Yes	No	No	-0.222	-0.799	0.778	0.201
Ictpun	No	Yes	No	No	0.141	-0.478	0.859	0.522
Cypcar	No	Yes	No	No	0.098	-0.578	0.902	0.422

Table 9-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows, grouped by months across years, in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.396, $r^2 = 0.081$, $p = 0.684$

Scheffe matrix:

	May	July	October
May	1.000		
July	0.876	1.000	
October	0.684	0.880	1.000

Table 9-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for May trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 206.177, $r^2 = 0.998$, $p = 0.050$

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.054	1.000	
1997	0.071	0.251	1.000

Table 9-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for July trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 347.005, $r^2 = 0.996$, $p = 0.000$*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.113	1.000	
1997	0.001*	0.000*	1.000

Table 9-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for October trips in Reach 6, RM 180.0-158.6 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7400.333, $r^2 = 1.000$, $p = 0.007$*

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.007*	1.000

Table 10-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows, grouped by months across years, in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 307.687, $r^2 = 0.706$, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 10-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 56.738, $r^2 = 0.845$, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.000*	1.000				
1994	0.012*	0.175	1.000			
1995	0.000*	1.000	0.170	1.000		
1996	0.546	0.000*	0.000*	0.000*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.005*	1.000

Table 10-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of sampling flows for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.05$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 46.744, $r^2 = 0.812$, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.996	1.000					
1993	0.374	0.771	1.000				
1994	0.000*	0.000*	0.008*	1.000			
1995	0.000*	0.001*	0.161	0.940	1.000		
1996	0.000*	0.000*	0.019*	1.000	0.993	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

differences were present in 11 of 15 (73.3 % of) comparisons for May trip flows between years (Table 10-b). In October significant differences were present in a smaller percentage, 14 of 21 (66.7%), of comparisons of trip flows between years (Table 10-c).

No significant difference were present in comparisons for June trip flows between the two years (Table 6-b). Mean flow on June trips was 2,735 CFS (SE = 100.828, CV = 0.152).

On summer trips, significant differences were present in all comparisons between years (Tables 4, 7-b). Mean flow on summer trips was 1,840 CFS (SE = 174.459, CV = 0.424).

Linear regression analysis indicated a negative influence of flows on CPUE for all four common large-bodied fish species. In other words, the higher the flows, the less fish were caught. These negative correlations were evident in 14 of 20 (70.0%) relationships examined (Table 8). These 14 negative correlations were divided almost equally among species -- three comparisons each for flannelmouth sucker and channel catfish, and four comparisons each for bluehead sucker and common carp (Table 8). Of the 14 negative correlations for flows versus CPUE, five (35.7%) were statistically significant. Three of these five significant negative correlations between flows and CPUE were with native fishes, including significant negative influences of flow on flannelmouth sucker ($r = -0.841$, $p = 0.018$) and bluehead sucker ($r = -0.834$, $p = 0.020$) CPUE on October trips in the core sampling area (RM 158.6-53.0) and bluehead sucker ($r = -0.993$, $p = 0.077$) CPUE in Reach 6 on May trips (Table 8). The other two significant negative correlations between flows and CPUE were with nonnative fishes, including significant negative influences of flow on channel catfish ($r = -0.774$, $p = 0.071$) and common carp ($r = -0.893$, $p = 0.017$) CPUE on May trips in the core sampling area (Table 8).

These findings agree with linear regression analysis results obtained by Lawrence (1999) that identified a significant negative influence of flows (using Four Corners gage data) on both flannelmouth sucker ($r = -0.84$, $p = 0.004$) and bluehead sucker ($r = -0.79$, $p = 0.011$) CPUE on October trips in the core sampling area (Lawrence 1999). Likewise, Pearson correlation coefficients calculated by Buntjer also noted a significant negative influence of flows (using Four Corners gage data) on both channel catfish ($r = -0.74$, $p = 0.09$) and common carp ($r = -0.94$, $p = 0.009$) CPUE on May trips in the core sampling area (Buntjer 1999).

Abundance, Distribution, and Relation to Flows

Between 1991 and 1997 a total of 242,163 fish representing seven orders, ten families, 26 species, and three hybrids were collected (Tables 11 and 12). Table 11 also denotes the six-letter codes used to represent these species in all graphs, tables, and charts in this report. Of the 26 species collected, 7 were native and 19 were nonnative (Table 11). The three hybrids collected included one native X native sucker hybrid (flannelmouth X bluehead sucker) and two nonnative X native sucker hybrids (flannelmouth X white sucker and bluehead X white sucker). Six species accounted for 99.0% of the total catch (Table 12). Three of these species were native (flannelmouth sucker, bluehead sucker, and speckled dace) and three were nonnative (channel catfish, common carp, and red shiner; Table 12, Figure 4).

Table 11. Scientific and common names, status, and six-letter codes for fish species collected during adult fish community monitoring (electrofishing) trips in the San Juan River, New Mexico, Colorado, and Utah, 1991-1997 (following Robins et al. 1991 and Nelson et al. 1998[a]).

SCIENTIFIC NAME	COMMON NAME	STATUS	CODE
Class Osteichthyes-Bony Fishes			
Order Atheriniformes			
Family Cyprinodontidae-killifishes			
Fundulus zebrinus	plains killifish	introduced	Funzeb
Order Clupeiformes			
Family Clupeidae-herrings			
Dorosoma petenense	threadfin shad	introduced	Dorpet
Order Cypriniformes			
Family Catostomidae-suckers			
Catostomus commersoni	white sucker	introduced	Catcom
Catostomus discobolus	bluehead sucker	native	Catdis
Catostomus latipinnis	flannelmouth sucker	native	Catlat
C.commersoni X *C.discobolus*	hybrid	introduced	comXdis
C.commersoni X *C.latipinnis*	hybrid	introduced	comXlat
C.latipinnis X *C.discobolus*	hybrid	native	latXdis
Xyrauchen texanus	razorback sucker	native	Xyrtex
Family Cyprinidae-carps and minnows			
Ctenopharyngodon idella	grass carp	introduced	Cteide
Cyprinella lutrensis	red shiner	introduced	Cyplut
Cyprinus carpio	common carp	introduced	Cypcar
Gila robusta	roundtail chub	native	Gilrob
Pimephales promelas	fathead minnow	introduced	Pimpro
Ptychocheilus lucius	Colorado pikeminnow[a]	native	Ptyluc
Rhinichthys osculus	speckled dace	native	Rhiosc
Order Perciformes			
Family Centrarchidae-sunfishes			
Lepomis cyanellus	green sunfish	introduced	Lepcya
Lepomis macrochirus	bluegill	introduced	Lepmac
Micropterus dolomieui	smallmouth bass	introduced	Micdol
Micropterus salmoides	largemouth bass	introduced	Micsal
Pomoxis annularis	white crappie	introduced	Pomann
Family Percichthyidae-temperate basses			
Morone saxatilis	striped bass	introduced	Morsax
Family Percidae-perches			
Stizostedion vitreum	walleye	introduced	Stivit
Order Salmoniformes			
Family Salmonidae-trouts			
Oncorhynchus mykiss	rainbow trout	introduced	Oncmyk
Salmo trutta	brown trout	introduced	Saltru
Order Scorpaeniformes			
Family Cottidae-sculpins			
Cottus bairdi	mottled sculpin	native	Cotbai
Order Siluriformes			
Family Ictaluridae-bullhead catfishes			
Ameiurus natalis	yellow bullhead	introduced	Amenat
Ameiurus melas	black bullhead	introduced	Amemel
Ictalurus punctatus	channel catfish	introduced	Ictpun

Table 12. Total number of fish collected in standardized electrofishing collections, 1991-1997.

Species(Status)	Total number of specimens 91-97	Percent of total 91-97	Rank 91-97	Frequency of occurrence 91-97	Collection RM[b] Most Upstream	Collection RM[b] Most Downstream
flannelmouth sucker(N)	143,741	59.4	1	4,475	179.0	2.9
channel catfish(I)	31,610	13.1	2	3,690	177.2	3.0
bluehead sucker(N)	29,388	12.1	3	3,580	179.0	17.0
common carp(I)	22,246	9.2	4	3,491	179.0	2.9
speckled dace(N)	8,808	3.6	5	2,221	178.3	13.0
red shiner(I)	4,006	1.7	6	1,171	163.0	2.9
fathead minnow(I)	709	0.3	7	272	176.0	5.0
threadfin shad (I)	452	0.2	8	25	20.0	2.9
bluehead X flannelmouth(H)	305	0.1	9	260	179.0	19.0
brown trout(I)	204	---[a]	10	145	178.3	59.0
mottled sculpin(N)	145	---	11	73	178.0	155.0
largemouth bass (I)	83	---	12	69	177.3	3.0
walleye (I)	65	---	13	60	108.3	5.0
razorback sucker (N)	63	---	14	59	159.0	37.0
green sunfish(I)	62	---	15	51	176.0	4.0
Colorado pikeminnow (N)	58	---	16	49	178.0	7.9
striped bass (I)	51	---	17	36	91.2	2.9
rainbow trout(I)	47	---	18	44	179.0	96.0
black bullhead(I)	39	---	19	33	176.0	15.0
roundtail chub(N)	22	---	20	22	177.3	78.0
smallmouth bass(I)	19	---	21	18	169.0	54.0
white sucker X flannelmouth(H)	11	---	22	9	177.2	138.0
white sucker(I)	10	---	23	10	175.0	96.0
white sucker X bluehead(H)	7	---	24	7	178.0	155.0
yellow bullhead(I)	4	---	25	4	158.0	107.0
white crappie(I)	3	---	26	2	171.0	170.0
bluegill(I)	3	---	26	3	164.0	141.0
plains killifish(I)	1	---	27	1	96.0	96.0
grass carp(I)	1	---	27	1	104.0	104.0
TOTAL	242,163		91-97 Native = 75.4% 91-97 Introduced = 24.6%		91-97 = 4606 collections	

[a] = less than 0.1%

[b] = These collection RM's are for our study only, many of these species occur farther up- and/or downstream

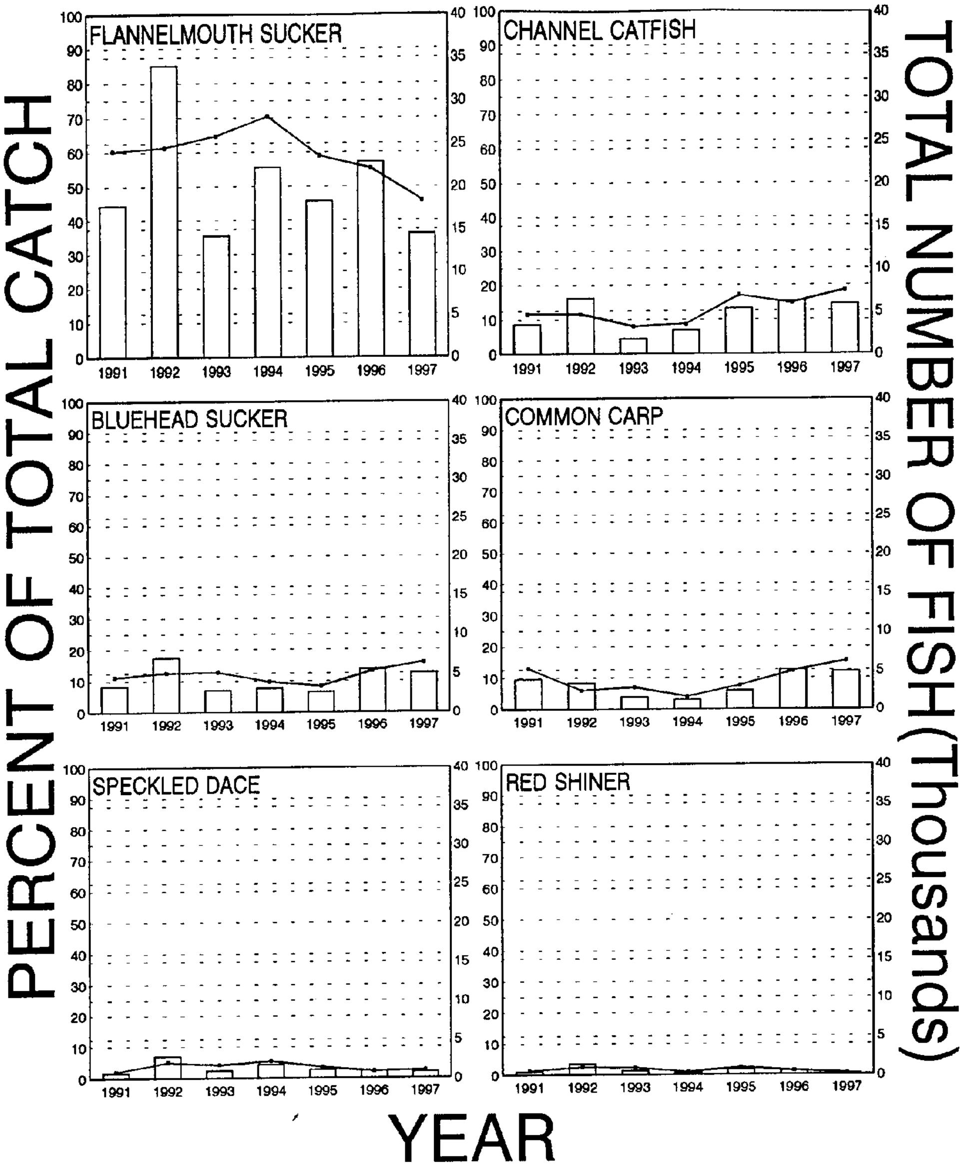


Figure 4. Percent of total catch (lines) and total number of fish, in thousands (bars), represented by each of the six most abundant fish species collected on adult fish community monitoring trips in the San Juan River, 1991-1997, all trips in a year combined.

Native Species

The eight native forms composed 75.4% of the total catch (182,530 individuals). The most abundant native species was flannelmouth sucker (n = 143,741, 59.4% of the total catch), followed by bluehead sucker (n = 29,388, 12.1%), speckled dace (n = 8,808, 3.6%), flannelmouth X bluehead hybrids (n = 305, 0.1%), mottled sculpin (n = 145, < 0.1%), razorback sucker (n = 63, < 0.1%), Colorado pikeminnow (n = 58, < 0.1%), and roundtail chub (n = 22, < 0.1%). Of the 58 Colorado pikeminnow captured, 39 were recaptures of juvenile fish (< 230 mm TL) stocked by the Utah Division of Wildlife Resources (UDWR) in 1996 and 1997 (Archer et al. 2000). All of the 63 razorback sucker were recaptures of fish stocked by the USFWS (1994-1996) in the San Juan River or by the UDWR (1995) at Piute Farms (RM 0.0) in Lake Powell (Ryden 2000). Of the eight native forms, only one, the Colorado pikeminnow, is a "top predator" that is an obligate piscivore as an adult. All the remaining native forms are omnivores (Table 13). All native forms with the exception of the mottled sculpin are soft-rayed fishes (Table 13).

Flannelmouth Sucker

During our sampling, flannelmouth sucker were ubiquitous, occurring in 97.2% of all collections between 1991 and 1997 (Table 12). Flannelmouth sucker was the most abundant species collected in every year of this study (Figures 4; Ryden and Pfeifer 1993, 1994a, 1995a, and 1996a).

---Reach 6 (RM 180.0-158.6)---

Comparisons of total flannelmouth sucker CPUE by month, grouped across years, in Reach 6 revealed significant differences between months (Kruskal-Wallis statistic = 58.738, p = 0.000). An ANOVA/Scheffe done on ranked CPUE data showed significantly more flannelmouth sucker being collected on October trips than on either July or May trips (Table 14-a, Figure 5). Flannelmouth sucker CPUE was also significantly higher on July trips than on May trips (Table 14-a). Comparisons by month, across years, showed an increasing trend in total flannelmouth sucker CPUE between 1992 and 1997 on May trips and between 1993 and 1997 on July trips (Figure 5). This increasing trend was not statistically significant for May trip data (Kruskal-Wallis statistic = 3.052, p = 0.217), with an ANOVA/Scheffe showing no significant differences between any of the three years (Table 14-b). The upward trend was statistically significant for July trips (Kruskal-Wallis statistic = 12.462, p = 0.002), however. An ANOVA/Scheffe showed no significant differences between 1993 and 1996 or 1996 and 1997 total CPUE data, but 1997 CPUE was significantly higher than that for 1993 (Table 14-c). The August 1994 trip, while presented in CPUE graphics is not considered in this analysis due to the abbreviated nature of that particular trip (Table 1). This same upward trend in total CPUE was not evident on October electrofishing trips, however, there were only two data points, 1996 and 1997 (Figure 5). Flannelmouth sucker total CPUE in

Table 13. Fin ray type, diet, and trophic level of fish species collected in the San Juan River, 1991-1997.

		Diet[a]						
Species(Status)[b]	Soft- or Spiny-rayed	Detritus	Plants/ Perphyton/ Algae	Plankton/ Micro-organisms	Invertebrates/ Aquatic and Terr. Insects	Fish Eggs/ Fish	Terrestrial Animals	Trophic Level
flannelmouth sucker(N)	soft	yes	yes		yes			omnivore
channel catfish(I)	spiny		yes		yes	yes	yes	omnivore
bluehead sucker(N)	soft	yes	yes	yes	yes			omnivore
common carp(I)	spiny	yes	yes		yes	yes		omnivore
speckled dace(N)	soft	yes	yes		yes			omnivore
red shiner(I)	soft		yes	yes	yes	yes		omnivore
fathead minnow(I)	soft		yes	yes	yes			omnivore
threadfin shad (I)	soft			yes				herbivore
bluehead X flannelmouth(H)[c]	soft	yes	yes	yes	yes			omnivore
brown trout(I)	soft				yes	yes	yes	carnivore
mottled sculpin(N)	spiny				yes	yes		carnivore
largemouth bass (I)	spiny			yes	yes	yes		carnivore
walleye (I)	spiny			yes	yes	yes	yes	omnivore
razorback sucker (N)	soft	yes	yes	yes	yes			omnivore
green sunfish(I)	spiny				yes	yes		carnivore
Colorado pikeminnow (N)	soft				yes	yes	yes	carnivore
striped bass (I)	spiny				yes	yes		carnivore
rainbow trout(I)	soft		yes		yes	yes		omnivore
black bullhead(I)	spiny	yes			yes	yes		carnivore
roundtail chub(	soft		yes		yes	yes		omnivore
smallmouth bass(I)	spiny		yes	yes	yes	yes		carnivore
white sucker X flannelmouth(H)[c]	soft	yes	yes		yes			omnivore
white sucker(I)	soft	yes	yes		yes			omnivore
white sucker X bluehead(H)[c]	soft	yes	yes	yes	yes			omnivore
yellow bullhead(I)	spiny	yes			yes	yes		carnivore
white crappie(I)	spiny				yes	yes		carnivore
bluegill(I)	spiny		yes	yes	yes			omnivore
plains killifish(I)	soft	yes		yes	yes			carnivore
grass carp(I)	spiny	yes	yes		yes			omnivore

[a] Sources for diet information: Beckman 1974, Pflieger 1975, McAda 1977, McGinnis 1984, Tyus and Minckley 1988, Buntjer and Brooks 1996, Utah Division of Wildlife Resources et al. 1999, and D. Ryden unpublished data

[b] N = native, I = introduced, H = hybrid

[c] Diet of these hybrid forms was not drawn from an actual study or reference, but interpolated from the diets of both parent species

Table 14-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 36.362, $r^2 = 0.198$, p = 0.000*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.000*	1.000	
October	0.000*	0.009*	1.000

Table 14-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.745, $r^2 = 0.012$, p = 0.477

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.507	1.000	
1997	0.928	0.714	1.000

Table 14-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7.036, $r^2 = 0.110$, p = 0.001*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.262	1.000	
1997	0.001*	0.124	1.000

Table 14-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.933, $r^2 = 0.017$, p = 0.338

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.338	1.000

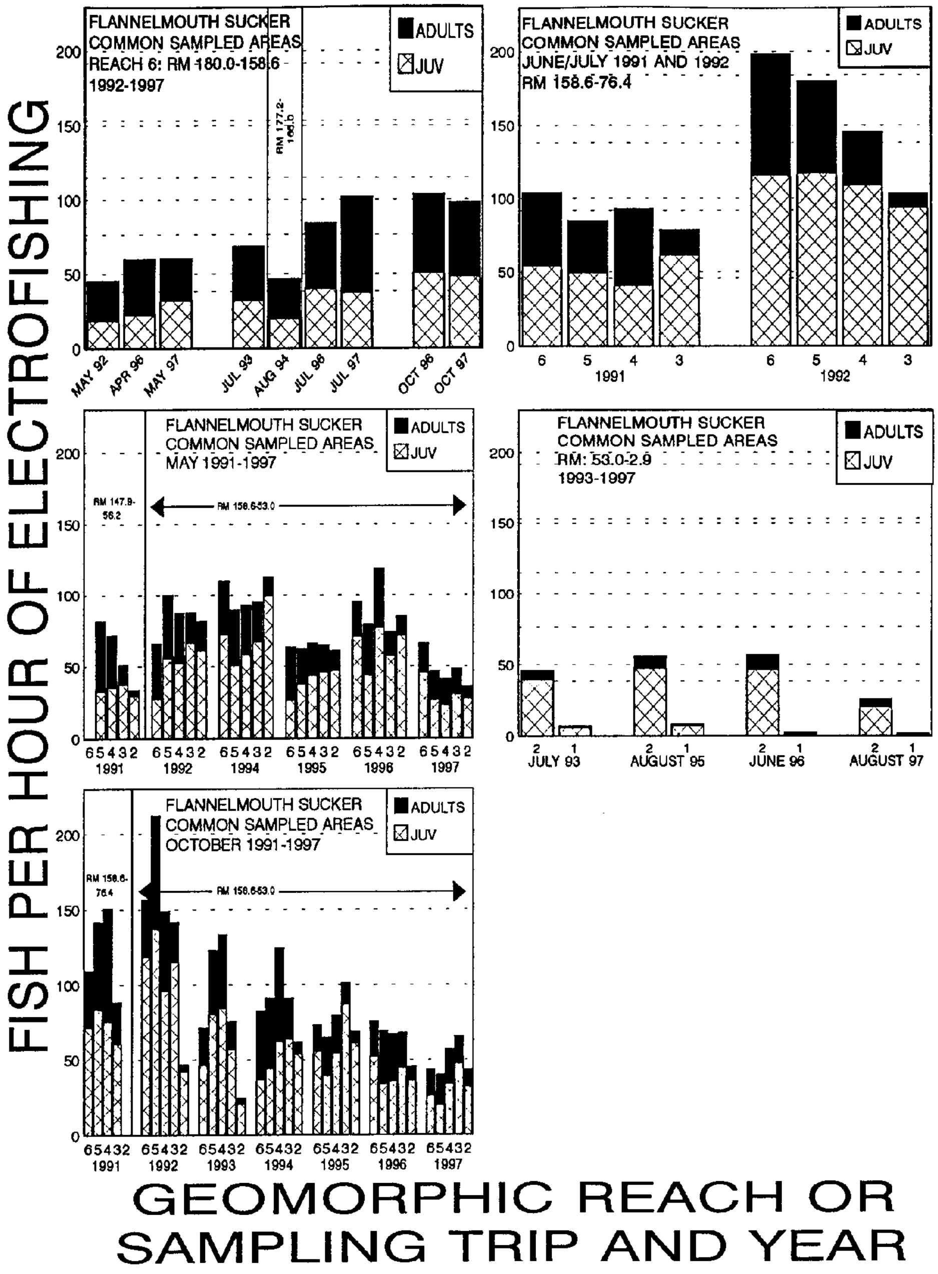


Figure 5. Number of flannelmouth sucker collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

October 1996 and 1997 were not significantly different (Mann-Whitney U test statistic = 464.000, p = 0.272; Table 14-d).

Comparisons of flannelmouth sucker mean TL in Reach 6, between months across years, and between years in a given month, via ANOVA/Scheffe, failed to show any clear trends (Table 15-a, Figure 6). Mean TL data grouped by month across years showed that flannelmouth sucker collected on May trips were significantly larger than those collected on July trips (Table 15-a, Figure 6). However, there was no significant difference in mean TL between flannelmouth sucker collected on May versus October or on July versus October trips (Table 15-a, Figure 6). Comparisons of mean TL in May across years indicated that flannelmouth sucker collected in April 1996 were significantly larger than in either May 1992 or May 1997, with no significant difference in mean TL between May 1992 and 1997 (Table 15-b). On July trips flannelmouth sucker mean TL showed significant increases between 1993 and 1997 in all years (Table 15-c). October trips showed a significant drop in flannelmouth sucker mean TL between 1996 and 1997, like that observed for May trips (Tables 15-b, 15-d).

Length-frequency histograms of flannelmouth sucker size classes collected in Reach 6 show that flannelmouth sucker caught in this section of the river were dominantly large juvenile and adult (i.e., > 301 mm TL) fish (Figure 7). Flannelmouth sucker less than age-2 (approximately 176-250 mm TL) were consistently rare in the catch in Reach 6, with the exceptions of May 1992 and July 1993 (Figure 7). Proportionally, fewer large fish were collected on July 1993, due to the capture of large numbers of age-1 (76-100 mm TL) and age-2 (151-200 mm TL) fish (Figure 7). The collection of relatively large numbers of smaller fish in July 1993 compared to July 1996 and 1997 trips and the subsequent recruitment of these fish into the large juvenile (i.e., 301-410 mm TL) and adult (i.e. >410 mm TL) size-classes may account for the significant differences in mean TL observed between July 1992, 1996, and 1997 (Table 15-c, Figure 6). The spike in numbers of young fish (226-275 mm TL) observed in May 1992 represents a fairly strong 1990 cohort while the spikes in age-1 and age-2 fish collected in July 1993 indicate strong 1991 and 1992 cohorts. Almost no flannelmouth sucker less than 200 mm TL were collected on October trips (Figure 7).

Plots of flannelmouth sucker mean biomass in Reach 6 for all life stages combined show increasing trends over time on both May and July trips (Figure 8). Unfortunately, biomass comparisons could not be made for October trips in Reach 6 as no fish were weighed on the October 1996 trip. Comparisons of mean biomass for all life stages combined, between months across years, via ANOVA/Scheffe, showed a significant decline between May and October trips (Table 16-a, Figure 8). Mean biomass was also significantly higher on July trips than it was on October trips, but May and July mean biomass were not significantly different (Table 16-a). Comparisons of mean biomass for all life stages combined in May across years showed a distinct upward trend over time with 1997 being significantly higher than 1992 (Table 16-b, Figure 8). Mean biomass in May 1996, while being intermediate, was not significantly different from either 1992 or 1997 (Table 16-b). On July trips flannelmouth sucker mean biomass also showed a significant increase between 1993 and 1997, with 1997 being higher than both 1993 and 1996, but 1993 and 1996 not being significantly different from one another (Table 16-c).

Plots of flannelmouth sucker mean K in Reach 6 for all life stages combined, juveniles only, and adults only (Figure 9) tracked very closely with

Table 15-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.990, $r^2 = 0.002$, p = 0.050*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.088*	1.000	
October	0.162	0.938	1.000

Table 15-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 15.203, $r^2 = 0.022$, p = 0.000*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.620	0.000*	1.000

Table 15-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 58.512, $r^2 = 0.107$, p = 0.000*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.000*	1.000	
1997	0.000*	0.000*	1.000

Table 15-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 50.378, $r^2 = 0.043$, p = 0.000*

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.000*	1.000

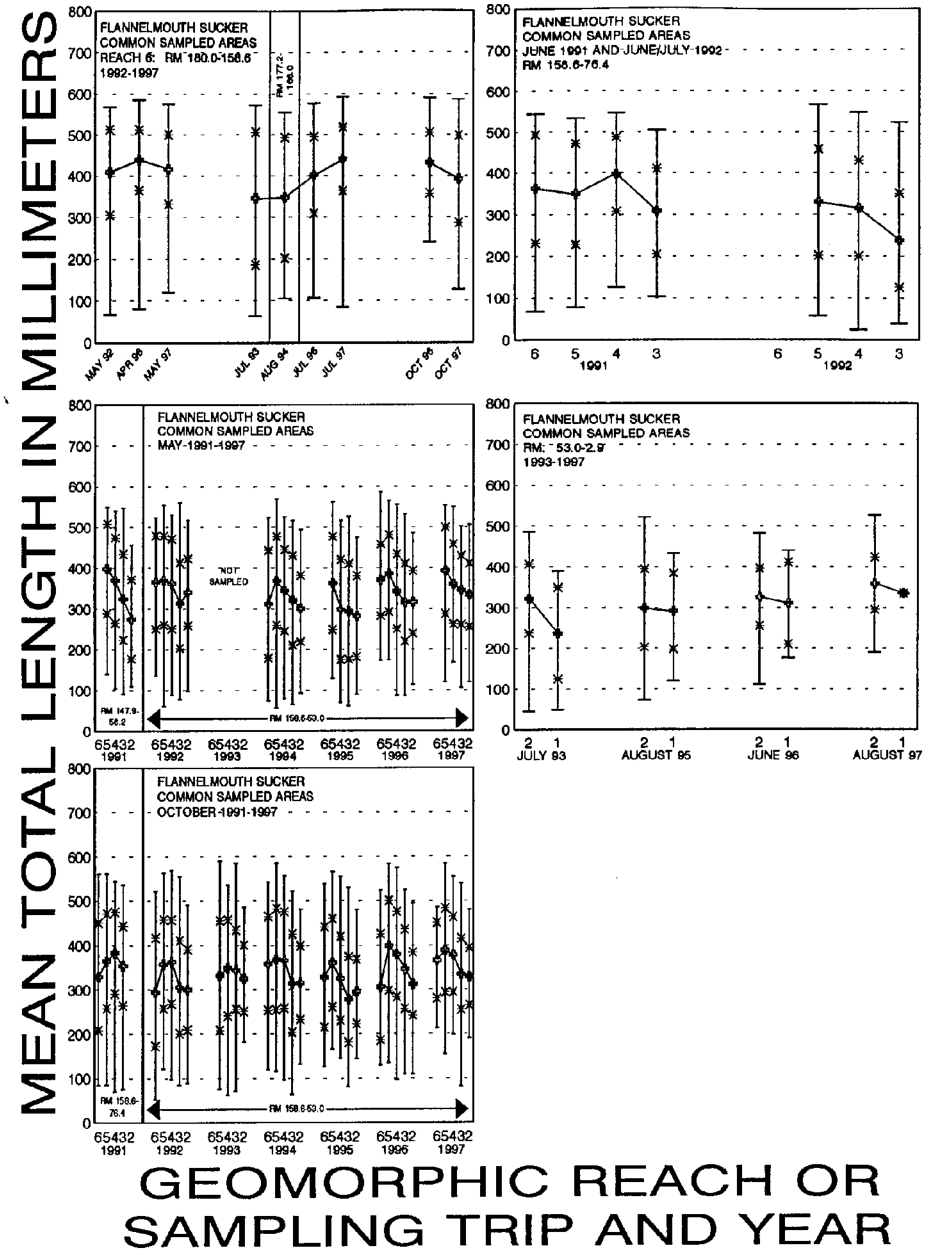


Figure 6. Mean total length (TL) in millimeters for flannelmouth sucker collected on standardized adult fish community monitoring trips, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river. Lines and crosses represent the mean values, error bars represent the range, and asterisks represent the standard deviation.

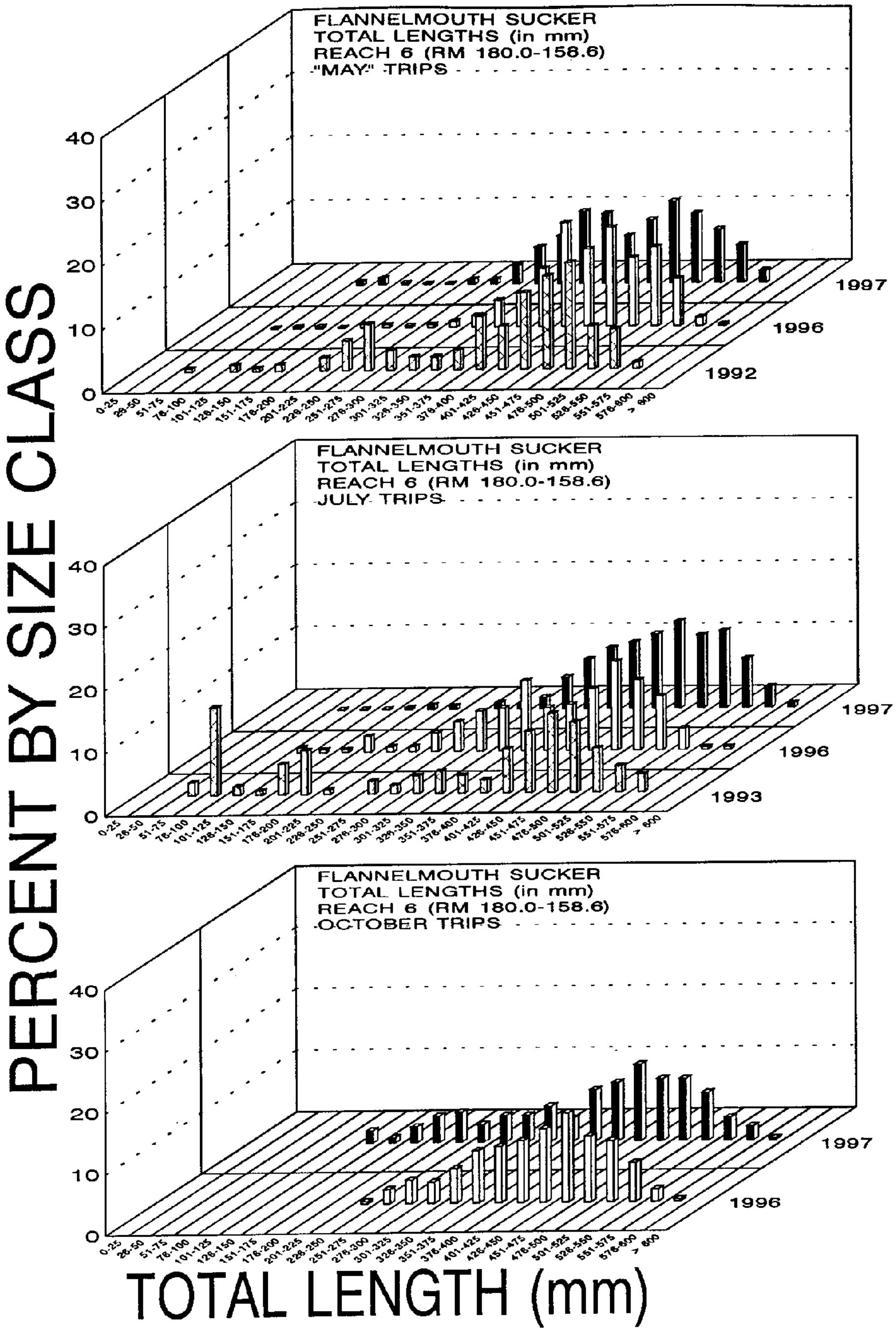


Figure 7. Length-frequency histograms for flannelmouth sucker collected and measured on designated miles during standardized adult fish community monitoring trips in Reach 6 (RM 180.0-158.6), 1992-1997.

Table 16-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 18.321, $r^2 = 0.026$, $p = 0.000$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.948	1.000	
October	0.000*	0.000*	1.000

Table 16-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 8.166, $r^2 = 0.029$, $p = 0.000$*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.056*	1.000	
1997	0.000*	0.204	1.000

Table 16-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 21.232, $r^2 = 0.067$, $p = 0.000$*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.694	1.000	
1997	0.000*	0.000*	1.000

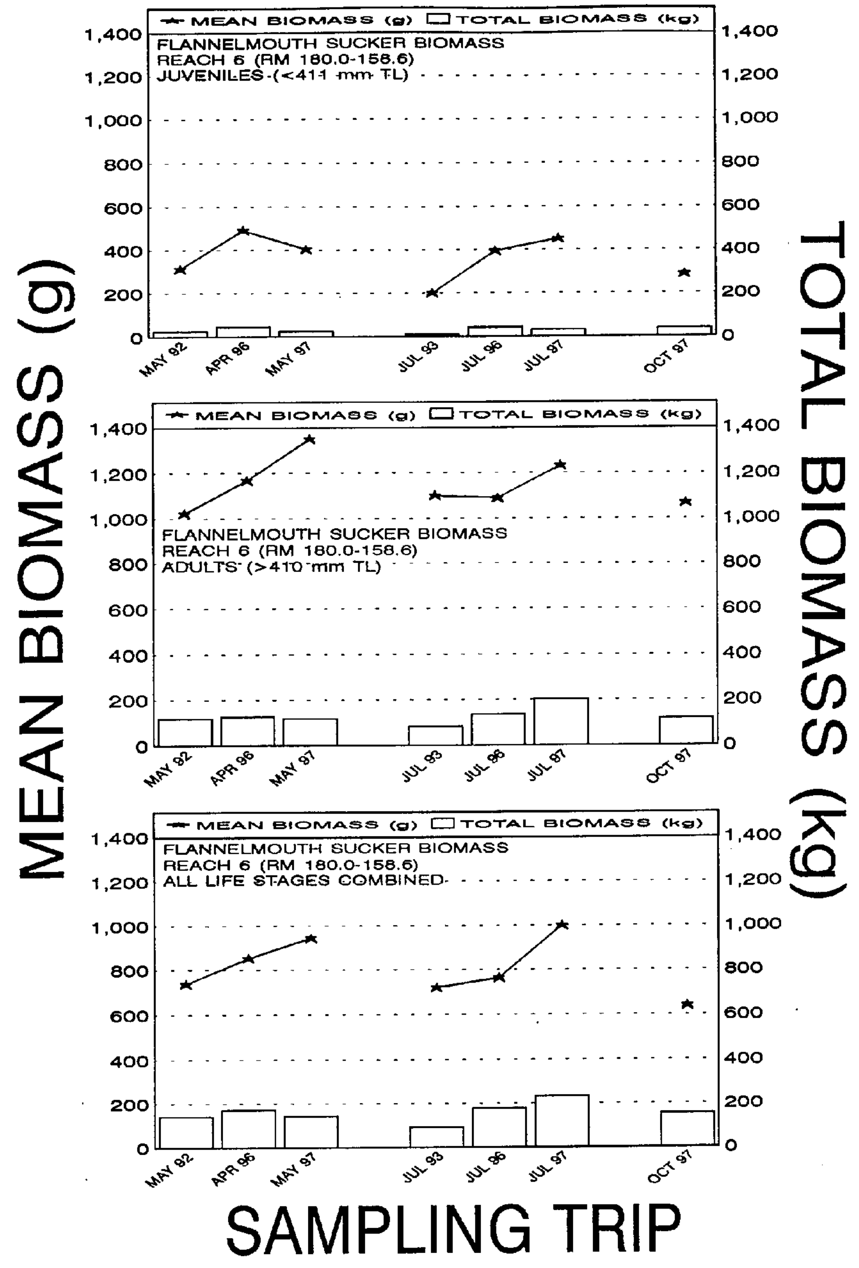


Figure 8. Total and mean biomass of flannelmouth sucker collected and weighed on designated miles during standardized adult fish community monitoring trips between RM 180.0-158.6 ("Reach 6"), 1991-1997.

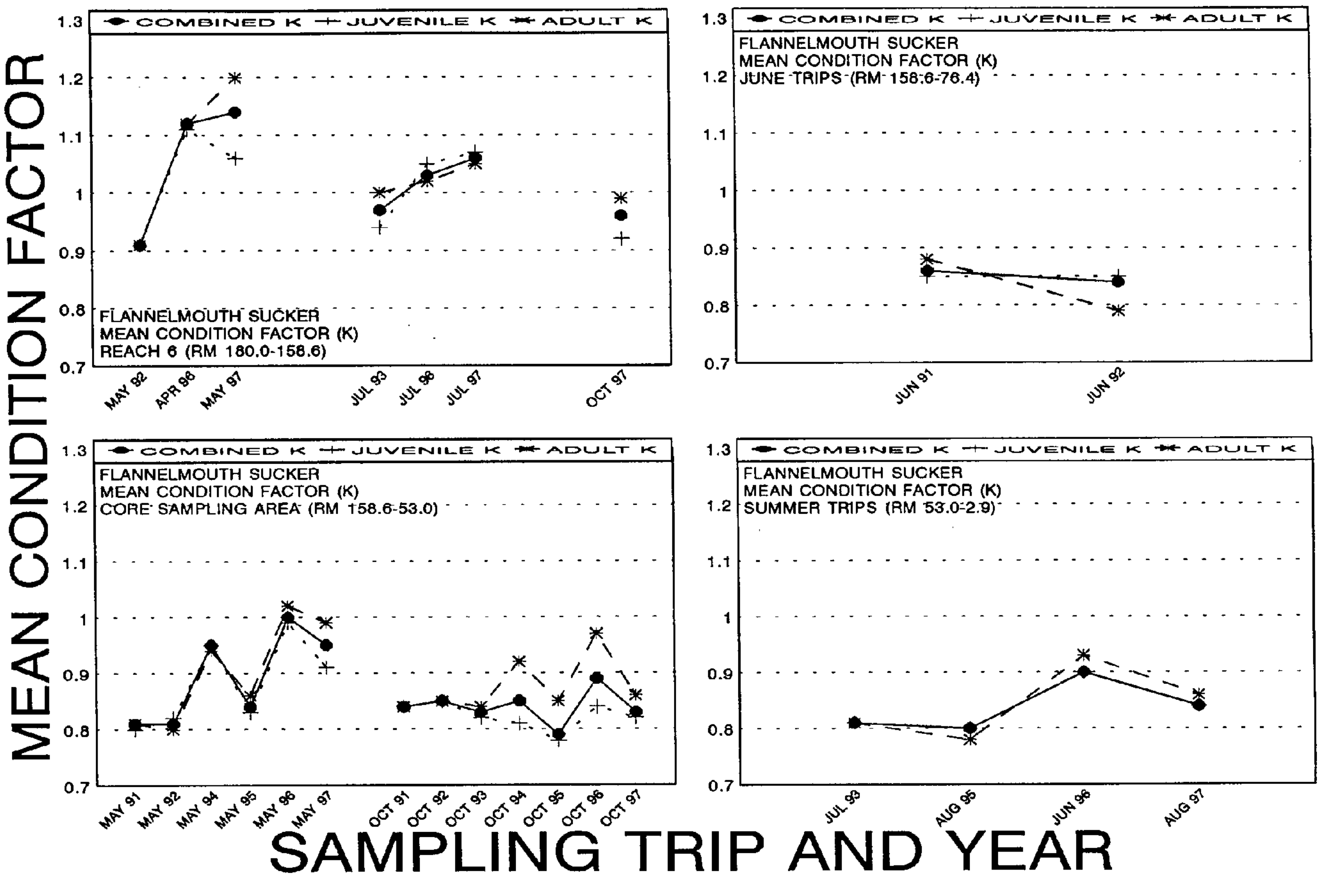


Figure 9. Mean condition factor of flannelmouth sucker collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips for common sampled areas between RM 180.0-2.9, 1991-1997.

plots of mean biomass for these same three categories (Figure 8), showing an increasing trend across years with the exception of juvenile biomass in May 1997. This decrease in both mean biomass and mean K among juvenile flannelmouth sucker in May 1997 was accompanied by a drop in mean TL (Figure 6) on this particular trip. Comparisons of flannelmouth sucker mean K between months, across years, via ANOVA/Scheffe, showed a significant decline in K between May and October trips (Table 17-a, Figure 9). This same trend was seen when trips within a single year were compared. The decline in mean K between April and June 1996 was significant (F-statistic = 36.843, r^2 = 0.079, p = 0.000) as was that between May, July, and October 1997 (F-statistic = 34.531, r^2 = 0.099, May vs. July p = 0.002, May vs. October p = 0.000, July vs. October p = 0.000). This seems to indicate, based on limited data, that flannelmouth sucker mean K drops significantly between May and October in Reach 6. This is likely due to an elevated condition factor among adult flannelmouth sucker during May sampling due to spawning, as this same trend did not hold true for juvenile flannelmouth sucker K in July 1997 (Figure 9). Flannelmouth sucker mean K was also significantly higher on July trips than it was on October trips, but May and July mean K were not significantly different (Table 17-a). Comparisons of mean K in May across years showed a significant increase between 1992 and 1997 with 1997 being significantly higher than 1992 (Table 17-b). Mean K in 1May 996, was also significantly higher than in 1992, but not significantly different from 1997 (Table 17-b). Mean K in July 1996 and 1997 were both significantly higher than in July 1993, but not significantly different from one another (Table 17-c). No comparisons could be made for K between October trips in Reach 6 as no fish were weighed on the October 1996 trip.

---Core Sampling Area (RM 158.6-53.0)---

In the core sampling area patterns of flannelmouth sucker CPUE varied greatly between May and October trips. Comparisons of CPUE grouped by month, across years, showed that flannelmouth sucker CPUE on October trips was significantly higher (Mann-Whitney U test statistic = 1368047.500, p = 0.000) than on May trips (Table 18-a, Figures 5 and 10).

Flannelmouth sucker CPUE on May trips was 64.03 fish/hr (range = 5.41-346.67) in 1991, rose consistently to a high of 95.72 fish/hr (range = 3.33-408.11) in 1994 and fell to a low of 45.44 fish/hr (range = 2.86-185.71) in 1997 (Figures 5 and 10). However, the decline between 1994 and 1997 was not a consistent decline over time as was evidenced by a spike (86.93 fish/hr; range = 6.25-303.23) in flannelmouth sucker CPUE in 1996 (Figures 5 and 10). Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) showed declining catch rates for both adult and juvenile flannelmouth sucker on May trips between 1992 and 1997 in Reach 5, but this same trend was not seen in Reaches 4 or 3 (Figure 11). A Kruskal-Wallis analysis indicated that significant differences in May flannelmouth sucker CPUE were present between years (test statistic = 248.428, p = 0.000). An ANOVA/Scheffe performed on flannelmouth sucker ranked CPUE data for May indicated that CPUE in May 1992, 1994, and 1996 were not significantly different (Table 18-b, Figures 5 and 10). Flannelmouth sucker total CPUE in May 1991 and 1995 were not significantly different from each other, but were

Table 17-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 18.660, r^2 = 0.026, p = 0.000*

Scheffe matrix:	May	July	October
May	1.000		
July	0.181	1.000	
October	0.000*	0.000*	1.000

Table 17-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 89.702, r^2 = 0.249, p = 0.000*

Scheffe matrix:	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.000*	0.424	1.000

Table 17-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7.619, r^2 = 0.025, p = 0.001*

Scheffe matrix:	1993	1996	1997
1993	1.000		
1996	0.033*	1.000	
1997	0.001*	0.312*	1.000

Table 18-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 67.195, $r^2 = 0.018$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 18-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 58.242, $r^2 = 0.149$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.000*	1.000				
1994	0.000*	0.992	1.000			
1995	0.974	0.000*	0.000	1.000		
1996	0.000*	0.988	0.798	0.000*	1.000	
1997	0.009*	0.000*	0.000*	0.000*	0.000*	1.000

Table 18-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker CPUE data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 75.413, $r^2 = 0.189$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.877	1.000					
1993	0.000*	0.000*	1.000				
1994	0.004*	0.000*	0.341	1.000			
1995	0.000*	0.000*	0.987	0.054*	1.000		
1996	0.000*	0.000*	0.000*	0.000*	0.002*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	0.071*	1.000

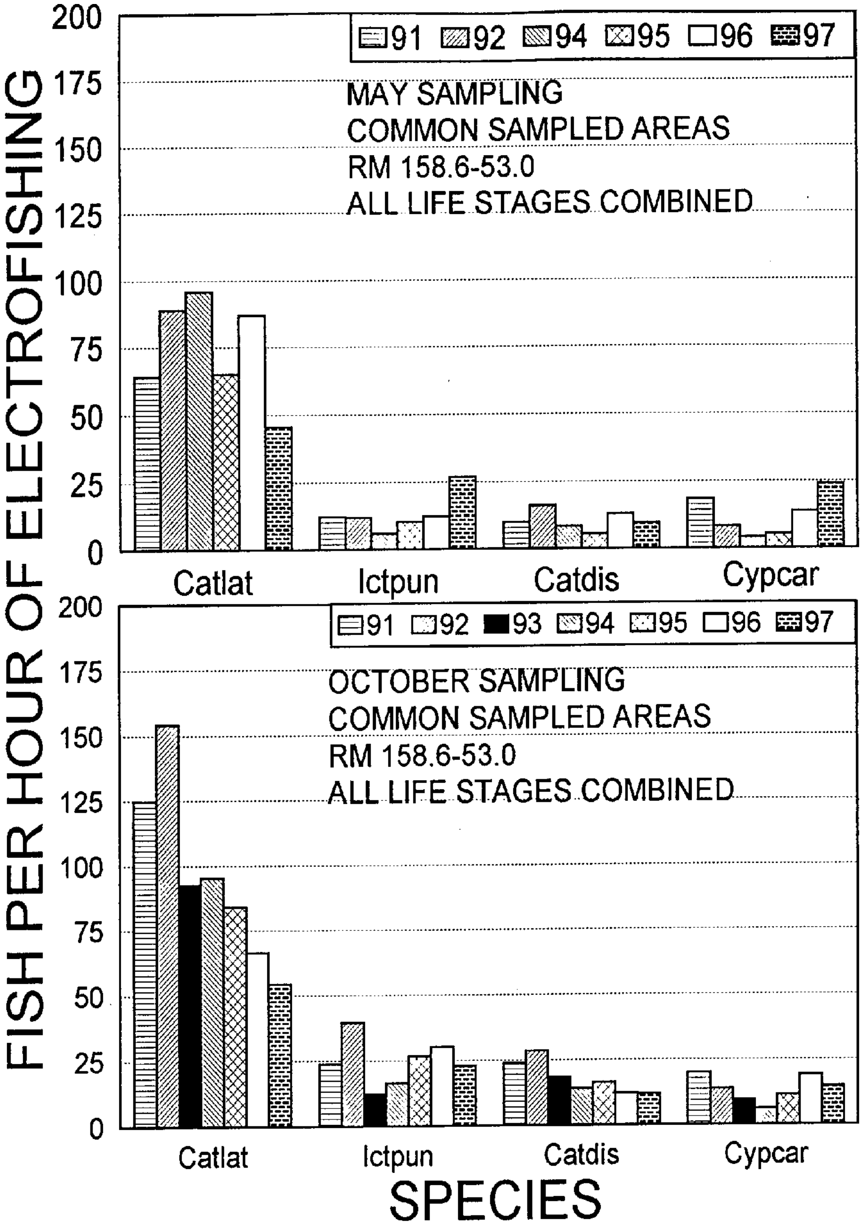


Figure 10. Number of fish collected per hour of electrofishing for the four common, large-bodied fish species on May and October standardized adult fish community monitoring trips in the core sampling area of the San Juan River (RM 158.6-53.0), 1991-1997, all life stages combined.

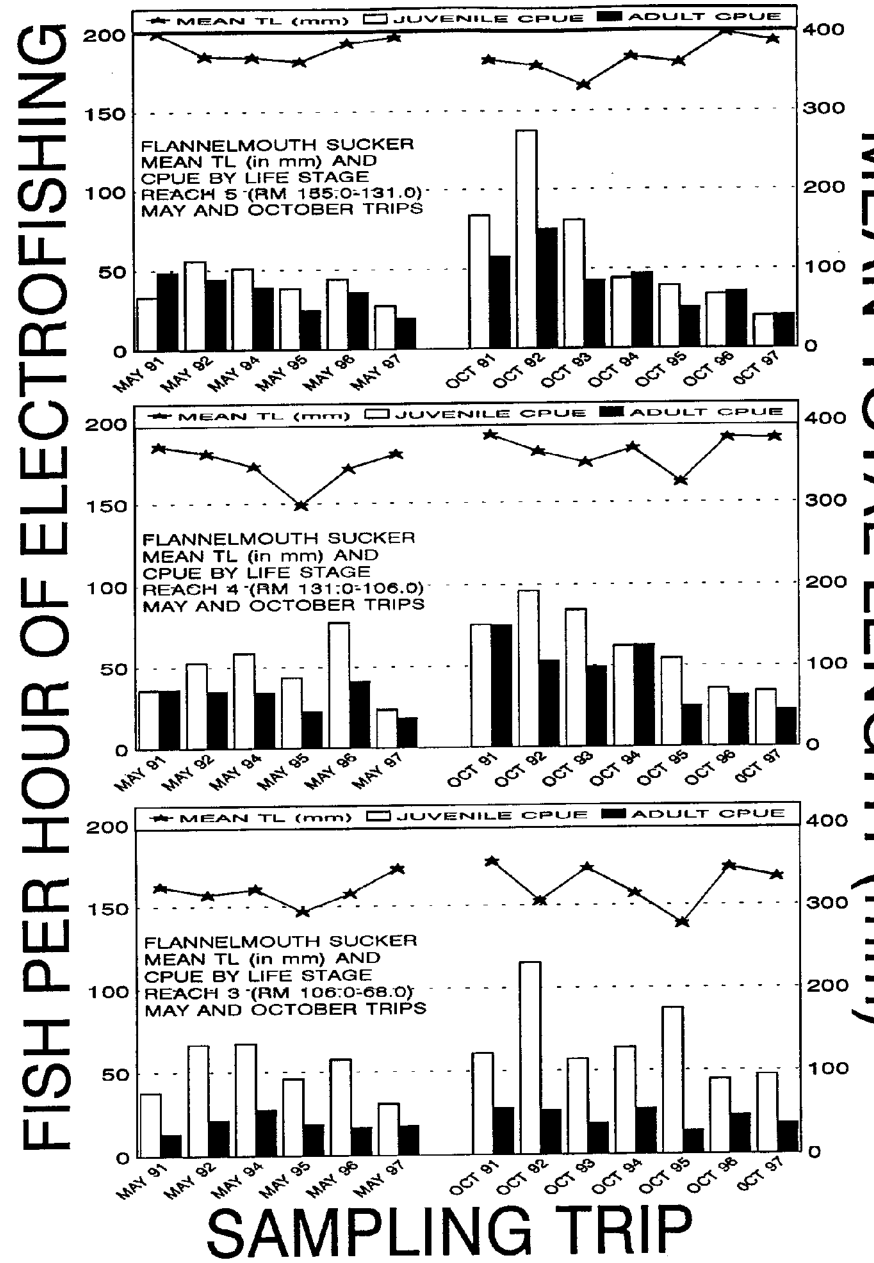


Figure 11. Number of fish collected by life stage per hour of electrofishing versus mean total length for flannelmouth sucker in geomorphic Reaches 3-5 on May and October standardized adult fish community monitoring trips in the core sampling area of the San Juan River (RM 158.6-53.0), 1991-1997.

significantly lower than CPUE in May 1992, 1994, and 1996, and yet significantly higher than CPUE in May 1997 (Table 18-b, Figures 5 and 10). May 1997 flannelmouth sucker CPUE was significantly lower than all other years (Table 18-b, Figures 5 and 10).

On October trips in the core sampling area, flannelmouth sucker CPUE was 124.59 fish/hr (range = 0.00-417.39) in 1991, rose to a high of 154.18 fish/hr (range = 9.80-448.65) in 1992 and then fell consistently over the next five years to a low of 54.31 fish/hr (range = 0.00-153.85) in 1997 (Figures 5 and 10). This decline represented a 64.8% drop in catch rate between October 1992 and 1997. Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) shows a strongly declining catch rate in juvenile flannelmouth sucker on October trips between 1992 and 1997 in Reaches 5 and 4 and lesser declining trends in adult flannelmouth sucker CPUE in Reaches 5 and 4 (Figure 11). However, this same trend was not apparent in juvenile or adult CPUE in Reach 3 (Figure 11). Like May trip data, significant differences were present between years in October flannelmouth sucker CPUE data (Kruskal-Wallis test statistic = 368.107, p = 0.000). An ANOVA/Scheffe performed on ranked October flannelmouth sucker CPUE data indicated that CPUE in October 1991 and 1992 were not significantly different from one another, but were significantly higher than all following years (Table 18-c, Figures 5 and 10). Flannelmouth sucker CPUE in October 1993 and 1994 were not significantly different from one another, but were significantly higher than October 1996 and 1997 (Table 18-c). Flannelmouth sucker CPUE in 1995 was not significantly different from October 1993, but significantly less than 1994 (Table 18-c, Figures 5 and 10). Flannelmouth sucker CPUE in 1995 was also significantly higher than in October 1996 and 1997 (Table 18-c, Figures 5 and 10). Flannelmouth sucker CPUE was significantly lower in 1996 than in all previous years, but significantly higher than October 1997 (Table18-c, Figures 5 and 10). Flannelmouth sucker CPUE in 1997 was significantly lower than in all preceding years (Table 18-c, Figures 5 and 10).

An ANCOVA by Lawrence found significant differences between the slopes of the regression lines for total CPUE ($F = 18.03$, $F_{0.05(1),1,10} = 4.96$), juvenile CPUE ($F = 20.46$), and adult CPUE ($F = 7.87$). This indicated that despite the significant negative flow effects on October CPUE, juvenile and adult flannelmouth sucker CPUE still appeared to decline in the core sampling area between 1991 and 1997.

A comparison of flannelmouth sucker October CPUE between 1988 and 1997 (RM 147.9-119.2), shows that CPUE for this species increased over twofold between 1988 and 1992, but by 1995 had fallen to below the levels observed in the late 1980's and remained comparatively through the end of our study (Figure 12).

Graphic comparisons of CPUE in both the May and October data sets showed that observed declining trends over the study period occurred in both juvenile and adult CPUE on May and October trips in Reach 5 and juvenile and adult CPUE on October trips in Reach 4, but showed little pattern elsewhere (Figure 11). Despite observed declines in CPUE in certain reaches over the research period, juvenile flannelmouth sucker remained the numerically dominant life stage for this species collected on all May and October trips, with this dominance increasing in the downstream reaches of the core sampling area (Figure 5).

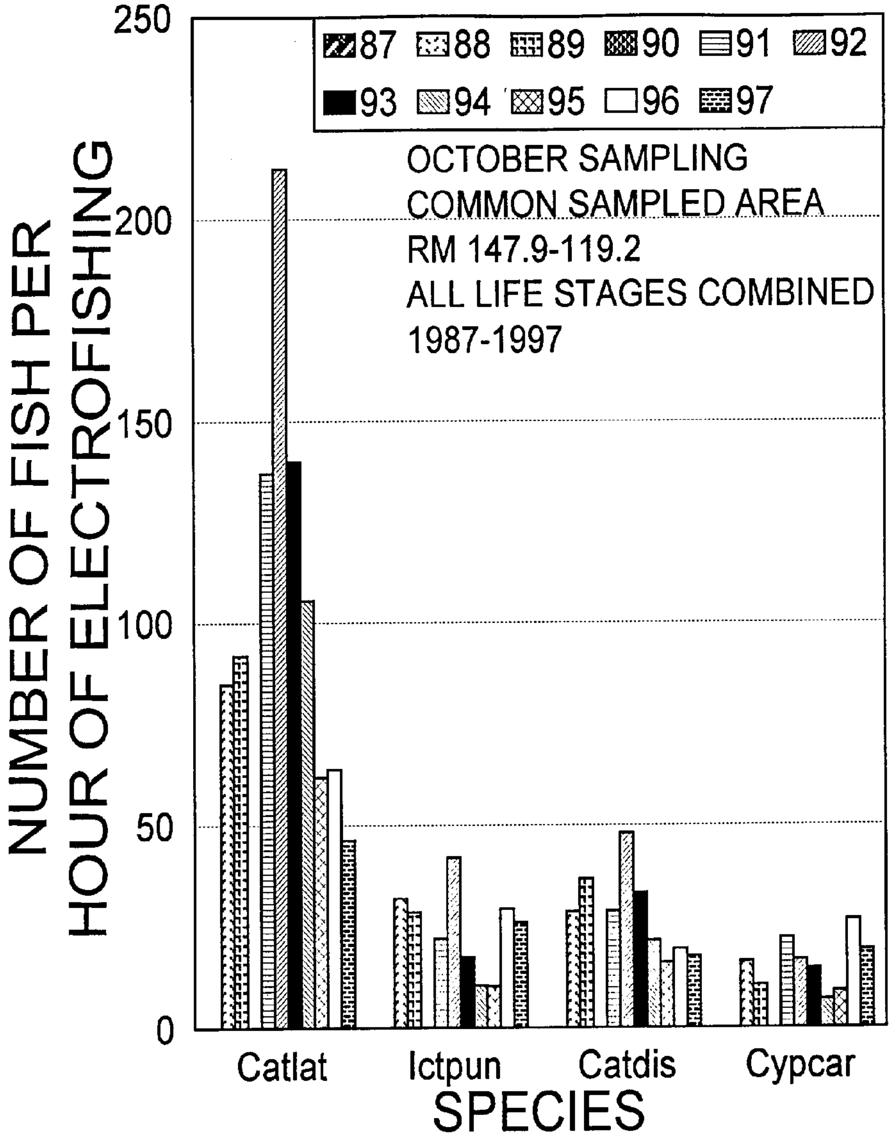


Figure 12. Number of fish per hour of electrofishing (i.e., total CPUE) for the four common, large-bodied fishes collected on October sampling trips in 1988, 1989, and 1991-1997 in the commom sampled area from RM 147.9-119.2.

Comparisons of flannelmouth sucker mean TL between May and October trips, all years combined and between trips in a given month across years, via ANOVA/Scheffe, showed a large number of significant differences (Table 19-a - 19-c), but graphic comparisons of the same data failed to show any clear trends in the same data (Figure 6). The one clear trend in May data was that mean TL tended to decline downstream of Reach 5 (Figure 6). This same trend was seen, albeit somewhat less clearly, on October trips between 1994 and 1997 (Figure 6). This is reflective of the relative increase in juvenile CPUE in relation to adult CPUE in downstream reaches of the core sampling area on both May and October trips (Figure 5).

Length-frequency histograms of flannelmouth sucker measured on DM’s in the core sampling area showed that the size range of fish collected was much broader than in Reach 6, with young fish (< 350 mm TL) making up a much greater percentage of the catch than in Reach 6 (Figures 7 and 13). This was true on both May and October trips throughout the study period. However, the occurrence of juveniles < 150 mm TL on May trips and juveniles < 200 mm TL on October trips did decrease in 1996 and 1997 compared to previous years (Figure 13). Based on the length-frequency histograms, the last strong cohort of flannelmouth sucker observed in the core sampling area was spawned in 1993, based on two-year-old fish seen in the May (151-200 mm TL) and October (176-250 mm TL) 1995 collections (Figure 13).

ANOVA/Scheffe tests showed that flannelmouth sucker mean biomass was significantly higher on May trips than on October trips (Table 20-a). Flannelmouth sucker mean biomass in the core sampling area increased significantly from just above 400 g in May 1991 to almost 600 g in May 1997 (Table 20-b, Figure 14). The lone exception to this on May trips was in May 1995. This drop in mean biomass in May 1995 was apparent in both juvenile and adult fish (Figure 14). A similar drop in mean biomass was observed for flannelmouth sucker collected in secondary channels in the spring of 1995 (D. Propst, pers. comm.). This same drop in mean biomass was apparent in October 1995 collections for both juvenile and adult fish (Figure 14). Mean biomass on October trips was more variable than on May trips with significant differences being present in 17 (81.0%) of 21 paired multiple comparisons between years as opposed to 10 (66.7%) of 15 comparisons in May (Tables 20-b and 20-c). Like mean TL, mean biomass declined in downstream reaches of the core sampling area, again reflecting the larger percentages of juvenile fish being collected in downstream reaches (Figures 15-17).

Like mean biomass, mean K of flannelmouth sucker, was significantly higher on May trips than on October trips (Table 21-a). Mean K increased significantly between 1991 and 1997 on May trips (Figure 20-b). Although mean K showed significant fluctuations during the study period, the values for 1991 and 1997 were not significantly different (Table 21-c). The largest increase observed for mean K on May trips and fluctuations on October trips were in Reach 5 (Figure 18). These increases and fluctuations decreased in magnitude in downstream reaches (i.e., Reaches 4 and 3; Figure 18). Unlike Reach 6, in the core sampling area, the significantly higher mean K overall on May trips compared to October trips cannot be accounted for by spawning adults (i.e., high condition factor fish) being collected in May. This is true for two reasons. First of all, the increasing trend in K observed on May trips was evident for both juvenile and adult fish (Figure 18). Second, the mean K on May 1991 and 1992 trips was less than that on October 1991 and 1992 trips (Figure 18). By plotting mean juvenile and adult K against river discharge,

Table 19-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 23.912, $r^2 = 0.001$, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 19-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 79.665, $r^2 = 0.044$, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.619	1.000				
1994	0.811	0.001*	1.000			
1995	0.000*	0.000*	0.000*	1.000		
1996	0.952	0.007*	0.995	0.000*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

Table 19-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 135.144, $r^2 = 0.048$, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.000*	1.000					
1993	0.000*	0.735	1.000				
1994	0.000*	0.422	0.999	1.000			
1995	0.000*	0.000*	0.000*	0.000*	1.000		
1996	0.000*	0.000*	0.000*	0.000*	0.000*	1.000	
1997	1.000	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

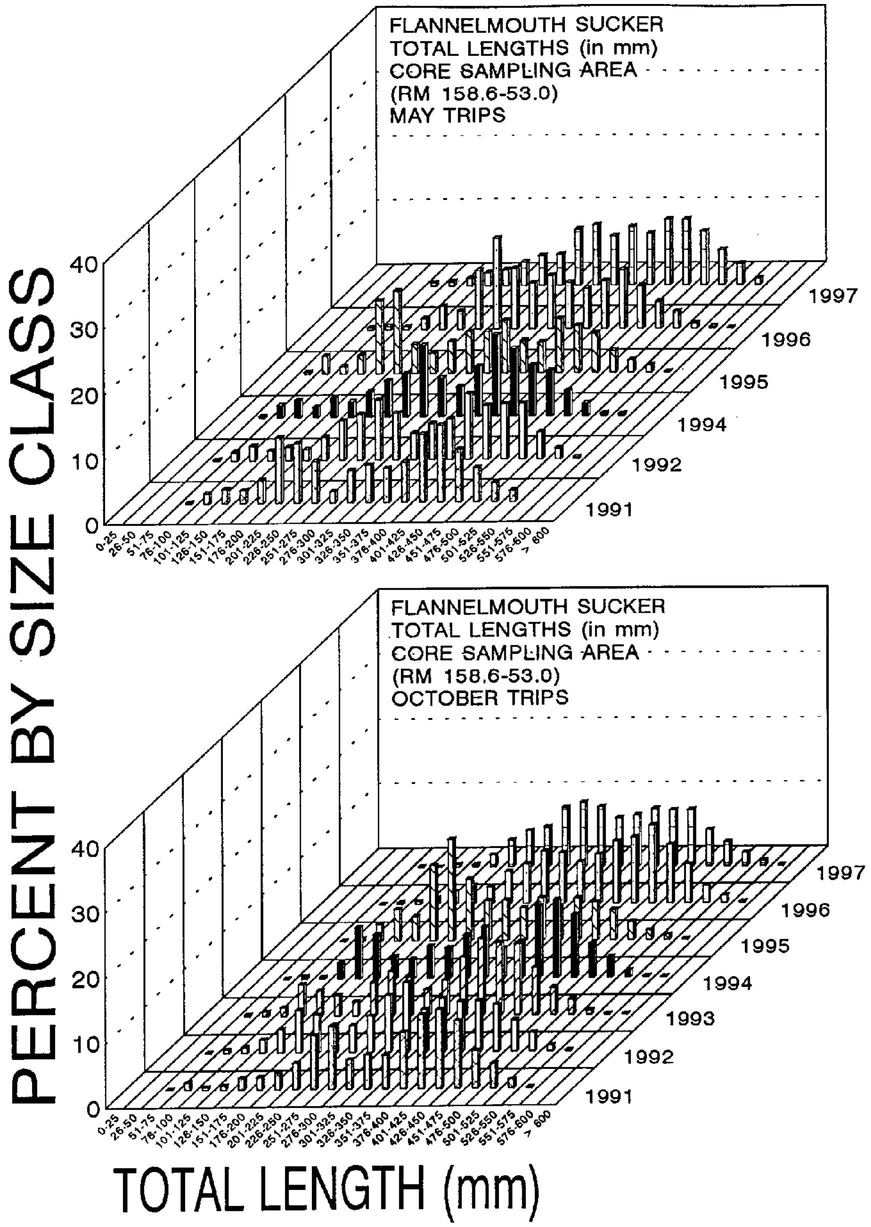


Figure 13. Length-frequency histograms for flannelmouth sucker collected and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 20-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 9.666, r^2 = 0.000, p = 0.002*

Scheffe matrix:

	May	October
May	1.000	
October	0.002*	1.000

Table 20-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 53.827, r^2 = 0.032, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.960	1.000				
1994	0.631	0.945	1.000			
1995	0.000*	0.000*	0.000*	1.000		
1996	0.097*	0.203	0.739	0.000*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

Table 20-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 85.626, r^2 = 0.033, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.000*	1.000					
1993	0.000*	0.969	1.000				
1994	0.852	0.000*	0.001*	1.000			
1995	0.000*	0.000*	0.000*	0.000*	1.000		
1996	0.001*	0.000*	0.000*	0.000*	0.000*	1.000	
1997	0.610	0.001*	0.033*	0.999	0.000*	0.000*	1.000

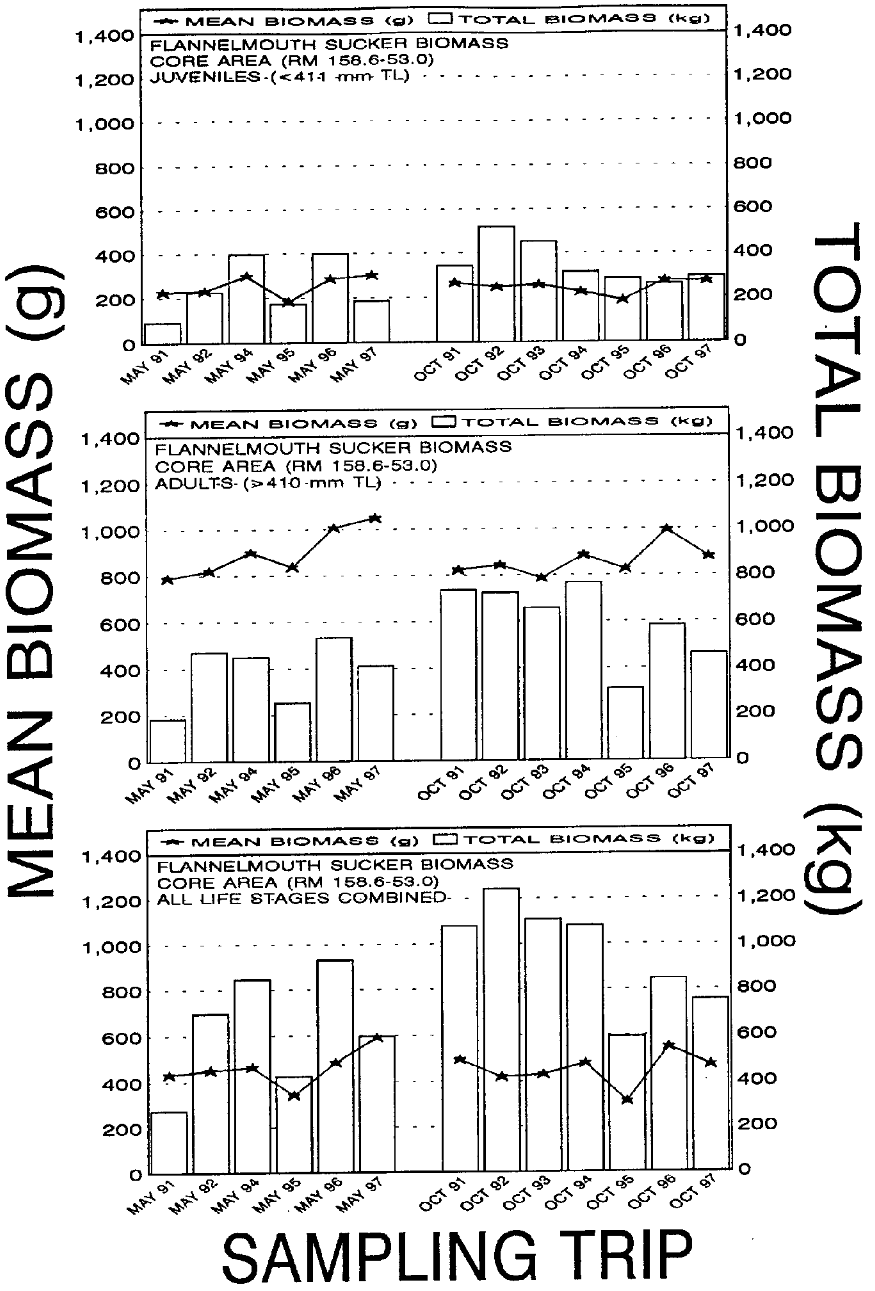


Figure 14. Total and mean biomass of flannelmouth sucker collected and weighed on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0).

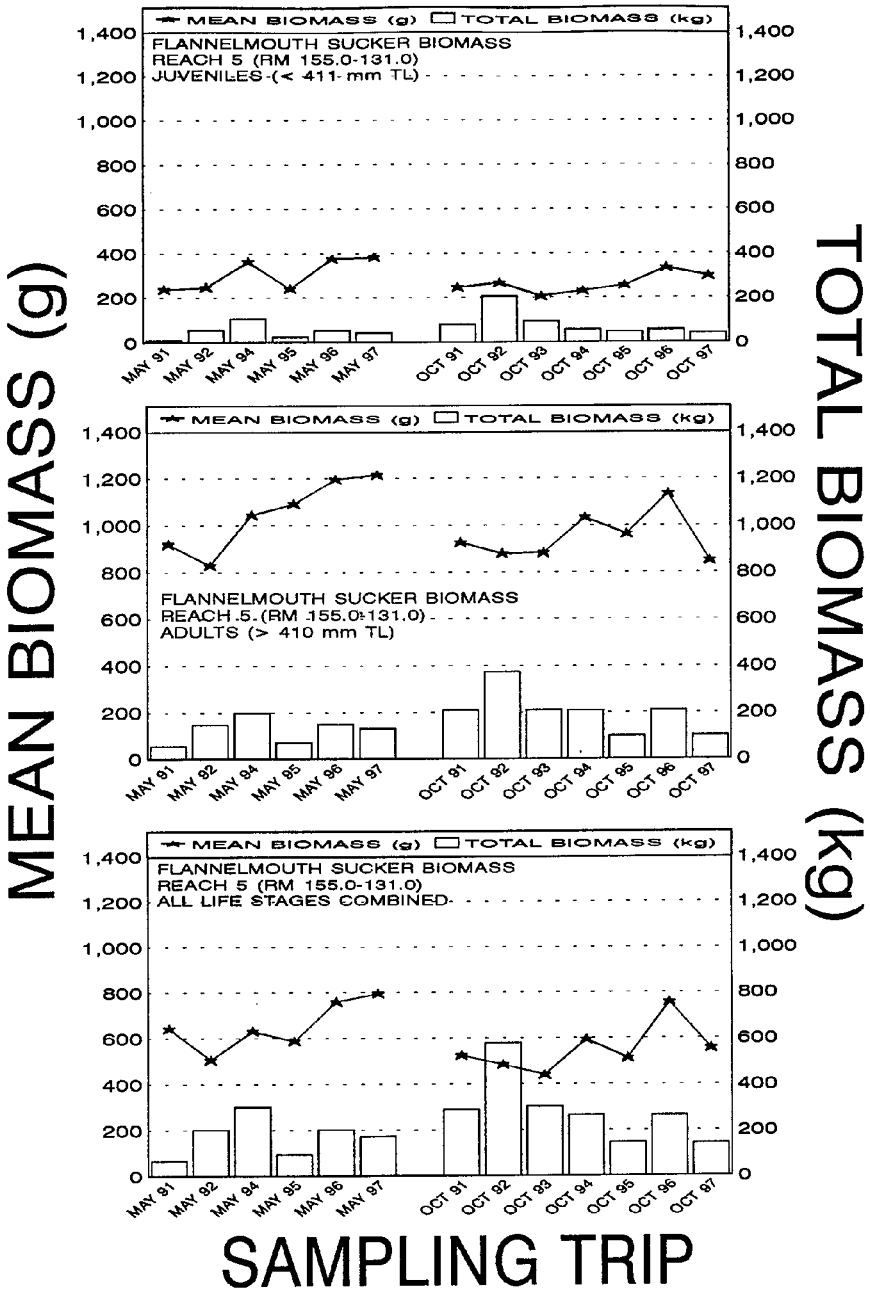


Figure 15. Total and mean biomass of flannelmouth sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 5 (RM 155.0-131.0).

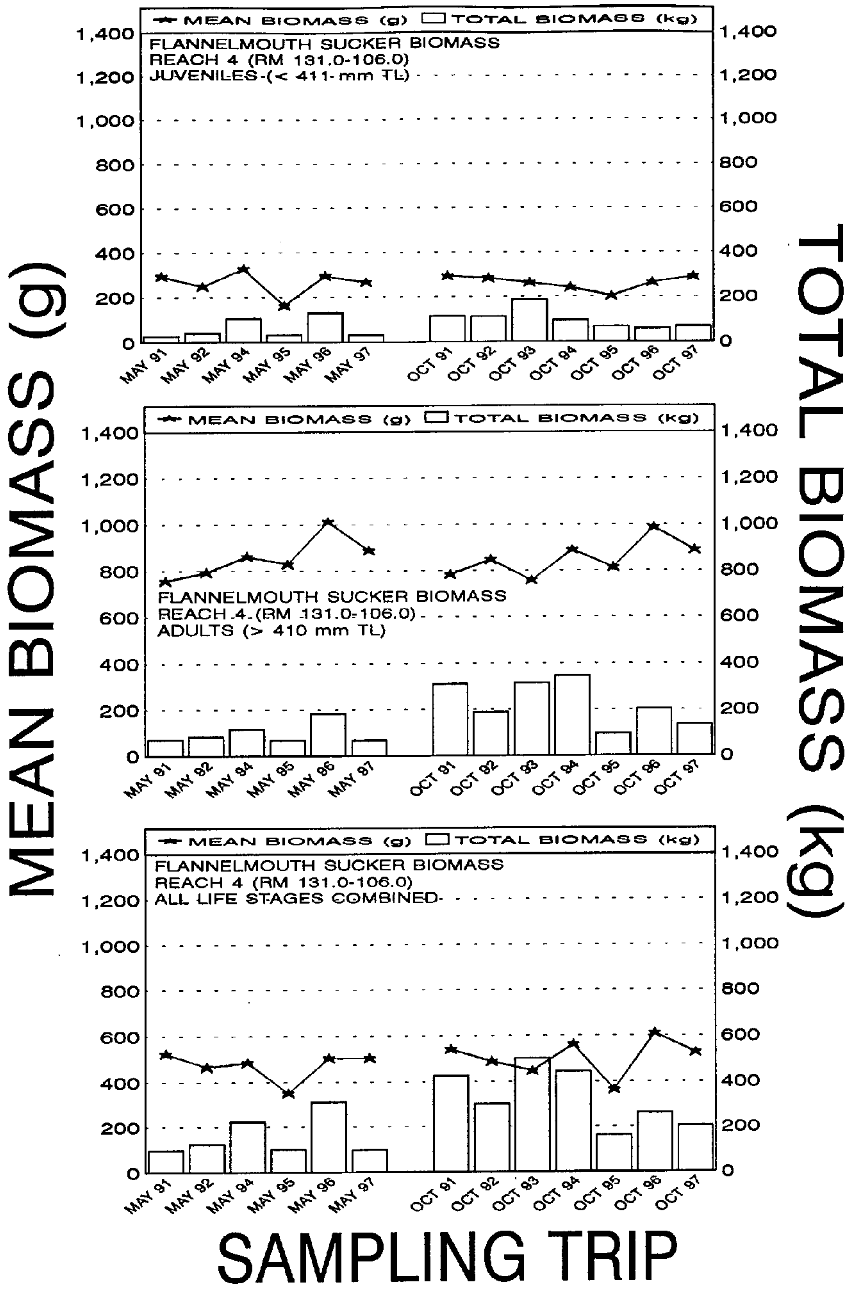


Figure 16. Total and mean biomass of flannelmouth sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 4 (RM 131.0-106.0).

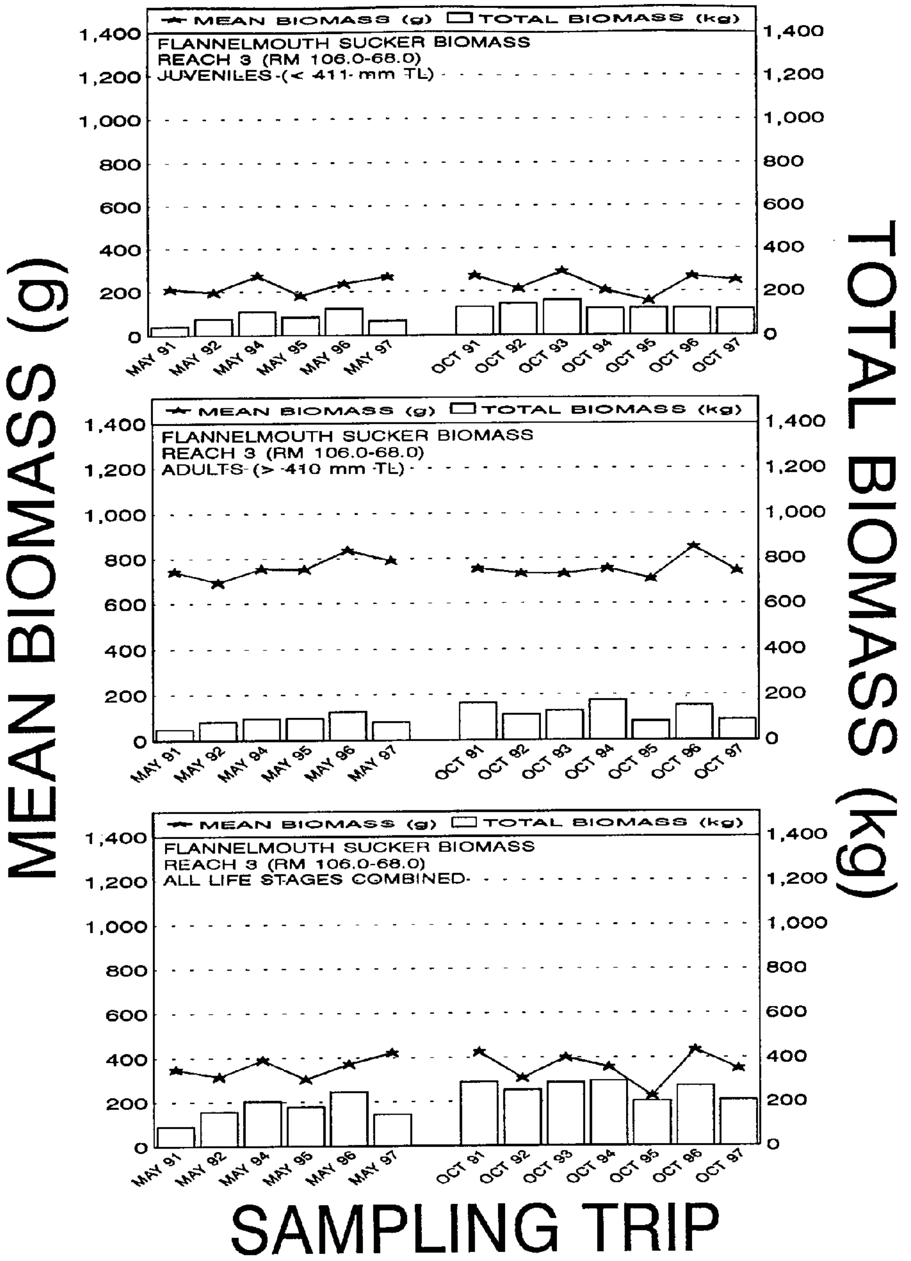


Figure 17. Total and mean biomass of flannelmouth sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 3 (RM 106.0-68.0).

Table 21-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 727.380, $r^2 = 0.030$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 21-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 288.587, $r^2 = 0.150$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.975	1.000				
1994	0.000*	0.000*	1.000			
1995	0.018*	0.022*	0.000*	1.000		
1996	0.000*	0.000*	0.000*	0.000*	1.000	
1997	0.000*	0.000*	1.000	0.000*	0.000*	1.000

Table 21-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 54.841, $r^2 = 0.021$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.699	1.000					
1993	0.088*	0.000*	1.000				
1994	0.582	1.000	0.000*	1.000			
1995	0.000*	0.000*	0.000*	0.000*	1.000		
1996	0.000*	0.000*	0.000*	0.000*	0.000*	1.000	
1997	0.525	0.007*	0.998	0.005*	0.000*	0.000*	1.000

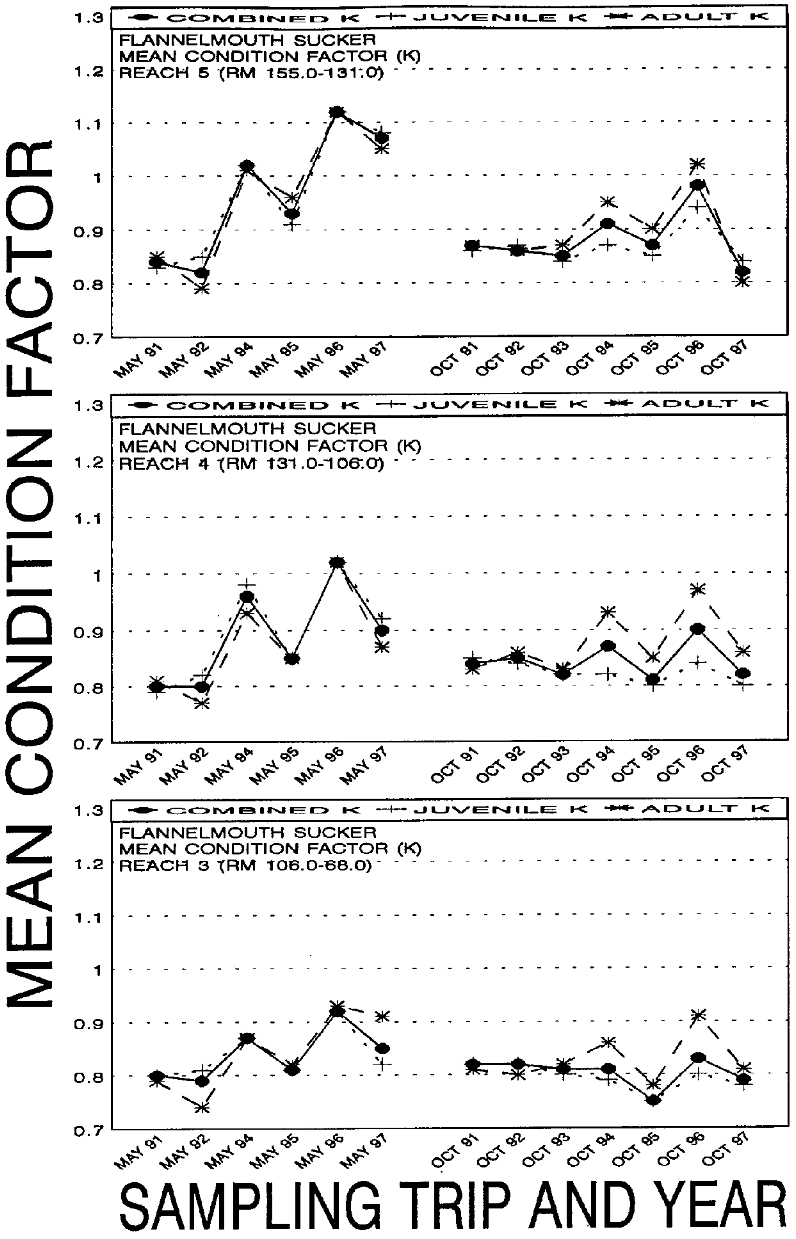


Figure 18. Mean condition factor, by whole geomorphic reach, of flannelmouth sucker, collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Lawrence (1999) demonstrated that the greatest increases in flannelmouth sucker mean K, for both life stages, occurred in conjunction with periods of stable winter base-flows. These stable winter base-flow periods included the winter of 1993-1994, 1995-1996, and to a lesser degree 1996-1997. The increases in mean K associated with these stable winter base-flow periods are reflected in the values for May 1994, May 1996, and to a lesser degree May 1997 (Figure 18).

---June Trips (RM 158.6-76.4)---

On June trips (RM 158.6-76.4) patterns of flannelmouth sucker CPUE resembled those of October 1991 and 1992 trips, with 1992 CPUE being significantly higher than in 1991 (Mann-Whitney U test statistic = 5248.500, p = 0.000; Table 2-a, Figure 5). As with October 1992, flannelmouth sucker CPUE in June 1992 was among the highest observed for this species during our study (Figure 5).

Flannelmouth sucker mean TL in June 1992 was significantly smaller than June 1991 (Table 22-b, Figure 6). This can be explained by the capture of a large number of age-1 and age-2 fish (76-150 mm TL) seen in the length-frequency histogram of flannelmouth sucker measured on the June 1992 trip (Figure 19). These smaller fish represent strong 1990 and 1991 cohorts. As with May and October trips in the core sampling area, mean TL generally declined in downstream reaches (Figure 6).

Flannelmouth sucker mean biomass was significantly lower on the June 1992 trip than on the June 1991 trip (Table 22-c, Figure 20). This is reflective of the large number of juvenile fish collected on the June 1992 trip (Figures 5 and 19). Flannelmouth sucker mean K also declined significantly between June 1991 and June 1992 (Figure 9), due to the large number of juvenile fish collected in June 1992 (Figures 5 and 19).

---Lower River (RM 53.0-2.9)---

Flannelmouth sucker CPUE was fairly consistent in three of the four sampling trips in the lower San Juan River (Figure 5). There was no significant difference between 1993, 1995, and 1996 flannelmouth sucker collections in this section of the river (Table 23-a). However, flannelmouth sucker CPUE in 1997 was significantly lower than all three previous years (Table 23-a, Figure 5). The flannelmouth sucker population between RM 53.0 and 2.9 was almost exclusively juvenile fish (Figure 5). Flannelmouth sucker CPUE stayed fairly high in the lower portion of Reach 2 (RM 53.0-17.0), hovering near 50 fish/hr, until 1997 (Figure 5). Flannelmouth sucker CPUE declined sharply in Reach 1 (Figure 5). Despite low CPUE values, flannelmouth sucker was the only native fish to be consistently collected in Reach 1 in addition to being the only native fish collected as far downstream as Clay Hills Landing (RM 2.9) during our study (Table 12).

Flannelmouth sucker mean TL showed increasing trends in both Reach 2 and Reach 1 between 1993 and 1997 (Figure 6), with mean TL for the entire section

Table 22-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker mean CPUE data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 61.189, r^2 = 0.171, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 22-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 129.960, r^2 = 0.035, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 22-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 187.711, r^2 = 0.051, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 22-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 9.137, r^2 = 0.003, p = 0.003*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.003*	1.000

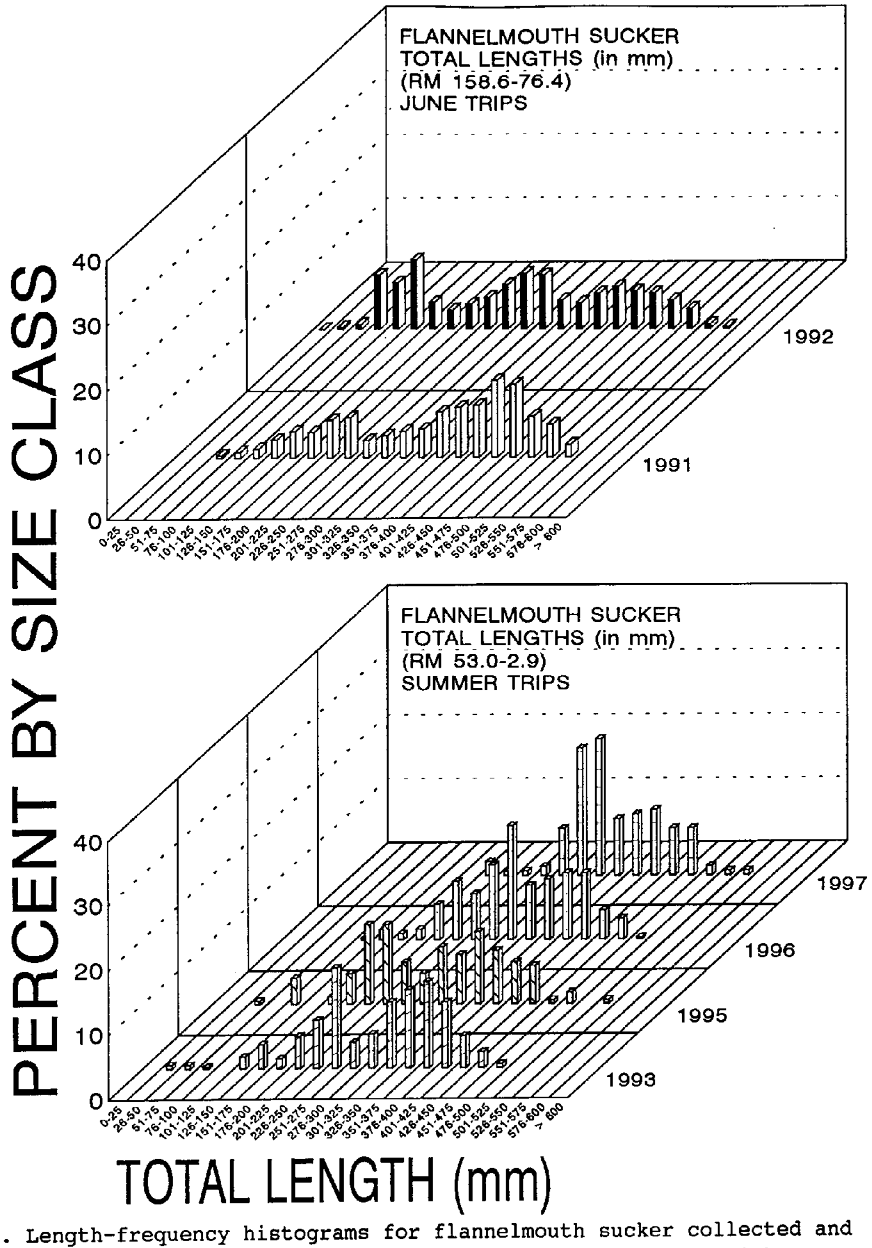


Figure 19. Length-frequency histograms for flannelmouth sucker collected and measured on designated miles during standardized adult fish community monitoring trips in June 1991 and 1992 (RM 158.6-76.4) and in the lower San Juan River (RM 53.0-2.9), 1993-1997.

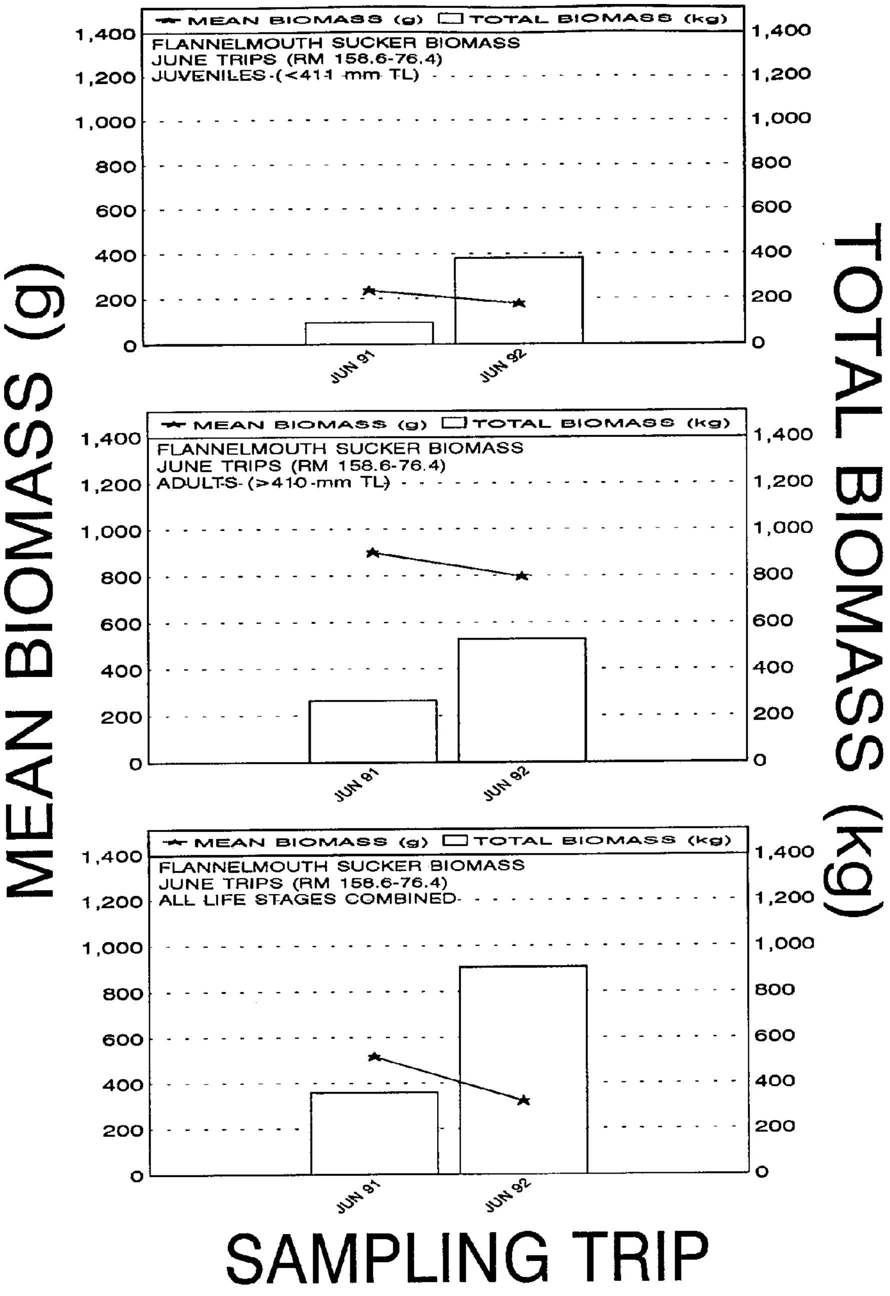


Figure 20. Total and mean biomass of flannelmouth sucker collected and weighed on designated miles during June 1991 and 1992 standardized adult fish community monitoring trips (RM 158.6-76.4).

Table 23-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) flannelmouth sucker mean CPUE data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 9.942, $r^2 = 0.078$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.682	1.000		
1996	0.919	0.938	1.000	
1997	0.002*	0.000*	0.000*	1.000

Table 23-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean TL data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 14.797, $r^2 = 0.045$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.054*	1.000		
1996	0.803	0.005*	1.000	
1997	0.000*	0.000*	0.001*	1.000

Table 23-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean biomass (WT in grams) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 13.089, $r^2 = 0.041$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.128	1.000		
1996	0.251	0.001*	1.000	
1997	0.000*	0.000*	0.045*	1.000

Table 23-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of flannelmouth sucker mean condition factor (K) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 39.902, $r^2 = 0.115$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.624	1.000		
1996	0.000*	0.000*	1.000	
1997	0.077*	0.008*	0.000*	1.000

of river (RM 53.0-2.9) being significantly higher in 1997 than in 1993 (Table 23-b). This rise in mean TL between 1993 and 1997 is reflected in the length-frequency histogram which shows fewer small fish (< 225 mm TL) being collected in 1996 and 1997 (Figure 19). However, even with this significant increase, mean TL was consistently lower in this section of the river than in all other upstream areas (Figure 6).

Along with the increase in mean TL, flannelmouth sucker mean biomass in the lower river showed a significant upward trend between 1993 and 1997 (Table 23-c, Figure 21). This same upward trend was also seen in mean K values between 1993 and 1997 (Table 23-d, Figure 9).

Bluehead Sucker

Bluehead sucker were the second-most abundant native species and third most abundant species overall collected during our study, occurring in 77.7% of all collections between 1991 and 1997 (Table 12). Longitudinal distribution for this species was very distinct with the highest catch rates occurring in upstream reaches (Reaches 6 and 5) of the river and, with only a few exceptions, catch rates decreasing dramatically in each consecutive downstream reach (Figure 22). Bluehead sucker disappeared from the catch altogether by RM 17.0 (Table 12, Figure 22).

---Reach 6 (RM 180.0-158.6)---

Comparisons of total bluehead sucker CPUE by month, grouped across years, in Reach 6 showed significant differences between months (Kruskal-Wallis statistic = 34.087, p = 0.000). An ANOVA/Scheffe done on ranked CPUE data showed significantly more bluehead sucker being collected on October trips than on either July or May trips (Table 24-a, Figure 22). Total bluehead sucker CPUE was not significantly different between May and July trips (Table 24-a). Comparisons by month, across years, showed an increasing trend in bluehead sucker CPUE between 1992 and 1996 on May trips and between 1993 and 1997 on July trips (Figure 22). This increasing trend was statistically significant for May trip data (Kruskal-Wallis statistic = 33.799, p = 0.000). An ANOVA/Scheffe showed no significant differences between May 1996 and 1997 total CPUE (Table 24-b, Figure 22). The upward trend was statistically significant for July trips between 1993 and 1997 (Kruskal-Wallis statistic = 4.649, p = 0.098). This same upward trend in total CPUE was evident, but not statistically significant on October electrofishing trips (Mann-Whitney U test statistic = 296.00, p = 0.106), however, there were only two data points, 1996 and 1997 (Table 24-c, Figure 22). The August 1994 trip, while presented in CPUE graphics is not considered in this analysis due to the abbreviated nature of that particular trip (Table 1).

Comparisons of mean TL between months, across years, and between years in a given month, via ANOVA/Scheffe, failed to show any clear trends (Table 25-a, Figure 23). Mean TL data grouped by month across years indicated that bluehead sucker collected on July trips were significantly smaller than those collected on May and October trips (Table 25-a, Figure 23). There was no

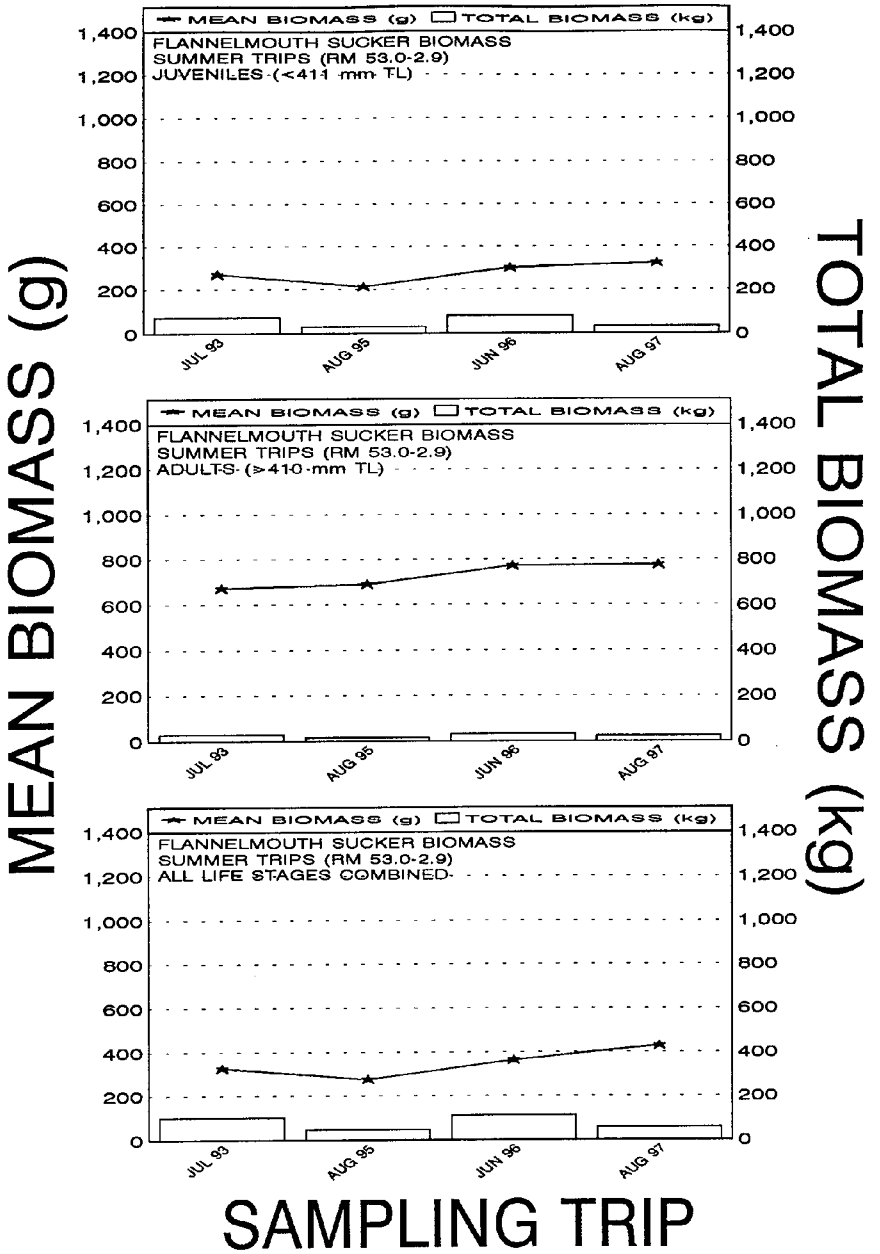


Figure 21. Total and mean biomass of flannelmouth sucker collected and weighed on designated miles during standardized adult fish community monitoring trips in the lower San Juan River (RM 53.0-2.9), 1993-1997.

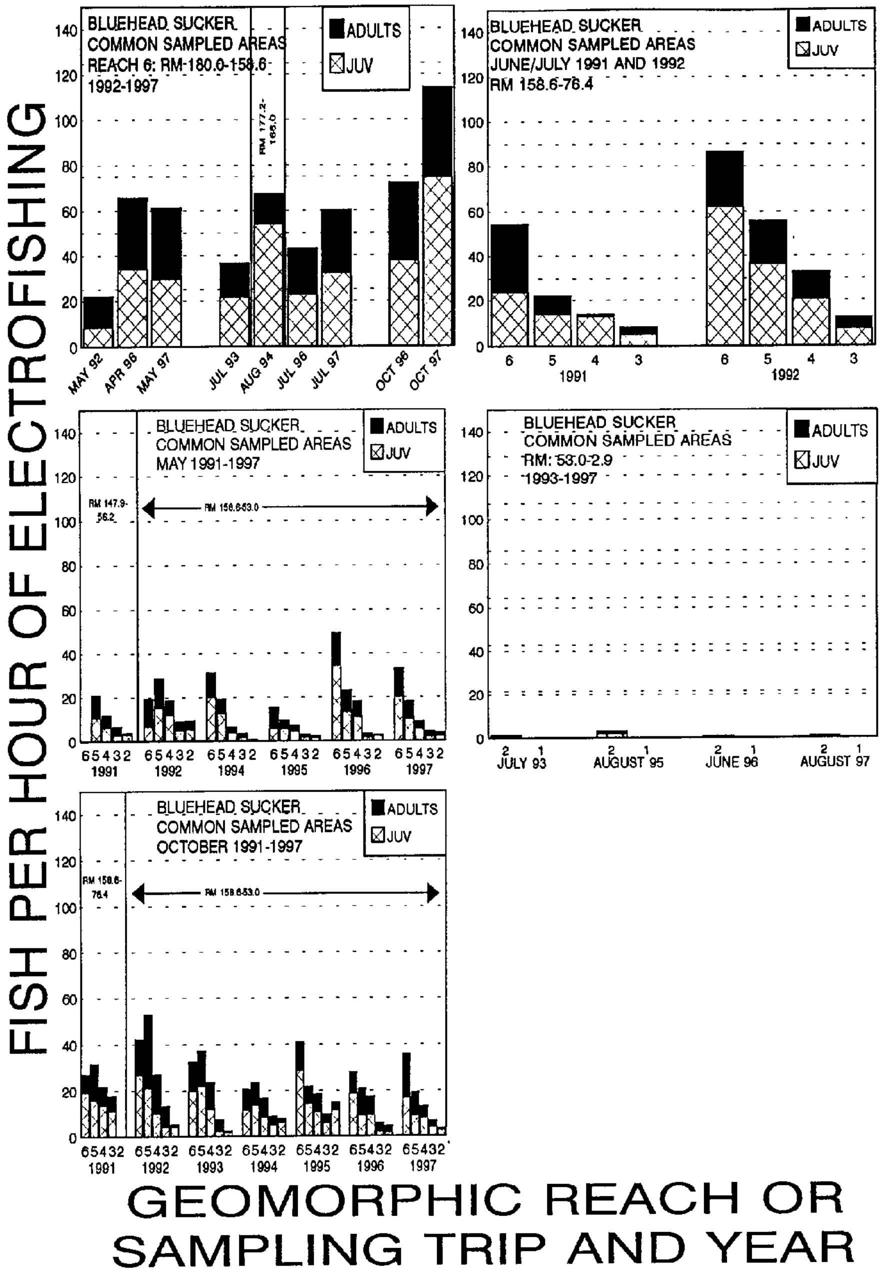


Figure 22. Number of bluehead sucker collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

Table 24-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 19.124, r^2 = 0.115, p = 0.000*

Scheffe matrix:	May	July	October
May	1.000		
July	0.295	1.000	
October	0.000*	0.000*	1.000

Table 24-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 23.770, r^2 = 0.282, p = 0.000*

Scheffe matrix:	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.000*	0.769	1.000

Table 24-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.672, r^2 = 0.045, p = 0.073*

Scheffe matrix:	1993	1996	1997
1993	1.000		
1996	0.484	1.000	
1997	0.074*	0.560	1.000

Table 24-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.646, r^2 = 0.046, p = 0.110

Scheffe matrix:	1996	1997
1996	1.000	
1997	0.110	1.000

Table 25-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, grouped by months across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 3.842, $r^2 = 0.003$, $p = 0.022$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.024*	1.000	
October	0.258	0.380	1.000

Table 25-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.745, $r^2 = 0.002$, $p = 0.475$

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.740	1.000	
1997	0.997	0.524	1.000

Table 25-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 24.046, $r^2 = 0.092$, $p = 0.000$*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.000*	1.000	
1997	0.000*	0.255	1.000

Table 25-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 227.160, $r^2 = 0.198$, $p = 0.000$*

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.000*	1.000

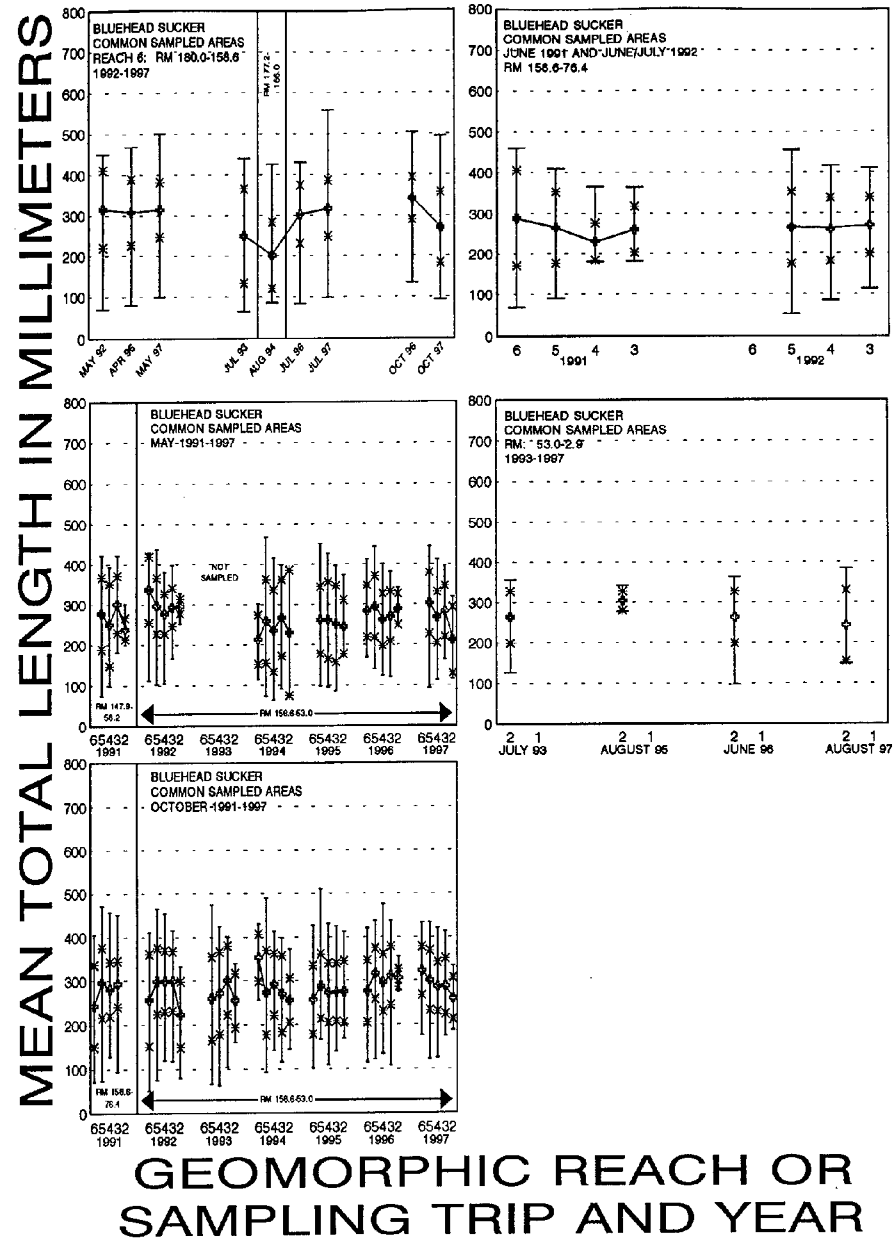


Figure 23. Mean total length (TL) in millimeters for bluehead sucker collected on standardized adult fish community monitoring trips, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river. Lines and crosses represent the mean values, error bars represent the range, and asterisks represent the standard deviation.

significant difference in mean TL of bluehead sucker collected on May and October trips (Table 25-a, Figure 23). Comparisons of mean TL in May across years indicated no significant differences in bluehead sucker mean TL across years (Table 25-b, Figure 23). On July trips, bluehead sucker collected in 1996 and 1997 were significantly larger than those in 1993 (Table 25-c, Figure 23). Mean Tl of bluehead sucker in July 1996 and 1997 were not significantly different. On October trips, bluehead sucker mean TL dropped significantly between 1996 and 1997 (Table 25-d, Figure 23).

Length-frequency histograms of bluehead sucker size classes collected in Reach 6 show that bluehead sucker caught in this section of the river were dominantly large juvenile (> 200 mm TL) and adult (> 300 mm TL) fish, with the exception of the July 1993 and October 1997 trips (Figure 24). The collection of the relatively large numbers of smaller fish in July 1993 compared to July 1996 and 1997 trips, and in October 1997 compared to October 1996 account for the significant differences in mean TL observed in Figure 23 (Figure 24). The spike in young fish (51-175 mm TL) collected in July 1993 represents strong 1991 and 1992 cohorts while the spikes in young bluehead sucker in October 1997 indicate a strong 1995 and 1996 cohorts (Figure 24).

Plots of bluehead sucker mean biomass for all life stages combined show that bluehead sucker collected on October trips were significantly lighter than those on May and July trips (Table 26-a, Figure 25). There were no significant differences between bluehead sucker biomass on either May or July trips in Reach 6 between years (Tables 26-b and 26-c, Figure 25). No biomass comparisons could be made for October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

In Reach 6, bluehead sucker mean K showed a significant drop between May and October trips, with July trips being intermediate to both, much like the trend noted for flannelmouth sucker (Table 17-a and 27-a, Figures 9 and 26). There was also a significant increase in bluehead sucker mean K between May 1992 and May 1996, for all life stages combined (Table 27-b, Figure 26). There was no significant difference between bluehead sucker mean K on any of the three July trips in Reach 6 (Table 27-c, Figure 26). No comparisons could be made for K between October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

---Core Sampling Area (RM 158.6-53.0)---

In the core sampling area patterns of bluehead sucker CPUE varied greatly between May and October trips. Comparisons of total CPUE, grouped by month across years, showed that bluehead sucker CPUE on October trips was significantly higher (Mann-Whitney U test statistic = 1120386.500, p = 0.000) than on May trips (Table 28-a, Figures 22 and 27).

Bluehead sucker CPUE fluctuated greatly on May trips, starting at 10.06 fish/hr (range = 0.00-66.67) in 1991, rising to a high of 16.02 fish/hr (range = 0.00-135.29) in 1992, dropping to a low of 5.51 fish/hr (range = 0.00-53.33) in 1995, continuing to fluctuate, then finishing at 9.56 fish/hr (range = 0.00-194.74) in 1997 (Figures 22 and 27). Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) shows a declining catch rate in both adult and juvenile bluehead sucker on May trips between 1992 and 1995, with catches rising again after May 1995 in Reaches 4

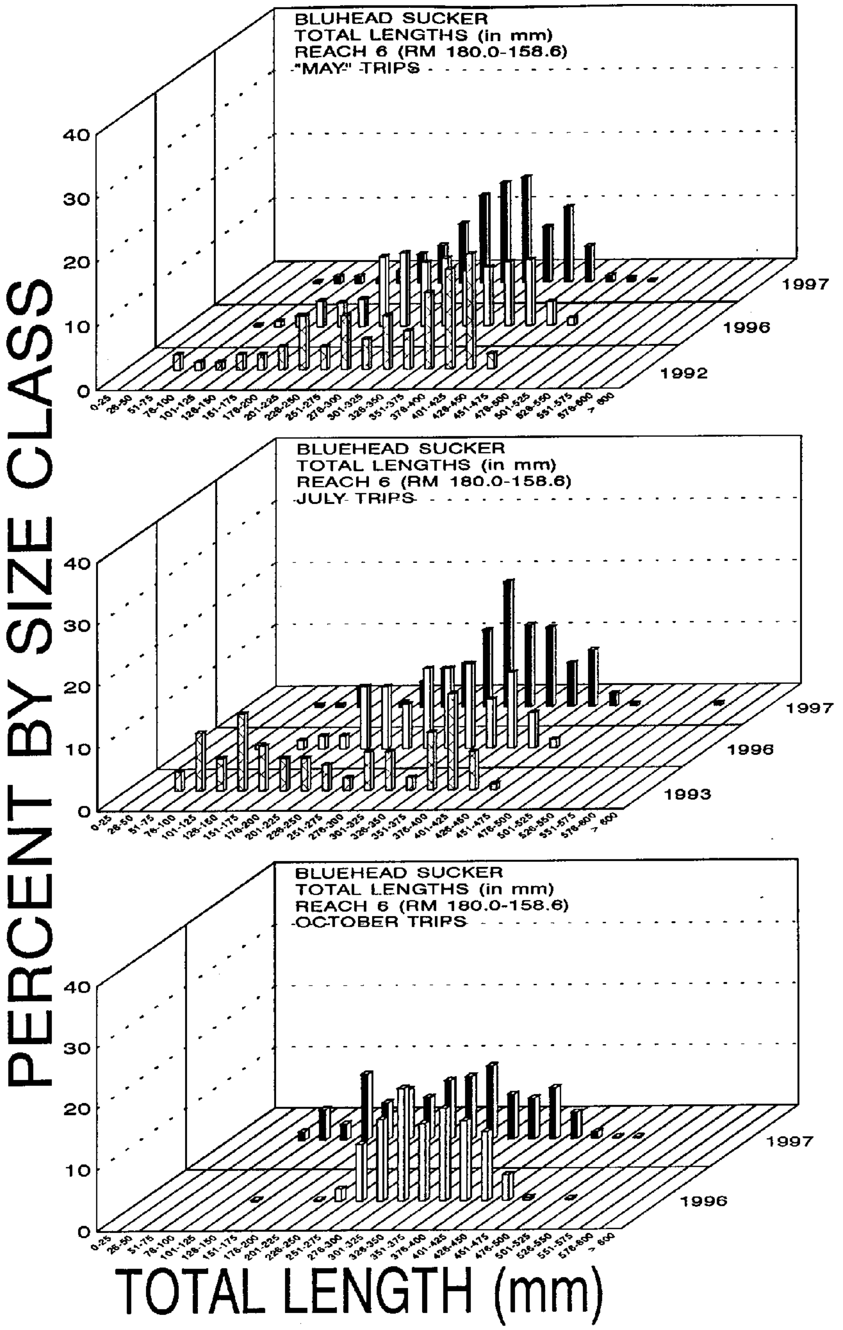


Figure 24. Length-frequency histograms for bluehead sucker collected and measured on designated miles during standardized adult fish community monitoring trips in Reach 6 (RM 180.0-158.6), 1992-1997.

Table 26-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 36.451, r^2 = 0.056, p = 0.000*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.433	1.000	
October	0.000*	0.000*	1.000

Table 26-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.718, r^2 = 0.008, p = 0.181

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.181	1.000	
1997	0.449	0.836	1.000

Table 26-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.811, r^2 = 0.004, p = 0.445

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.604	1.000	
1997	0.468	0.969	1.000

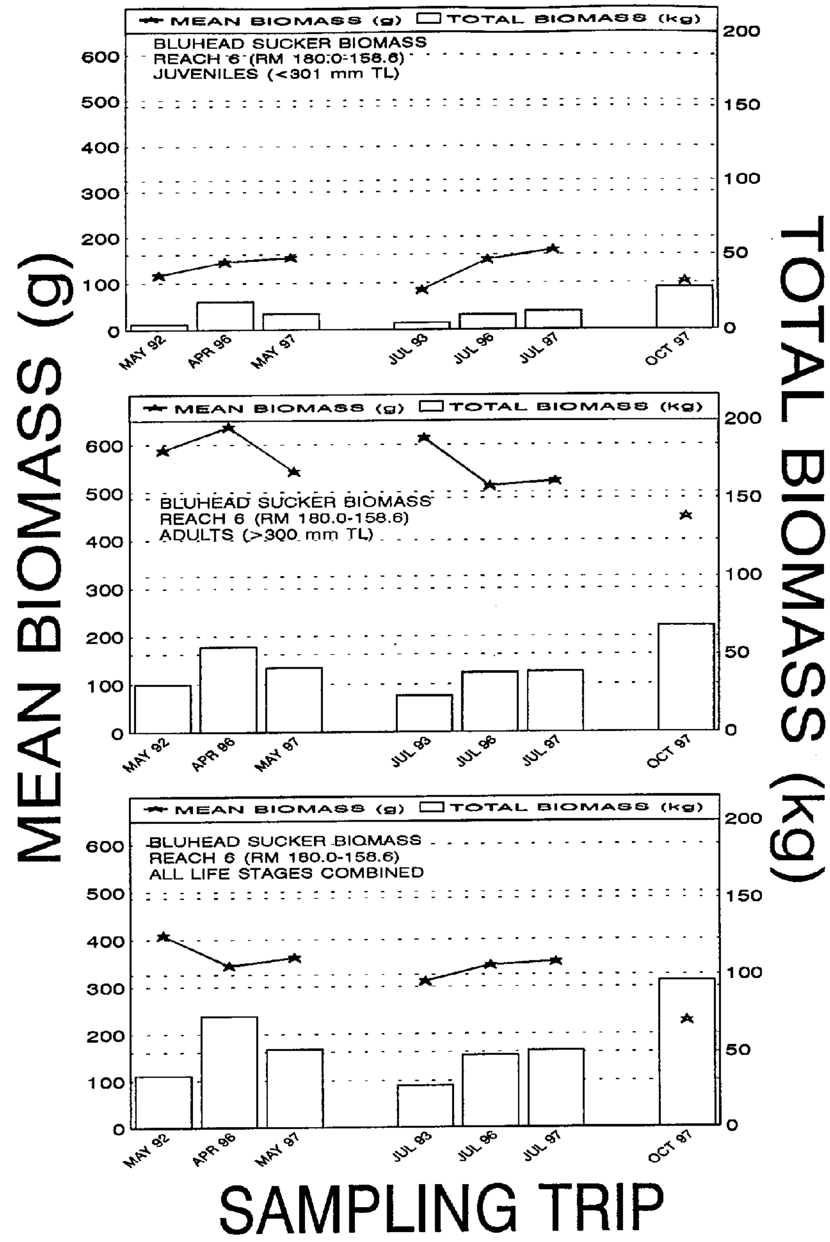


Figure 25. Total and mean biomass of bluehead sucker collected and weighed on designated miles during standardized adult fish community monitoring trips between RM 180.0-158.6 ("Reach 6"), 1991-1997.

Table 27-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 106.384, r^2 = 0.148, p = 0.000*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.000*	1.000	
October	0.000*	0.000*	1.000

Table 27-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 18.255, r^2 = 0.077, p = 0.000*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.001*	0.043*	1.000

Table 27-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.611, r^2 = 0.009, p = 0.201

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.318	1.000	
1997	0.986	0.308	1.000

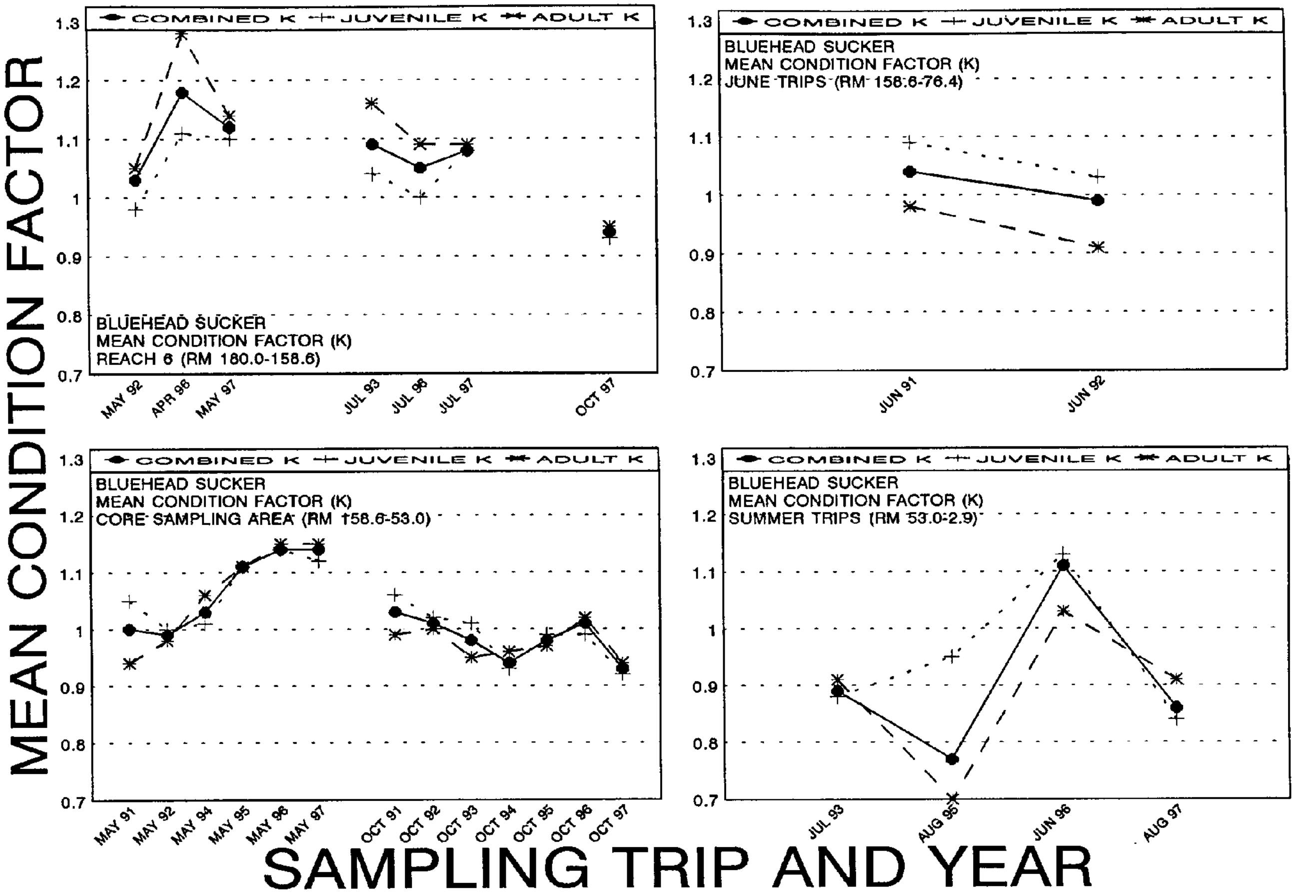


Figure 26. Mean condition factor of bluehead sucker collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips for common sampled areas between RM 180.0-2.9, 1991-1997.

Table 28-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker sucker CPUE data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 277.460, r^2 = 0.071, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 28-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 25.894, r^2 = 0.072, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.022*	1.000				
1994	0.133	0.000*	1.000			
1995	0.001*	0.000*	0.449	1.000		
1996	1.000	0.001*	0.010*	0.000*	1.000	
1997	0.998	0.000*	0.134	0.000*	0.989	1.000

Table 28-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker CPUE data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 33.436, r^2 = 0.094, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.992	1.000					
1993	0.000*	0.000*	1.000				
1994	0.000*	0.000*	1.000	1.000			
1995	0.000*	0.000*	0.942	0.966	1.000		
1996	0.000*	0.000*	0.254	0.234	0.013*	1.000	
1997	0.000*	0.000*	0.017*	0.016*	0.000*	0.978	1.000

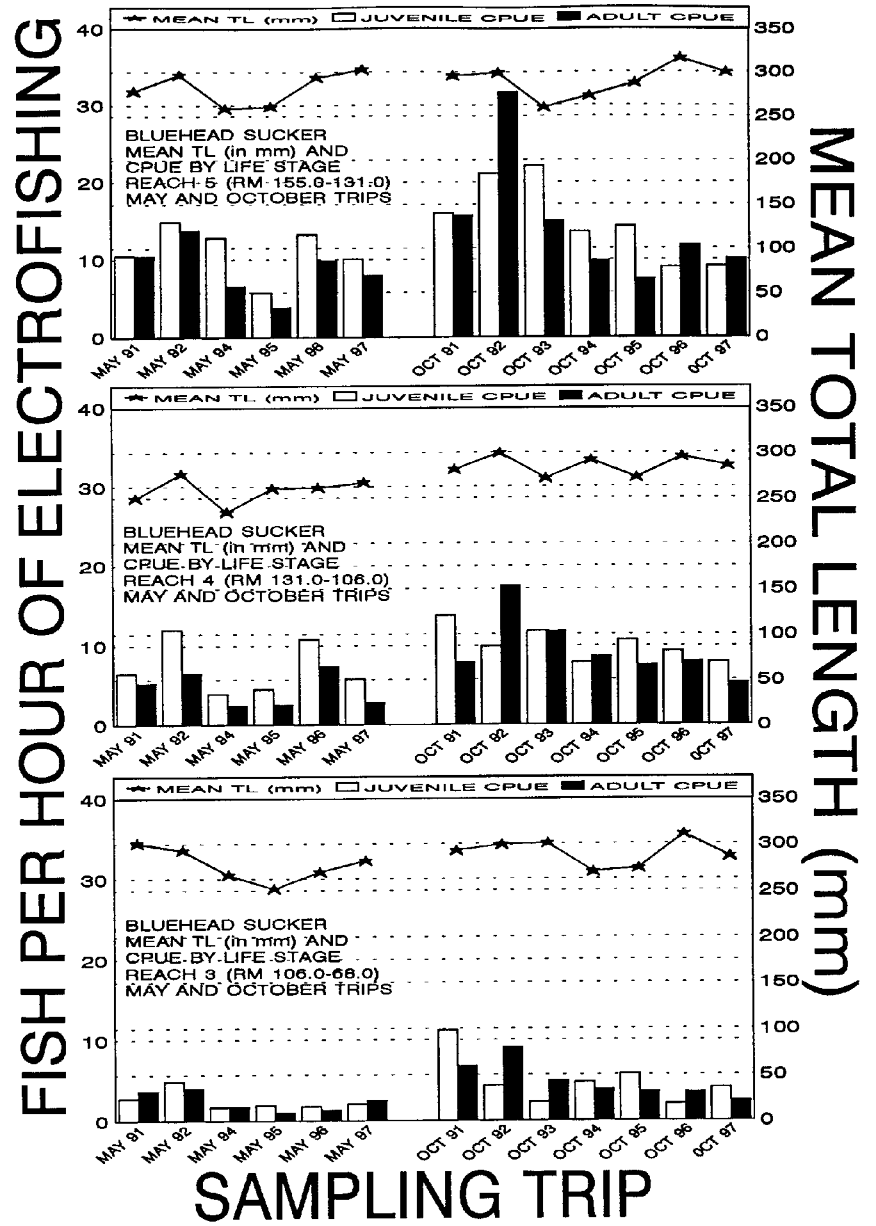


Figure 27. Number of fish collected by life stage per hour of electrofishing versus mean total length for bluehead sucker in geomorphic Reaches 3-5 on May and October standardized adult fish community monitoring trips in the core sampling area of the San Juan River (RM 158.6-53.0), 1991-1997.

and 5, but remaining low in Reach 3 (Figure 27). Significant differences in bluehead sucker CPUE were present between years on May trips (Kruskal-Wallis test statistic = 116.397, p = 0.000). An ANOVA/Scheffe done on ranked May bluehead sucker CPUE data indicated that CPUE in May 1992 was significantly higher than all other years, while CPUE for May 1995 was consistently lower than all other years with the exception of May 1994 (Table 28-b). Other than that, few significant differences existed in bluehead sucker CPUE among May trips in the core sampling area (Table 28-b, Figures 22 and 27).

Bluehead sucker CPUE on October trips in the core sampling area was 23.72 fish/hr (range = 0.00-102.70) in 1991, rose to a high of 28.46 fish/hr (range = 0.00-121.57) in 1992 and then declined fairly consistently over the next five years to a low of 11.86 fish/hr (range = 0.00-285.37) in 1997 (Figures 22 and 27). This decline represented a 58.3% drop in catch rate between October 1992 and 1997 and was statistically significant (Table 28-c). Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) shows declining catch rates in juvenile bluehead sucker on October trips between 1993 and 1997 in Reach 5, between 1991 and 1997 in Reaches 4 and 3, and declining catch rates in adult bluehead sucker CPUE between 1992 and 1997 in all three reaches (Figure 27). Significant differences in bluehead sucker CPUE were present between years on October trips (Kruskal-Wallis test statistic = 189.489, p = 0.000). An ANOVA/Scheffe done on ranked October bluehead sucker CPUE data indicated that CPUE in October 1991 and 1992 were not significantly different from on another, but were significantly higher than all following years (Table 28-c, Figures 22 and 27). Bluehead sucker CPUE in October 1993-1996 were not significantly different from each other (Table 28-c). Bluehead sucker CPUE in October 1997 was significantly lower than in all previous years with the exception of October 1996 (Table 28-c).

An ANCOVA done by Lawrence found significant differences between the slopes of the regression lines for total (F = 9.02, $F_{0.05(1),1,10}$ = 4.96) and juvenile CPUE (F = 6.86), but not adult CPUE (F = 4.56). This indicated that despite the significant negative flow effect on October CPUE, juvenile and total bluehead sucker CPUE still appeared to decline in the river between RM 158.6 and 53.0 over the seven-year research period (Lawrence 1999). Lawrence qualified these findings by stating that at times at least half the number of bluehead sucker collected were found between RM 180.0 and 158.6, and in order to better detect changes in this population it would be necessary to focus on Reach 6 where bluehead sucker are more abundant.

A comparison of bluehead sucker CPUE on October trips between 1988 and 1997 (RM 147.9-119.2) showed that CPUE increased between 1988 and 1992, but then declined fairly steadily between 1992 and 1997, falling to levels below those observed in the late 1980's (Figure 12).

Comparisons of bluehead sucker mean TL between May and October trips, all years combined and between trips in a given month across years, via ANOVA/Scheffe, showed fewer significant differences than did these same comparisons for flannelmouth sucker (Tables 19-a - 19-c and 29-a - 29-c). Graphic comparisons of bluehead sucker mean TL data failed to show any clear trends in the same data (Figure 23). The trend of declining mean TL in Reaches downstream of Reach 5 observed among flannelmouth sucker was not seen among bluehead sucker (Figures 6 and 23). Length-frequency histograms of bluehead sucker measured on DM’s in the core sampling area showed that small size-class bluehead sucker accounted for a larger percentage of the catch than in Reach 6 (Figures 24 and 28). This was true on both May and October trips

Table 29-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.825, $r^2 = 0.000$, $p = 0.177$

Scheffe matrix:

	May	October
May	1.000	
October	0.177	1.000

Table 29-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 20.418, $r^2 = 0.065$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.147	1.000				
1994	0.453	0.000*	1.000			
1995	0.823	0.000*	0.995	1.000		
1996	1.000	0.022*	0.099*	0.506	1.000	
1997	0.010*	0.779	0.000*	0.000*	0.000*	1.000

Table 29-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 43.332, $r^2 = 0.065$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.746	1.000					
1993	0.059*	0.000*	1.000				
1994	0.966	0.181	0.667	1.000			
1995	0.529	0.008*	0.988	0.986	1.000		
1996	0.000*	0.000*	0.000*	0.000*	0.000*	1.000	
1997	0.926	0.031*	0.343	1.000	0.952	0.000*	1.000

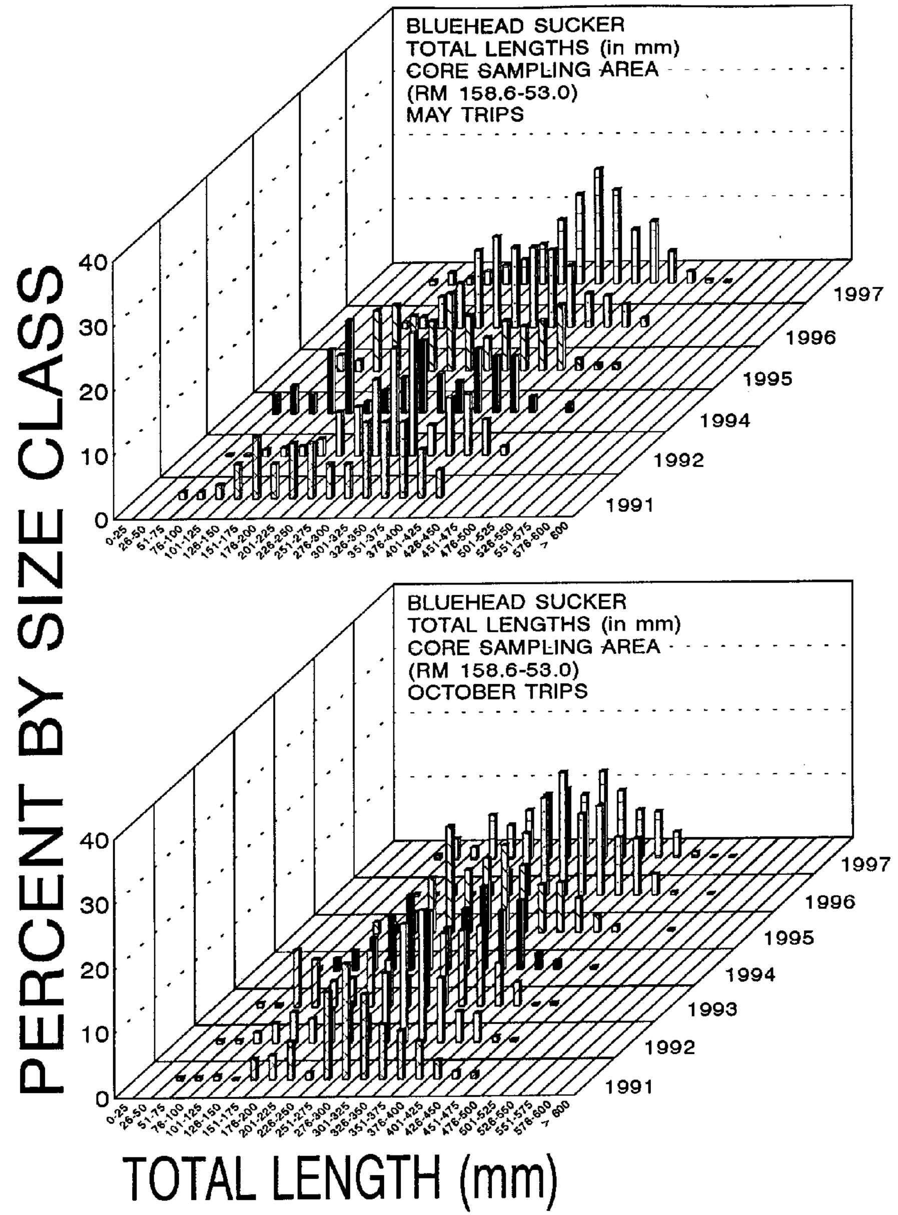


Figure 28. Length-frequency histograms for bluehead sucker collected and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

throughout the study period. However, the percent of young juveniles (< 176 mm TL) in DM's did decline in both 1996 and 1997 compared to other years in the core sampling area (Figure 28). Based on the length-frequency histograms, strong cohorts of bluehead sucker were spawned in 1991 and 1992, based on age-2 fish observed in May 1994 (126-175 mm TL) and October 1993 (101-150 mm TL) collections (Figure 28).

Bluehead sucker mean biomass was significantly higher on May trips than on October trips (Table 30-a). This was especially true among adult fish (Figure 29). Mean biomass of bluehead sucker in the core sampling area was not significantly different in 1997 compared to 1991, on either May or October trips (Tables 30-b and 30-c). Both months showed few significant differences in comparisons between sampling years (Tables 30-b and 30-c). Unlike flannelmouth sucker mean biomass (Figures 15-17), bluehead sucker mean biomass did not decline appreciably in downstream reaches of core sampling area (Figures 30-32).

Like mean biomass, mean condition factor of bluehead sucker, was significantly higher on May trips than on October trips (Table 31-a, Figure 33). Mean K increased significantly between 1991 and 1997 on May trips (Table 30-b, Figure 33), but decreased significantly between 1991 and 1997 on October trips (Table 30-c, Figure 33). Like mean TL and mean biomass, bluehead sucker mean K in the core sampling area was very similar in all reaches (Figure 33). Like flannelmouth sucker K in the core sampling area, the significant increase in May bluehead sucker mean K over the study period cannot be accounted for by the collection of adult fish in spawning condition, because the increasing trend in mean K was observed in both juvenile and adult fish (Figure 33). By plotting mean juvenile and adult K against river discharge, Lawrence demonstrated that the greatest increases in bluehead sucker mean K occurred in conjunction with periods of stable winter base-flows (Lawrence 1999). This was true for both juvenile and adult fish. These stable winter base-flow periods included the winter of 1993-1994 and 1995-1996.

---June Trips (RM 158.6-76.4)---

On June trips (RM 158.6-76.4) patterns of bluehead sucker CPUE resembled those of October 1991 and 1992 trips, with 1992 CPUE being significantly higher than in 1991 (Mann-Whitney U test statistic = 7061.000, p = 0.000; Table 32-a, Figure 22).

Bluehead sucker mean TL on the June 1992 was not significantly different between June 1991 and 1992 (Table 32-b, Figure 23). A length-frequency histogram of bluehead sucker measured on the June trips shows that like the May and October trips in the core sampling area, many small size-class fish were collected (Figure 34). As with May and October trips in the core sampling area, bluehead sucker mean TL did not appreciably decline in downstream reaches (Figure 23). Bluehead sucker mean biomass was significantly lower on the June 1992 trip than on the June 1991 trip (Table 32-c, Figure 35). Bluehead sucker mean K also declined significantly between June 1991 and June 1992 (Table 32-d, Figure 26).

Table 30-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 18.529, $r^2 = 0.004$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 30-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 5.920, $r^2 = 0.023$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.868	1.000				
1994	0.986	0.172	1.000			
1995	1.000	0.574	0.999	1.000		
1996	0.990	0.986	0.602	0.909	1.000	
1997	0.113	0.262	0.001*	0.018*	0.106	1.000

Table 30-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 12.799, $r^2 = 0.023$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.397	1.000					
1993	0.632	0.001*	1.000				
1994	0.993	0.106	0.983	1.000			
1995	0.336	0.000*	0.998	0.857	1.000		
1996	0.078*	0.955	0.000*	0.014*	0.000*	1.000	
1997	0.272	0.000*	1.000	0.886	1.000	0.000*	1.000

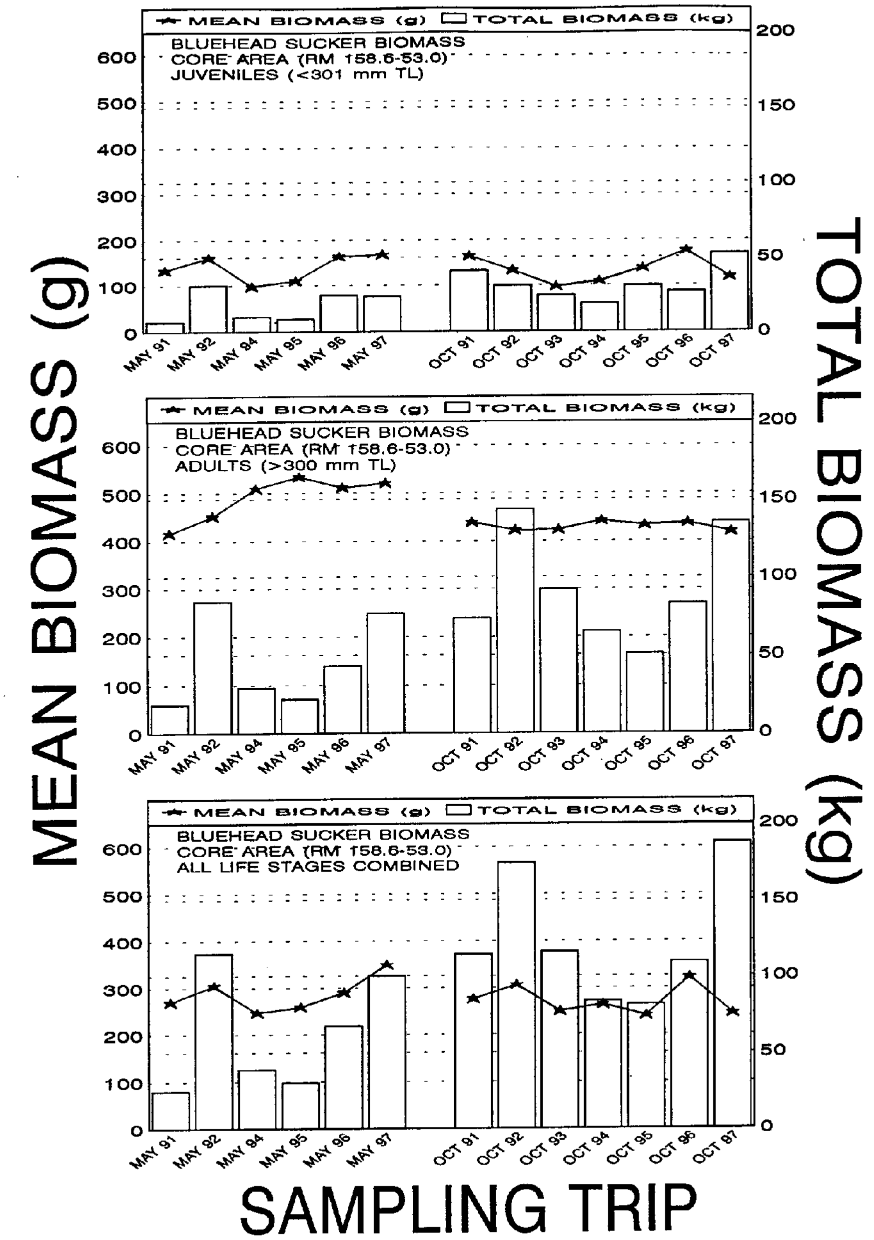


Figure 29. Total and mean biomass of bluehead sucker collected and weighed on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0).

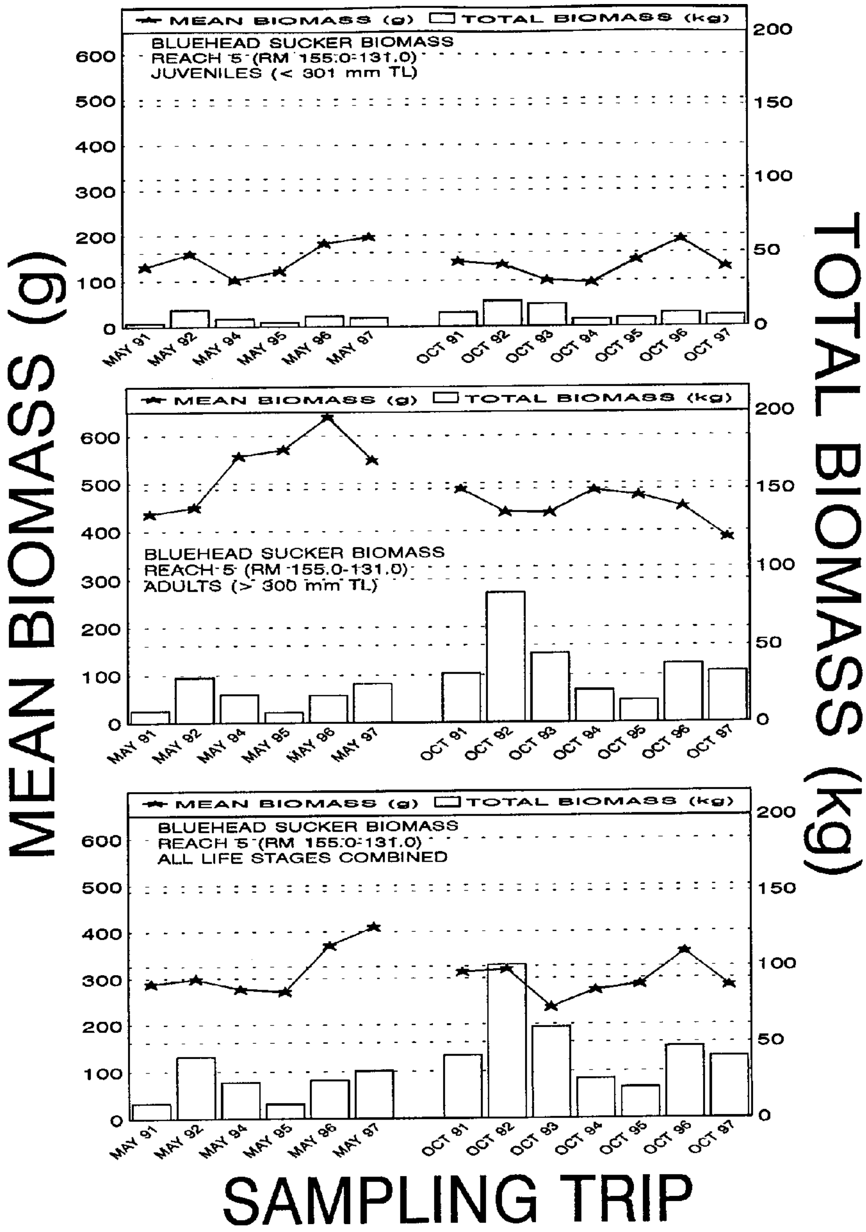


Figure 30. Total and mean biomass of bluehead sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 5 (RM 155.0-131.0).

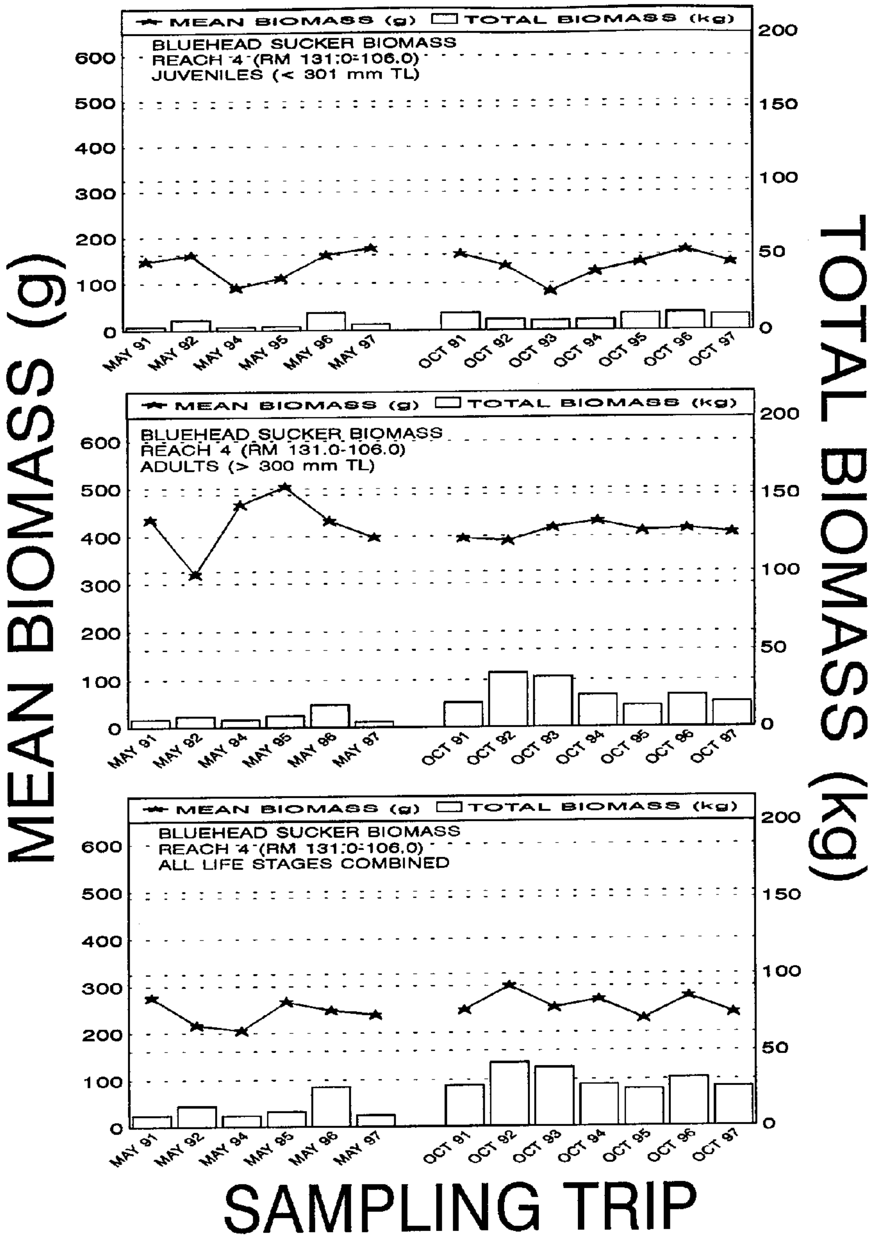


Figure 31. Total and mean biomass of bluehead sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 4 (RM 131.0-106.0).

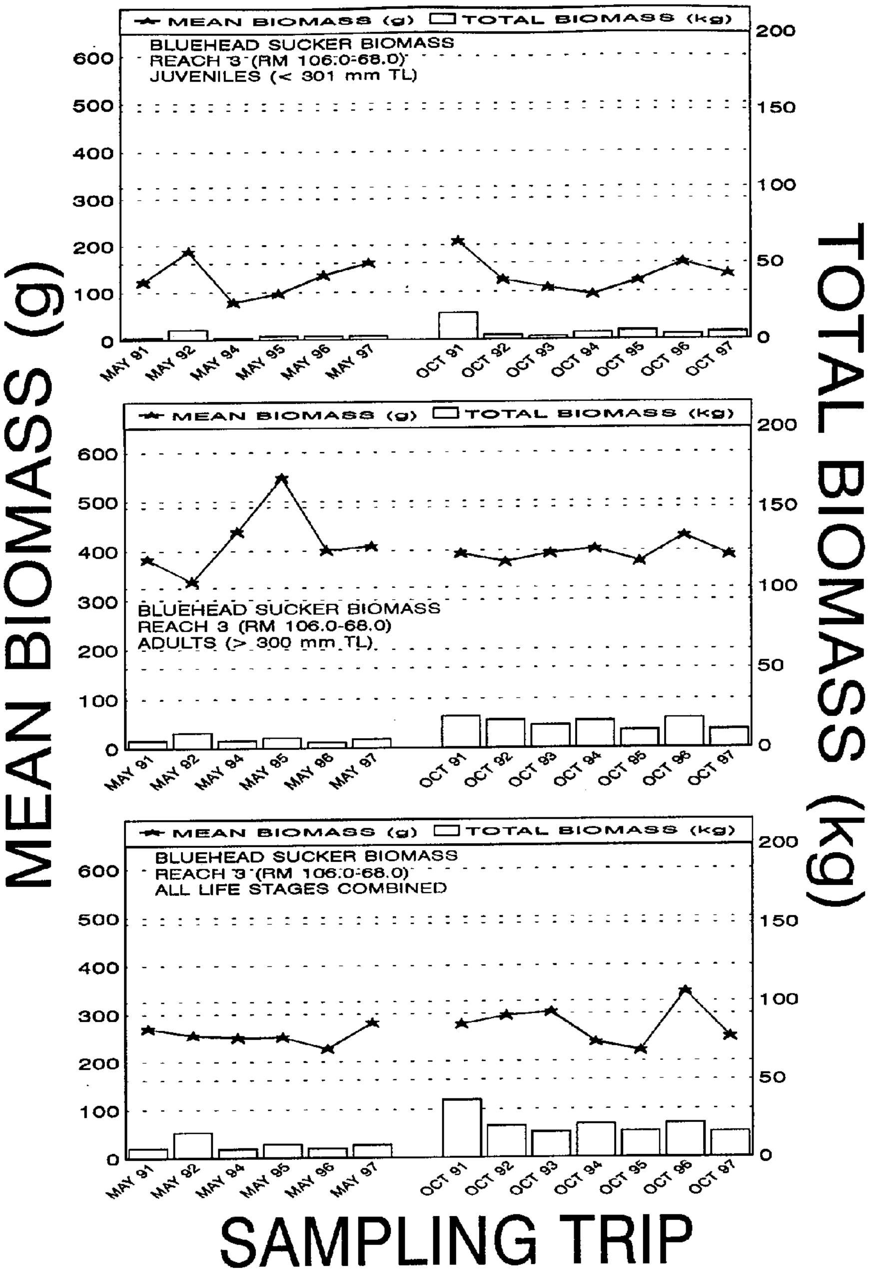


Figure 32. Total and mean biomass of bluehead sucker, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 3 (RM 106.0-68.0).

Table 31-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 200.998, $r^2 = 0.043$, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 31-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 27.856, $r^2 = 0.100$, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	1.000	1.000				
1994	0.937	0.546	1.000			
1995	0.010*	0.000*	0.059*	1.000		
1996	0.000*	0.000*	0.000*	0.860	1.000	
1997	0.000*	0.000*	0.000*	0.923	1.000	1.000

Table 31-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 23.945, $r^2 = 0.043$, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.458	1.000					
1993	0.002*	0.412	1.000				
1994	0.000*	0.000*	0.217	1.000			
1995	0.005*	0.477	1.000	0.345	1.000		
1996	0.641	1.000	0.560	0.001	0.596	1.000	
1997	0.000*	0.000*	0.000*	0.939	0.003*	0.000*	1.000

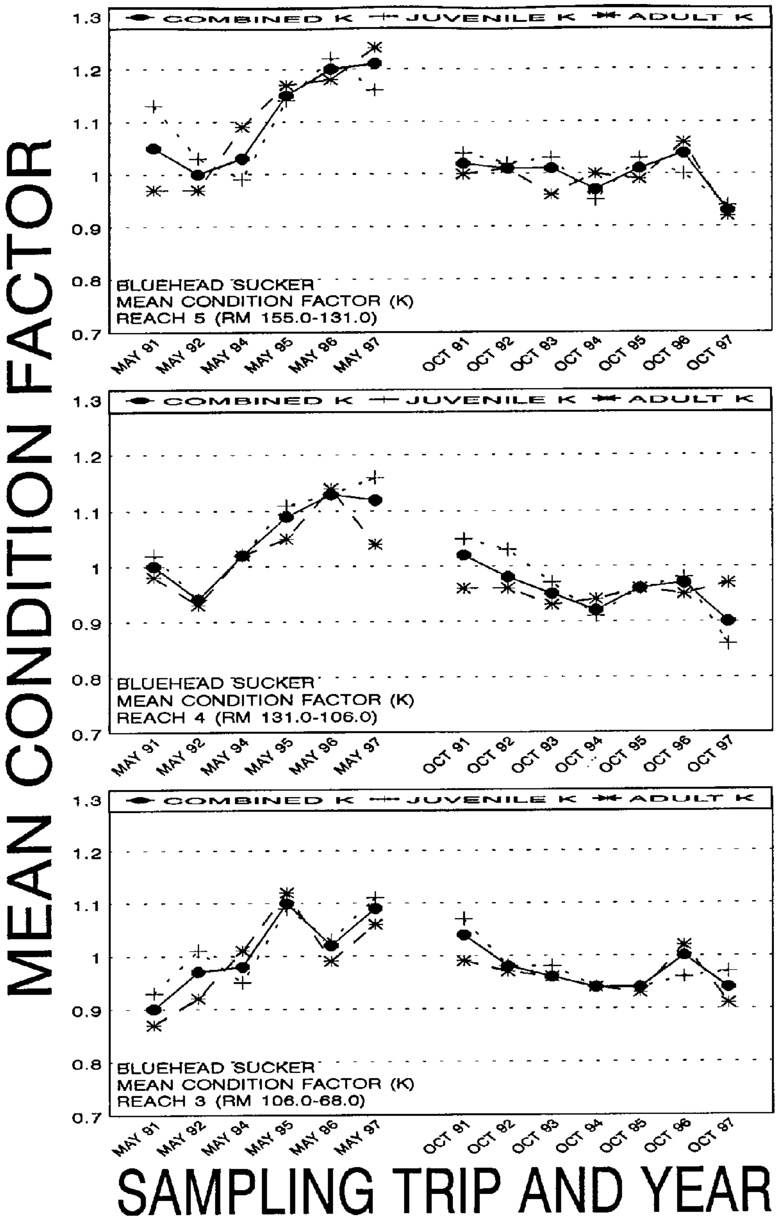


Figure 33. Mean condition factor, by whole geomorphic reach, of bluehead sucker, collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 32-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker mean CPUE data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 21.315, $r^2 = 0.067$, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 32-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.432, $r^2 = 0.002$, p = 0.232

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.232	1.000

Table 32-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 12.502, $r^2 = 0.016$, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 32-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 12.695, $r^2 = 0.016$, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

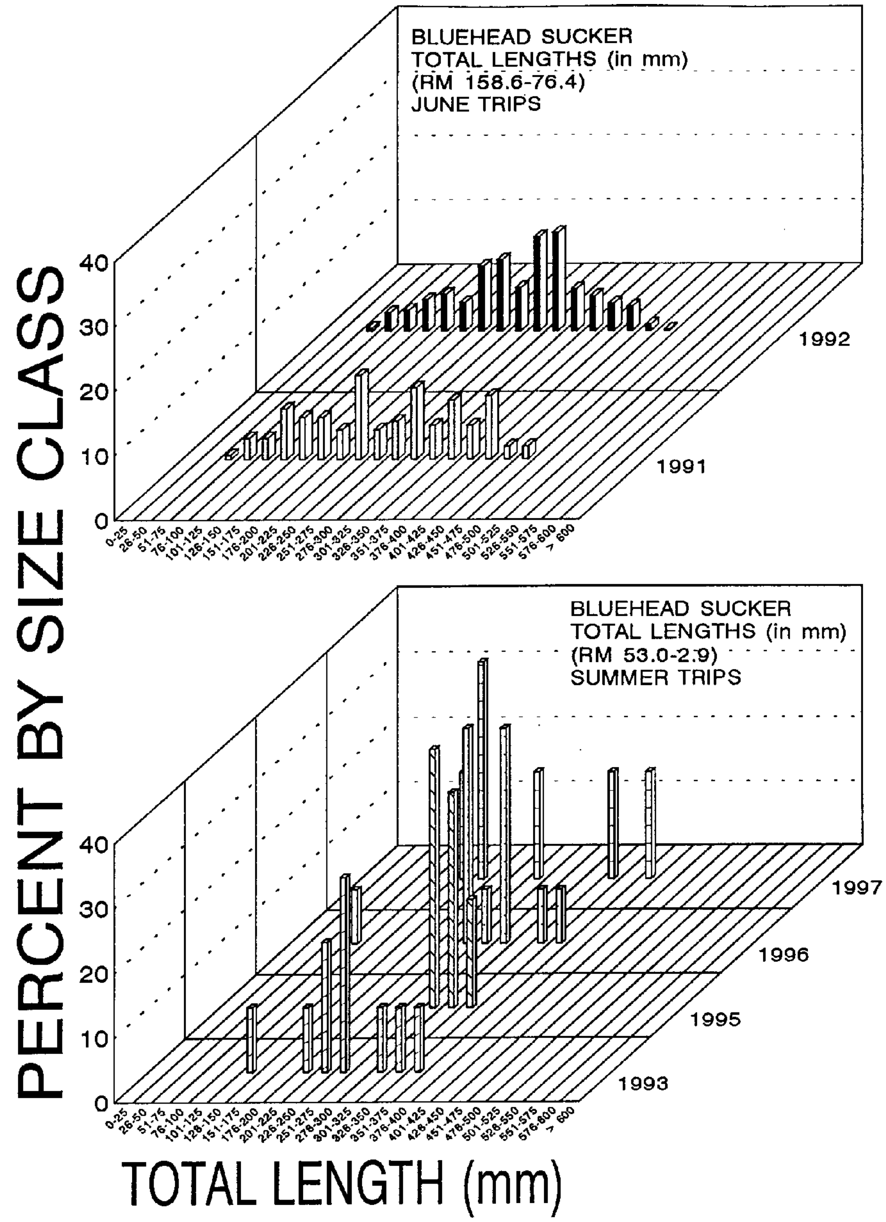


Figure 34. Length-frequency histograms for bluehead sucker collected and measured on designated miles during standardized adult fish community monitoring trips in June 1991 and 1992 (RM 158.6-76.4) and in the lower San Juan River (RM 53.0-2.9), 1993-1997.

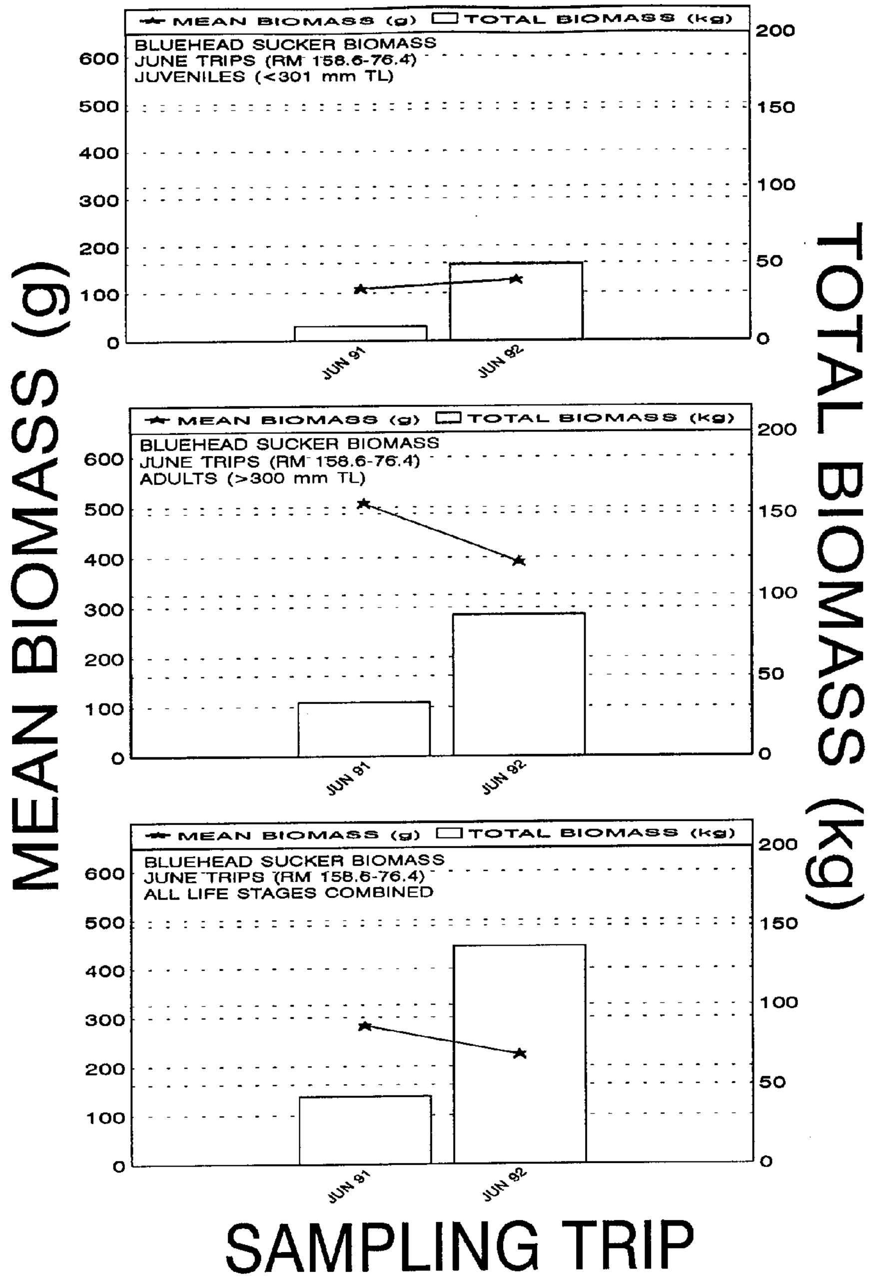


Figure 35. Total and mean biomass of bluehead sucker collected and weighed on designated miles during June 1991 and 1992 standardized adult fish community monitoring trips (RM 158.6-76.4).

---Lower River (RM 53.0-2.9)---

Although always extremely low in the lower river, bluehead sucker CPUE was significantly higher (Kruskal-Wallis test statistic = 12.688, p = 0.005) in August 1995 than on any of the other three sampling trips in the lower river (Table 33-a, Figure 22). There was no significant difference between 1993, 1996, and 1997 bluehead sucker CPUE in this section of the river (Table 33-a). Bluehead sucker were never collected in Reach 1 during our study (Table 12).

There were no significant differences in bluehead sucker mean TL on any of the four trips in the lower river (Table 33-b, Figure 23). Bluehead sucker mean TL in the lower river was very close to that for bluehead sucker in other areas of the river (Figure 23). As with mean TL, bluehead sucker mean biomass showed no significant differences between 1993 and 1997 (Table 33-c, Figure 36). Bluehead sucker mean K in the lower river was significantly higher in 1996 than all other years (Table 33-d, Figure 26). There were no significant differences in bluehead sucker mean K between 1993, 1995 and 1997 in the lower river (Table 33-d).

Speckled Dace

Speckled dace were the third most abundant native species, fifth overall, to be collected in our study (Table 12). Speckled dace was one of only three native fish species (flannelmouth sucker and bluehead sucker being the other two) to be collected in relatively large numbers during this study and to be considered common throughout the adult monitoring study area.

Longitudinal distribution patterns of speckled dace varied greatly between spring and fall collections. During October collections, longitudinal distribution of speckled dace was similar to that of bluehead sucker with steadily declining catch rates from upstream to downstream reaches being observed in 5 of 7 years--1992 and 1997 being the exceptions (Figure 37). Speckled dace distribution during May collections was much more variable with speckled dace being most abundant in Reach 5 in 1991, Reach 4 in 1992, 1994, 1995, and Reach in 6 1996 and 1997 (Figure 37). Longitudinal distribution of collected speckled dace in May 1997 was very similar to the pattern seen on most October trips. Longitudinal distribution of speckled dace on June/July 1991 and 1992 trips show both distribution patterns (Figures 37).

Speckled dace become rare, at best, in the catch below RM 68.0 (Figure 37) and disappear from main channel electrofishing collections altogether by RM 13.0 (Table 12, Figure 37).

One glaring anomaly is evident when examining speckled dace catch data. In August 1994, speckled dace CPUE in Reach 6 was over four times as high (68.9 fish/hr) as at any time before or since in this river reach, or any other reach sampled during our study (Figure 37).

Table 33-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) bluehead sucker mean CPUE data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 4.349, r^2 = 0.036, p = 0.005*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.025*	1.000		
1996	1.000	0.030*	1.000	
1997	0.989	0.011*	0.979	1.000

Table 33-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean TL data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.870, r^2 = 0.080, p = 0.467

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.730	1.000		
1996	1.000	0.698	1.000	
1997	0.945	0.495	0.946	1.000

Table 33-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean biomass (WT in grams) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.714, r^2 = 0.069, p = 0.552

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.997	1.000		
1996	0.716	0.898	1.000	
1997	0.995	0.977	0.658	1.000

Table 33-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of bluehead sucker mean condition factor (K) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 5.645, r^2 = 0.369, p = 0.004*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.685	1.000		
1996	0.065*	0.010*	1.000	
1997	0.995	0.862	0.084*	1.000

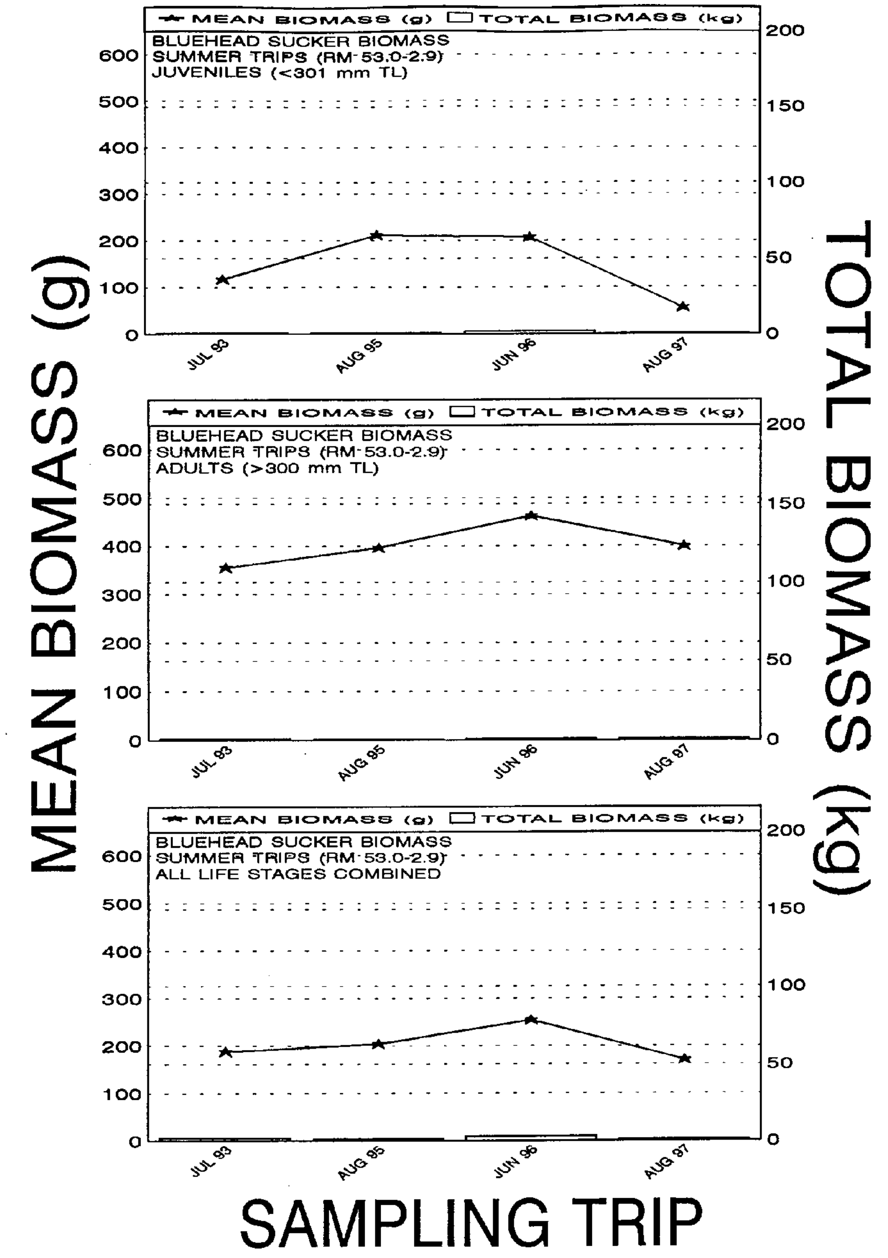


Figure 36. Total and mean biomass of bluehead sucker collected and weighed on designated miles during standardized adult fish community monitoring trips in the lower San Juan River (RM 53.0-2.9), 1993-1997.

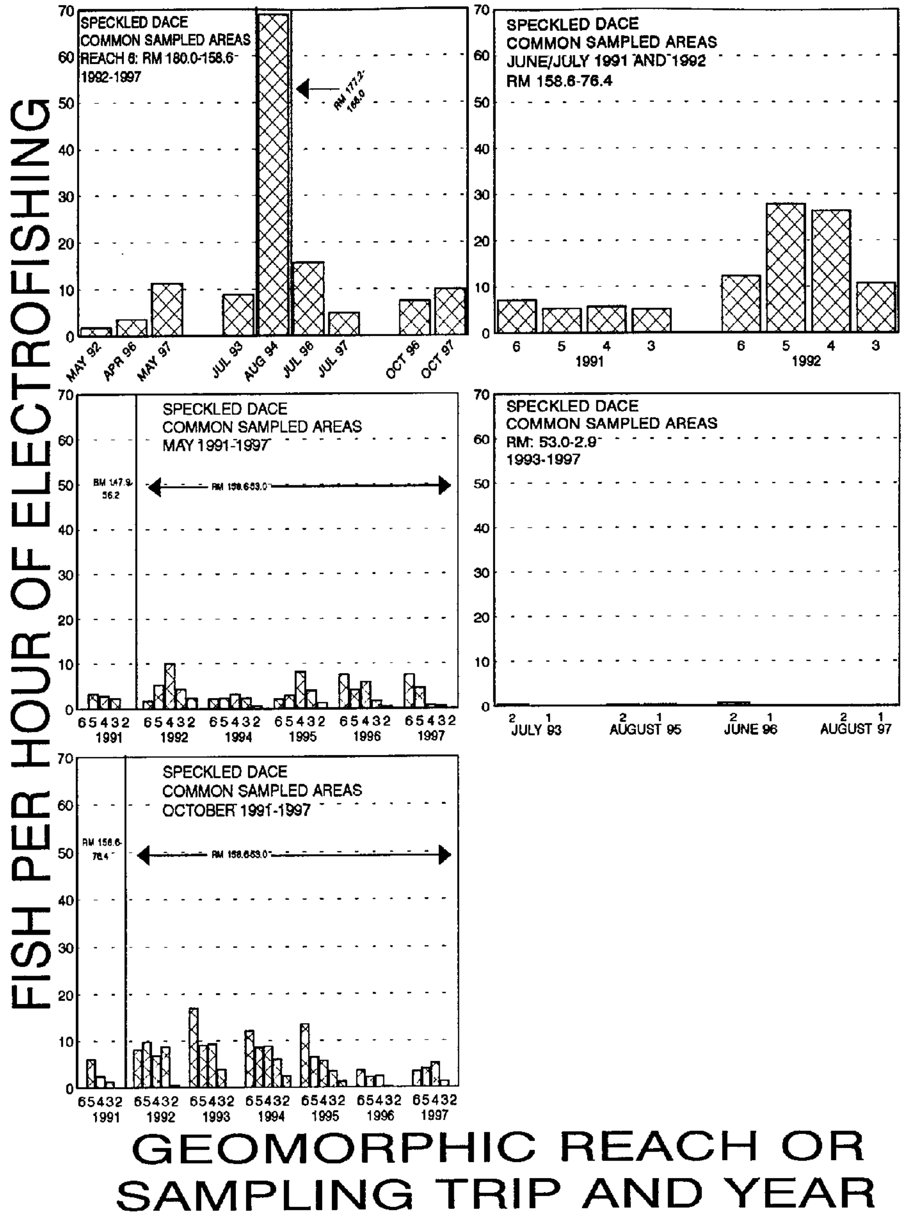


Figure 37. Number of speckled dace collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

Rare Native Fishes

Roundtail Chub

Between 6 May 1991 and 1 July 1997, a total of 24 adult and juvenile roundtail chub were collected during adult monitoring collections (Table 34). These fish had a mean TL of 236 mm (range = 124-414). PIT tags were implanted in 19 of the 24 roundtail chub. Only 7 of the roundtail chub collected were adult fish (> 260 mm TL; Figure 38). The other 17 were juveniles (< 261 mm TL). No YOY roundtail chub were collected during our study. A single roundtail chub adult was recaptured once. This fish had passed downstream over Cudei Diversion (RM 142.0) between the time of its initial capture (13 May 1992; 278 mm TL) and its recapture (8 October 1992; 294 mm TL). Collections of roundtail chub ranged from RM 177.7 to 78.4, placing all captures between the Animas River confluence and the upstream end of the canyon (RM 180.0-68.0; Table 34, Figure 39).

Another 155 roundtail chub were collected from the San Juan River during other studies between 1987 and 1997, mostly by seining (summarized in Table A-1 in Appendix A). These fish ranged in size from 7 mm SL to 208.5 mm TL, and were collected between RM 176.0 and 11.8 (Table A-1 in Appendix A). None of these fish were marked or tagged.

Collections of roundtail chub in the San Juan River were relatively rare between 1987 and 1997, with only 179 individual fish being collected (Tables 9 and 10). Of these, the large majority, 97 (54.2%) were YOY ($\leq$ 55 mm TL). Another 55 (30.7%) were juvenile (56-260 mm TL) fish, and 7 (3.9%) were adult fish ($\geq$ 261 mm TL). The remaining 20 (11.2%) did not have TL or SL listed by which life stage could be determined. However, SL ranges reported for 15 (75.0%) of the 20 unknown life stage roundtail chub place them in either the late YOY (i.e., > 32 mm SL) or early juvenile (i.e., < 100 mm SL) life stage category. Roundtail chub collected during both our study and other studies located predominantly upstream of RM 68.0 (Table 34, Table A-1 in Appendix A, Figures 39 and 40).

Razorback Sucker

No wild razorback sucker have been collected in the San Juan River since 1988 (Platania 1990, Ryden and Pfeifer 1994b, Ryden 1997). As a result of this lack of wild fish, an experimental stocking study for razorback sucker was begun in 1994 (Ryden and Pfeifer 1994b). Numerous razorback sucker stocked between March 1994 and October 1996 were recaptured on adult monitoring trips. For detailed information on razorback sucker stocked and subsequently recaptured between 1994 and 1997, the reader is referred to Ryden (2000). In order to avoid redundancy between reports, only the total numbers of razorback sucker collected on adult monitoring trips is reported herein (Table 12).

Table 34. Juvenile and adult roundtail chub captured during adult fish community monitoring trips in the San Juan River, New Mexico, Colorado, and Utah, 1991-1997.

Date of Capture	PIT Tag Number	Total Length (mm)	Standard Length (mm)	Weight (grams)	Sex	River Mile
05/06/91	7F7D073336	237	195	140	?	137.90
06/08/91	7F7D026830	256	210	190	?	135.30
05/13/92	7F7D142D70	278	225	220	?	147.90
10/07/92	7F7D100559	242	190	100	?	147.90
10/08/92®	7F7D142D70	294	245	220	?	137.70
10/12/92	None	129	100	16	?	96.40
05/13/93	None	130	114	14	?	120.90
05/14/93	7F7D027315	355	298	550	?	121.50
04/15/94	1F204B4B2B	288	247	250	?	135.10
10/04/94	None	124	97	10	?	135.00
10/04/94	None	123	98	16	?	132.00
10/05/94	1F7440604D	269	225	165	?	121.00
05/08/95	1F743C7041	234	195	125	?	146-145
05/12/95	1F73355168	251	210	180	?	106.50
05/14/95	1F73236566	221	178	105	?	78.40
10/09/95	1F412B284D	184	143	44	?	86-84.8
04/15/96	1F6D185B01	414	355	840	F	131.30
05/13/96	1F40424718	171	137	49	?	148.20
10/14/96	1F74766512	243	196	120	?	177.70
10/14/96	1F5B01760F	255	204	155	?	177.60
10/16/96	1F400E1300	220	175	100	?	158.10
10/20/96	7F7B194F20	215	170	80	?	115.50
04/28/97	7F7B180675	280	243	180	?	170.90
04/28/97	None	230	186	108	?	162.00
07/01/97	7F7B0D5004	319	272	302	M	174.10

® = This collection was a recapture of a previously captured and tagged fish

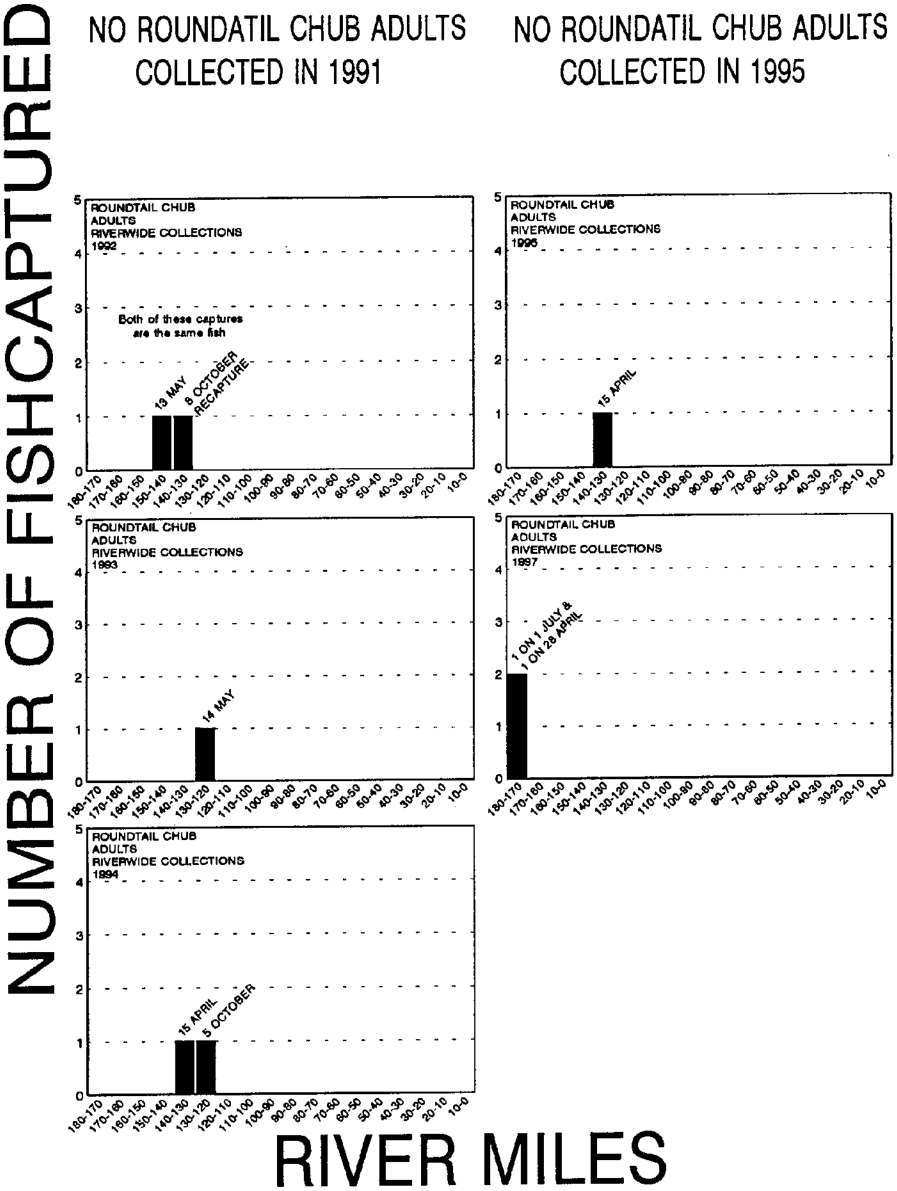


Figure 38. Spatial and temporal distribution of adult roundtail chub collections in the San Juan River during adult fish community monitoring studies, 1991-1997.

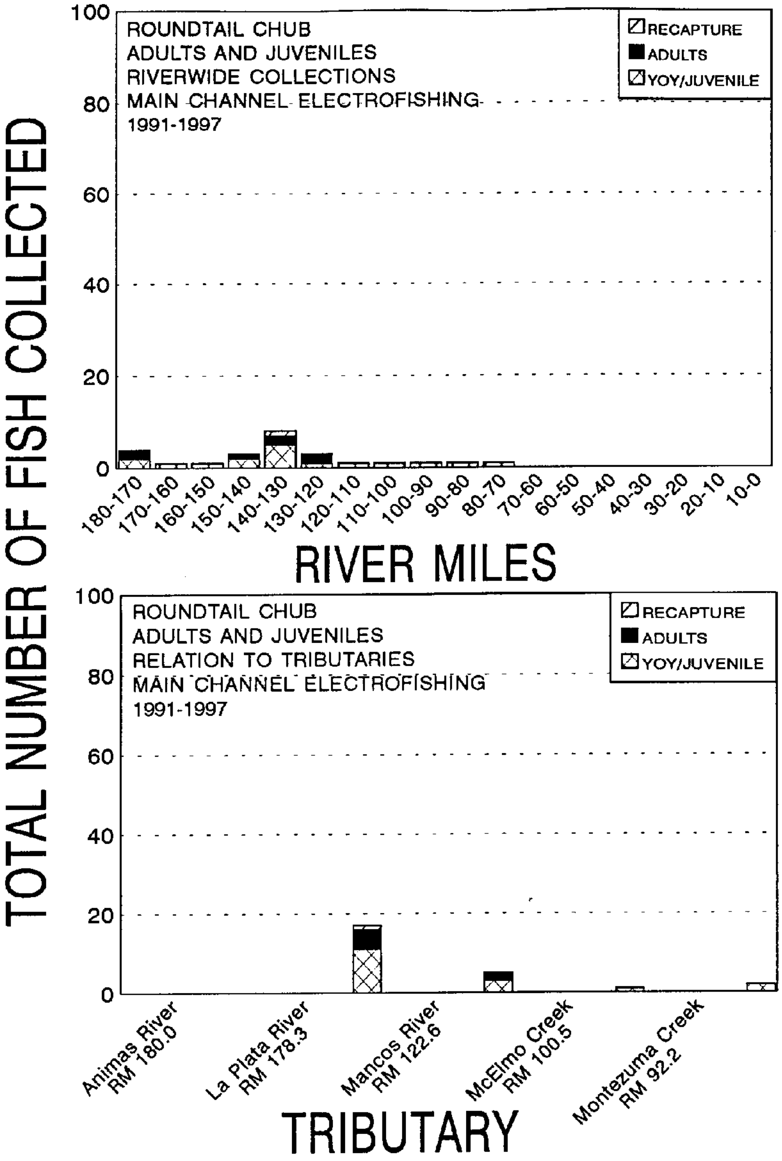


Figure 39. Spatial distribution of all roundtail chub collections, by life stage, in the San Juan River during adult fish community monitoring studies, 1991-1997 (top). Relation of roundtail chub collections, by life stage, during adult fish community monitoring trips, 1991-1997, to major tributaries of the San Juan River (bottom).

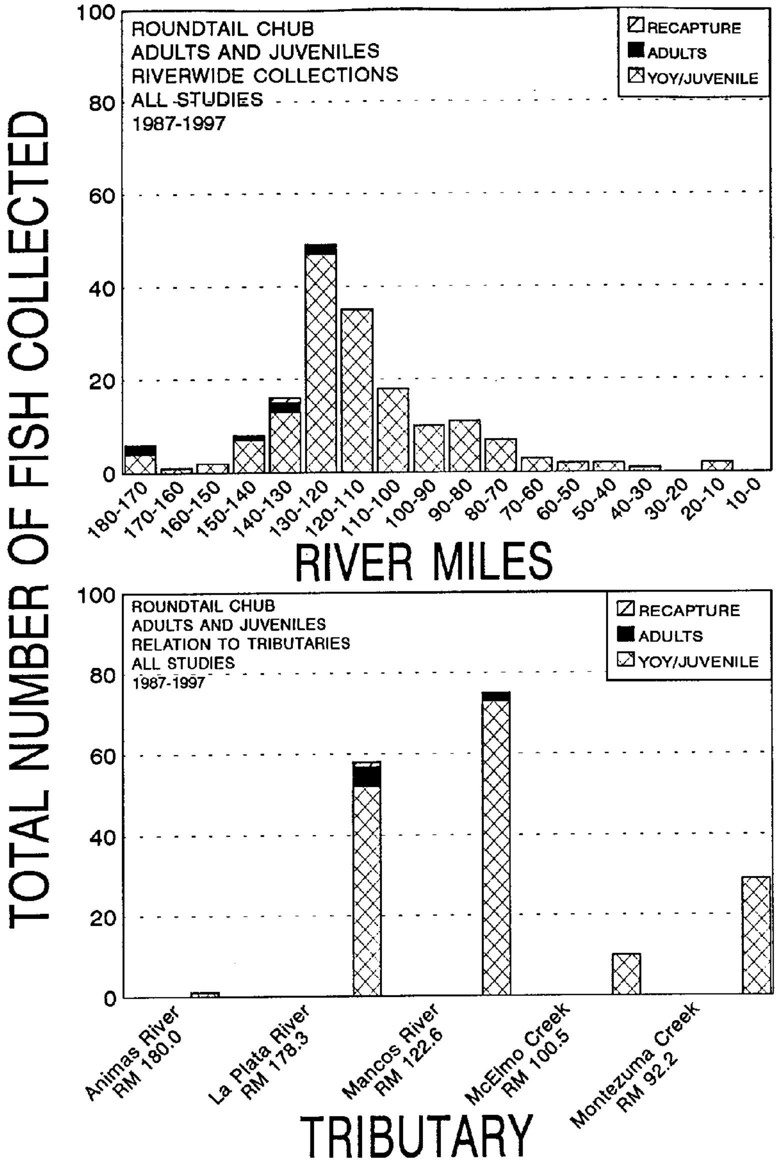


Figure 40. Spatial distribution of all roundtail chub collections, by life stage, in the San Juan River during all studies, 1987-1997 (top). Relation of all roundtail chub collections, by life stage, during all studies, 1987-1997, to major tributaries of the San Juan River (bottom).

Colorado Pikeminnow

---Stocked Fish---

In order to study habitat use by YOY and juvenile Colorado pikeminnow, the UDWR stocked approximately 50,000 Colorado pikeminnow at both Shiprock (Hwy. 64) bridge (RM 147.9) and at Mexican Hat, UT (RM 53.0) on 4 November 1996, and again on 19 August 1997. Beginning in August 1997, these fish started to appear in main channel electrofishing collections (Table 35). Between 14 August and 8 October 1997, 39 of these fish were collected. Recaptures ranged from RM 156.0-18.2. Six of these were implanted with PIT tags, and all but one were returned alive to the river. The single mortality, a 170 mm TL fish, was preserved in 10% formalin and is being retained at the USFWS's CRFP office in Grand Junction, CO.

Recaptures of stocked fish ranged in size from 44-235 mm TL, with 38 of these fish being in the 124-235 mm TL range. The smallest individual Colorado pikeminnow recaptured during our sampling (44 mm TL = 1997 stocking) had moved approximately eight miles upstream from its stocking site in just a little over six weeks (Table 35). Most of the juvenile Colorado pikeminnow recaptured on October trips in the core sampling area were collected along shallow shorelines (< 1 ft deep) with little to no velocity. Often these fish would be within a ft of the shoreline. These habitats were often associated with the inside of large bends in the river channel or some other feature, such as the head of an island, that deflected the majority of the river's current elsewhere, forming a low velocity habitat. The three juvenile Colorado pikeminnow recaptured in the lower river in August 1997 were all collected just upstream of Slickhorn Canyon (RM 17.7) in the lower San Juan River. Two of these fish were collected from a pocket water habitat (i.e., water that flows through the jumbles of large rocks and boulders that are common along the shorelines in the canyon reaches of river) at RM 18.5 and 18.4 on river left. The third fish was collected from a deep, steep-banked, swift, shoreline run habitat at RM 18.2 on river right. Both habitats were several ft deep and would have been impossible to sample with a seine.

---Wild Fish---

Nineteen wild Colorado pikeminnow were captured during electrofishing collections between 1991 and 1996 (Table 36). Nine of these were captured in 1991, three in 1992, three in 1993, two in 1994, and two more in 1996 (Table 36). Sixteen of the 19 Colorado pikeminnow were collected from RM 141.8-122.1 (Table 36). All 16 of these Colorado pikeminnow were large adults, ranging from 519-945 mm TL. Of these 16 fish, six were males and ten were females. A large, adult, female Colorado pikeminnow (753 mm TL), referred to hereafter as the "Bluff fish" was collected at RM 74.8 on 8 October 1993. In addition, two juvenile Colorado pikeminnow (363 and 432 mm TL) were collected in 1996, at RM 7.9 and 12.9 respectively.

Table 35. Recaptured, juvenile Colorado pikeminnow from experimental stockings performed by the Utah Division of Wildlife Resources in the San Juan River in 1996 and 1997. These fish were all collected during adult fish community monitoring (electrofishing) trips.

Date of Capture	PIT Tag Number	Year Class	Total Length (mm)	Weight (grams)	River Mile
08/14/97	None	1996	143	25	18.5
08/14/97	None	1996	124	17	18.4
08/14/97	1F63723C50	1996	161	26	18.2
09/30/97	None	1997	44	--	157-156
10/01/97	None	1996	160	24	146.8
10/01/97	None	1996	145	19	140-139
10/01/97	None	1996	148	18	139.9
10/01/97	None	1996	170	--	Mort.[a] 138.4
10/01/97	None	1996	144	23	137-136
10/01/97	None	1996	187	46	136.5
10/02/97	None	1996	136	15	133.0
10/02/97	None	1996	151	27	131.2
10/02/97	None	1996	155	24	129-128
10/04/97	None	1996	201	47	115-114
10/04/97	None	1996	186	45	110-109
10/04/97	None	1996	198	50	109-108
10/04/97	None	1996	200	--	108-107
10/04/97	None	1996	136	17	107.3
10/04/97	1F5B3B2229	1996	215	67	106-105
10/04/97	None	1996	150	30	105-104
10/04/97	None	1996	170	37	104.6-104.3
10/04/97	None	1996	178	40	104.6-104.3
10/04/97	None	1996	171	35	104.6-104.3
10/04/97	None	1996	194	51	104.6-104.3
10/04/97	1F5B34775B	1996	203	65	104.6-104.3
10/05/97	None	1996	197	45	97-96
10/05/97	None	1996	176	35	94-93
10/06/97	None	1996	204	55	90-89
10/06/97	None	1996	190	46	89-88
10/06/97	None	1996	182	35	88.3
10/06/97	None	1996	202	55	88.1
10/06/97	None	1996	172	32	88-87
10/06/97	None	1996	171	32	88-87
10/06/97	None	1996	181	58	86-85
10/06/97	None	1996	185	48	82-81
10/07/97	1F681D510B	1996	215	91	79.6
10/07/97	None	1996	169	20	73.9
10/08/97	1F6D6E2660	1996	235	54	70-69
10/08/97	1F660D7876	1996	213	85	63.8

[a] = Mortality

Table 36. Adult and juvenile Colorado pikeminnow collected from the San Juan River, New Mexico, Colorado, and Utah, 1987-1997.

Date of Capture	Carlin or PIT Tag Number	Radio Freq.	Total Length (mm)	Standard Length (mm)	Weight (grams)	Sex	River Mile	Source Report
Carlin-tagged Colorado pikeminnow								
04/07/87	0070	None	615	---	1920	?	0.00[a]	Platania 1990
09/08/87	0070®	None	632	---	2300	?	79.02[a]	Platania 1990
05/07/87	1514	None	540	---	1100	?	133.68[a]	Platania 1990
05/08/87	1821	None	780	645	5500	F	122.70[a]	Platania 1990
03/25/88	3241	None	539	445	1100	?	134.45[a]	Platania 1990
03/26/88	3207	None	737	615	4400	F	127.71[a]	Platania 1990
04/23/88	0040	None	568	---	1400	?	114.13[a]	Platania 1990
10/23/88	5002	None	665	530	2750	?	144.74[a]	Platania 1990
05/23/89	0006	None	680	---	3300	?	103.74[a]	Paltania 1990
PIT-tagged Colorado pikeminnow								
06/08/91	7F7D086412	030	571	480	1650	M	134.95	Ryden and Pfeifer 1993
06/09/91	7F7D026448	Mort.	687	575	3450	F[b]	122.60	Ryden and Pfeifer 1993
06/09/91	7F7D073422	150	702	590	3350	F	122.60	Ryden and Pfeifer 1993
06/09/91	7F7D075115	770	610	510	2300	M	122.60	Ryden and Pfeifer 1993
10/17/91	7F7D07737A	None	660	555	2750	F	141.80	Ryden and Pfeifer 1993
10/19/91	7F7D03060E	739	615	507	1695	F	127.70	Ryden and Pfeifer 1993
10/19/91	7F7D027A16	630	945	805	5035	F	127.10	Ryden and Pfeifer 1993
10/19/91	7F7D090D43	760	647	540	2500	F	125.80	Ryden and Pfeifer 1993
10/19/91	7F7D087E58	None	576	478	1450	M	124.00	Ryden and Pfeifer 1993
05/14/92	7F7F187D20	800	519	430	1250	M	130.50	Ryden and Pfeifer 1993
06/28/92	7F7D226615	450	595	495	1855	M[b]	131.40	Ryden and Pfeifer 1993
10/08/92	7F7D1E1C05	690	705	605	3000	F	138.20	Ryden and Pfeifer 1993
10/09/92	7F7F187D20®	800	527	---	1120	M	128.00	Ryden and Pfeifer 1993
04/13/93	7F7F187D20®	800/200	527	445	1200	M	130.60	Ryden and Pfeifer 1994

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

[b] These fish were freely expressing gametes at the time of capture

® These collections are recaptures of previously captured and tagged fish

Table 36, continued.

Date of Capture	PIT Tag Number	Radio Freq.	Total Length (mm)	Standard Length (mm)	Weight (grams)	Sex	River Mile	Source Report
04/14/93	7F7D225E24	980	797	685	5550	F	128.80	Ryden and Pfeifer 1994
04/14/93	7F7D027A16®	630/100	948	820	8050	F	126.20	Ryden and Pfeifer 1994
05/13/93	7F7D075167	030	764	643	4760	F	122.10	Ryden and Pfeifer 1994
10/03/93	7F7D225E24®	980	820	700	5510	F	129.30	Ryden and Pfeifer 1994
10/08/93	7F7D075651	910	753	642	3900	F	74.80	Ryden and Pfeifer 1994
04/12/94	7F7D225E24®	980/848	820	700	5810	F	133.20	Ryden and Pfeifer 1995a
04/14/94	7F7D073422®	150/940	754	628	4450	F	120.60	Ryden and Pfeifer 1995a
04/15/94	7F7D077A18	280	617	510	2000	M	133.20	Ryden and Pfeifer 1995a
05/16/94	7F7D075651®	910	759	642	4000	F	76.00	Ryden and Pfeifer 1995a
10/04/94	7F7D03060E®	739	630	528	2100	F	128.10	Ryden and Pfeifer 1995a
10/05/94	1F74387F36	None	823	695	4370	F	123.60	Ryden and Pfeifer 1995a
10/09/94	7F7D075651®	910	762	642	3800	F	74.40	Ryden and Pfeifer 1995a
04/26/95	1F74387F36®	None	824	695	4350	F	123.10	Ryden and Pfeifer 1996a
04/27/95	7F7D073422®	150/940	754	628	3550	F	122.60	Ryden and Pfeifer 1996a
06/21/96	7F7B133B64	None	363	305	700	?	7.90	first reporting here
07/18/96	7F7D14061D[c]	None	432	357	688	?	12.90	first reporting here

® These collections are recaptures of previously captured and tagged fish

[c] = This fish was collected by personnel from the Utah Division of Wildlife Resources' Wahweap office (Craig Schaugaard)

Seven Colorado pikeminnow were recaptured a total of 11 times during our study, one in 1992, three in 1993, five in 1994, and two in 1995 (Table 36). Of the seven recaptured individuals, four were recaptured twice. Six adult Colorado pikeminnow, all originally collected between RM 130.5 and RM 122.6 accounted for 9 of the 11 recaptures. These nine recaptures, were all from RM 133.2-120.6. The other two recaptures both occurred with the "Bluff fish," at RM 76.0 and 74.4 (Table 36).

In addition to captures and recaptures, there were 12 Colorado pikeminnow observed that were not collected between 1991 and 1995 (Table 37). Of the 12 observations, nine (75.0%) occurred from RM 137.8-115.1 (Table 37). Two of the three remaining observations were at RM 158.4 and 154.2, just downstream of the Hogback Diversion (RM 158.6). The other observation occurred at RM 65.6, less than ten miles downstream of the "Bluff fish" capture location in 1993 (Table 37).

Early life stage, wild Colorado pikeminnow collected during other studies between 1987 and 1997 were predominately distributed downstream of the areas occupied by adult fish (Table 36, Table A-2 in Appendix A). All larval and juvenile Colorado pikeminnow, including those collected in the 1987-1989 study (Platania 1990, Platania et al. 1991) were collected downstream of the presumed spawning areas within the Mixer, being distributed from just below the Mixer (RM 128.0) to Lake Powell (Buntjer et al. 1993, 1994, Lashmett 1993, 1994, Archer et al. 1995, 1996, Platania 1996, 1997). Most of these were collected below the town of Aneth, UT (RM 101.0). Two large, juvenile Colorado pikeminnow (363 and 432 mm TL) were collected at RM 7.9 and 12.9 (Table 36). Of the 47 YOY and two age-1 (49 and 59 mm TL) Colorado pikeminnow collected between 1987 and 1997, 43 (87.8%) were collected downstream of Aneth. Of the 43 fish collected downstream of Aneth, 39 (90.7%; 37 YOY and both age-1 fish) were collected in the canyon reaches downstream of Bluff, UT (Table A-2 in Appendix A). The other four YOY fish were collected upstream of the Four Corner's (Hwy. 160) bridge three by seining and one in a drift net. The individual captured in the drift net (at RM 128.0 on 2 August 1996) was very small (8.6 mm TL) and might well have drifted some distance and into the lower river before either selecting or eddying out into a suitable habitat had it had not been collected.

Other Native Fishes

Two other native fishes were collected during adult monitoring trips between 1991 and 1997. The first, mottled sculpin, was only collected between the Animas River confluence and RM 155.0, although collections downstream of the PNM Weir (RM 166.6) were rare (Table 12). The second native form was a hybrid between the native flannelmouth and bluehead sucker. Though total numbers collected were low, hybrid suckers were collected on almost every sampling trip.

Table 37. Colorado pikeminnow that were observed, but not collected, during sampling in the San Juan River, 1987-1997.

Source Report	Date of Sighting	River Mile	Sample Number	Reliability of Identification
Platania 1990	06/11/87	79.54[a]	-------[b]	--------
Platania 1990	08/10/87	132.63[a]	-------	--------
Ryden and Pfeifer 1993	05/14/91	65.60	DLP2001	Positive
Ryden and Pfeifer 1993	06/06/91	154.20	DLP2041	Probable
Ryden and Pfeifer 1993	10/18/91	137.80	JEB1156	Possible
Ryden and Pfeifer 1993	06/28/92	133.10	GJT0107	Probable
Ryden and Pfeifer 1994	04/14/93	130.40[c]	GJT0274	Probable
Ryden and Pfeifer 1994	04/14/93	130.20[c]	GJT0274	Probable
Ryden and Pfeifer 1994	05/13/93	122.10	GJT0306	Probable
Ryden and Pfeifer 1995a	04/12/94	135.40	DWR0018	Probable
Ryden and Pfeifer 1995a	04/12/94	132.70	DWR0018	Possible
Ryden and Pfeifer 1995a	04/15/94	134.80	JEB1625	Positive
Ryden and Pfeifer 1995a	10/02/94	158.40	DWR0057	Probable
Ryden and Pfeifer 1996a	10/07/95	115.10	JEB1802	Positive

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

[b] Not recorded in the source report

[c] This fish may well have been two sightings of the same fish. A large Colorado pikeminnow was observed, but could not be netted at the top of a small secondary channel at river right. The same boat observed a Colorado pikeminnow of approximately the same size at the bottom (mouth) of the same side channel where it rejoins the main channel. After the fish was observed, it was seen swimming upstream, back into the secondary channel.

Nonnative Species

Twenty-one nonnative fish species accounted for 24.6% of the total catch (59,633 individuals). The most abundant among these were channel catfish (n = 31,610, 13.1% of total catch), followed by common carp (n = 22,246, 9.2%), red shiner (n = 4,006, 1.7%), fathead minnow (n = 709, 0.3%), and threadfin shad (n = 452, 0.2%). The remaining 16 nonnative species combined contributed 610 individuals to the total catch (Table 12). Thirteen of 21 nonnative fishes are potential or documented predators upon various life stages of native species (Table 13, Tyus and Saunders 1996). Of the 21 nonnative species, 9 are soft-rayed fishes and 12 are spiny-rayed fishes (Table 13). This is significant given the documented choking hazards that spiny-rayed, introduced fishes, specifically channel catfish, pose when ingested by Colorado pikeminnow (McAda 1983, Pimental et al. 1985, Quartarone 1993). In addition, significant dietary overlap among species (Table 13) suggests a strong competitive pressure being placed upon native San Juan River fishes by their nonnative counterparts.

Channel Catfish

Channel catfish were the most abundant nonnative species and second most abundant species overall collected during our study, occurring in 80.1% of all collections between 1991 and 1997 (Table 12). Channel catfish were extremely rare in Reach 6 upstream of the PNM Weir (RM 166.6), but were common throughout the river downstream of that point (Table 12).

Channel catfish were collected from almost every major habitat type that occurs in the San Juan River, but large adults tended to be more common along quiet shoreline areas with little to no velocity and near-shore, boulder-strewn shoreline habitats in the canyon reaches (downstream of RM 68.0) of the river.

---Reach 6 (RM 180.0-158.6)---

Channel catfish catch rates were consistently the lowest total CPUE of the four common, large-bodied fishes in Reach 6 (Figure 41). The one exception to this was in October 1996, but even on this trip, channel catfish total CPUE was less than that of both native suckers (Figures 5, 22, and 41). Channel catfish were almost non-existent in Reach 6 upstream of the PNM Weir (RM 166.6). Of the 1,712 channel catfish collected in Reach 6 between 1991 and 1997, only ten (0.6%) were collected upstream of the PNM Weir at RM 166.6. Nine of the ten channel catfish collected upstream of the PNM Weir were adults and one was a juvenile. All ten of these fish were collected in 1996 or 1997.

Comparisons of channel catfish CPUE by month, grouped across years, in Reach 6 showed significant differences between months (Kruskal-Wallis statistic = 7.106, p = 0.029). An ANOVA/Scheffe done on ranked CPUE data showed significantly more channel catfish being collected on October trips than on either July or May trips (Table 38-a, Figure 41). Channel catfish

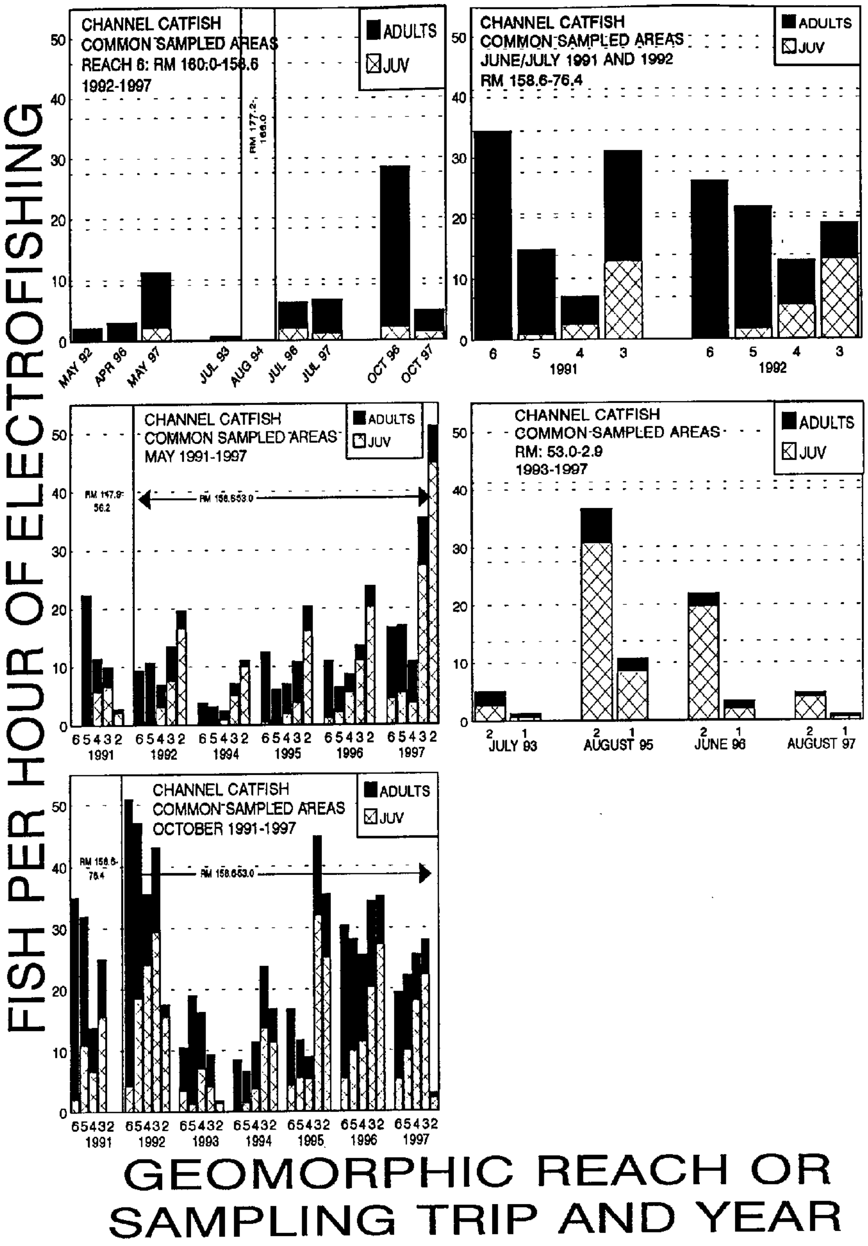


Figure 41. Number of channel catfish collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

Table 38-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 3.615, $r^2 = 0.024$, $p = 0.028$*

Scheffe matrix:	May	July	October
May	1.000		
July	1.000	1.000	
October	0.049*	0.051*	1.000

Table 38-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.995, $r^2 = 0.047$, $p = 0.056$*

Scheffe matrix:	1992	1996	1997
1992	1.000		
1996	0.918	1.000	
1997	0.095*	0.144	1.000

Table 38-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 5.937, $r^2 = 0.094$, $p = 0.004$*

Scheffe matrix:	1993	1996	1997
1993	1.000		
1996	0.006*	1.000	
1997	0.045*	0.725	1.000

Table 38-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 3.079, $r^2 = 0.053$, $p = 0.085$*

Scheffe matrix:	1996	1997
1996	1.000	
1997	0.085*	1.000

CPUE was not significantly different between May and July trips (Table 38-a). Comparisons by month, across years, showed an increasing trend in channel catfish CPUE between 1992 and 1996 on May trips and between 1993 and 1997 on July trips, but a decline in CPUE between October 1996 and 1997 (Tables 38-b - 38-d, Figure 41). These trends were statistically significant for May (Kruskal-Wallis statistic = 5.669, p = 0.059), July (Kruskal-Wallis statistic = 10.744, p = 0.005), and October trips (Mann-Whitney U test statistic = 511.00, p = 0.042). The August 1994 trip, while presented in CPUE graphics is not considered in this analysis due to the abbreviated nature of that particular trip (Table 1).

Comparisons of channel catfish mean TL between months, across years, and between years in a given month, via ANOVA/Scheffe, failed to show any clear trends (Tables 39-a - 39-d, Figure 42). Channel catfish collected on May trips were significantly larger than those collected on July and October trips (Table 39-a, Figure 42). However, there was no significant difference in mean TL between channel catfish collected on July versus October (Table 39-a, Figure 42). Comparisons of mean TL in May across years indicated no significant differences in channel catfish mean TL across years (Table 39-b, Figure 42). Channel catfish collected in July 1993 and 1996 were significantly larger than those collected in July 1997 (Table 39-c, Figure 42), but July 1993 and 1996 were not significantly different from one another. Channel catfish mean TL on October trips was not significantly different between 1996 and 1997 (Table 39-d, Figure 42).

Length-frequency histograms of channel catfish size classes collected in Reach 6 show that channel catfish caught in this section of the river were almost exclusively adult fish (> 300 mm TL), with the exception of October 1997 when a large number of juveniles (276-300 mm TL) were collected (Figure 43).

Plots of mean channel catfish biomass for all life stages combined show a very similar trend to that of channel catfish mean TL in Reach 6 (Tables 39-a - 39-d and 40-a - 40-c, Figures 42 and 44). In other words, there were no significant differences in May channel catfish mean biomass between 1992 and 1997 and mean channel catfish biomass declined significantly between 1993 and 1997 (Tables 40-b and 40-c, Figure 44). However, unlike mean TL, channel catfish mean biomass was not significantly different between May and October trips, with the values for both months being significantly heavier than those for July trips (Table 40-a, Figure 44). This was caused by the significant decline in mean biomass in July 1997 (Table 40-c, Figure 44). No biomass comparisons could be made for October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

Plots of channel catfish mean K in Reach 6 showed trends that were, again, close to those for mean TL and mean biomass within months, but not across months. Channel catfish mean K for May and July trips were not significantly different, but both were significantly higher than October (Table 41-a, Figure 45). Channel catfish mean K increased significantly between May 1992 and 1997 (Table 41-b, Figure 45), while it declined significantly between July 1993 and 1997 (Table 41-c, Figure 45). No comparisons could be made for K between October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

Table 39-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, grouped by months across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 8.860, r^2 = 0.045, p = 0.000*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.001*	1.000	
October	0.001*	0.471	1.000

Table 39-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.490, r^2 = 0.023, p = 0.616

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.956	1.000	
1997	0.827	0.657	1.000

Table 39-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 14.667, r^2 = 0.389, p = 0.000*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.520	1.000	
1997	0.000*	0.001*	1.000

Table 39-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.194, r^2 = 0.001, p = 0.660

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.660	1.000

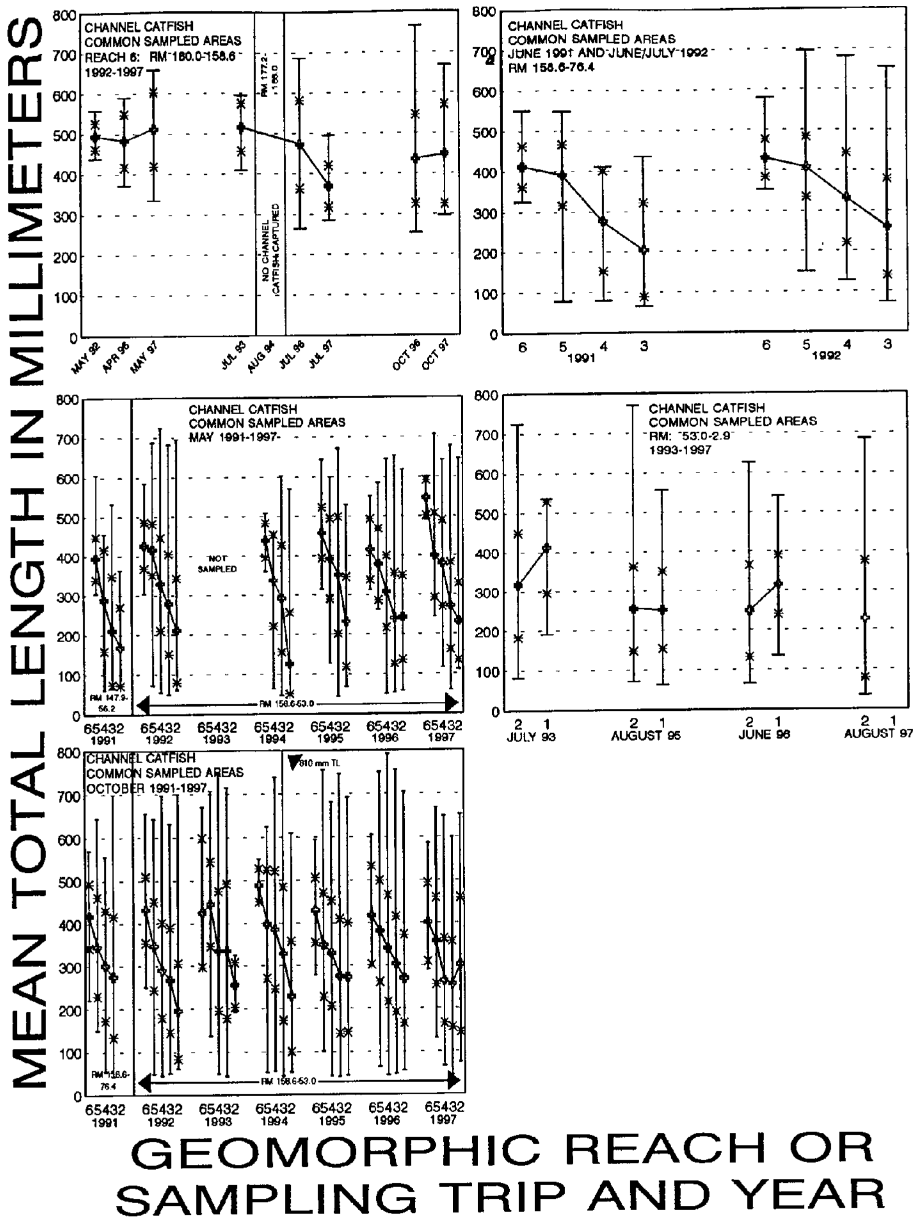


Figure 42. Mean total length (TL) in millimeters for channel catfish collected on standardized adult fish community monitoring trips, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river. Lines and crosses represent the mean values, error bars represent the range, and asterisks represent the standard deviation.

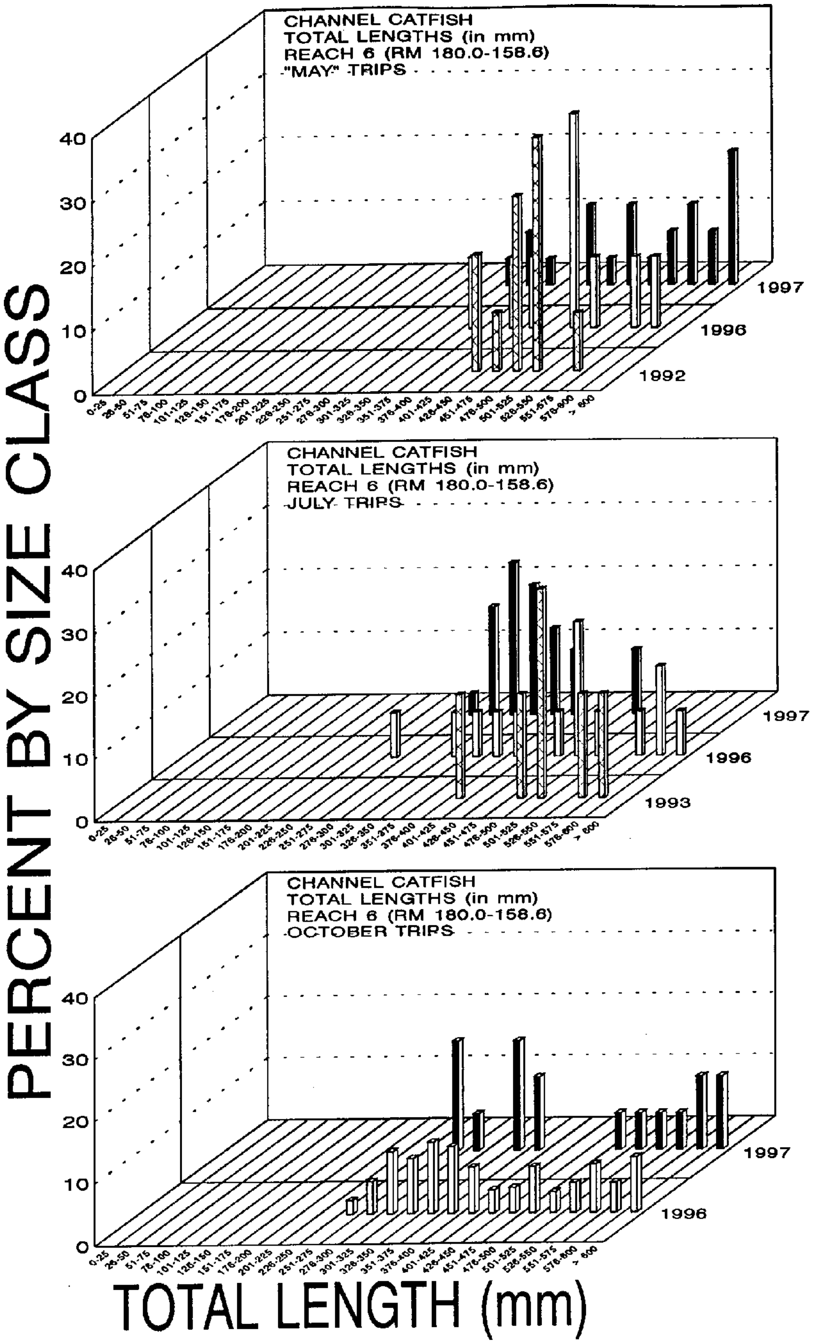


Figure 43. Length-frequency histograms for channel catfish collected and measured on designated miles during standardized adult fish community monitoring trips in Reach 6 (RM 180.0-158.6), 1992-1997.

Table 40-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 4.530, r^2 = 0.082, p = 0.013*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.014*	1.000	
October	0.265	0.845	1.000

Table 40-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.452, r^2 = 0.128, p = 0.100

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.982	1.000	
1997	0.159	0.277	1.000

Table 40-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 14.191, r^2 = 0.387, p = 0.000*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.846	1.000	
1997	0.001*	0.000*	1.000

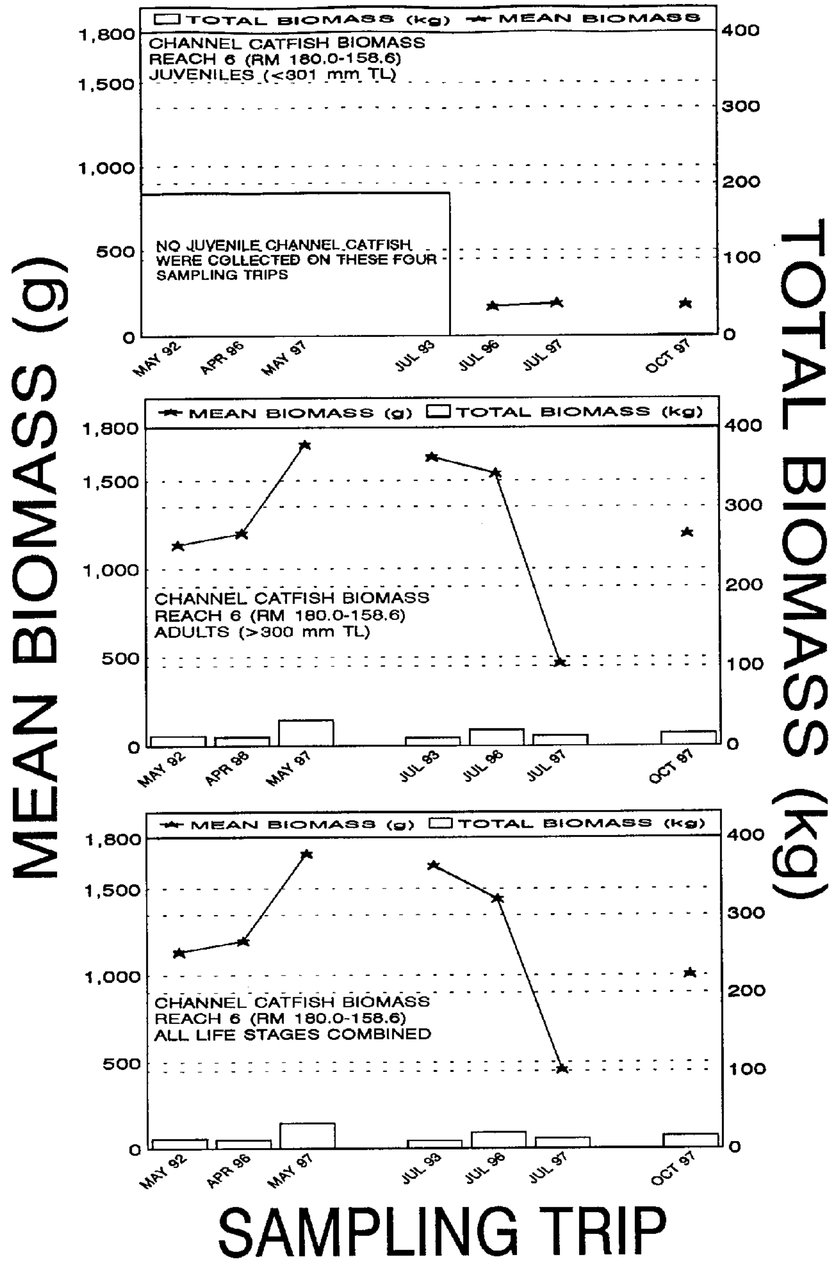


Figure 44. Total and mean biomass of channel catfish collected and weighed on designated miles during standardized adult fish community monitoring trips between RM 180.0-158.6 ("Reach 6"), 1991-1997.

Table 41-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 4.177, $r^2 = 0.076$, $p = 0.018$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.289	1.000	
October	0.020*	0.230	1.000

Table 41-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.917, $r^2 = 0.139$, $p = 0.067$*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.490	1.000	
1997	0.067*	0.659	1.000

Table 41-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 26.094, $r^2 = 0.537$, $p = 0.000$*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.991	1.000	
1997	0.000*	0.000*	1.000

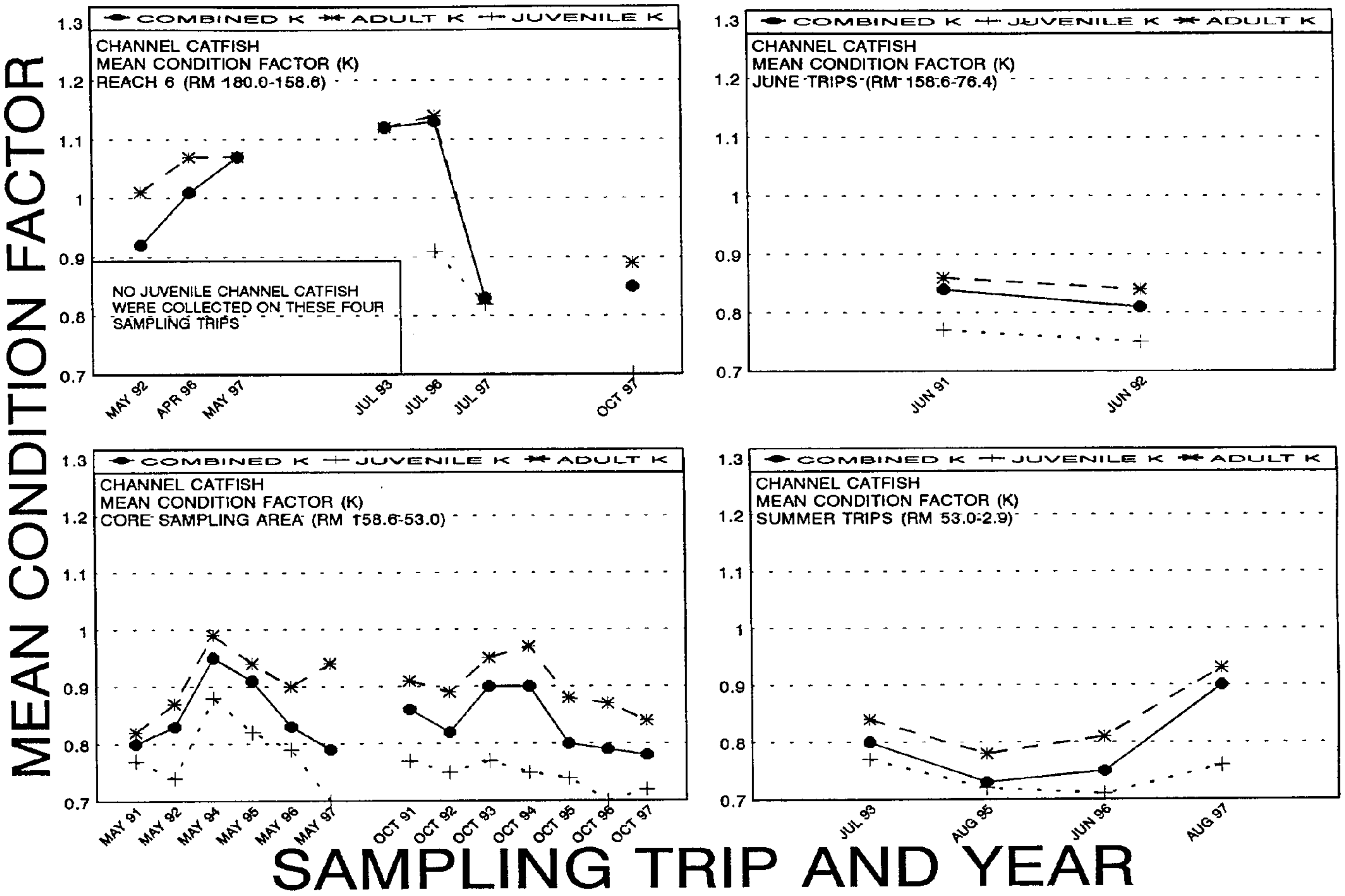


Figure 45. Mean condition factor of channel catfish collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips for common sampled areas between RM 180.0-2.9, 1991-1997.

---Core Sampling Area (RM 158.6-53.0)---

In the core sampling area (RM 158.6-53.0) patterns of channel catfish CPUE varied greatly between May and October trips. Comparisons of total CPUE grouped by month, across years, showed that channel catfish CPUE on October trips was significantly higher (Mann-Whitney U test statistic = 1047154.500, p = 0.000) than on May trips (Table 42-a, Figure 41). Significant differences were present in channel catfish CPUE between years in May collections (Kruskal-Wallis test statistic = 257.252, p = 0.000). However, an ANOVA/Scheffe done on ranked CPUE data showed that the only two significant differences in May channel catfish CPUE were that May 1994 CPUE was significantly lower than all other years and May 1997 CPUE was significantly higher than all other years (Table 42-b). Channel catfish CPUE on May trips started at 12.17 fish/hr (range = 0.00-200.00) in 1991, falling to a low of 5.88 fish/hr (range = 0.00-83.87) in 1994, then rising to the highest levels seen during our study at 26.83 fish/hr (range = 0.00-205.13) in 1997 (Figure 41 and 46). This represents a 356.3% increase in channel catfish CPUE between 1994 and 1997 on May trips. Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) show that the upward trend in channel catfish CPUE between 1994 and 1997 was largely accounted for by increases in juvenile channel catfish CPUE in Reaches 5 and 3 over previous years (Figure 46). The other pattern evident in channel catfish CPUE on May trips was that beginning in May 1992 channel catfish usually had steadily increasing catch rates proceeding downstream from Reach 5, with juveniles accounting for more of the catch the farther downstream you were.

Significant differences in channel catfish CPUE were also present between years in October collections (Kruskal-Wallis test statistic = 258.052, p = 0.000). An ANOVA/Scheffe done on ranked CPUE data showed that many more significant differences in channel catfish CPUE were present among October trips than among May trips (Table 42-c). Channel catfish CPUE on October trips in the core sampling area was 23.75 fish/hr (range = 0.00-104.55) in 1991, fell to a low of 12.26 fish/hr (range = 0.00-67.86) in 1993 (the trip just before the low seen in May 1994) and then rose again to a high of 30.29 fish/hr (range = 0.00-126.09) in 1997 (the trip before the high seen in May 1997), before falling again in October 1997 to 22.84 fish/hr (range = 0.00-115.15; Figure 41 and 46). This represents a 147.1% increase in channel catfish CPUE between 1993 and 1996 on October trips. Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) show that the upward trend in channel catfish CPUE between 1993 and 1996 was accounted for largely by increases in juvenile channel catfish CPUE in Reach 3 over previous years (Figure 46). Patterns in channel catfish CPUE on October trips were almost nonexistent. However, beginning in October 1994 channel catfish CPUE in Reach 3 (RM 106-68.0) were always higher than anywhere else in the core sampling area with the exception of Reach 2 in 1996 (Figure 41). In addition, as on May trips, juveniles became more prevalent in the catch the farther downstream you were (Figures 41 and 46).

A comparison of channel catfish CPUE on October trips between 1988 and 1997 (RM 147.9-119.2) shows that, with the exception of October 1992, the downward trend in CPUE observed between 1991 and 1994 was part of a continuing trend from the late 1980's (Figure 12). In addition, the increase in channel catfish CPUE observed between 1993 and 1996 brought catch rates back up to a

Table 42-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 372.530, $r^2 = 0.094$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 42-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 63.143, $r^2 = 0.160$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.999	1.000				
1994	0.000*	0.000*	1.000			
1995	0.730	0.827	0.000*	1.000		
1996	1.000	0.982	0.000*	0.327	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

Table 42-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish CPUE data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 42.710, $r^2 = 0.117$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.000*	1.000					
1993	0.000*	0.000*	1.000				
1994	0.000*	0.000*	0.455	1.000			
1995	0.850	0.000*	0.000*	0.034*	1.000		
1996	0.063*	0.649	0.000*	0.000*	0.000*	1.000	
1997	0.989	0.000*	0.000*	0.004*	0.998	0.002*	1.000

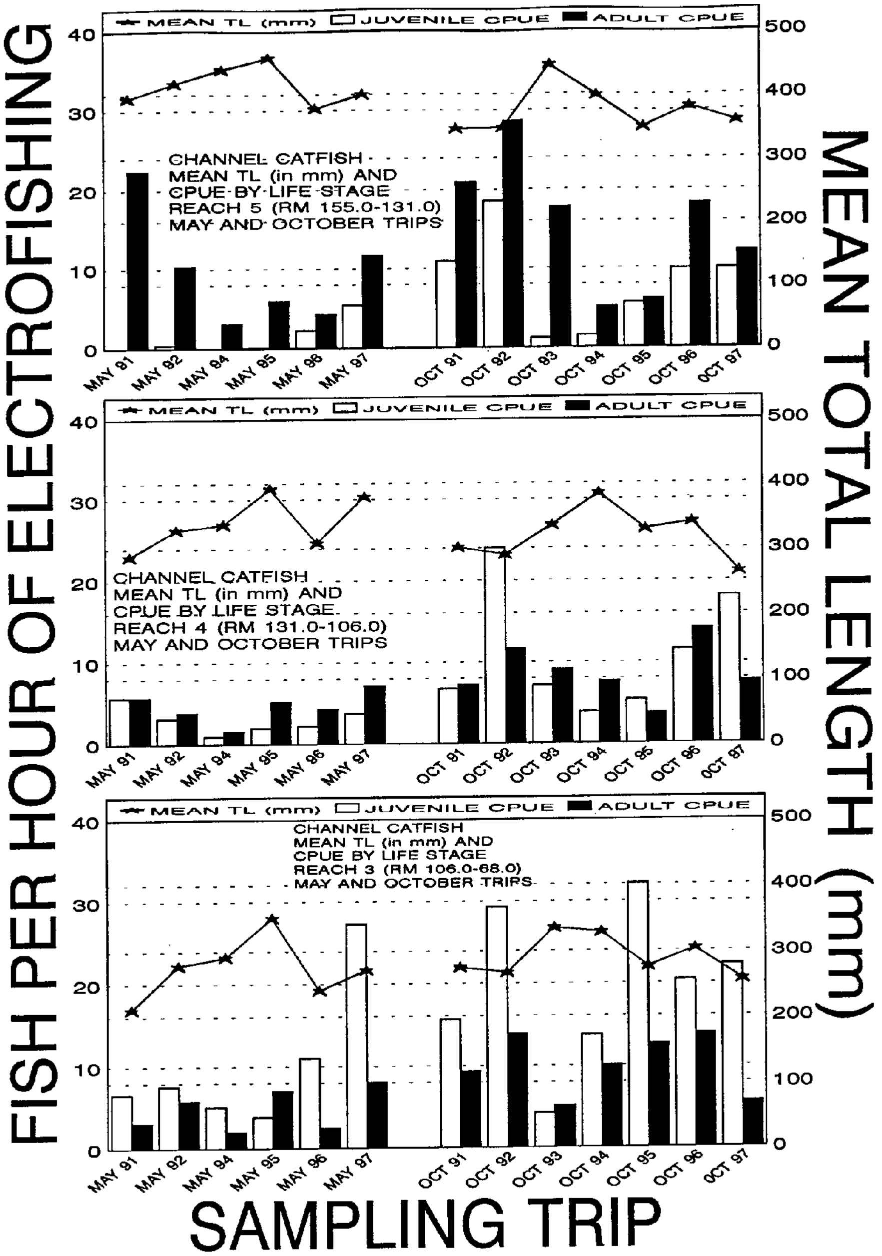


Figure 46. Number of fish collected by life stage per hour of electrofishing versus mean total length for channel catfish in geomorphic Reaches 3-5 on May and October standardized adult fish community monitoring trips in the core sampling area of the San Juan River (RM 158.6-53.0), 1991-1997.

level comparable to those seen in 1998 and 1989 in this section of the river (Figure 12).

Channel catfish collected on May trips in the core sampling area were significantly smaller than those collected on October trips (Table 43-a, Figure 42). As with CPUE, more significant differences were present in comparisons between channel catfish mean TL on October trips than in comparisons between channel catfish mean TL on May trips (Tables 43-b and 43-c). However, despite the differences, on both May and October trips, channel catfish mean TL consistently declined in downstream reaches (Figure 42). This corresponded to the increase in juvenile fish in the catch seen in CPUE graphics (Figures 41 and 46). Length-frequency histograms of channel catfish measured on DM’s in the core sampling area showed that channel catfish of all size-class were collected in almost every year, with October 1996 and 1997 being possible exceptions (Figure 47). On these two trips, channel catfish <150 mm TL were rarely collected (Figure 47). Relatively large numbers of age-1 fish (51-75 mm TL) collected on May 1991 and May 1993 indicate strong cohorts from 1990 and 1992 (Figure 47).

Channel catfish mean biomass was significantly higher on October trips than on May trips (Table 44-a). This was due more to differences among adult fish between the two months than to differences between juveniles fish (Figure 48). Mean biomass of channel catfish in the core sampling area was not significantly different in 1997 compared to 1991 on either May or October trips, despite fluctuations between years during the study that were significant (Tables 44-b and 44-c, Figure 48). Channel catfish mean biomass was higher in Reach 5 than in Reaches 4 and 3 (Figures 49-51). Channel catfish mean biomass in Reaches 4 and 3 were not greatly different from one another (Figures 50 and 51).

Mean K of channel catfish was significantly higher on May trips than on October trips (Table 45-a, Figure 52). Mean K for channel catfish did not change significantly between 1991 and 1997 on May trips (Table 45-b, Figure 52), but decreased significantly between 1991 and 1997 on October trips (Table 45-c, Figure 52). Interestingly, three of the four trips on which the highest channel catfish mean K were recorded during our study (i.e., May 1994, October 1993, and October 1994) corresponded to the lowest CPUE values recorded for channel catfish (Figures 41 and 45). Mean K for channel catfish varied widely between geomorphic reaches (Figure 52). Overall, mean K declined between 1991 and 1997 in all three whole geomorphic sampled (i.e., 3, 4, and 5) on October trips, while on May trips it rose in Reaches 4 and 5, but fell in Reach 3 (Figure 52).

---June Trips (RM 158.6-76.4)---

On June trips (RM 158.6-76.4) patterns of channel catfish CPUE were different than those seen on either May or October 1991 and 1992 trips (Figure 41). Like the native suckers, CPUE for channel catfish was significantly different between June 1991 and 1992 (Mann-Whitney U test statistic = 7584.500, p = 0.000; Table 46-a). However, unlike the native suckers, channel catfish CPUE in June 1992 was not among the highest recorded during the study period (Figures 5, 22, and 41). About the only similarity between CPUE on June trips and that on May and October trips in the core sampling area was the

Table 43-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7.216, r^2 = 0.001, p = 0.007*

Scheffe matrix:

	May	October
May	1.000	
October	0.007*	1.000

Table 43-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 17.246, r^2 = 0.043, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.271	1.000				
1994	1.000	0.195	1.000			
1995	0.003*	0.106	0.003*	1.000		
1996	0.727	0.000*	0.951	0.000*	1.000	
1997	1.000	0.003*	0.998	0.000*	0.253	1.000

Table 43-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 31.032, r^2 = 0.039, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.674	1.000					
1993	0.000*	0.000*	1.000				
1994	0.333	0.001*	0.011*	1.000			
1995	0.728	1.000	0.000*	0.001*	1.000		
1996	0.002*	0.000*	0.073*	0.926	0.000*	1.000	
1997	0.294	0.988	0.000*	0.000*	0.974	0.000*	1.000

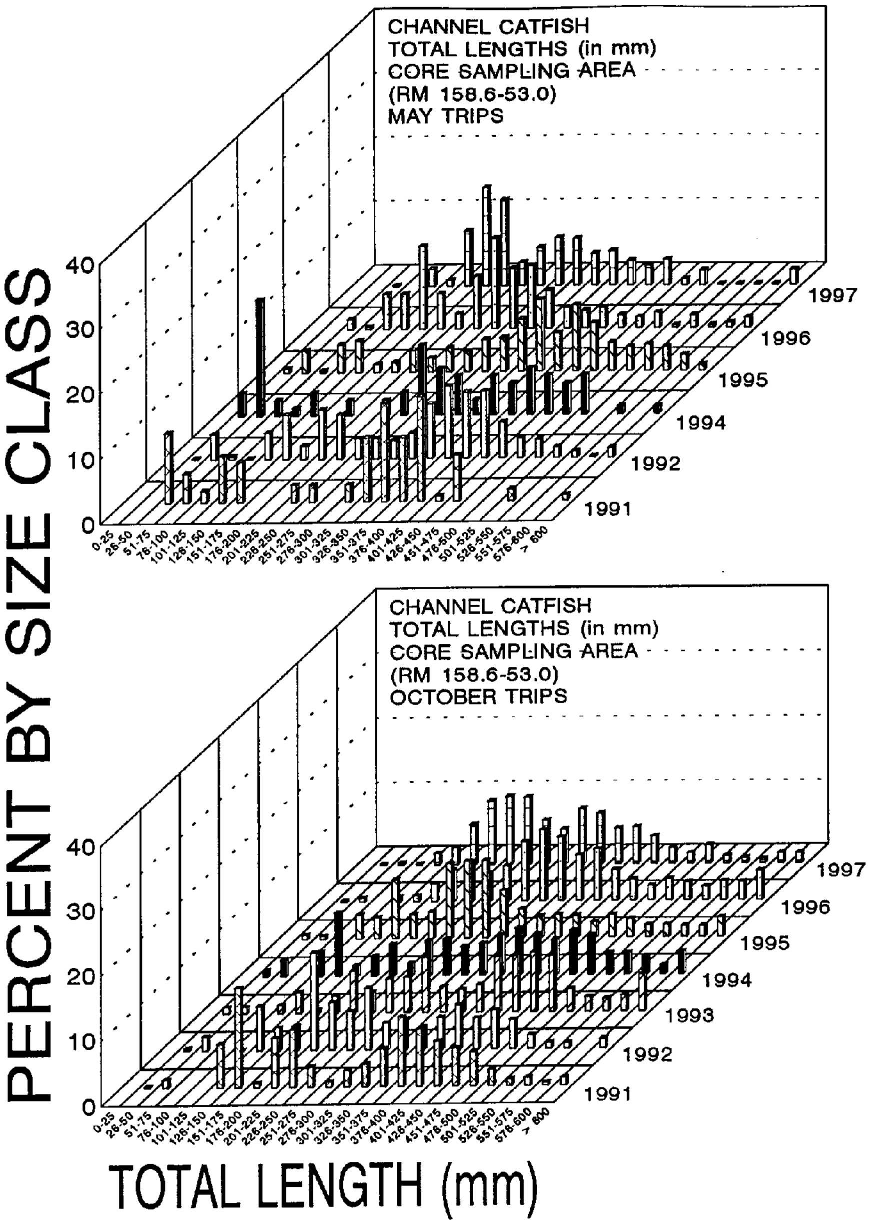


Figure 47. Length-frequency histograms for channel catfish collected and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 44-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.625, $r^2 = 0.000$, $p = 0.429$

Scheffe matrix:

	May	October
May	1.000	
October	0.429	1.000

Table 44-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 11.395, $r^2 = 0.029$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.670	1.000				
1994	0.899	1.000	1.000			
1995	0.001*	0.001*	0.262	1.000		
1996	0.986	0.017*	0.443	0.000*	1.000	
1997	0.952	0.912	0.996	0.000*	0.220	1.000

Table 44-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 24.501, $r^2 = 0.033$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.797	1.000					
1993	0.000*	0.000*	1.000				
1994	0.006*	0.000*	0.327	1.000			
1995	0.998	0.944	0.000*	0.000*	1.000		
1996	1.000	0.807	0.000*	0.001*	1.000	1.000	
1997	0.280	0.954	0.000*	0.000*	0.421	0.255	1.000

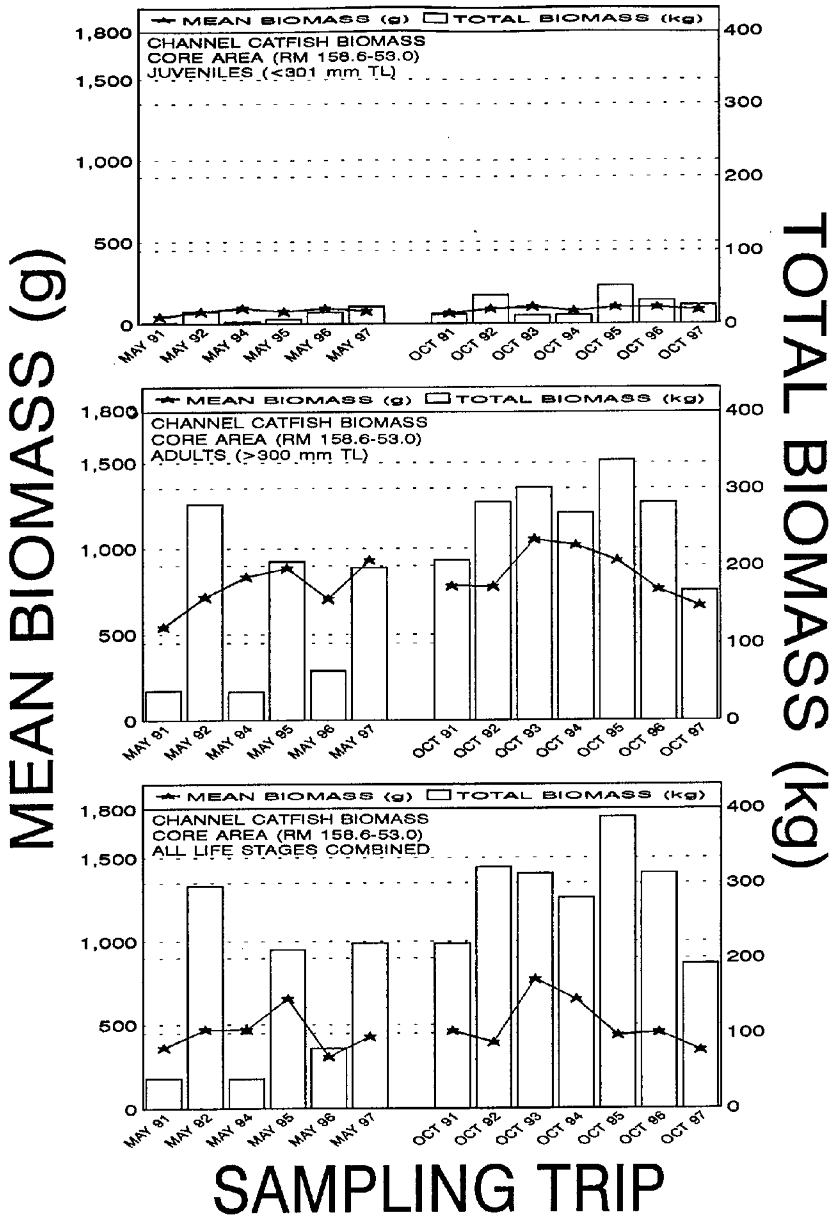


Figure 48. Total and mean biomass of channel catfish collected and weighed on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0).

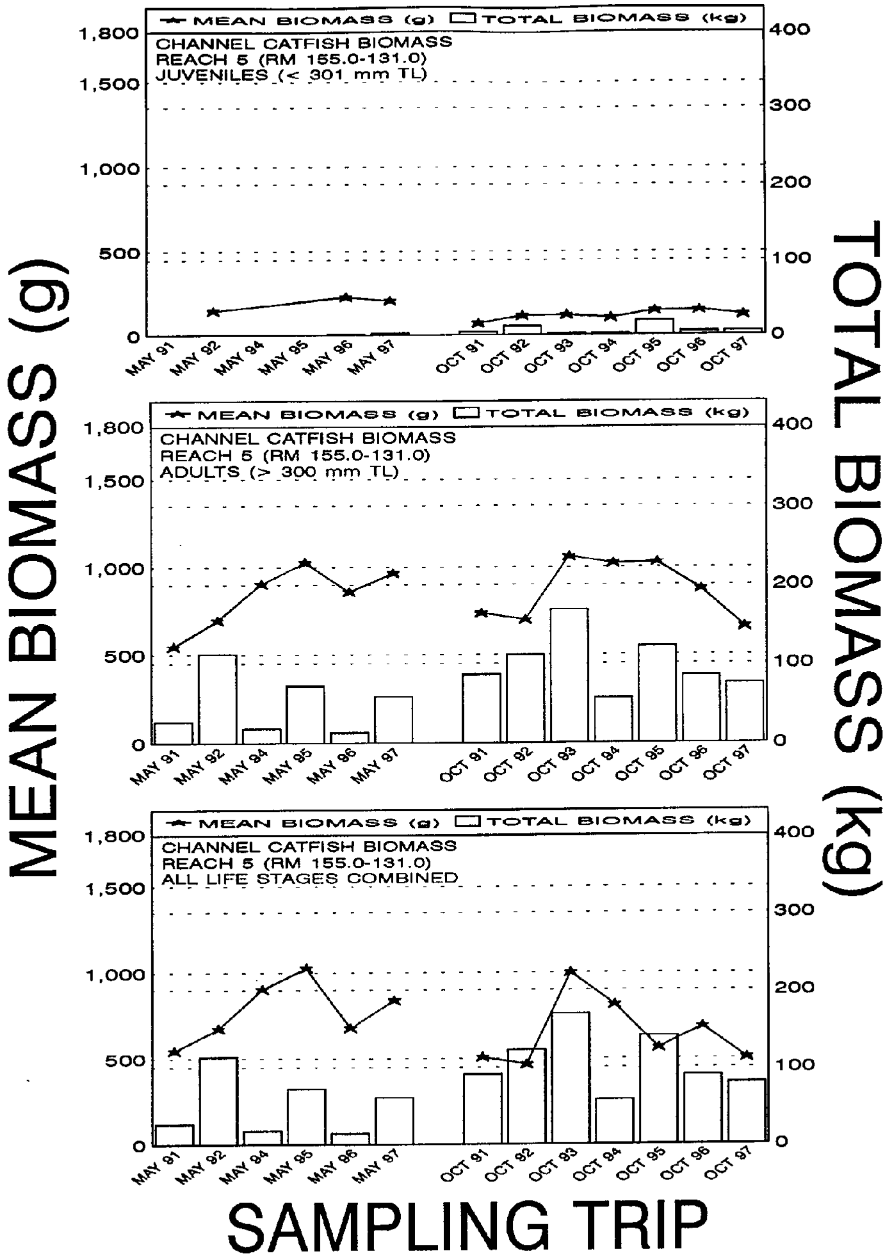


Figure 49. Total and mean biomass of channel catfish, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 5 (RM 155.0-131.0).

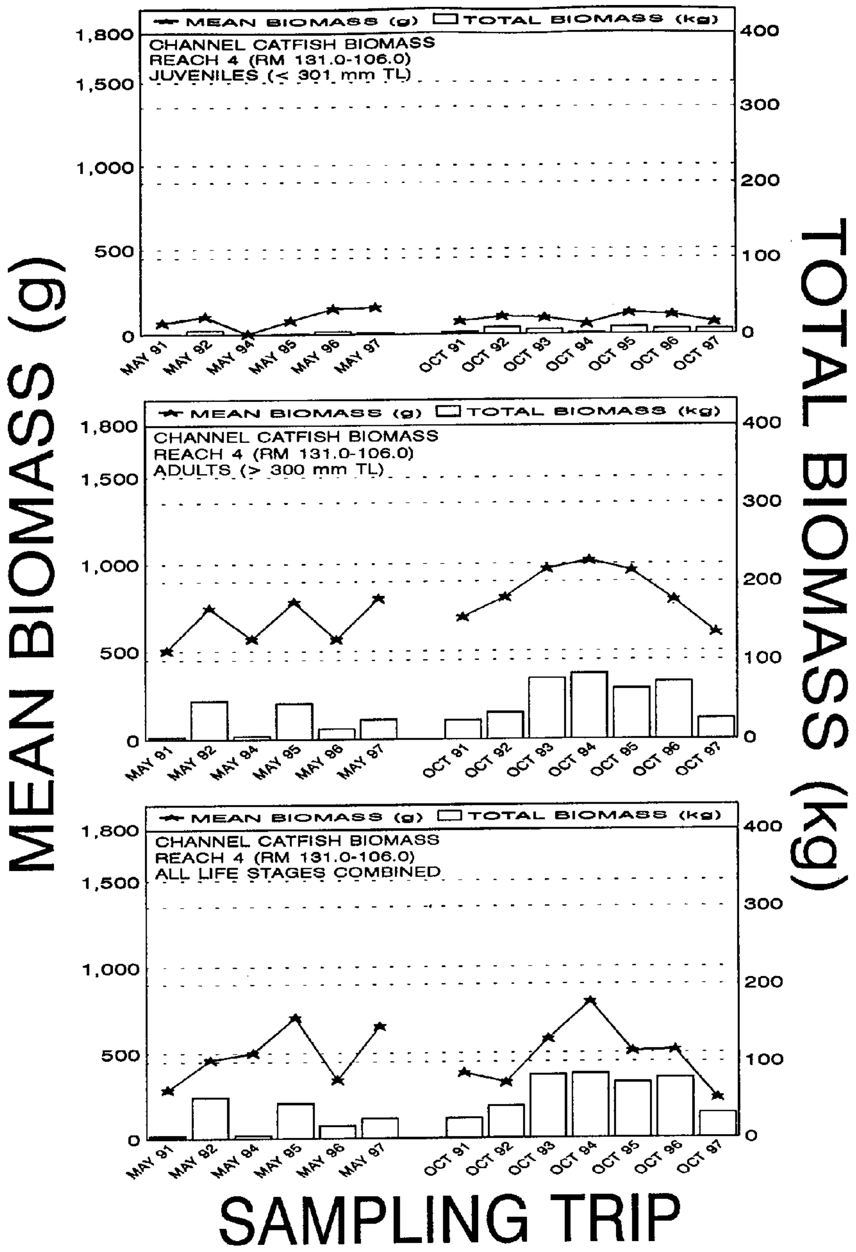


Figure 50. Total and mean biomass of channel catfish, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 4 (RM 131.0-106.0).

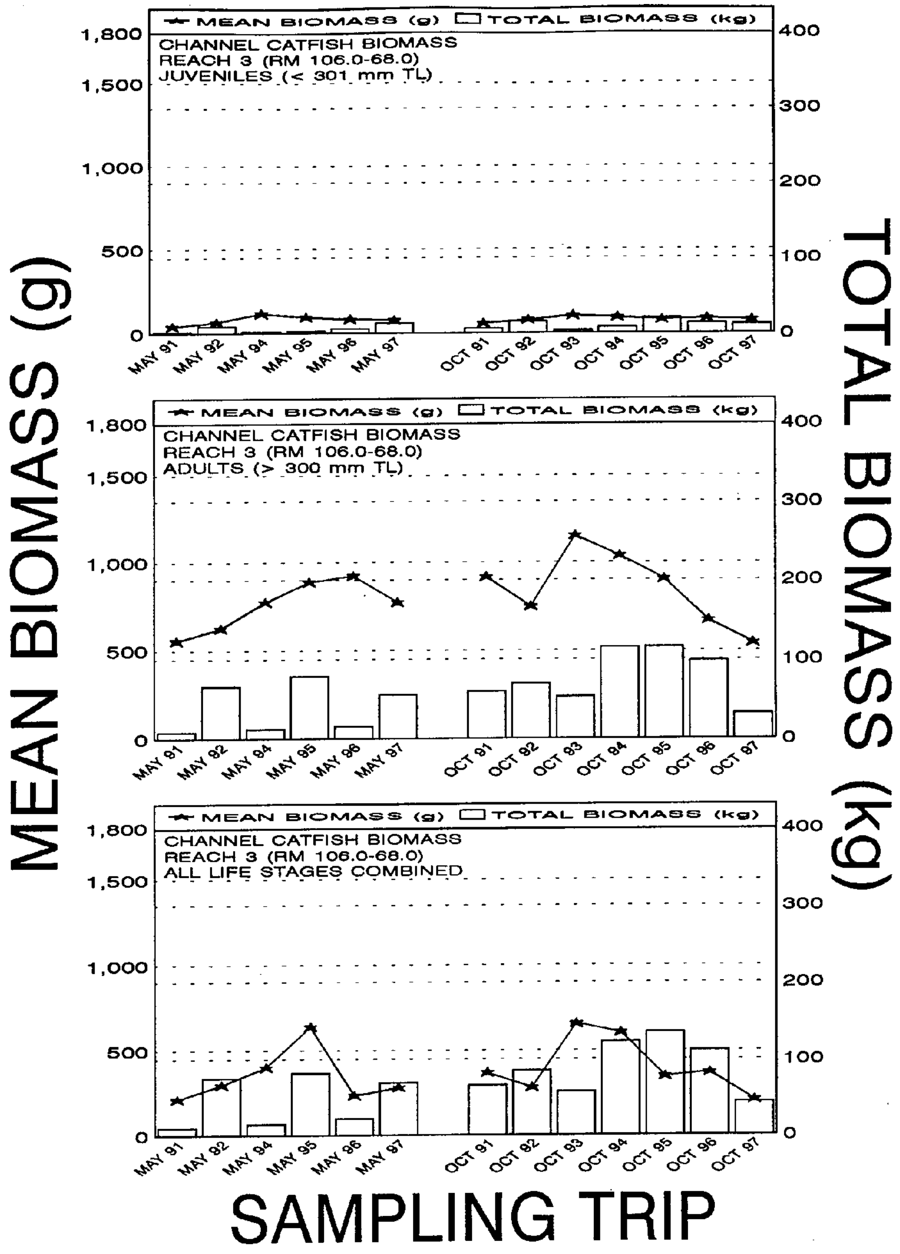


Figure 51. Total and mean biomass of channel catfish, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 3 (RM 106.0-68.0).

Table 45-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.818, r^2 = 0.000, p = 0.093*

Scheffe matrix:

	May	October
May	1.000	
October	0.093*	1.000

Table 45-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 17.784, r^2 = 0.045, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.967	1.000				
1994	0.000*	0.000*	1.000			
1995	0.001*	0.000*	0.784	1.000		
1996	0.920	0.999	0.001*	0.002*	1.000	
1997	0.999	0.298	0.000*	0.000*	0.335	1.000

Table 45-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 27.441, r^2 = 0.037, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.294	1.000					
1993	0.156	0.000*	1.000				
1994	0.260	0.000*	1.000	1.000			
1995	0.002*	0.554	0.000*	0.000*	1.000		
1996	0.000*	0.262	0.000*	0.000*	0.998	1.000	
1997	0.000*	0.016*	0.000*	0.000*	0.654	0.944	1.000

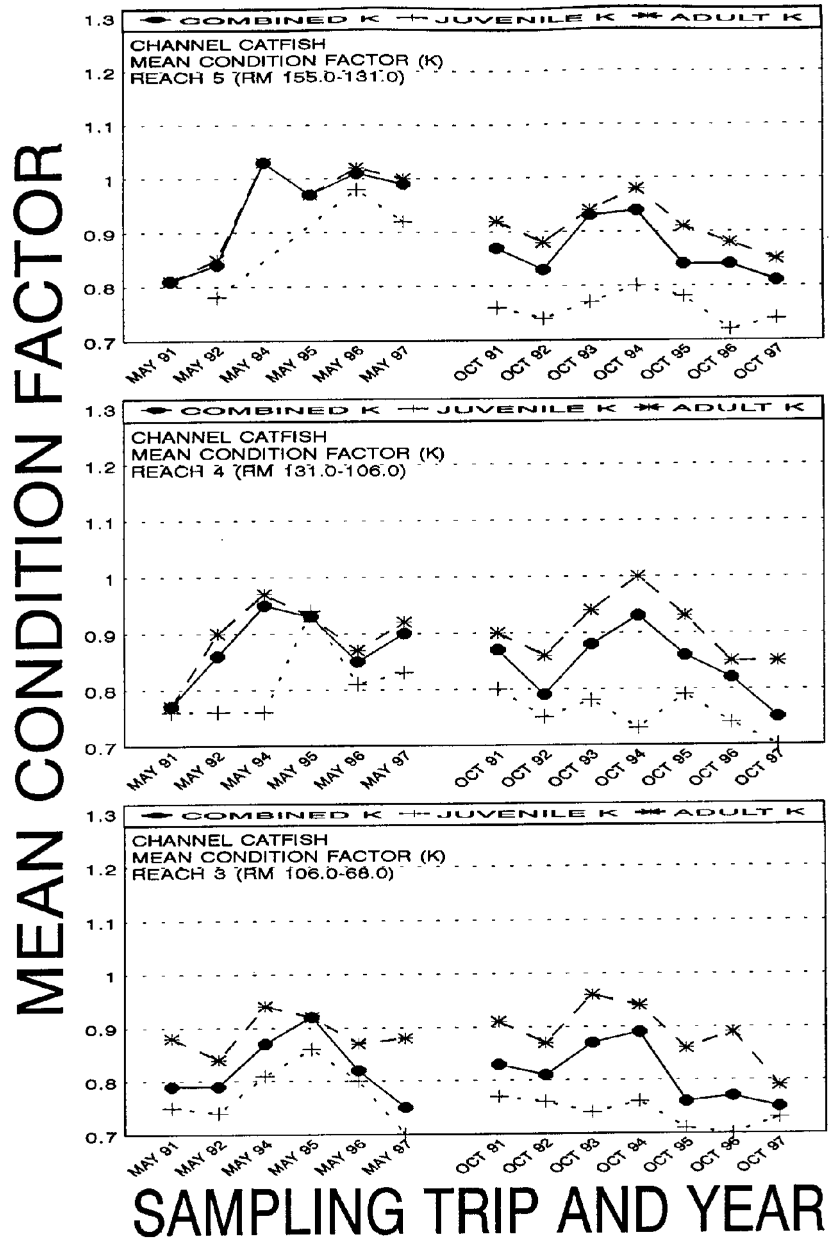


Figure 52. Mean condition factor, by whole geomorphic reach, of channel catfish, collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 46-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish mean CPUE data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 14.446, $r^2 = 0.046$, $p = 0.000$*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 46-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.238, $r^2 = 0.001$, $p = 0.266$

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.266	1.000

Table 46-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.853, $r^2 = 0.001$, $p = 0.356$

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.356	1.000

Table 46-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.167, $r^2 = 0.003$, $p = 0.141$

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.141	1.000

increased catch rate for juvenile channel catfish in downstream reaches (Figure 41).

Channel catfish mean TL was not significantly different between June 1991 and 1992 (Table 46-b, 42). Like May and October trips in the core sampling area, channel catfish mean TL decreased in each successive downstream reach (Figure 42). A length-frequency histogram of channel catfish measured on June trips shows that like the May and October trips in the core sampling area, almost all size-classes of fish were collected (Figure 53). There were no significant differences in channel catfish mean TL, biomass, or mean K between June 1991 and 1992 trips (Tables 46-b - 46-d, Figures 42, 45, and 54).

---Lower River (RM 53.0-2.9)---

Channel catfish CPUE was fairly low in 1993, increased dramatically in 1995, then dropped steadily over the next two years back to close the levels seen in 1993 (Figure 41). This increase between 1993 and 1995 was significant (Kruskal-Wallis test statistic = 120.541, p = 0.000). In fact, channel catfish CPUE in 1995 was significantly higher than all other trips in the lower river (Table 47-a, Figure 41). The high CPUE values for channel catfish in the lower river followed the inundation of the waterfall at the San Juan River-Lake Powell interface in spring 1995.

Channel catfish mean TL was significantly higher in 1993 than in all following years in which this reach was sampled (Table 47-b, Figure 42), indicating the presence of more juvenile fish in collection after 1993 (Figure 41). After 1993, there was no significant difference between mean TL on any sampling trip (Table 47-b, Figure 42).

As with mean TL, channel catfish mean biomass showed no significant differences between 1993 and 1997 (Table 33-c, Figure 36). Like mean TL, mean biomass dropped significantly between 1993 and 1995, stayed low in 1996 and rose slightly in 1997 (Table 47-c, Figure 55). This again is due to the relatively large number of juvenile channel catfish collected on 1995 and 1996 summer trips (Figure 41).

Much like mean TL and mean biomass, channel catfish mean K dropped significantly between 1993 and 1995, and stayed low in 1996 compared to 1993 (Table 47-d, Figure 45). However, channel catfish mean K rose in 1997 collections to levels significantly higher than all three previous trips (Table 47-d, Figure 45).

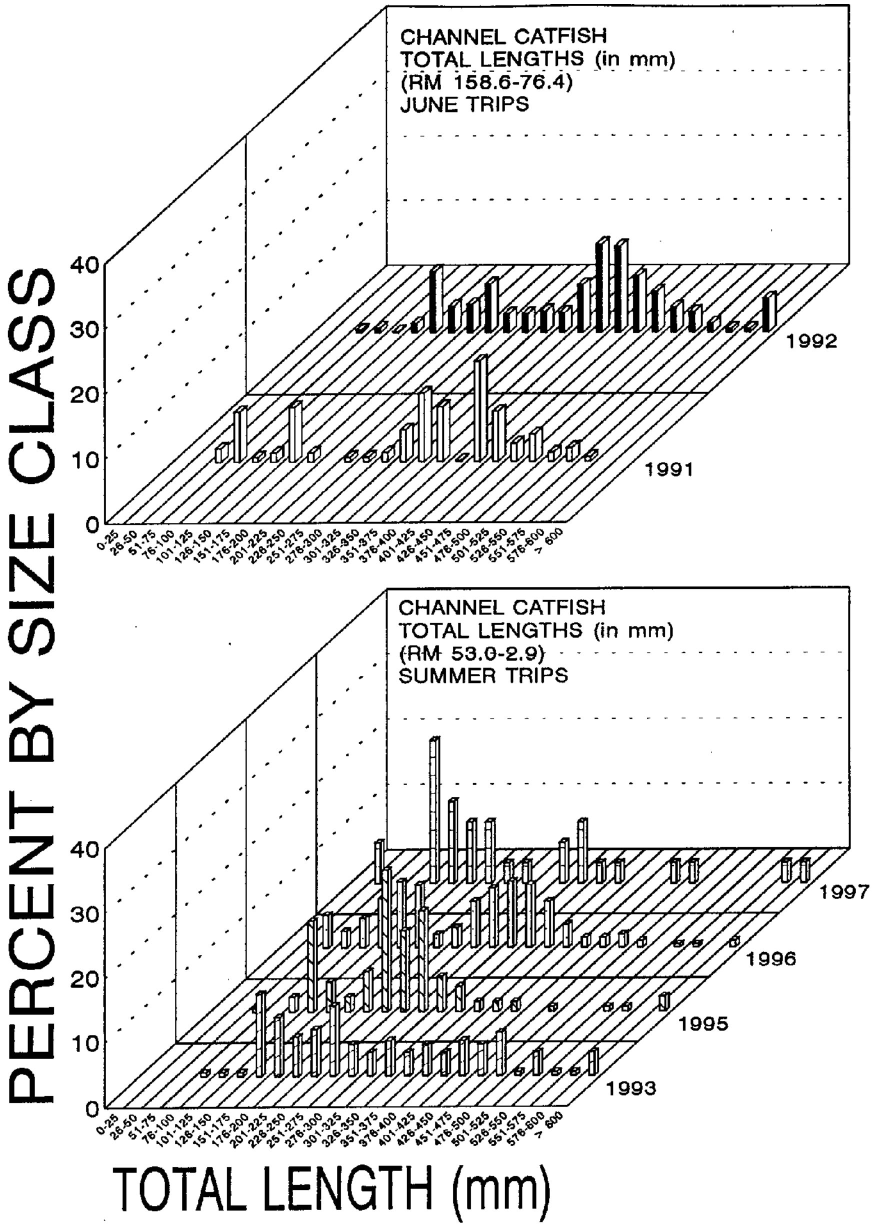


Figure 53. Length-frequency histograms for channel catfish collected and measured on designated miles during standardized adult fish community monitoring trips in June 1991 and 1992 (RM 158.6-76.4) and in the lower San Juan River (RM 53.0-2.9), 1993-1997.

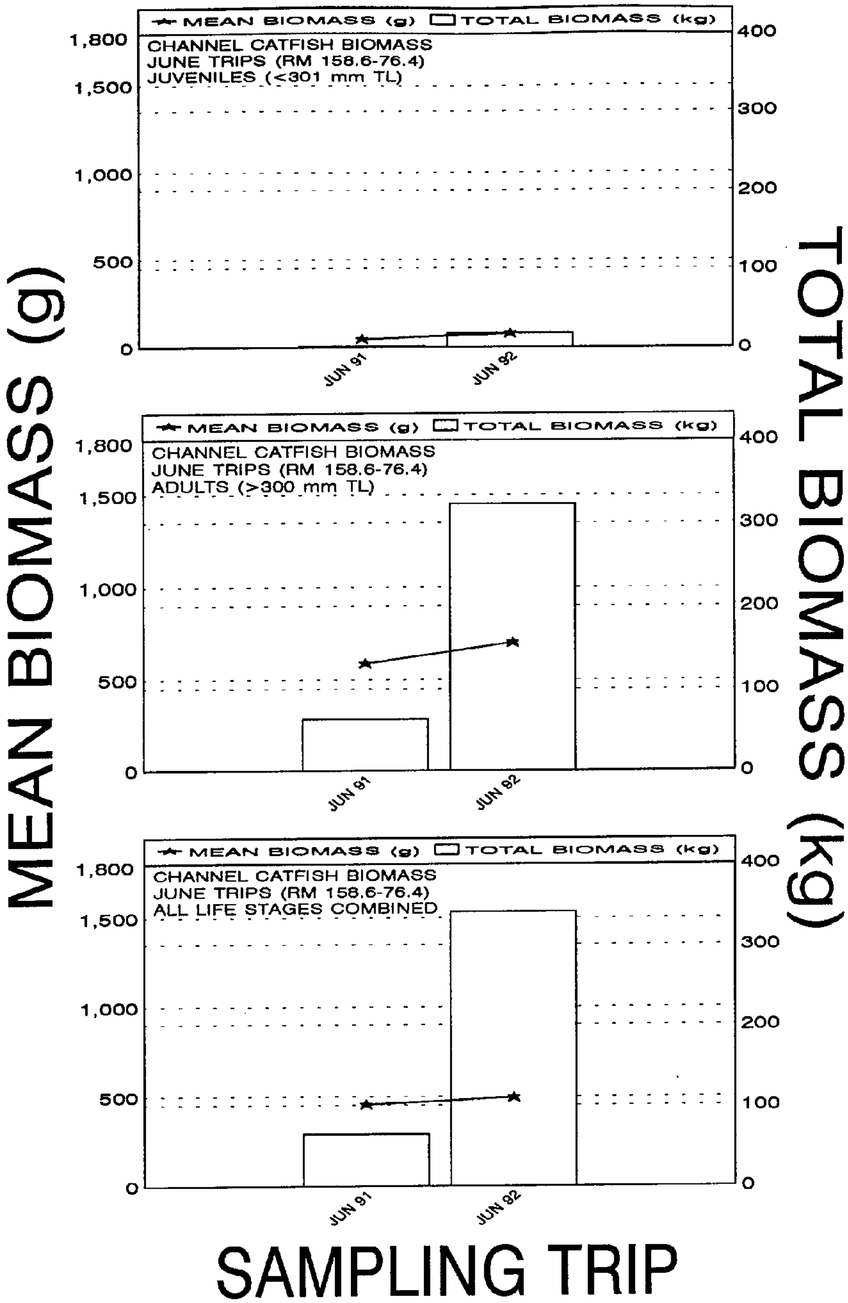


Figure 54. Total and mean biomass of channel catfish collected and weighed on designated miles during June 1991 and 1992 standardized adult fish community monitoring trips (RM 158.6-76.4).

Table 47-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) channel catfish mean CPUE data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 60.324, $r^2 = 0.340$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.000*	0.000*	1.000	
1997	0.719	0.000*	0.000*	1.000

Table 47-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean TL data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 12.769, $r^2 = 0.069$, $p = 0.000$

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.000*	0.998	1.000	
1997	0.001*	0.726	0.641	1.000

Table 47-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean biomass (WT in grams) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 5.659, $r^2 = 0.032$, $p = 0.001$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.009*	1.000		
1996	0.004*	0.999	1.000	
1997	0.539	0.948	0.960	1.000

Table 47-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of channel catfish mean condition factor (K) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 10.782, $r^2 = 0.059$, $p = 0.000$*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.009*	1.000		
1996	0.065*	0.790	1.000	
1997	0.030*	0.000*	0.000*	1.000

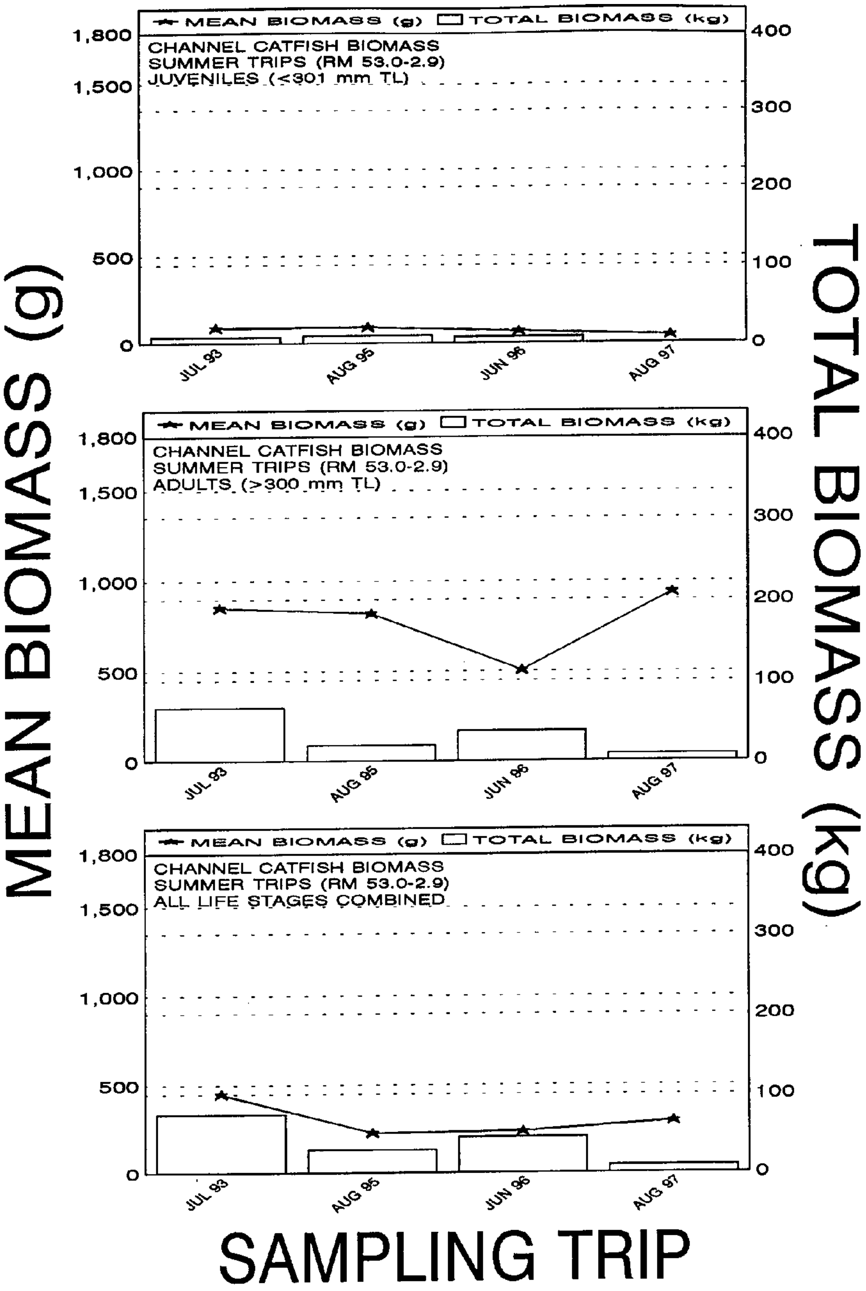


Figure 55. Total and mean biomass of channel catfish collected and weighed on designated miles during standardized adult fish community monitoring trips in the lower San Juan River (RM 53.0-2.9), 1993-1997.

Common Carp

Common carp were the second most abundant nonnative species and the fourth most abundant species collected, overall, occurring in 75.8% of all main channel electrofishing collections (Table 12). They were ubiquitous, occurring throughout the entire study area and in almost every habitat type sampled.

---Reach 6 (RM 180.0-158.6)---

Common carp CPUE in Reach 6 was less than that of both flannelmouth sucker and bluehead sucker, but, with the exception of October 1996, were consistently higher than channel catfish catch rates in Reach 6 (Figures 5, 22, 41, 56). Comparisons of common carp CPUE by month, grouped across years, in Reach 6, showed significant differences between months (Kruskal-Wallis statistic = 7.109, p = 0.027). An ANOVA/Scheffe done on ranked CPUE data showed significantly more common carp being collected on May trips than on July trips (Table 48-a, Figure 56). Common carp CPUE was not significantly different between May and October or between July and October trips (Table 48-a). Comparisons by month showed significant differences between years on May trips (Kruskal-Wallis statistic = 39.384, p = 0.000) and July trips (Kruskal-Wallis statistic = 15.337, p = 0.000), but not on October trips (Mann-Whitney U test statistic = 472.00, p = 0.219). Common carp CPUE significantly increased between May 1992 and 1996 (Table 48-b, Figure 56). Common carp CPUE consistently declined between 1996 and 1997 on May trips, between 1993 and 1997 on July trips and between 1996 and 1997 on October trips (Figure 56). However, the only statistically significant decline in common carp CPUE was that between July 1993 and July 1997 (Tables 48-b - 48-d, Figure 56). The August 1994 trip, while presented in CPUE graphics is not considered in this analysis due to the abbreviated nature of that particular trip (Table 1).

Comparisons of common carp mean TL between months, across years, and between years in a given month, via ANOVA/Scheffe, indicated that common carp collected on May and October trips were significantly larger than those collected in July (Table 49-a, Figure 57). However, there was no significant difference in common carp mean TL between May and October trips (Table 49-a, Figure 57). Comparisons of mean TL in May across years indicated that common carp collected in May 1992 were significantly smaller than those in May 1996, with no significant difference between May 1992 and 1997 or May 1996 and 1997 (Table 49-b, Figure 57). There were no significant differences in mean TL between years on either July or October trips (Tables 49-c and 49-d, Figure 57). Almost all common carp collected in Reach 6 were large, adult fish with mean TL’s near 500 mm (Figures 56 and 57). Length-frequency histograms of channel catfish size-classes collected in Reach 6 show that very few common carp under 375 mm TL were caught fish caught in this section of the river (Figure 58).

Plots of common carp mean biomass for all life stages combined show a very similar trend to that of mean TL in Reach 6 (Tables 49-a - 49-d and 50-a - 50-c, Figures 57 and 59). In other words, common carp mean biomass was significantly lower on July trips than on May and October trips (Table 50-a),

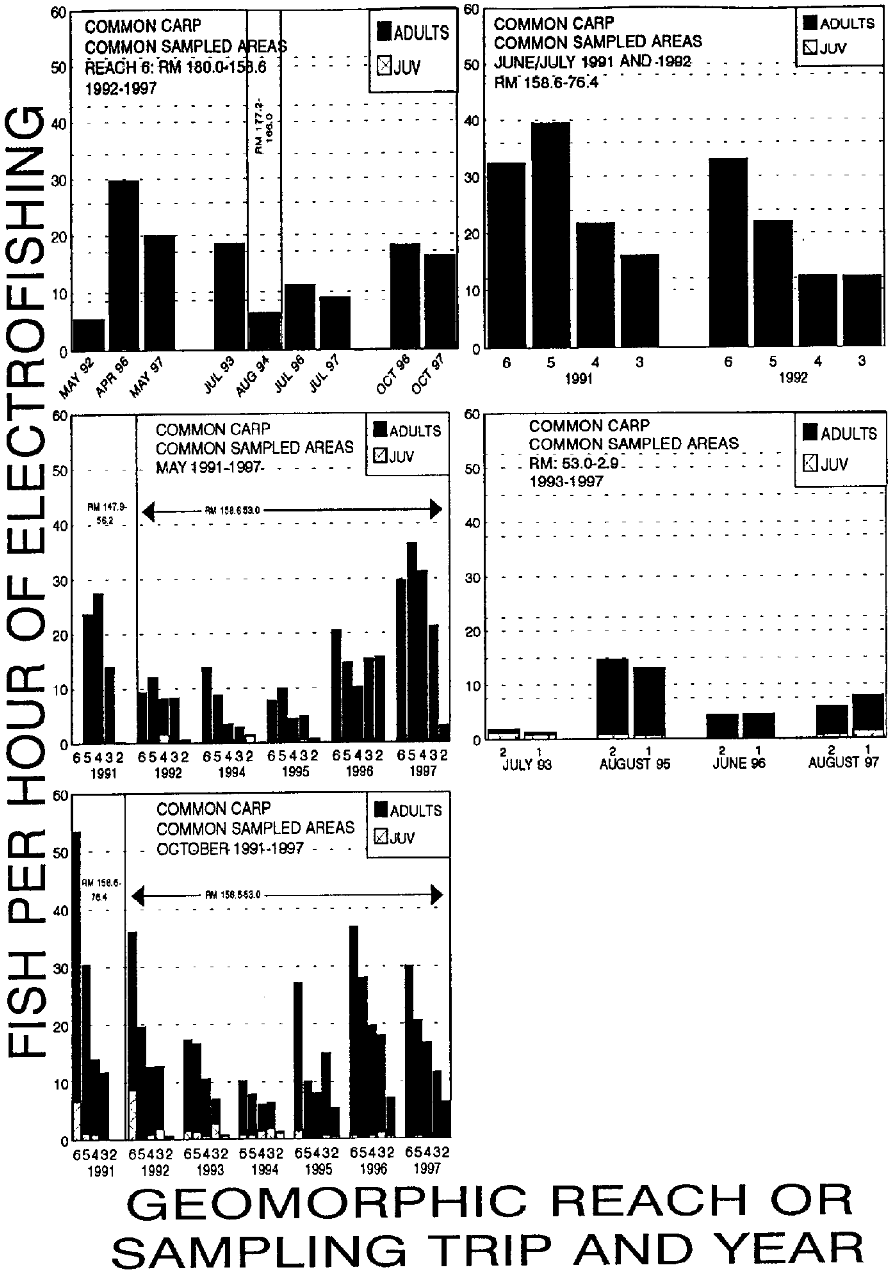


Figure 56. Number of common carp collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

Table 48-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 3.615, $r^2 = 0.024$, $p = 0.028$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.033*	1.000	
October	0.881	0.281	1.000

Table 48-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 28.990, $r^2 = 0.324$, $p = 0.000$*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.000*	0.130	1.000

Table 48-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 8.420, $r^2 = 0.129$, $p = 0.000$*

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.122	1.000	
1997	0.000*	0.142	1.000

Table 48-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.427, $r^2 = 0.025$, $p = 0.237$

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.237	1.000

Table 49-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, grouped by months across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 7.567, $r^2 = 0.022$, $p = 0.001$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.004*	1.000	
October	0.994	0.007*	1.000

Table 49-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 2.626, $r^2 = 0.025$, $p = 0.075$*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.081*	1.000	
1997	0.125	0.990	1.000

Table 49-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.861, $r^2 = 0.006$, $p = 0.424$

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.913	1.000	
1997	0.448	0.712	1.000

Table 49-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for October trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.318, $r^2 = 0.002$, $p = 0.573$

Scheffe matrix:

	1996	1997
1996	1.000	
1997	0.573	1.000

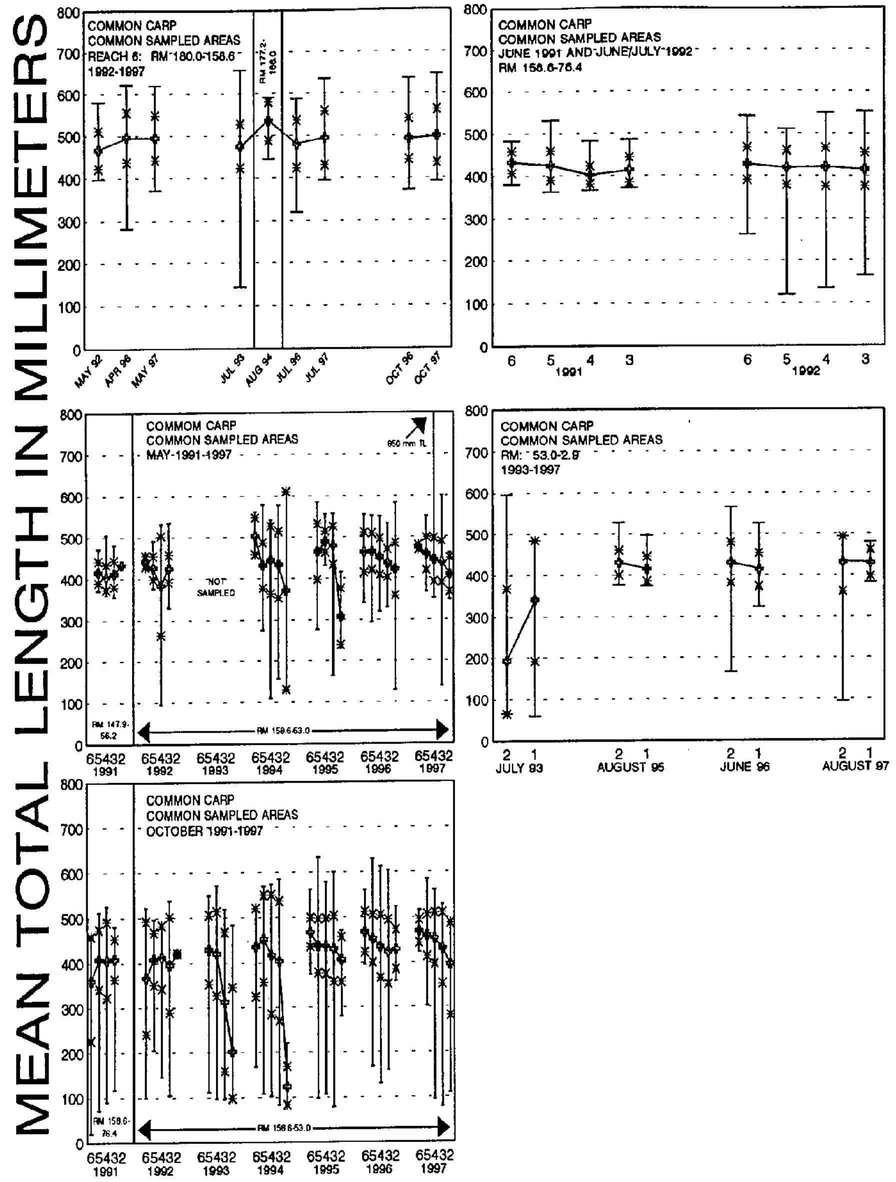
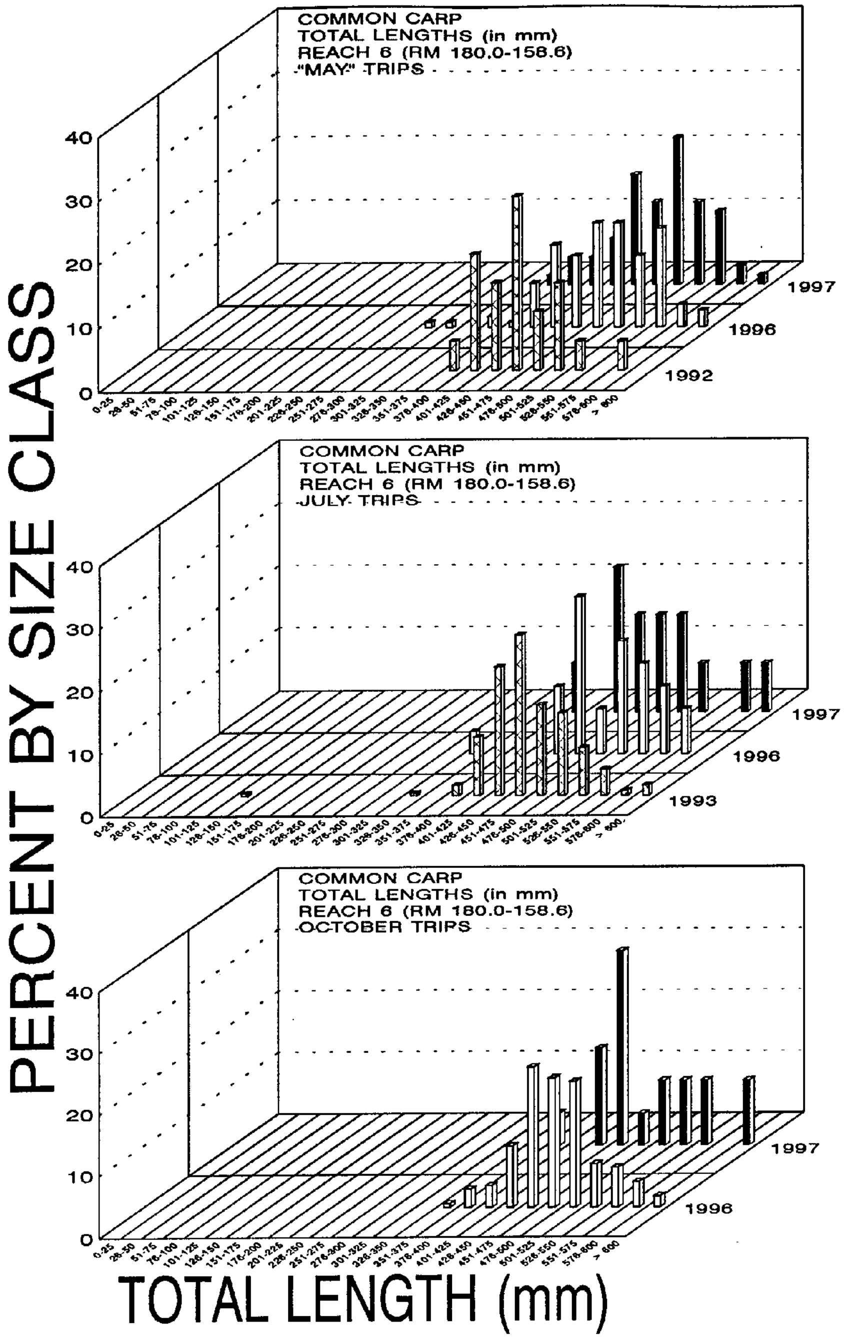


Figure 57. Mean total length (TL) in millimeters for common carp collected on standardized adult fish community monitoring trips, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river. Lines and crosses represent the mean values, error bars represent the range, and asterisks represent the standard deviation.

 COMMON CARP
TOTAL LENGTHS (in mm)
REACH 6 (RM 180.0-158.6)
"MAY" TRIPS

COMMON CARP
TOTAL LENGTHS (in mm)
REACH 6 (RM 180.0-158.6)
JULY TRIPS

COMMON CARP
TOTAL LENGTHS (in mm)
REACH 6 (RM 180.0-158.6)
OCTOBER TRIPS

Figure 58. Length-frequency histograms for common carp collected and measured on designated miles during standardized adult fish community monitoring trips in Reach 6 (RM 180.0-158.6), 1992-1997.

Table 50-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 13.470, r^2 = 0.052, p = 0.000*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.000*	1.000	
October	0.634	0.539	1.000

Table 50-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 11.962, r^2 = 0.108, p = 0.000*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.000*	0.849	1.000

Table 50-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 1.159, r^2 = 0.009, p = 0.315

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.837	1.000	
1997	0.355	0.686	1.000

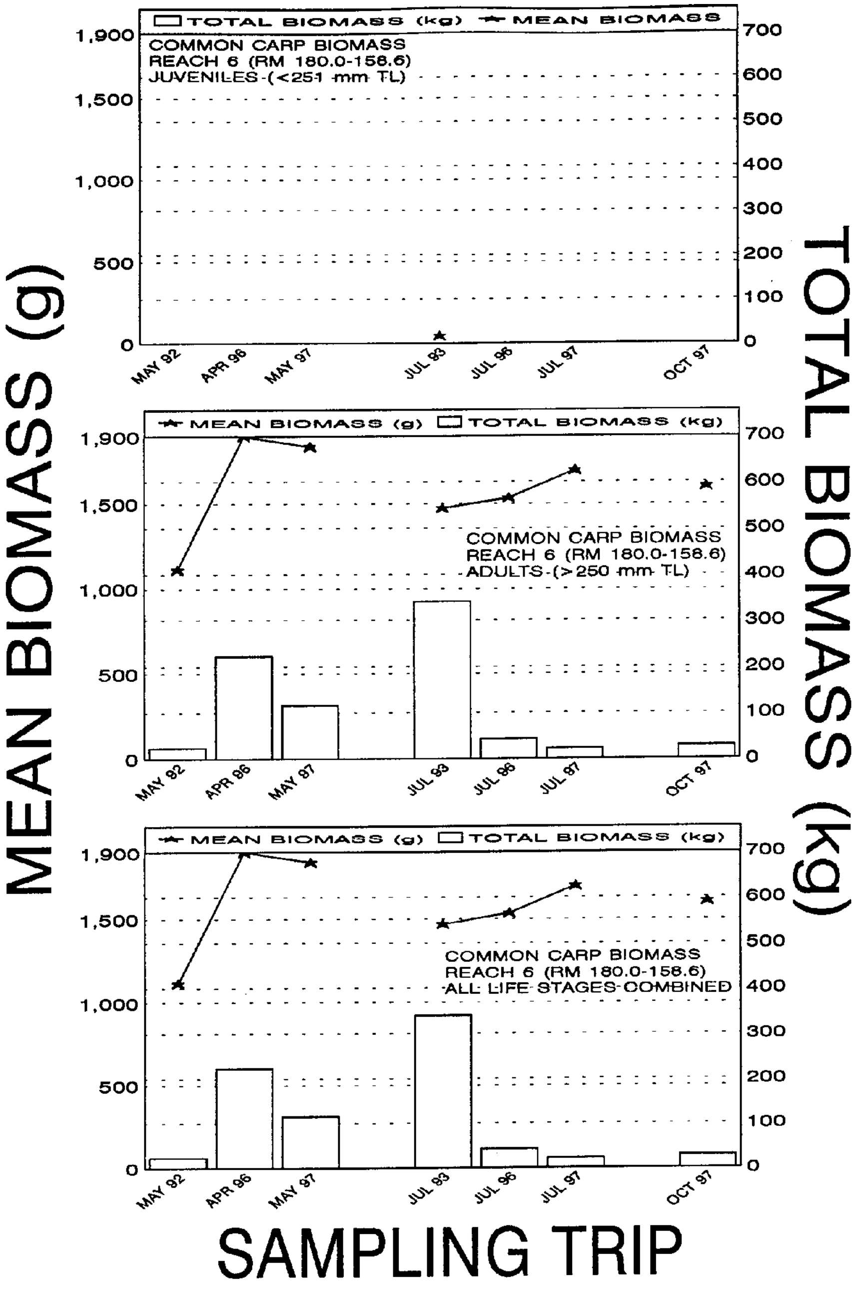


Figure 59. Total and mean biomass of common carp collected and weighed on designated miles during standardized adult fish community monitoring trips between RM 180.0-158.6 ("Reach 6"), 1991-1997.

mean biomass was significantly lower in May 1992 than May 1996 (and May 1997 in this case; Table 50-b), and there was no significant difference in mean biomass on any of the three July trips (Table 50-c). No biomass comparisons could be made for October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

Plots of common carp mean K in Reach 6 showed trends that were, again, close to those for mean TL and mean biomass within months, but not across months. Common carp mean K declined significantly between May and July trips and then declined, again significantly, between July and October trips (Table 51-a, Figure 60). Like mean biomass, mean K was significantly lower in May 1992 than in May 1996 or 1997 (Table 51-b) and like both mean TL and mean biomass, there were no significant differences between any of the July trips. No comparisons could be made for condition factor between October trips in Reach 6 (RM 180.0-158.6) as no fish were weighed on the October 1996 trip.

---Core Sampling Area (RM 158.6-53.0)---

In the core sampling area common carp CPUE showed patterns very similar to those seen in channel catfish CPUE. Comparisons of CPUE grouped by month, across years, showed that common carp CPUE on October trips was significantly higher (Mann-Whitney U test statistic = 1353531.500, p = 0.000) than on May trips (Table 52-a, Figure 56). Significant differences in common carp CPUE were present between years in May collections (Kruskal-Wallis test statistic = 404.084, p = 0.000). Common carp CPUE fell significantly between 1991 and 1994, remained essentially the same between 1994 and 1995, then rose significantly between 1995 and 1997, with 1997 CPUE being significantly higher than in 1991 (Table 52-b, Figure 56). Common carp CPUE on May trips started at 18.30 fish/hr (range = 0.00-113.51) in 1991, fell to a low of 4.15 fish/hr (range = 0.00-54.55) in 1994, then rose to the highest levels seen during our study at 23.96 fish/hr (range = 0.00-113.95) in 1997 (Figure 56 and 61). This represents a 477.3% increase in channel catfish CPUE between 1994 and 1997 on May trips. Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) show that the observed upward trend in common carp CPUE between 1994 and 1997 was accounted for by increases in adult common carp CPUE in all three reaches over previous years (Figure 61). The other pattern evident in common carp CPUE on May trips was that, with the exception of the May 1996 trip, beginning in May 1991 common carp tended to have steadily declining CPUE proceeding downstream from either Reach 4 or 5 depending on the particular trip (Figure 56). Juvenile common carp were rare on all May trips (Figure 56).

Significant differences in common carp CPUE were also present between years in October collections (Kruskal-Wallis test statistic = 214.680, p = 0.000). Fewer significant differences in common carp CPUE were present among October trips (12 of 21 comparisons = 57.1%) than among May trips (10 of 15 comparisons = 66.7%; Tables 52-b and 52-c). Common carp CPUE on October trips in the core sampling area was 19.71 fish/hr (range = 0.00-178.95) in 1991, fell significantly to a low of 6.01 fish/hr (range = 0.00-77.78) in 1994 (the trip in between the two low CPUE values observed for common carp on May trips), and then rose to another peak of 18.91 fish/hr (range = 0.00-70.59) in 1997 (the trip before the high seen in May 1997), before falling again in

Table 51-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, grouped by months, across years, in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 28.407, $r^2 = 0.104$, $p = 0.000$*

Scheffe matrix:

	May	July	October
May	1.000		
July	0.000*	1.000	
October	0.000*	0.017*	1.000

Table 51-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for May trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 30.849, $r^2 = 0.238$, $p = 0.000$*

Scheffe matrix:

	1992	1996	1997
1992	1.000		
1996	0.000*	1.000	
1997	0.000*	0.838	1.000

Table 51-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for July trips in Reach 6, RM 180.0-158.6 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.086, $r^2 = 0.001$, $p = 0.918$

Scheffe matrix:

	1993	1996	1997
1993	1.000		
1996	0.930	1.000	
1997	0.991	0.943	1.000

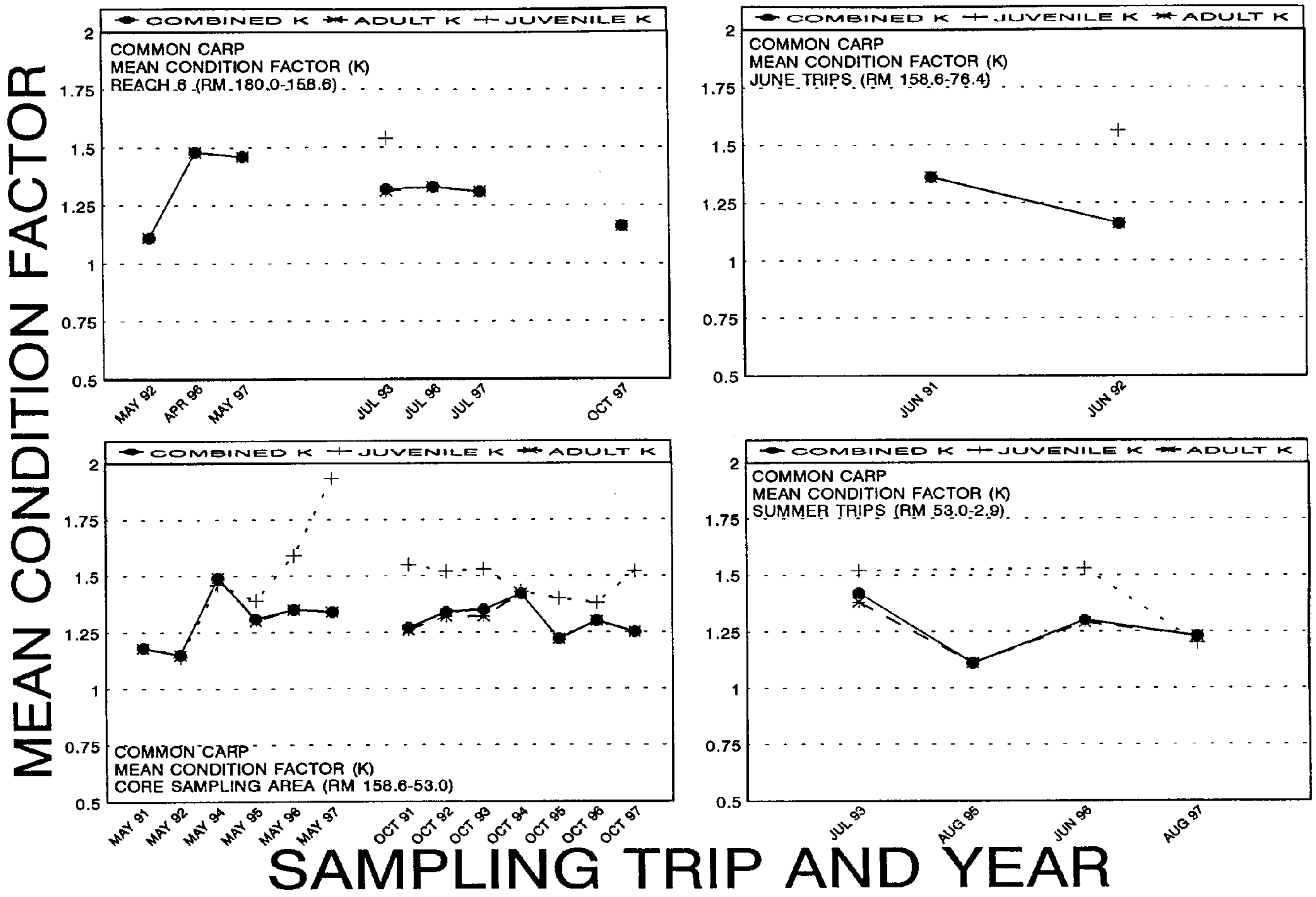


Figure 60. Mean condition factor of common carp collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips for common sampled areas between RM 180.0-2.9, 1991-1997.

Table 52-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 73.207, $r^2 = 0.020$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 52-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 107.998, $r^2 = 0.246$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.001*	1.000				
1994	0.000*	0.000*	1.000			
1995	0.000*	0.003*	0.759	1.000		
1996	0.513	0.000*	0.000*	0.000*	1.000	
1997	0.000*	0.000*	0.000*	0.000*	0.000*	1.000

Table 52-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp CPUE data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 39.909, $r^2 = 0.110$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.486	1.000					
1993	0.000*	0.005*	1.000				
1994	0.000*	0.000*	0.037*	1.000			
1995	0.116	0.997	0.024*	0.000*	1.000		
1996	0.686	0.004*	0.000*	0.000*	0.000*	1.000	
1997	1.000	0.317	0.000*	0.000*	0.047*	0.757	1.000

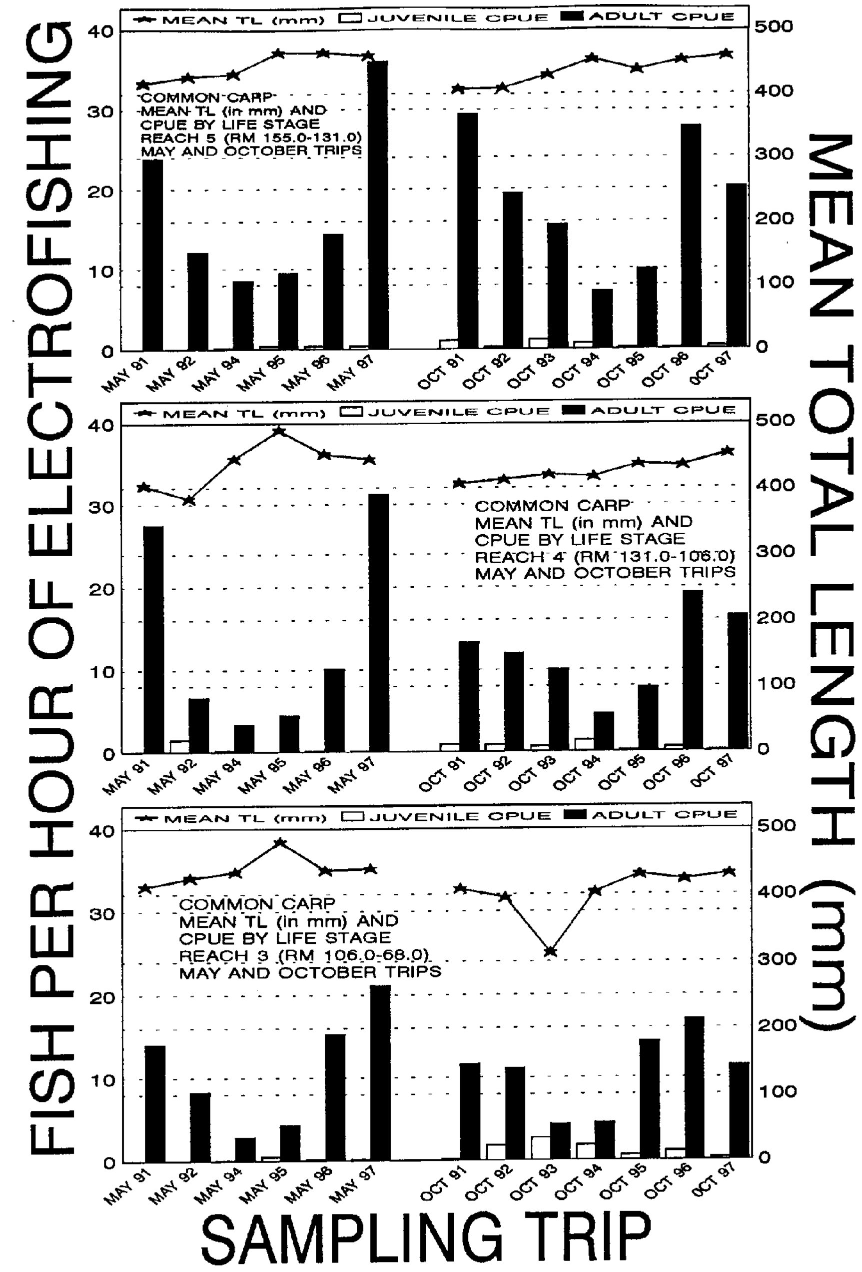


Figure 61. Number of fish collected by life stage per hour of electrofishing versus mean total length for common carp in geomorphic Reaches 3-5 on May and October standardized adult fish community monitoring trips in the core sampling area of the San Juan River (RM 158.6-53.0), 1991-1997.

October 1997 to 14.62 fish/hr (range = 0.00-62.50; Figure 56 and 61). This represents a 214.6% increase in common carp CPUE between 1994 and 1996 on October trips. Breakdowns of juvenile and adult CPUE by whole geomorphic reach (i.e., reaches 3, 4, and 5 only) show that the increase in common carp CPUE between 1994 and 1996 was accounted for by changes in the numbers of adult fish in all three reaches (Figure 61). Juvenile common carp were collected more often on October trips in the core sampling area than on May trips, however, collections of this life stage were still very rare (Figure 61). For the most part, common carp CPUE declined steadily between Reaches 6 and 2 on October trips (Figure 56). In addition, between 1992 and 1997 October trips, juvenile common carp became more prevalent in the catch in downstream reaches of the core sampling area (Figures 61).

A comparison of common carp total CPUE on October trips between 1988 and 1997 (RM 147.9-119.2) shows that the relatively high CPUE values seen for this species in 1991-1992 and again in 1996-1997 may very well be fluctuations in a cycle that causes numbers of common carp to peak and then bottom out on a three- to four-year cycle (Figure 12). Common carp CPUE values for 1996 represent the high value in this section of the river over the last ten years (Figure 12).

Common carp collected on October trips in the core sampling area had a significantly smaller mean TL than those collected on May trips (Table 53-a, Figure 57). In comparisons between years, within months, mean TL rose almost linearly (with the exception of a spike in May 1995) between 1991 and 1997, with common carp in all years after 1992 being significantly larger than in May 1991 and 1992 (Table 53-b, Figure 57). Common carp mean TL was significantly higher in May 1995 than on all other May trips (Table 53-a). On October trips, mean TL declined between 1991 and 1993, then rose linearly between 1993 and 1996, leveling off between 1996 and 1997 (Figure 57). The changes in mean TL between 1991 and 1994 were not significantly different, but the rise in mean TL between 1994 and 1996-1997 was (Table 53-c). On both May and October trips after 1992, common carp mean TL consistently declined in downstream reaches (Figure 57). This decline was sometimes quite dramatic, as was the case in Reach 2 in October 1994 (Figure 57). On October trips, this decline in mean TL is tied, at least in part, to the collection of more juvenile common carp in downstream reaches. However, given the relatively small numbers of juvenile common carp collected on October trips and the fact that almost no juveniles were collected on May trips, the declines in mean TL in downstream reaches of the core sampling area seem to point to adult common carp being smaller in these downstream areas (Figures 57 and 61). Length-frequency histograms of common carp measured on DM’s in the core sampling area verify these assumptions (Figure 62). Length-frequency histograms also showed that common carp show up briefly in the catch as age-1 fish (i.e., 101-150 mm TL) on October trips, then basically disappear from the catch until they reach TL’s of 325 mm or greater (Figure 62). Following specific cohorts of common carp using length-frequency histograms based on adult monitoring data appears to be impossible.

Common carp mean biomass was significantly higher on May trips than on October trips (Table 54-a). Both May and October mean biomass rose significantly between 1991 and 1997 (Tables 54-b and 54-c). Like mean TL, there was a spike in common carp mean biomass in May 1995 that was significantly higher than all other May trips (Table 54-b, Figure 63). A similar spike was seen in October 1994, where common carp mean biomass was

Table 53-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 47.031, r^2 = 0.012, p = 0.000*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 53-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 19.850, r^2 = 0.070, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.797	1.000				
1994	0.087*	0.629	1.000			
1995	0.000*	0.000*	0.000*	1.000		
1996	0.000*	0.012*	0.815	0.001*	1.000	
1997	0.000*	0.000*	0.130	0.039*	0.642	1.000

Table 53-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 31.447, r^2 = 0.069, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.977	1.000					
1993	0.762	0.997	1.000				
1994	0.826	0.296	0.079*	1.000			
1995	0.000*	0.000*	0.000*	0.318	1.000		
1996	0.000*	0.000*	0.000*	0.000*	0.121	1.000	
1997	0.000*	0.000*	0.000*	0.002*	0.364	1.000	1.000

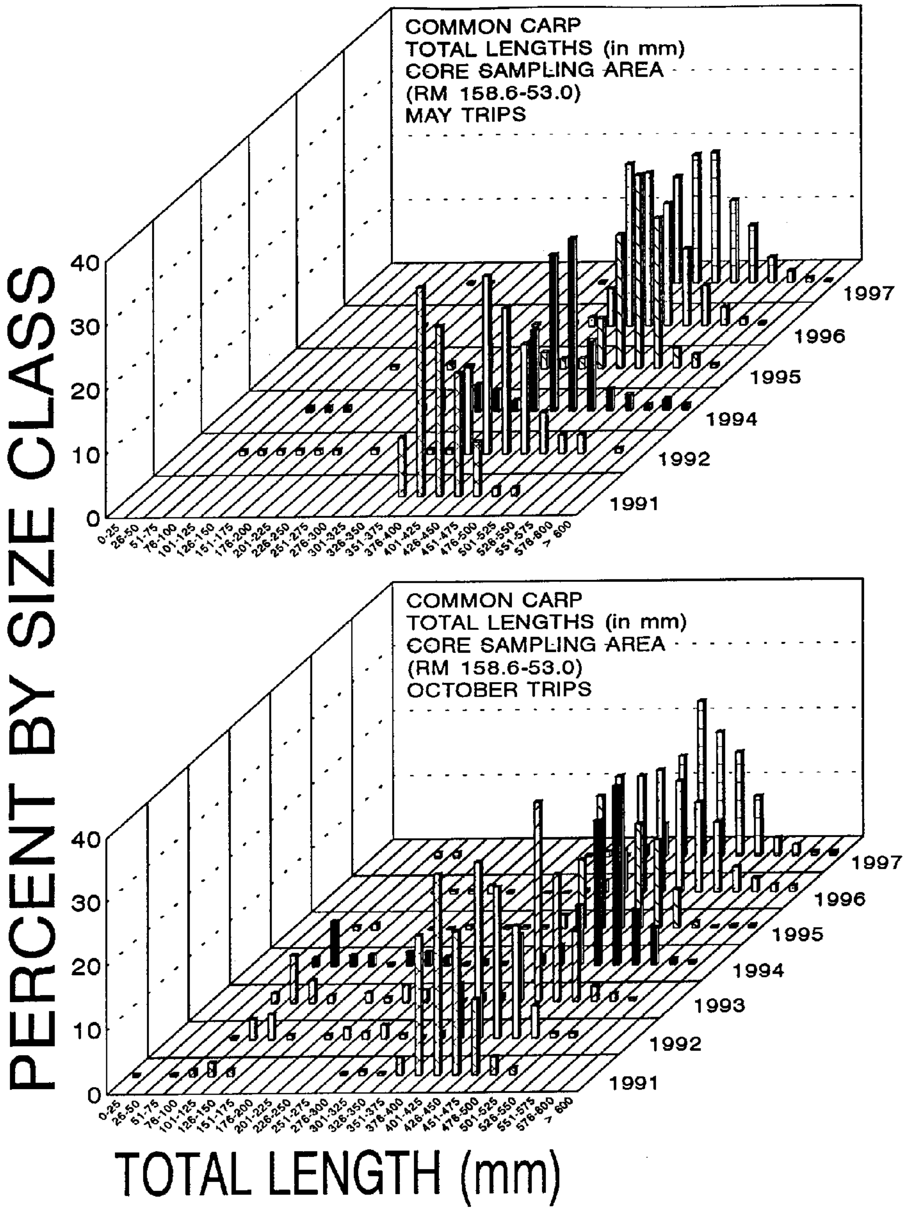


Figure 62. Length-frequency histograms for common carp collected and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 54-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 75.455, $r^2 = 0.020$, $p = 0.000$*

Scheffe matrix:

	May	October
May	1.000	
October	0.000*	1.000

Table 54-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 33.208, $r^2 = 0.112$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.900	1.000				
1994	0.000*	0.000*	1.000			
1995	0.000*	0.000*	0.922	1.000		
1996	0.000*	0.000*	0.481	0.008*	1.000	
1997	0.000*	0.000*	0.917	0.091*	0.832	1.000

Table 54-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 26.623, $r^2 = 0.064$, $p = 0.000$*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.998	1.000					
1993	0.765	0.975	1.000				
1994	0.000*	0.000*	0.000*	1.000			
1995	0.002*	0.031*	0.466	0.000*	1.000		
1996	0.000*	0.000*	0.001*	0.042*	0.178	1.000	
1997	0.000*	0.000*	0.000*	0.521	0.008*	0.923	1.000

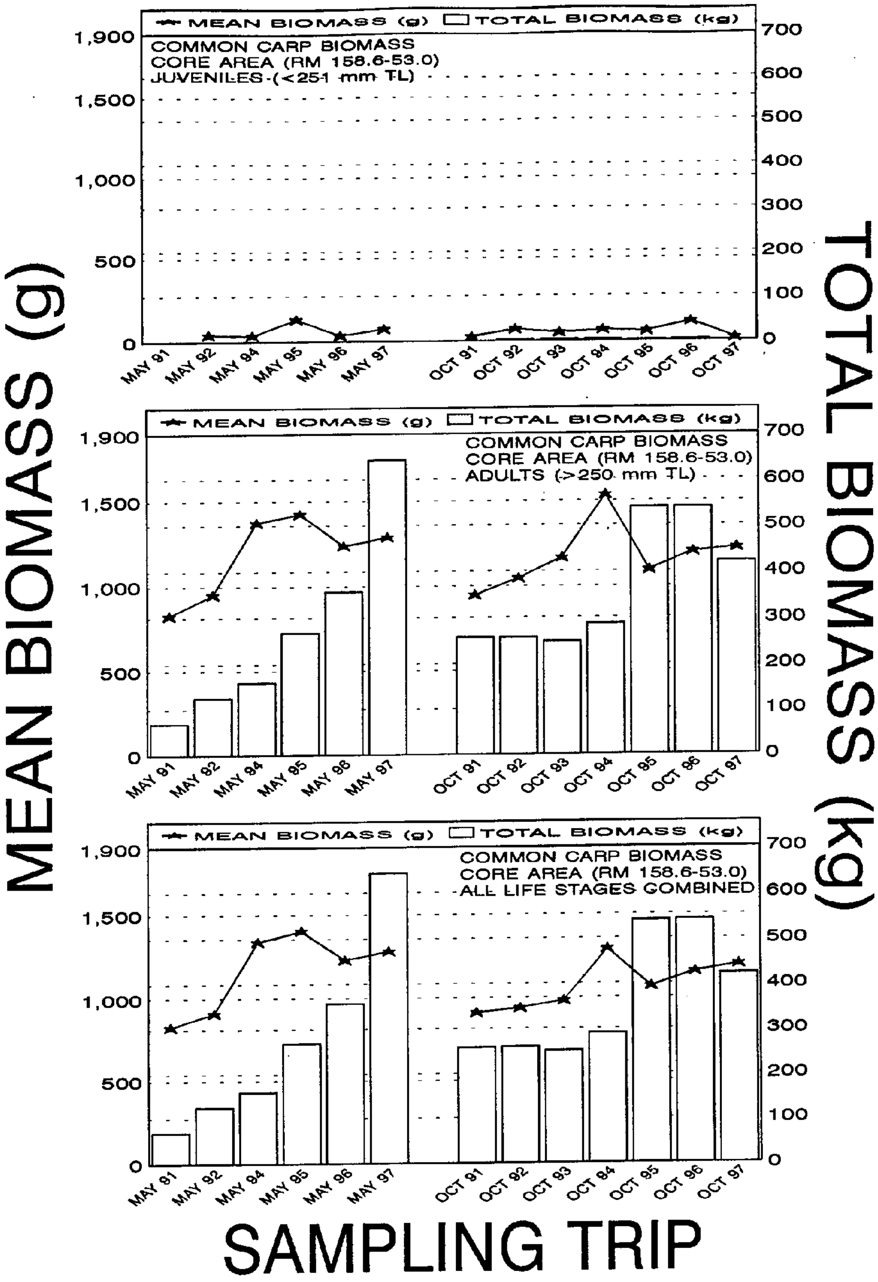


Figure 63. Total and mean biomass of common carp collected and weighed on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0).

significantly higher than all other October trips with the exception of 1997 (Table 54-c, Figure 63). The spike in mean biomass in May 1995 was reflected in whole-reach breakdown of mean biomass in Reaches 4 and 3, but not Reach 5 (Figures 64-66). The spike in mean biomass in October 1994 was reflected in whole-reach breakdowns for all three reaches (Figures 64-66). Other than these similarities, mean biomass varied greatly between specific geomorphic reaches over the study period and trends were almost impossible to determine when data had been partitioned to this level (Figures 64-66).

Like mean TL and mean biomass, mean K of common carp was significantly higher on May trips than on October trips (Table 55-a). Mean K for common carp rose significantly between May 1991 and 1997 (Table 55-b, Figures 60 and 67). Like mean TL and mean biomass there was a spike in mean K that was significantly higher than all other May trips. However, Unlike mean TL and mean biomass, the spike in mean K came in May 1994 and not May 1995 (Figures 60 and 67). This spike in May 1994 was mainly caused by common carp in Reaches 5 and 4 of the core sampling area (Figure 67). In contrast, the spike in mean TL and mean biomass seen on the October 1994 was also seen in mean K in October 1994 (Figure 67). Like the other parameters, October 1994 mean K was significantly higher than all other October trips (Table 55-c). However, despite fluctuations over the study period, common carp mean K was not significantly different in October 1997 compared to October 1991 (Table 55-c).

---June Trips (RM 158.6-76.4)---

On June trips, patterns of common carp CPUE were almost identical to those seen on May or October trips (Figure 56). Like the native suckers and channel catfish, CPUE for common carp was significantly different between June 1991 and 1992, with June 1991 CPUE being higher than 1992 (Mann-Whitney U test statistic = 13017.500, p = 0.000; Table 56-a). Like channel catfish and unlike the native suckers, common carp CPUE in June 1992 was not among the highest recorded during the study period, but June 1991 was (Figures 5, 22, and 41, 56). Like common carp CPUE on May and October trips, CPUE on June trips steadily declined in reaches downstream of Reach 5 in May and Reach 6 in October (Figure 56). Few juvenile common carp were collected on DM’s on June trips (Figure 68).

Common carp mean TL was not significantly different between June 1991 and 1992 (Table 56-b, Figure 57). On both trips, mean TL declined slightly between Reaches 6 and 3 (Figure 57). A length-frequency histogram of common carp measured on June trips showed that the great majority of common carp collected on June trips were adult fish > 351 mm TL (Figure 68). Both mean biomass and mean K were significantly lower in June 1992 than in June 1991 (Table 56-c and 56-d, Figures 60 and 69). The significantly lower mean K in June 1992 was likely an artifact of the significantly lower mean biomass on this same trip.

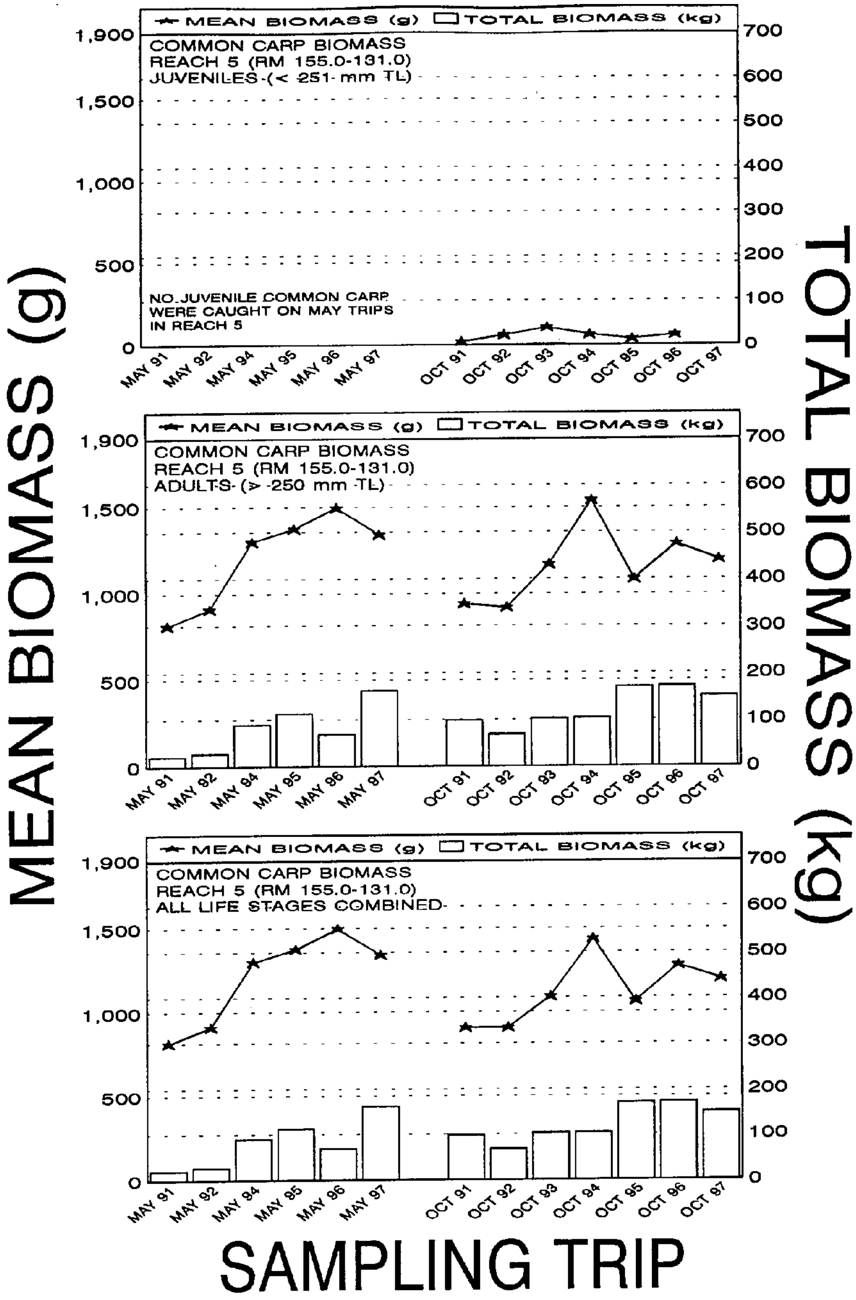


Figure 64. Total and mean biomass of common carp, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 5 (RM 155.0-131.0).

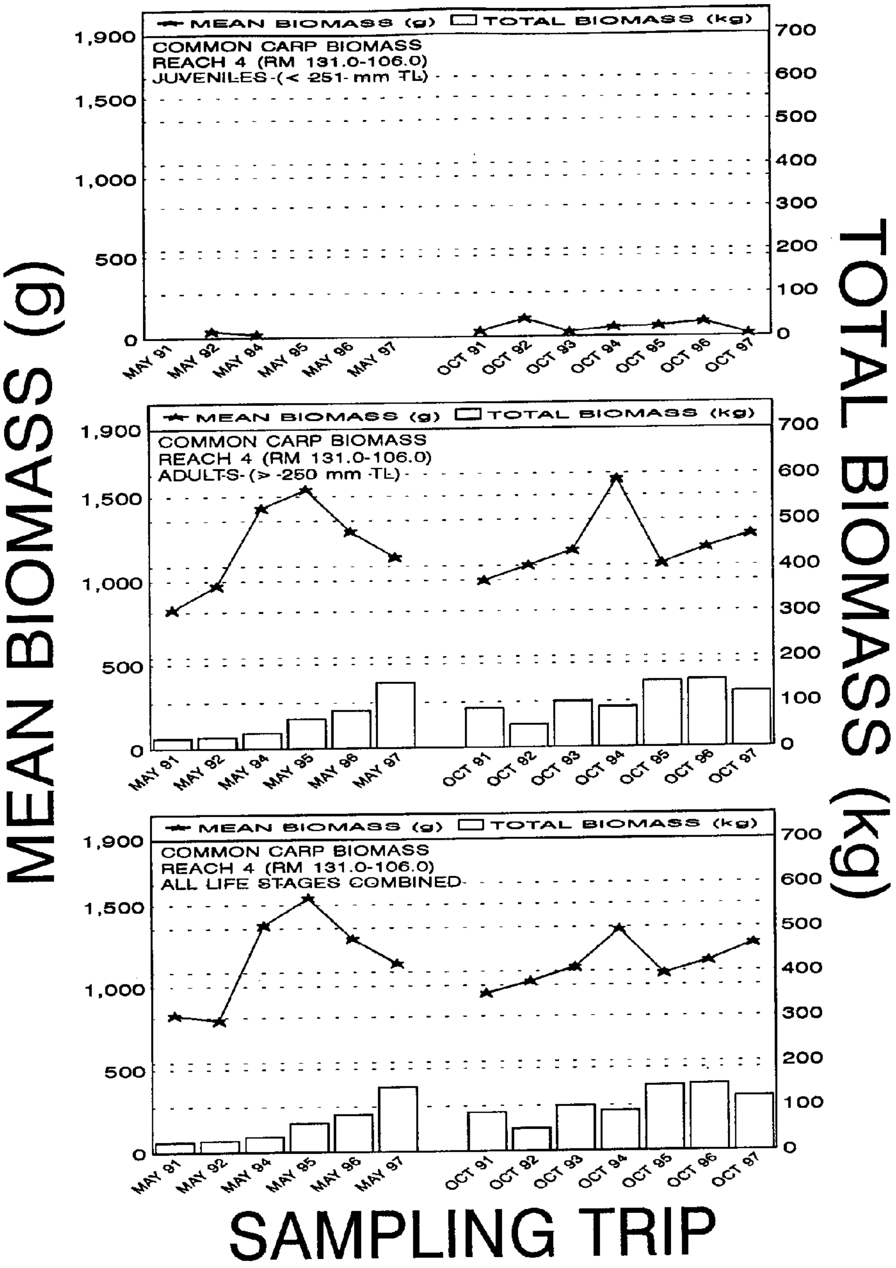


Figure 65. Total and mean biomass of common carp, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 4 (RM 131.0-106.0).

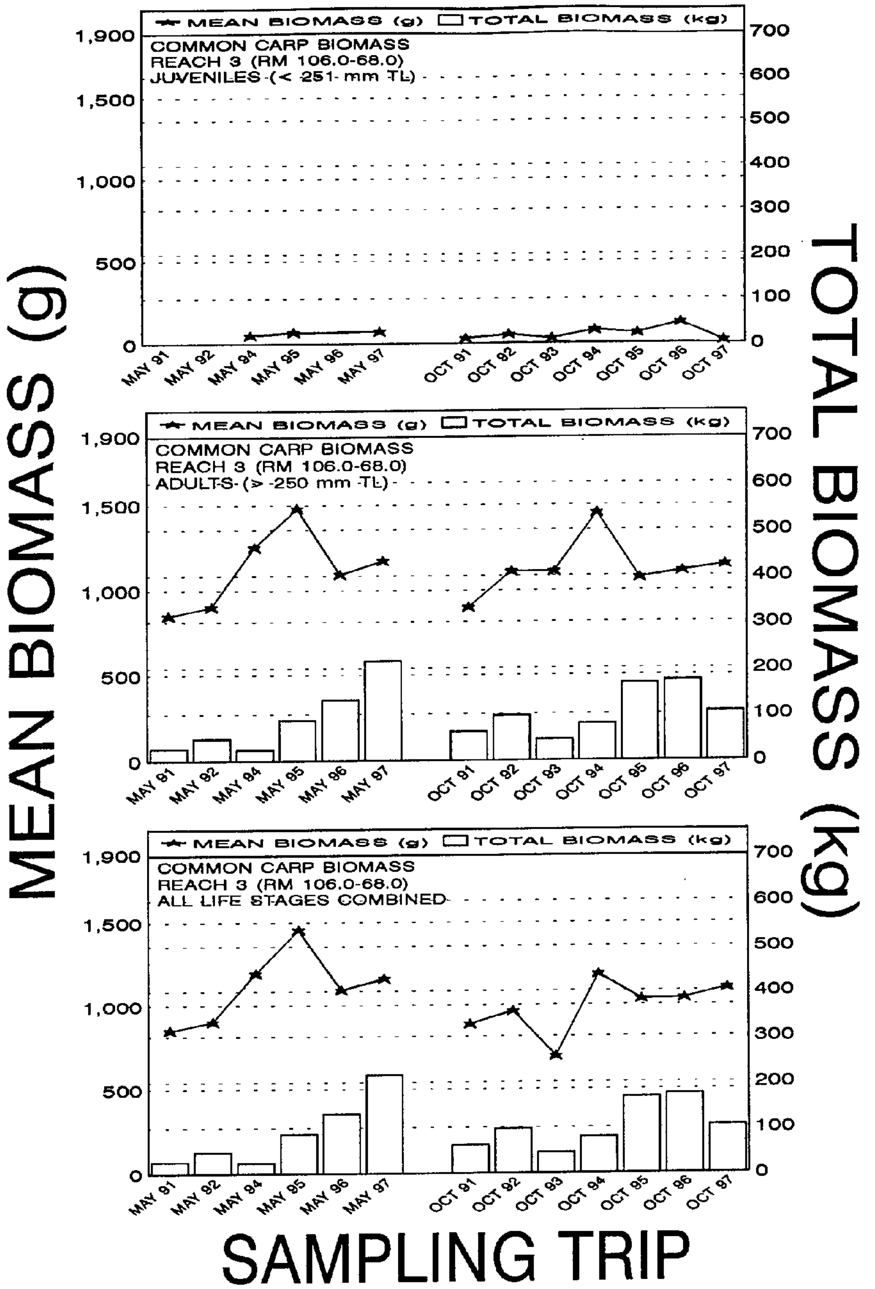


Figure 66. Total and mean biomass of common carp, by life stage, collected and weighed on designated miles during standardized adult fish community monitoring trips in Reach 3 (RM 106.0-68.0).

Table 55-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, grouped by months, across years, in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 11.277, $r^2 = 0.003$, p = 0.001*

Scheffe matrix:

	May	October
May	1.000	
October	0.001*	1.000

Table 55-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for May trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 44.713, $r^2 = 0.146$, p = 0.000*

Scheffe matrix:

	1991	1992	1994	1995	1996	1997
1991	1.000					
1992	0.921	1.000				
1994	0.000*	0.000*	1.000			
1995	0.001*	0.000*	0.000*	1.000		
1996	0.000*	0.000*	0.000*	0.458	1.000	
1997	0.000*	0.000*	0.000*	0.569	0.999	1.000

Table 55-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for October trips in the core sampling area, RM 158.6-53.0 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 35.106, $r^2 = 0.082$, p = 0.000*

Scheffe matrix:

	1991	1992	1993	1994	1995	1996	1997
1991	1.000						
1992	0.024*	1.000					
1993	0.001*	0.989	1.000				
1994	0.000*	0.001*	0.031*	1.000			
1995	0.078*	0.000*	0.000*	0.000*	1.000		
1996	0.769	0.422	0.067*	0.000*	0.000*	1.000	
1997	0.948	0.000*	0.000*	0.000*	0.611	0.073*	1.000

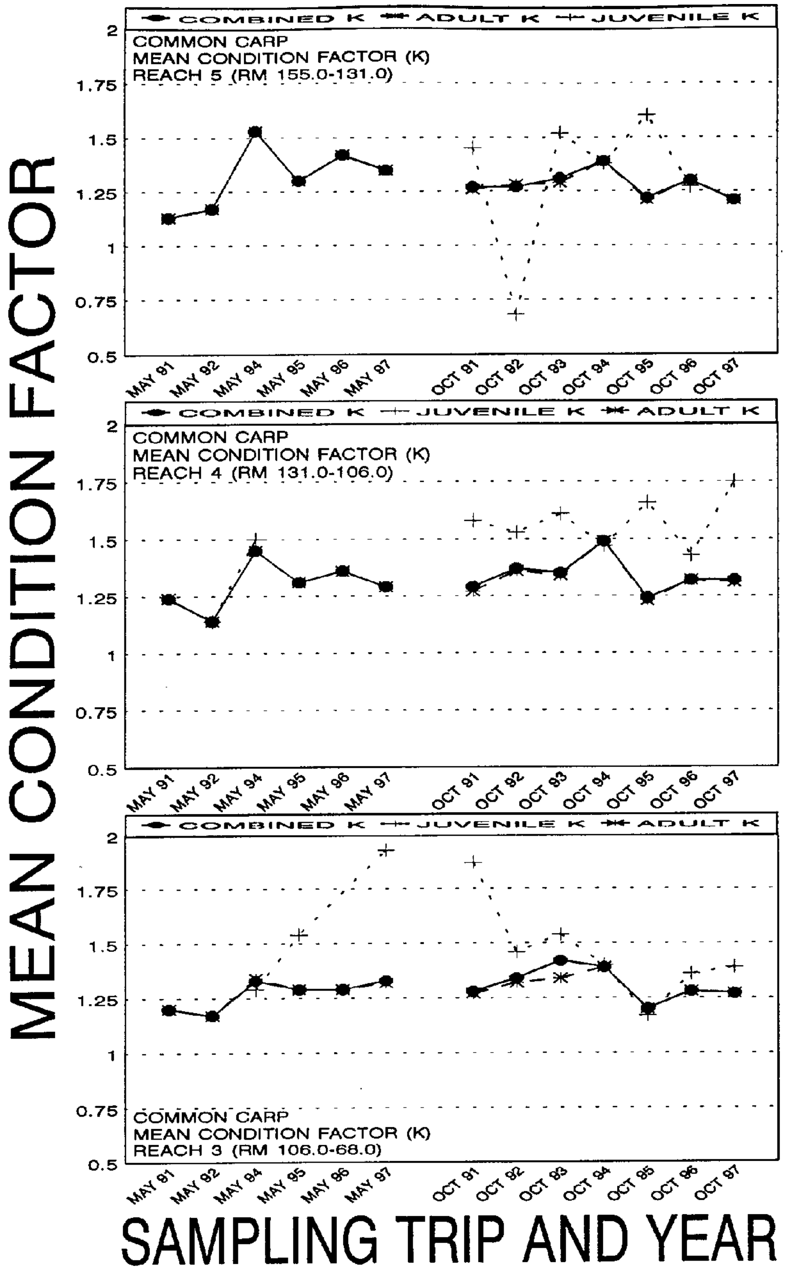


Figure 67. Mean condition factor, by whole geomorphic reach, of common carp, collected, weighed, and measured on designated miles during standardized adult fish community monitoring trips in the core sampling area (RM 158.6-53.0), 1991-1997.

Table 56-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp mean CPUE data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 11.580, r^2 = 0.038, p = 0.001*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.001*	1.000

Table 56-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 0.013, r^2 = 0.000, p = 0.908

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.908	1.000

Table 56-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 31.380, r^2 = 0.047, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

Table 56-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for June trips, RM 158.6-76.4 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 98.881, r^2 = 0.136, p = 0.000*

Scheffe matrix:

	1991	1992
1991	1.000	
1992	0.000*	1.000

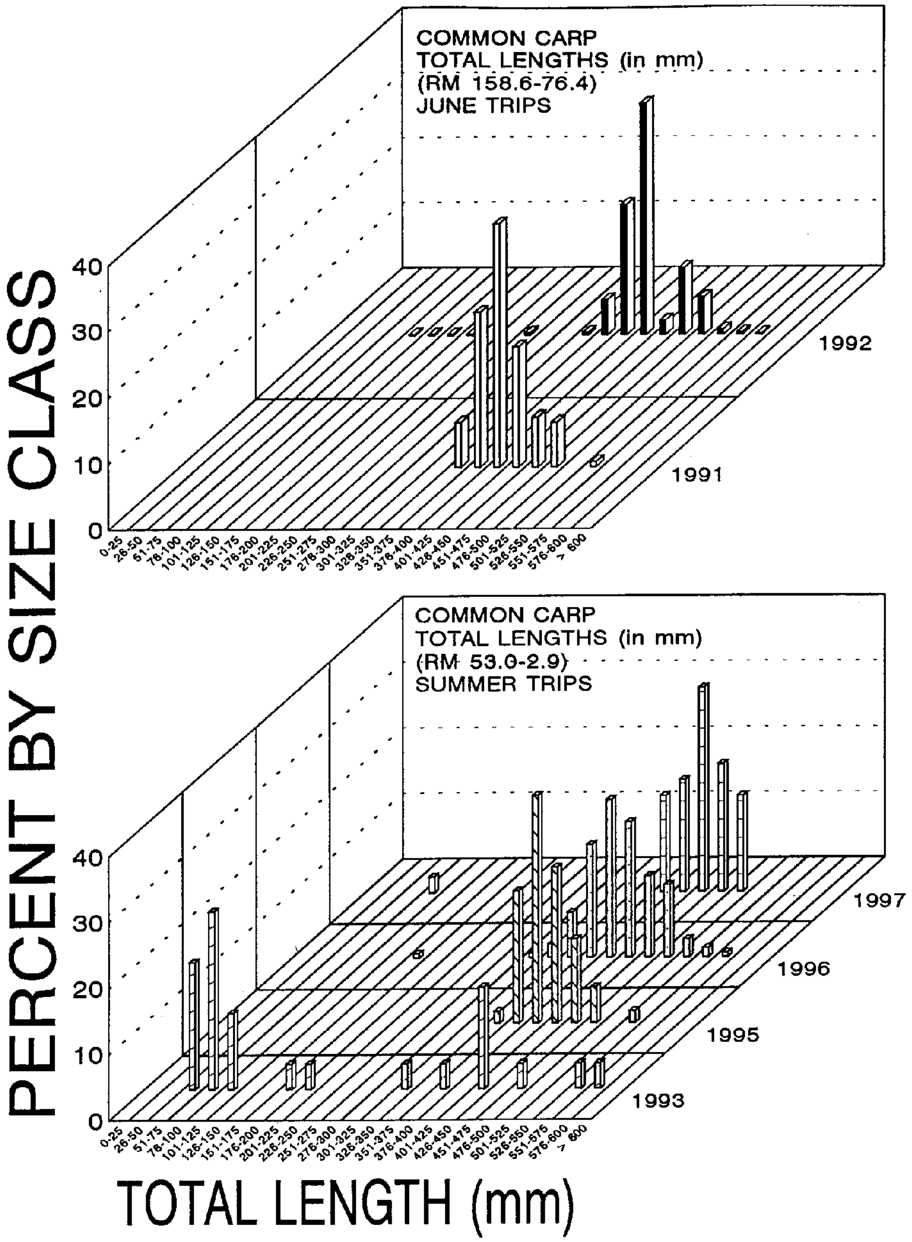


Figure 68. Length-frequency histograms for common carp collected and measured on designated miles during standardized adult fish community monitoring trips in June 1991 and 1992 (RM 158.6-76.4) and in the lower San Juan River (RM 53.0-2.9), 1993-1997.

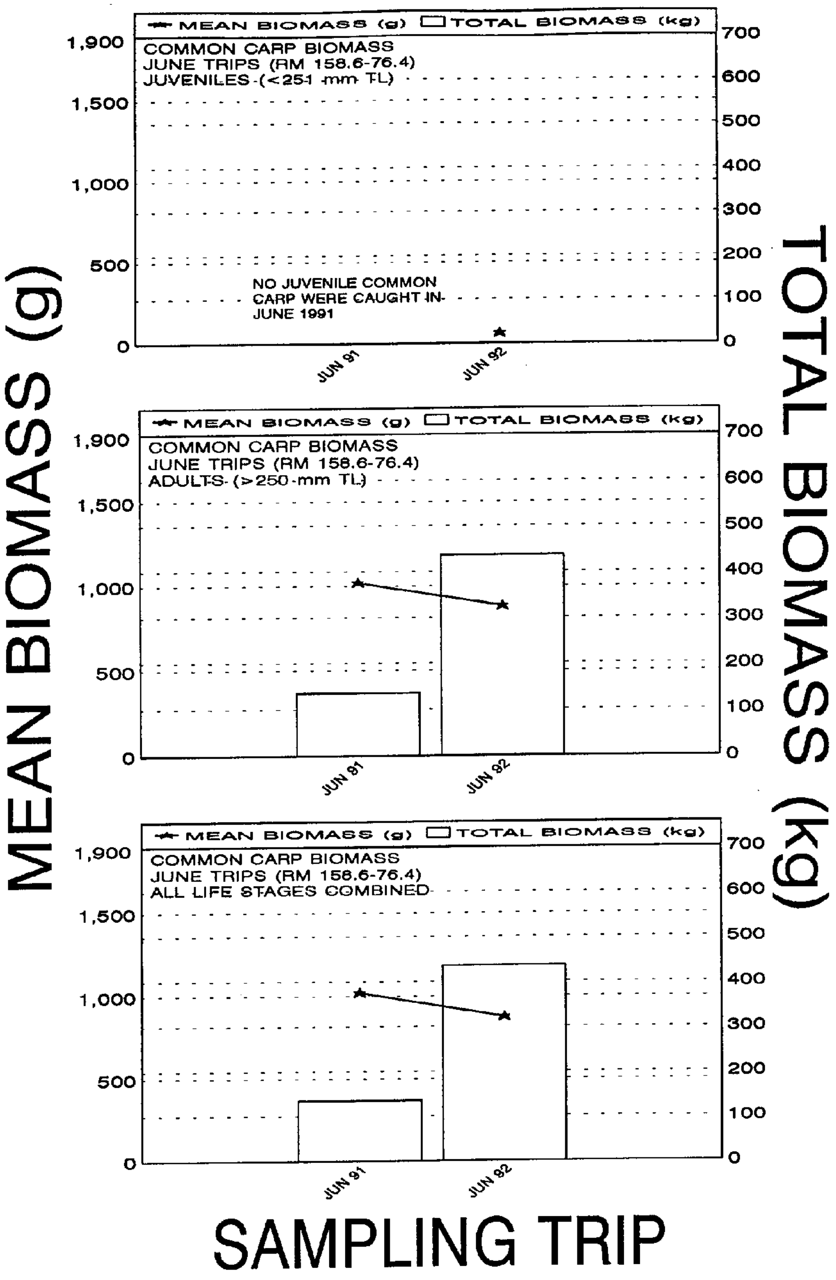


Figure 69. Total and mean biomass of common carp collected and weighed on designated miles during June 1991 and 1992 standardized adult fish community monitoring trips (RM 158.6-76.4).

---Lower River (RM 53.0-2.9)---

Common carp total CPUE in the lower river varied significantly between years (Kruskal-Wallis test statistic = 95.219, p = 0.000). Common carp CPUE was significantly lower in 1993 than on all following trips (Table 57-a, Figure 56). After 1993, common carp CPUE rose to the highest levels observed during our study (significantly higher than all trips in the lower river), then fell again in 1996 and 1997 to levels intermediate to 1993 and 1995 (Table 57-a, Figure 56). Common carp CPUE in 1996 and 1997 were not significantly different from one another (Table 57-a). The relatively high CPUE values for common carp in the lower river in 1995 followed the inundation of the waterfall at the San Juan River-Lake Powell interface in spring 1995.

Common carp mean TL was significantly lower in 1993 than in all following years in which this reach was sampled (Table 57-b, Figure 57). There was no significant difference between common carp mean TL on the 1995-1997 summer trips (Table 57-b, Figure57). Length-frequency histograms of common carp measured in the lower river show that the significantly lower mean TL in 1993 collections were due to many more juvenile common carp in 1993 collections compared to other years (Figure 68). On the 1993 summer trip juvenile common carp between 51 and 125 mm TL were the dominant size-class collected (Figure 68). A small group of age-2 fish (176-225 mm TL) was also collected on this trip (Figure 68). This was the only trip, in any river reach in which age-2 common carp were collected in any appreciable numbers. After 1993, length-frequency of common carp in the lower river very closely resembled that of the core sampling area on May and June trips with the catch being almost exclusively large, adult common carp (Figure 68). The large relative percentage of age-1 common carp collected in the lower river in 1993 indicates a very strong 1992 cohort.

Like mean TL, common carp mean biomass was also significantly lower in 1993 collections than on all following trips, with no significant differences between 1995 and 1997 collections (Table 57-c, Figure 70). Mean biomass of adult common carp dropped noticeably between 1993 and collections on following years (Figure 70).

Common carp mean K did not mirror the trends seen in mean TL and mean biomass. Common carp mean K was highest in 1993, dropped to a low (significantly lower than all other trips) in 1995 rose again in 1996 only to drop again in 1997 (Table 57-d, Figure 60).

Red Shiner

Red shiner were by far the most abundant, small-bodied, nonnative fish (fathead minnow, threadfin shad, green sunfish, western mosquitofish, and plains killifish being the others) collected by electrofishing during our study (Table 12). Red shiner were not collected above the PNM Weir (RM 166.6), but occurred consistently in collections from that point downstream to Lake Powell (Table 12, Figures 71).

In Reach 6, red shiner were rare (Figure 71). On May and October trips in the core sampling area, red shiner showed only one discernible trend. That was a consistent drop in total CPUE between 1992 and 1997 on October trips

Table 57-a. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of ranked total (juvenile + adult) common carp mean CPUE data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 43.007, $r^2 = 0.268$, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.001*	0.000*	1.000	
1997	0.000*	0.000*	0.281	1.000

Table 57-b. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean TL data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 62.915, $r^2 = 0.417$, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.000*	0.999	1.000	
1997	0.001*	0.996	0.984	1.000

Table 57-c. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean biomass (WT in grams) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 10.506, $r^2 = 0.110$, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.014*	1.000		
1996	0.000*	0.129	1.000	
1997	0.000*	0.386	1.000	1.000

Table 57-d. One-way ANOVA statistics and matrix of Scheffe pairwise comparisons of common carp mean condition factor (K) data, for summer trips, RM 53.0-2.9 ($p < 0.10$ = * = statistically significant relationship).

One-way ANOVA: F-statistic = 13.213, $r^2 = 0.135$, p = 0.000*

Scheffe matrix:

	1993	1995	1996	1997
1993	1.000			
1995	0.000*	1.000		
1996	0.122	0.000*	1.000	
1997	0.015*	0.098*	0.393	1.000

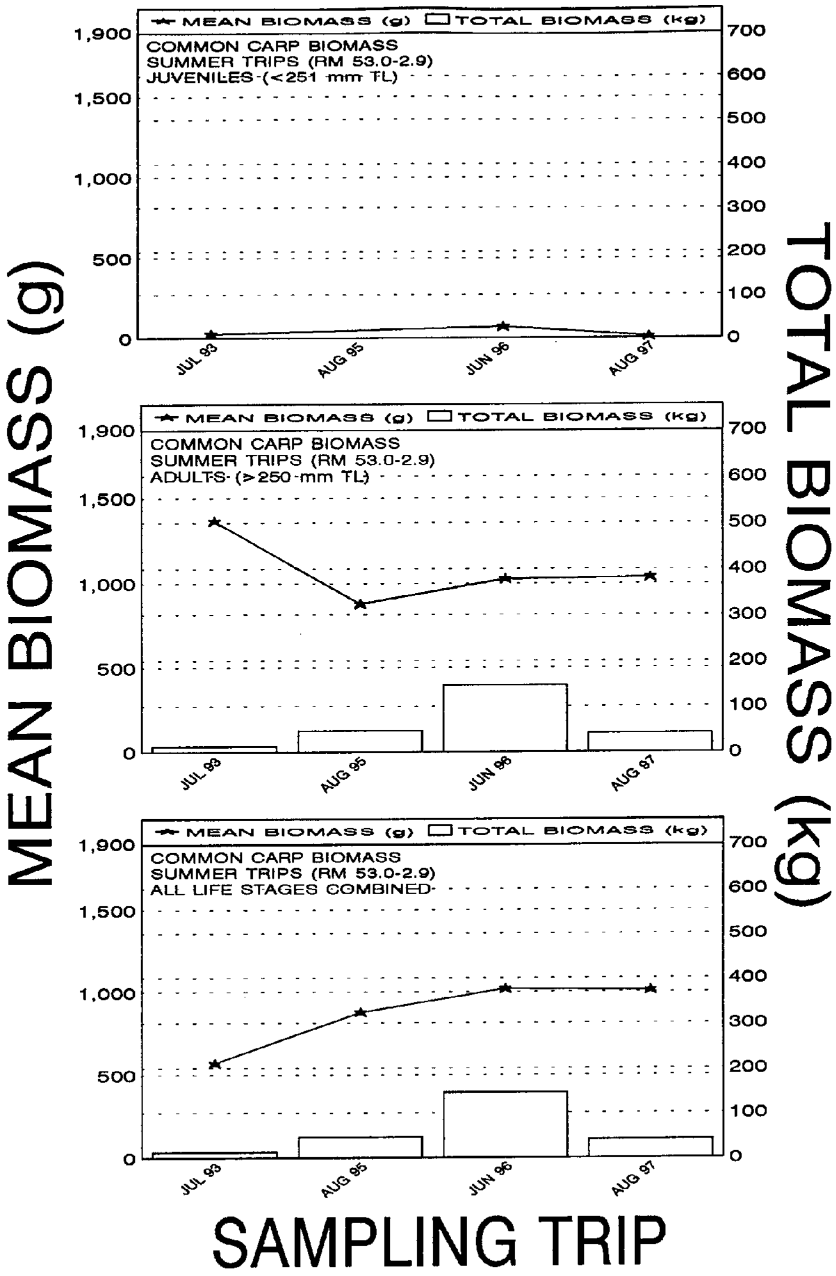


Figure 70. Total and mean biomass of common carp collected and weighed on designated miles during standardized adult fish community monitoring trips in the lower San Juan River (RM 53.0-2.9), 1993-1997.

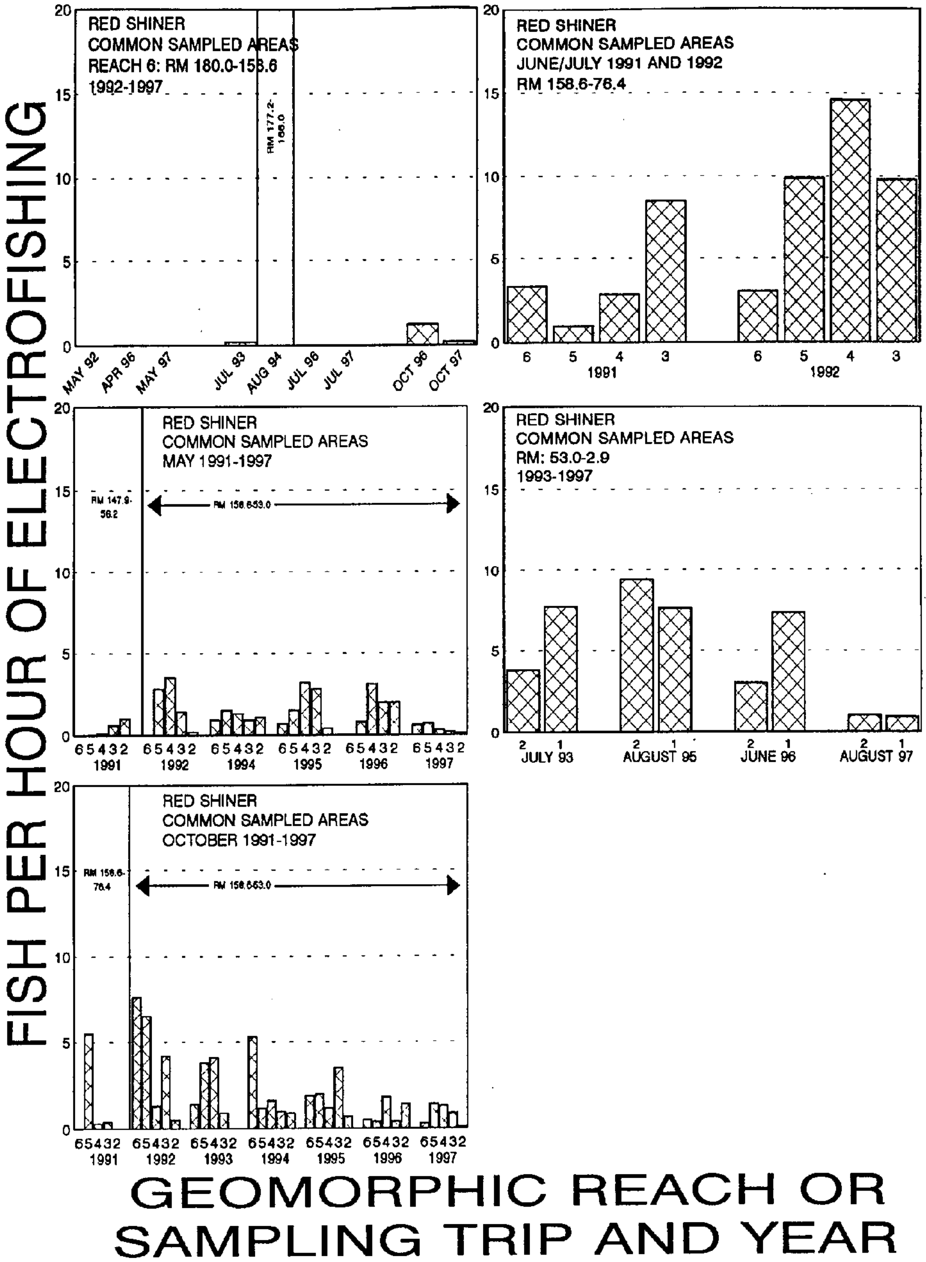


Figure 71. Number of red shiner collected per hour of electrofishing on standardized adult fish community monitoring trips in the San Juan River, 1991-1997. Data is grouped by geomorphic reach and year within common sampled areas of the river.

(Figure 71). Red shiner CPUE was consistently higher during shoreline electrofishing on June trips (i.e., high flow trips), than on May and October trips in the same year (Figure 71). CPUE for red shiner was higher on three of the four sampling trips in the lower river than it was in upstream reaches during May and October trips of the same year (Figure 71). The exception was August 1997 when red shiner CPUE was low, riverwide, in all reaches and on all trips (Figures 71).

White Sucker

Between 1993 and 1997, ten white sucker were collected from RM 175.0-96.0 (Tables 12 and 58). Between 1994 and 1997, 18 white sucker hybrid forms (flannelmouth X white sucker and bluehead X white sucker) were also collected (Tables 12 and 58). Eleven of these were flannelmouth X white sucker hybrids collected from RM 177.2-138.0. The other seven were bluehead X white sucker hybrids collected from RM 178.0-155.0.

Lacustrine Species

After the inundation of the waterfall at RM 0.0 in spring 1995, three lacustrine fishes were collected that hadn't previously been seen during our study. These included 452 threadfin shad, 65 walleye, and 51 striped bass (Table 12). The most upstream collection of walleye during our study was at RM 108.3, while striped bass were collected as far upstream as RM 91.2. However, the large majority of both of these species were collected in the canyon-bound reaches downstream of Mexican Hat, UT (RM 53.0; Table 59).

Threadfin shad were never collected above Government Rapid (RM 20.2) during our study, but were collected in large numbers within a few meters downstream of the rapid. The large majority of threadfin shad (429) were collected in August 1995, when the water in the lower river was relatively clear. Numbers of threadfin shad collected in the lower river dropped to 23 in 1996 and were absent in 1997 collections.

In addition to walleye, striped bass, and threadfin shad, both largemouth and smallmouth bass were collected in small numbers throughout the study period. Largemouth bass were distributed throughout the study area (Tables 12 and 59). In Reach 6, captures of small size-class (<250 mm TL) largemouth bass often occurred in close proximity to irrigation return channels. In August and October 1995, the largest number of largemouth bass captured during any two consecutive trips (30) were collected (Table 59). Over half of these (16) were collected from RM 52-11.

Smallmouth bass collected during our study were few in number, small in size, and were restricted to the river upstream of Mexican Hat (Tables 12 and 59).

Table 58. Summary statistics for white sucker and white sucker X native sucker hybrids captured in the San Juan River, 1992-1997.

Trip	Number Captured (Measured)	Total Length in mm, or life stage	Date of Capture	Range Of River Miles For Captures And Observations
WHITE SUCKER:				
May 1992	1 (1)	278 = Juvenile	05/11/92	165.0-164.0
October 1993	2 (0)	Not recorded	10/01/93	158.6-157.0 &
		Not recorded	10/06/93	97.0- 96.0
May 1994	1 (0)	Juvenile	05/10/94	157.0-156.0
October 1996	1 (0)	Juvenile	10/14/96	176.0-175.0
March 1997	1 (1)	381 = Adult	03/11/97	166.0
April 1997	2 (0)	Adult	04/28/97	169.0-168.0 &
		Juvenile	04/29/97	157.0-156.0
July 1997	1 (0)	Juvenile	07/02/97	164.0-163.0
October 1997	1 (0)	Adult	09/29/97	175.0-174.0
WHITE SUCKER X BLUEHEAD SUCKER HYBRIDS:				
May 1994	1 (0)	Juvenile	05/10/94	156.0-155.0
April 1996	2 (1)	324 = Adult	04/16/96	179.0-178.0 &
		Juvenile	04/16/96	175.0-174.0
October 1996	2 (0)	Juvenile	10/14/96	179.3-178.0 &
		Adult	10/14/96	168.0-167.0
July 1997	2 (1)	Adult	07/02/97	166.0-165.0
		282 = Juvenile	07/02/97	163.0-162.0
WHITE SUCKER X FLANNELMOUTH SUCKER HYBRIDS:				
October 1995	1 (0)	Adult	10/04/95	139.0-138.0
October 1996	2 (1)	273 = Juvenile	10/14/96	178.0-177.2 &
		Juvenile	10/14/96	177.1-176.0
July 1997	5 (1)	Juvenile	07/01/97	175.0-174.0 &
		500 = Adult	07/01/97	168.0-167.0 &
		3 Adults	07/02/97	165.0-164.0
October 1997	3 (0)	Juvenile	09/29/97	176.0-175.0 &
		Juvenile	09/29/97	175.0-174.0 &
		Juvenile	10/01/97	146.0-145.0

Table 59. Summary statistics for predatory lacustrine fish species captured on adult fish community monitoring trips in the San Juan River, 1991-1997.

Trip	Number Captured (Measured)	Total Length Mean (Range) in mm	Number Observed	Range Of River Miles For Captures And Observations
WALLEYE:				
August 1995	12 (3)	580 (502-646)	4	47.0- 5.0
October 1995	14 (9)	502 (407-578)	1	108.3- 53.0
May 1996	9 (7)	511 (458-631)	2	71.0- 54.0
June 1996	20 (20)	521 (420-634)	3	53.0- 8.0
October 1996	1 (1)	471	0	77.95
August 1997	8 (4)	378 (220-505)	9	43.0- 15.0
October 1997	1 (1)	332	0	77.4
STRIPED BASS:				
August 1995	34 (7)	561 (461-604)	13	52.0- 2.9
May 1996	3 (3)	573 (561-581)	0	91.2- 58.0
June 1996	14 (14)	557 (398-610)	8	49.0- 3.0
LARGEMOUTH BASS:				
June 1992	2 (2)	95 (75-115)	0	133.9-123.0
October 1992	5 (3)	311 (294-335)	0	154.0- 74.0
October 1993	7 (5)	207 (171-309)	0	154.0-137.0
August 1994	2 (2)	269 (230-307)	0	177.2-176.0
October 1994	14 (6)	178 (115-326)	0	153.0- 79.0
May 1995	1 (0)	Not recorded	0	90.0- 89.0
August 1995	16 (2)	288 (271-304)	2	52.0- 11.0
October 1995	14 (9)	314 (128-412)	0	123.0- 57.0
May 1996	4 (2)	230 (115-345)	0	101.0- 54.0
June 1996	10 (10)	209 (177-236)	0	45.0- 3.0
October 1996	6 (2)	213 (176-250)	0	168.0- 95.2
October 1997	2 (1)	509	0	177.3-175.0
SMALLMOUTH BASS:				
October 1991	1 (0)	Not recorded	0	92.0- 91.0
May 1992	1 (1)	61	0	120.0-119.0
June 1992	6 (1)	82	0	155.0- 87.6
May 1994	2 (2)	218 (211-225)	0	153.0-107.0
October 1995	3 (1)	249	0	129.0- 89.0
April 1996	1 (0)	Not recorded	0	170.0-169.0
May 1996	2 (0)	Not recorded	0	98.0- 54.0
October 1996	3 (0)	Not recorded	0	157.0-156.0

DISCUSSION

Sampling Speed and Flows vs. CPUE

Adult monitoring studies used a broad-based approach of sampling the area of the river felt to be most important to adult native fishes (particularly the three rare fishes) in three time periods of the year in order to obtain a good overview of San Juan River fish community and its reaction to test flows from Navajo Dam. Thus, most of our sampling was originally concentrated from RM 158.6-53.0. In 1993, June sampling trips in this core sampling area were discontinued, because it was felt that sampling via this technique just prior Colorado pikeminnow spawning season might adversely effect this species.

Sampling efforts in Reach 6 and the lower river were less frequent than those in the core sampling area, because it was initially thought that these two areas of the San Juan River were less important to the native fish community than the core sampling area, based on previous sampling. Reach 6 and the lower river were included in our study area because of the possibility they may still contain rare fishes. In addition, the presence of numerous instream diversion structures in Reach 6 was theorized to have an impact on the ability of San Juan River fishes (especially rare fishes) to move freely throughout the river (see Chapter 4). By 1996, it had become apparent that Reach 6 was probably much more important to native fishes (especially bluehead sucker) than had originally been thought. In addition, the lack of movement of radio-tagged Colorado pikeminnow in relation to instream diversion structures (see Chapter 4) prompted the FLOY-tagging of native suckers in Reach 6 to facilitate analyzing the effect of these structures on native fishes. Very low catch rates of adult native fishes in the lower river, especially Reach 1, confirmed that this section of the San Juan River was not as important to the native fish community as upstream reaches, so efforts in this reach were kept to a minimum, with emphasis on inventorying changes in the overall fish community (mostly nonnative species) and, after 1995, analyzing the upstream movements of nonnative and rare fishes from Lake Powell.

This sampling approach yielded data sets from multiple years and months for both Reach 6 and the core sampling area. Yet, large differences existed in trends observed between sampled months in a given river section (i.e. May vs. October in the core sampling area). Trends from different months were often ambiguous and, in the worst cases, completely contrary to one another. This made data interpretation complicated, to say the least. Where conflicting or ambiguous comparison between months were present, it became necessary to try to determine which data sets (e.g., May or October in the core sampling area) were the more representative of true fish population trends. In order to do this we examined two factors that effected CPUE, flows and sampling speed.

When CPUE was regressed against sampling speed, there were negative correlations in 13 of 20 linear regressions. Yet, none of these negative correlations were statistically significant. Thus, it appears that sampling speed has no significant effect on CPUE values and is not really a helpful measure in determining which data sets might be more representative.

When CPUE was regressed against trip flows, there were negative correlations in 14 of 20 linear regressions. Of the 14 negative correlations, five were significant. One of these significant negative correlations one was with bluehead sucker in Reach 6 on May trips, two were with channel catfish and common carp on May trips, and the remaining two were with flannelmouth sucker and bluehead sucker on October trips. There were no significant negative correlations between flow and CPUE on any summer trip in any river reach. Again, a somewhat ambiguous result. ANCOVA's done by Lawrence on flannelmouth sucker and bluehead sucker CPUE vs. flows on October trips revealed that despite the significant negative correlations, the trends observed on October trips were, apparently, real.

Flows on May trips were inherently much more variable, due to the wide range of flows, than flows on October trips (i.e., flows in October were more closely grouped and thus had less inherent variability). Thus, it is inherently harder to obtain a significant negative correlation between flows and CPUE on May trips than on October trips. In addition, even though both flannelmouth sucker and bluehead sucker CPUE was significantly correlated with trip flows, CPUE for both of these species, as well as channel catfish and common carp were significantly higher on October trips than on May trips. The larger sample sizes obtained on October trips would inherently make them more representative of the population as a whole.

Fish physiology and behavior were also important when considering which data sets were most representative. Both native and nonnative fishes display a range of specialized behaviors, fluctuations in condition factor, and use of specialized habitats, associated with spawning, avoidance of high spring flows, and other factors throughout the year (e.g., Ryden and Pfeifer 1995b, 1996b). The exact timing of these physiological and behavioral differences varies depending upon the species, but is usually ended by late summer (e.g., Ryden and Pfeifer 1995a, 1995b, 1996a, 1996b). Many particular habitat types used by fish species for spawning, nursery areas, and other specialized behaviors are only available, or have the right conditions for occupancy (i.e., deep enough water, suitable temperatures) by a given fish species during higher-water periods (e.g., flooded vegetation, certain tributary mouths, backwaters, and numerous secondary channels; K. Lawrence, pers. comm.; Ryden and Pfeifer 1996b, Bliesner and Lamarra 1995, 1996). October (i.e., base flow) sampling trips represent the only time that the main channel fish community is sampled during the year when both juvenile and adult native fishes are using, or are forced to use, almost exclusively main channel habitats. Thus fish that may be missed during sampling at other times of the year due to their using flooded vegetation, flooded tributary mouths, backwaters, or secondary channels (D. Propst pers. comm.) are more likely to be sampled on October trips.

Analysis of CPUE values in main channels vs. secondary channels by Propst and Hobbes (2000), indicates that there is no significant difference between main channel and secondary channel CPUE's on May trips. This indicates that when secondary channels become sufficiently inundated in the spring, fish spread out into secondaries and use them in equal proportion to main channel habitats. This would not only help explain why fewer fish are collected in spring samples, but would also tend to indicate that by sampling less fish, May samples are probably less representative of true population trends than are October data. Additionally, the relative proportion of the river channel, both depth and width, is much lower than in fall, making a representative sample that much harder to obtain.

Another point to consider is that no standardized electrofishing trip was conducted in May 1993. Instead, two Colorado pikeminnow "hunts" took its place that year (Table 1). Thus, there is a "hole" in the May data sets. Additionally, the long-term monitoring program for the SJR-RIP, with which this data will be compared to determine long-term trends in the fish community will take place in the fall (late September and early October). So, even though both May and October electrofishing data were analyzed and presented, where conflicting or ambiguous trends in data sets between months for the same sections of river are present, the October data sets will be relied upon to draw conclusions from the data.

Numerous other factors such as water clarity (turbidity), water temperatures, individual efficiency of netters, fish that have become "trained" by repeated electrofishing to avoid the electrical fields put out by electrofishing boats, and unmarked fish that are returned to the river at the end of one mile and subsequently recaptured in the next mile's electrofishing sample can further complicate the analysis of electrofishing data. However, these factors are impossible to quantify and, hopefully, somewhat self-equalizing over the duration of a long study such as ours. No attempt was made to quantify these particular factors in our analysis of the 1991-1997 electrofishing data.

Abundance, Distribution, and Relation to Flows

As can be seen from data presented in the RESULTS section, even when analyzing trends across large areas of the river (i.e., Reach 6, core sampling area, and lower river), trying to draw conclusions about the San Juan river fish community and the effect of mimicry of a natural hydrograph on that community can be tedious and confusing. In most cases, finding truly meaningful year-to-year relationships when partitioning data to the level of geomorphic reach is almost impossible. There are several reasons for this. First, the four common, large-bodied fish species for which most of the data was obtained are long-lived. Therefore, detecting and interpreting trends on these fishes in a relatively short, seven-year time period, is problematic. Even relatively large increases and declines in any given population parameter (i.e., CPUE, mean TL, mean biomass, mean K) may or may not mean something important. A single spike or dip in what, otherwise, appears to be a discernible trend may just be an artifact of a less than perfect sampling design, poor sampling conditions (i.e., weather, water clarity) during a given trip, netter efficiency, etc. Second, gear type constraints do not allow for representatively sampling even large-bodied fish species until they are at least two years of age. Thus, the fish we sample have, in almost all cases, cleared the major hurdles to long-term survival (e.g., larval drift, the predation threshold, starvation) and are fairly resilient to any but the most drastic of changes in selective pressures. Thus, factors such as mimicry of a natural hydrograph and mechanical removal efforts, which tend to effect large juvenile and adult fish populations slowly, take much longer to be reflected in our sampling. Third, since we do not effectively start to sample fishes until they are at least two years of age, the changes in the adult fish community we can observe are more often related to events two or three years previous that effected larval survival and recruitment, as opposed to events that happened recently. Determining the exact mechanism that caused an observed change in the adult fish community is often impossible. Thus, adult monitoring data is more useful in recognizing and analyzing riverwide trends in fish species abundance and distribution over many years rather than year-to-year changes on a reach by reach basis.

Overall, native fishes are more common in San Juan River main channel electrofishing collections than are nonnative fishes. The catch ratio for all native fishes to all nonnative fishes in the San Juan River for all reaches sampled between 1991 and 1997 (i.e., all areas of the river in which Colorado pikeminnow could likely occur) is 3.06:1 (Table 12). Two native and two nonnative species accounted for 93.8% of all fish collected during our study: flannelmouth sucker (59.4%), bluehead sucker (12.1%), channel catfish (13.1%), and common carp (9.2%; Table 12). Comparatively, in a similar section of the Colorado River (i.e., all areas of the river in which Colorado pikeminnow would likely occur) from the Green River confluence upstream to DeBeque, CO, the catch ratio for all native fishes to all nonnative fishes in 1994 and 1995 was 2.80:1. Five fish species in the Colorado River accounted for 95.4% of the catch: flannelmouth sucker (31.9%), bluehead sucker (36.4%), roundtail chub (4.3%), common carp (17.1%), and channel catfish (5.7%; Osmundson 1999). In a similar section of the Gunnison River (i.e., all areas of the river in which Colorado pikeminnow would likely occur) from the Colorado River confluence to upstream of Delta, CO, the catch ratio for all native fishes to all nonnative fishes in 1992 and 1993 was 3.89:1. Again, five fish species in the Gunnison accounted for 93.9% of the catch: flannelmouth sucker (28.4%), bluehead sucker (33.4%), roundtail chub (14.6%), common carp (8.0%), white sucker and white sucker hybrids (9.5%; Burdick 1995). Channel catfish are almost nonexistent in the Gunnison River and are limited to the lower 2.3 RM of the river, due to a diversion structure (Burdick 1995).

When making between-river fish community comparisons, it is important to remember that due of the relative size and depth of the Colorado River, a smaller percentage of channel catfish are collected in this river via electrofishing, although they are certainly at least as abundant as they are in the San Juan River (D. Osmundson, pers. comm.). Interestingly, in the Gunnison River, white sucker and its hybrid forms seem to have numerically replaced the absent channel catfish. Also of note is that bluehead sucker are more abundant than flannelmouth sucker in the Colorado and Gunnison rivers and three times more abundant percentage-wise in those rivers than in the San Juan River. Additionally, flannelmouth sucker make up less than a third of the catch in both the Colorado and Gunnison rivers, as opposed to over half in the San Juan River. It also appears that as the relative percent of channel catfish collected in a given river increases, the relative percent of roundtail chub collected in that same river decreases.

Native Species

Flannelmouth Sucker

While longitudinal distribution of flannelmouth sucker was highly variable between geomorphic reaches, trips, and years, flannelmouth sucker was the most abundant species captured in every geomorphic reach of our study with the exception of Reach 1, immediately adjacent to Lake Powell. Though less abundant than other species collected in Reach 1, flannelmouth sucker was the only native species that was consistently collected in this reach.

Almost without exception, the flannelmouth sucker population was numerically dominated by juvenile fish in all reaches, with this dominance becoming more pronounced in downstream reaches, especially Reaches 2 and 1. This corresponds to a consistent decline in mean total length in reaches downstream of Reach 5.

Even though overall numbers of flannelmouth sucker collected declined between 1992 and 1997, it would probably be a misrepresentation to label this decline a crash in the population. Several pieces of evidence argue against a population crash. First, despite declining catch rates riverwide over the last seven years, flannelmouth sucker still remained the most abundant species collected in every year our study. Second, flannelmouth sucker remained the most common species collected in every geomorphic reach of our study with the exception of Reach 1 (immediately adjacent to Lake Powell) throughout our study. Third, the decline in flannelmouth sucker catch rates was not consistent or universal throughout the river. Flannelmouth sucker catch rates actually increased in Reach 6 between 1992 and 1997. Fourth, all life stages of flannelmouth sucker are still being collected, indicating that successful reproduction and recruitment are still taking place throughout the river. However, the drop in relative percentage of early life stage flannelmouth sucker in the catch between 1991 and 1997 does warrant further monitoring. Fifth, mean K for flannelmouth sucker was significantly higher on May and July trips in Reach 6, on May trips in the core sampling area, and on summer trips, in 1997 than it was at the beginning of the study period. On October trips in the core sampling area, flannelmouth sucker mean K fluctuated significantly between 1991 and 1997, but was not significantly different in 1997 compared to 1991. Lastly, relative percentages of flannelmouth sucker collected in the San Juan River between 1991 and 1997 are much higher than those seen in both the Gunnison and Colorado rivers, where flannelmouth sucker populations are considered to be healthy. (Burdick 1995, Osmundson 1999).

One possible explanation of these observed trends (decreasing CPUE, but increasing Mean K values) is that the flannelmouth sucker population, not being subject to a great deal of selective pressure during the stable, low-flow drought years of the late 1980's and early 1990's, had exceeded its carrying capacity. In other words, there was an overabundance of low condition factor (low condition factor = poor health) flannelmouth sucker in river. The initiation of research flows and mimicry of a natural hydrograph in the 1990's induced a strong selective pressure on the San Juan River flannelmouth sucker population, "weeding-out" less fit individuals and causing the flannelmouth sucker population to reset to a more natural state. In other words large numbers of fish in poor health gave way to fewer numbers of healthier fish. If this is indeed the case, CPUE for flannelmouth sucker should stop declining and level off while condition factor ceases to increase and stabilizes at some point in the future.

It has been suggested that the observed increases in mean K may be related to a general increase in productivity in riffle and run habitats since the initiation of the research flows in the early 1990's (Holden 1999). Along these same lines, it has been suggested that fewer storm perturbations in the latter half of the study period may also have led to greater food availability and thus a higher mean K among flannelmouth sucker (K. Lawrence pers. comm.). Another possibility is that as flannelmouth sucker numbers declined over the study period there was less competition for food thus leading to a higher mean K among the remaining flannelmouth sucker (R. Ryel pers. comm.). While all of these explanations seem plausible, there is no direct evidence available to refute or support them. Conversely, it has been suggested that the declining CPUE observed for flannelmouth sucker are related to a loss of food items (i.e., benthic detritus) that may have been flushed from the system with the mimicry of a natural hydrograph between 1992 and 1997 (V. Lamarra pers. comm.). However, the increases in flannelmouth sucker Mean K over the study period would seem to argue against a large-scale loss of important food items in the system.

A second explanation for the decline in flannelmouth sucker CPUE is that we are observing the declining limb of a cyclical fluctuation in this population. Flannelmouth sucker can live to be up to nine years old (McAda 1977), thus the data collected over the last seven years represents a very short time period when looking at this long-lived species. A plot of flannelmouth sucker CPUE between 1987 and 1997 (RM 147.9-119.2) seem to indicate that CPUE for this species from 1991-1993 were very high compared to both previous and following years.

A third possible explanation would be that mimicry of a natural hydrograph is detrimental to the flannelmouth sucker population in the San Juan River. If this is the case, flannelmouth sucker CPUE will continue to decline. However, common sense would argue that the closer to “natural” San Juan River flows are, the more beneficial they would tend to be for all native fish species.

Lawrence indicated that the observed increases in flannelmouth sucker mean K were closely associated with periods of stable winter base flows, a condition which is impossible to manage artificially.

Whatever the explanation, to realistically make any definitive statements about the relative health, stability, or trends among the San Juan River flannelmouth sucker population, several more years of data will be needed.

Bluehead Sucker

Longitudinal distribution and abundance of bluehead sucker was very different than that of flannelmouth sucker. Bluehead sucker were most abundant in Reach 6 and became consistently less abundant in downstream reaches, disappearing from the catch altogether by RM 17.0. This tendency of bluehead sucker to be less common in sandy-bottomed downstream reaches of a river was also noted in the Green River (McAda 1977) and the Colorado River. On six of the eight sampling trips in Reach 6, bluehead sucker were most common upstream of the PNM Weir (RM 166.6), than downstream. Channel catfish and other nonnative predators and competitors are much more rare upstream of the PNM Weir.

Although less abundant than flannelmouth sucker, bluehead sucker appeared to be less affected by mimicry of a natural hydrograph than did flannelmouth sucker. In Reach 6 where the majority of the bluehead sucker population resides, numbers of this species increased significantly over the study period. In the core sampling area, bluehead sucker declined slightly between 1991 and 1997, but to a much lesser degree than did flannelmouth sucker in this same section of river. In fact, when comparing bluehead sucker CPUE from 1987 to 1997, on October trips (RM 147.9 and 119.2), it appears that the decrease in bluehead sucker CPUE observed in the core sampling area may be part of a cyclical fluctuation. Mean K of bluehead sucker increased significantly on May trips between 1991 and 1997 indicating that fish were in better condition to spawn at the end of the study period than at the beginning. In addition, fewer significant changes in both mean TL and mean biomass among bluehead sucker as opposed to flannelmouth sucker seem to indicate less impact of overall river conditions on the bluehead sucker population during the study period.

Even though overall numbers of bluehead sucker collected in the core sampling area declined slightly between 1992 and 1997, increases in the bluehead sucker population in Reach 6 over the test period appear to be indicative of an overall improvement for this species in the San Juan River. Reasons for this may include not only where this species occurs in the San Juan River, but also its basic life history. The majority of the bluehead sucker population occurs in areas upstream of many of the seasonal tributaries (i.e., the Chaco River, Red Wash, the Mancos River, McElmo and Montezuma Creeks) that tend to load the river with sediment during storm events. Thus, storm events that may effect flannelmouth sucker food sources and mean K areas downstream of these tributaries are less likely to effect the bluehead sucker population. In addition, the bluehead sucker is a grazer whose mouth is designed to scrape larger cobbles found in high velocity habitats such as riffles as opposed to flannelmouth sucker whose fleshy lips are adapted to more generalized feeding in softer substrates (Smith 1966, Minckley 1973, McAda 1977). During our study, bluehead sucker were always more abundant in habitats with cobble substrates than in other habitat types. This was especially true in the river downstream of the Four Corners (Hwy. 160) bridge, where clean cobble sources become much less abundant, and fish collected from a single riffle often accounted for all of the bluehead sucker collected in a mile of electrofishing. This strong tie of bluehead sucker to cobble-type substrate has been documented in other UCRB rivers as well (McAda 1977). These higher velocity habitats are likely less effected by storm events and possibly even by long periods of low flows, than are many of the areas in which flannelmouth sucker feed (e.g., eddies, pools). If, as was previously theorized, mimicry of a natural hydrograph has indeed improved overall biological productivity in the riffles and runs, this would help explain the observed increase in bluehead sucker mean K over the study period.

The fact that the largest gains in bluehead sucker mean K are tied to periods of stable winter base flows also makes sense when examined in the context of bluehead sucker feeding behavior. Radio telemetry data for razorback sucker in the San Juan River has shown that this native sucker stays active throughout most of the winter and weight gains in recaptured individuals indicate active feeding during winter periods (Ryden 2000). Given this data, it would make sense that both flannelmouth sucker and bluehead sucker are also both actively feeding during all but the colder periods of the winter as well. The San Juan River tends to carry much less of a sediment load during periods of stable winter flows, allowing more light penetration, which in turn results in larger standing crops of algae. This would provide better feeding conditions for bluehead sucker, thus increasing their mean K.

It is unknown what the lifespan of bluehead sucker in the San Juan River is, however, it is assumed that is somewhere between five and ten years. Thus as with flannelmouth sucker the changes that have been observed in the bluehead sucker population during our study may reflect cyclical fluctuations effecting one or two generations of fish. In order to realistically make any definitive statements about the relative health, stability, or trends among the San Juan River bluehead sucker population, several more years of data will be needed. In addition, future monitoring of this species should be conducted at least as far upstream as the Animas River confluence (RM 180.0) if not farther on a regular basis.

Speckled Dace

CPUE for speckled dace in our study, almost certainly, greatly under-represent the actual numbers of this species in the main channel fish community. One reason for this is that raft-borne electrofishing units, such as those used during our collections, cannot representatively sample small-bodied fishes (i.e., those fishes < 150 mm TL), and speckled dace are small-bodied fish, even as adults. The mean TL for speckled dace collected during our study was 74 mm (range = 28-164 mm). Small-bodied fish tend not to be stunned as hard, or for as long a period of time as large-bodied fish during electrofishing. In addition, small fish (< 100 mm TL) tend to pass through the mesh in dip nets. This is especially true if a netter is trying to capture more than one fish at a time, pulling the dip net through the water column several times and giving smaller fish several chances to pass through the net's mesh. A second reason is that the large majority of speckled dace observed and captured during our study were in turbulent, high-velocity riffles. These areas make it harder for netters to see and collect fish, even large-bodied species. Often, while electrofishing in riffles, numerous (sometimes hundreds of) adult speckled dace would be observed, but only one or two would be successfully collected.

Given the relative difficulty of collecting speckled dace with electrofishing gear, it is hard to assign too much weight to CPUE values for speckled dace. Be that as it may, one fact is clear when examining speckled dace CPUE data, Reaches 2 and 1 are not good speckled dace habitat. Given several aspects of speckled dace life history, however, this fact is not surprising. First, the diet of adult speckled dace consists almost entirely of aquatic insects (Greger and Deacon 1988). The heavy sediment loads and shifting sand substrates in Reaches 2 and 1 make these reaches relatively barren of aquatic insects. Second, speckled dace are most common in riffles and runs with moderate to rapid velocity water over gravel and cobble substrates (Gido et al 1997, Gido and Propst 1999). Again the heavy sediment loads in Reaches 2 and 1 make cobble substrates rare. Third, speckled dace because of their relative size are a prime forage fish for larger predators (Sigler and Miller 1963). Channel catfish which are extremely abundant in Reaches 2 and 1 have been documented to prey upon speckled dace in the San Juan River.

The reasons for the extremely high catch rates of speckled dace in the upper half of Reach 6 in August 1994 is unclear. The flow during August 1994 sampling was low, 450 CFS, but not the lowest flow at which Reach 6 was sampled during our study. Flows during April and July 1996 sampling in this same reach of river were actually lower, though still very close to the same, 439 and 442 CFS, respectively. Nowhere near as many speckled dace were collected in this section of river during April and July 1996 as in August 1994, even though speckled dace must have been just as highly concentrated in the river during all three trips, due to low water levels. Additionally, none of the large-bodied fish species common in Reach 6 demonstrated anywhere near the same large change in catch rates, either positive or negative, in August 1994, compared to other sampling trips in Reach 6. One possible explanation for the large spike in speckled dace catch rates in August 1994 is that the Fruitland Diversion (RM 178.5) had just been extensively rebuilt the week before this river reach was sampled. To rebuild Fruitland Diversion, heavy equipment enter the river channel and push large amounts of river bed material up to form a large berm that spans the entire width of the river channel, disturbing or destroying the entire benthic community of the river for several hundred yards around, specifically downstream of, the diversion. It is possible that the large numbers of speckled dace collected in August 1994 were, in large part, individuals displaced downstream by the reconstruction work and then concentrated by the low flows present in the river. Unfortunately, due to the very low flows and our subsequent inability to negotiate several diversion structures (including Fruitland Diversion) on this trip, only RM 178.5-166.6 could be sampled in August 1994. Perhaps, if the entirety of Reach 6 could have been sampled it would have provided a more clear cut explanation to this observed phenomenon.

Roundtail Chub

Five of seven adult roundtail chub were collected between RM 150 and 120, the exception being 1997 (Figure 38). However adult roundtail chub collections were temporally segregated from one another, with no more than two adults being collected in any given year. Even if the assumption were to be made that all the adult roundtail chub collected during our study composed a viable spawning population, it still appears that numbers of adults would be too few to account for the disproportionately large number of YOY and juvenile roundtail chub collected during all studies between 1991 and 1997. Failure to recapture any, but a single adult roundtail between 1991 and 1997 (and that in the same year it was originally captured and tagged), would seem to argue against a large resident population in the San Juan River.

Both recent (1992-1994) and historic (pre-1992) surveys of the tributaries that join the San Juan River downstream of Navajo Reservoir have documented the presence of roundtail chub populations in the Animas, La Plata, and Mancos Rivers, as well as Navajo Wash, a tributary of the Mancos River (Platania 1990, Anderson et al. 1993, Miller et al. 1993, Miller 1994b, San

Juan River Recovery Implementation Program 1997). No roundtail chub were collected in either the McElmo Creek or Montezuma Creek drainages (Anderson et al 1993). In fact, no native fishes of any species were reported from the Montezuma Creek drainage in Colorado (Anderson et al. 1993).

Plots of the longitudinal distribution of roundtail chub collections form 1987-1997 show that the large majority of roundtail chub captures in the mainstem San Juan River occur downstream of the La Plata and Mancos River drainages, both of which have documented roundtail chub populations (Figures 39 and 40). In addition, over two-thirds of roundtail chub captures occur upstream of McElmo Creek, RM 100.5 (Figures 39 and 40). The close proximity of most roundtail chub collected from the San Juan River each year to tributaries documented to support stable resident populations of this species indicates that roundtail chub captured in the mainstem river likely originate from these tributaries, specifically the Animas, La Plata, and Mancos River drainages. Roundtail chub, especially earlier life stages, likely enter the mainstem San Juan River when high flow events in tributaries flush them into the river. There is thought to be a large overlap in diet and habitat use between roundtail chub and channel catfish (F. Pfeifer, pers. comm.). This likely puts roundtail chub (especially early life stages) in the San Juan River in a position where they must compete for essential resources with channel catfish (a much more abundant species) and where they are likely to be preyed upon by the latter species (F. Pfeifer, pers. comm.).

At present, it appears that no long-term, resident population of roundtail chub exists in the San Juan River.

Colorado Pikeminnow

---Stocked Fish---

At least some of the Colorado pikeminnow stocked by the UDWR appear to be surviving and retaining throughout the San Juan River. The eight-mile upstream movement of a 44 mm TL stocked Colorado pikeminnow was unexpected, given the large downstream displacements usually associated with recently stocked hatchery fish in a riverine environment (Brooks 1986, Hendrickson 1993, Ryden and Pfeifer 1996b). This movement shows that young, stocked Colorado pikeminnow are not completely at the mercy of river currents and can selectively move to habitats of their choice.

Main channel electrofishing has proven to be effective in sampling experimentally-stocked Colorado pikeminnow as they grow to sizes at which they can no longer be effectively sampled by seining, due to their mobility (i.e., about 150 mm TL; T. Chart pers. comm.). In addition, electrofishing allowed researchers to collect stocked juvenile Colorado pikeminnow from habitats which could not have been effectively sampled by other means (i.e., seining and trammel netting).

---Wild Fish---

Though rare, a small extant population of Colorado pikeminnow still resides in the San Juan River, with representatives of almost all life stages being captured between 1991 and 1997. While present only in low numbers, Colorado pikeminnow have managed to persist in the San Juan River where both wild razorback sucker and roundtail chub have apparently disappeared from the main channel fish community. The large number of captures, recaptures and sightings of adult Colorado pikeminnow in the section of the San Juan River between Cudei Diversion and RM 115.0 indicate an affinity of adult Colorado pikeminnow for that area of the river. The pattern of earlier life stage Colorado pikeminnow occurring in reaches downstream of adult fish is quite similar to Colorado pikeminnow life stage distributions documented in other UCRB rivers (Tyus 1986, Osmundson and Burnham 1996). It is unknown if these early life stage Colorado pikeminnow were progeny of adult fish spawning in the Mixer or elsewhere, but at present, no other aggregations of adult Colorado pikeminnow have been documented elsewhere in the San Juan River.

The observed responses of wild adult Colorado pikeminnow to research flows during our study were closely tied to spawning behavior, and differences in habitat use during presumed spawning seasons (Ryden and Ahlm 1996). The data gathered on Colorado pikeminnow habitat use and spawning behavior are summarized in Chapters 2 and 3.

Other Native Fishes

Mottled sculpin were rare even in the section of Reach 6 in which they were collected. This is not unusual, given that this species is much more prolific in the colder headwater reaches and tributaries of all UCRB rivers (Sigler and Miller 1963, Beckman 1974, Woodling 1985). Mottled sculpin were rarely collected downstream of the PNM Weir (RM 166.6) which acts as an artificial barrier to channel catfish colonization of upstream reaches. It is likely that large adult channel catfish downstream of the PNM Weir in Reach 6 do prey upon mottled sculpin when they are present. Mottled sculpin also provide a food source for nonnative trout in upstream reaches of rivers where they coexist (Woodling 1985).

Hybrids between native flannelmouth and bluehead suckers are common in rivers throughout the UCRB. The fact that a relatively small number of these hybrids were collected over the course of this study indicates that hybridization between these two species is not a problem in the San Juan River.

Nonnative Species

Channel Catfish

Two factors inherent in channel catfish reactions to electrofishing fields complicate the analysis of CPUE data for this species. First, when channel catfish are shocked, they almost instantly enter a state of tetany, at which point they sink in the water column and roll along the bottom at the mercy of the current. In contrast, other common species (e. g., flannelmouth sucker, bluehead sucker, common carp) will swim vigorously toward or away from the electrofishing field, or jump completely from the water (e.g., speckled dace). This makes these other species easier to observe, and thus, collect. Thus, shocked channel catfish will not surface at all, or if they do surface, it is far upstream of the electrofishing raft after it has passed. This makes them especially difficult, and sometimes impossible, to collect in the usually turbid waters of the San Juan River. It is not uncommon to have large numbers of channel catfish float by in an almost continuous stream for several minutes after electrofishing crews have pulled over at the end of a RM to work up fish. In one instance (24 October 1997), hundreds of juvenile channel catfish (approximately 100-200 mm TL) were observed floating downstream in the current at RM 70.0 (downstream of Bluff, UT) approximately 20-30 ft. from the river right shoreline as crews counted fish that had been collected from RM 71.0-70.0. On this occasion, approximately ten minutes elapsed before no further juvenile channel catfish were observed floating by.

Second, large (> 500 mm TL) channel catfish tend to literally "stand on their head" when exposed to an electrical field (i.e., orienting their head to the substrate and caudal fin towards the water's surface). This behavior makes it difficult for a netter to get a dip net around the head (i.e., the heavy part) of large channel catfish, thus causing the fish to slide out of the net as the raft proceeds downstream and away from the fish. This behavior combined with the propensity large channel catfish have for occupying habitats that are hard to sample, including boulder-strewn shorelines in canyon-bound reaches, makes this size-class channel catfish difficult to collect. These two factors almost certainly result in a smaller percentage of the total channel catfish population being sampled than with other common large-bodied fish species. These behaviors were verified by visual observations of channel catfish made during electrofishing trips where clear water conditions were present.

Channel catfish CPUE was highly variable, riverwide, during the study period, with very few clear patterns being discernable. However, it was clear that numbers of channel catfish collected were high in 1991 and 1992, dropped dramatically to lows in 1994 or 1995 (depending on the data set being examined) and then increased steadily again through 1996, but have not increased since. Like flannelmouth sucker and bluehead sucker, looking at these fluctuations in the light of October 1988 and 1989 CPUE data makes the highs and lows in CPUE observed during our study look like cyclical fluctuations.

On the majority of sampling trips in the core sampling area after 1993, channel catfish CPUE increased in reaches downstream of Reach 5. This contrasted with channel catfish CPUE data for 1991 to 1993 in the core sampling area and CPUE data for other common species, which showed declining CPUE in reaches downstream of Reach 5. Channel catfish CPUE was consistently low in Reach 1, adjacent to Lake Powell, throughout our study, but this is likely due to our poor sampling efficiency in this lake-influenced reach of the river, and probably does not reflect true numbers of this species in this reach.

Channel catfish had a very distinctive pattern of juvenile to adult spatial distribution that remained constant throughout the research period. Almost all of the channel catfish collected in Reaches 6 and 5 were adults. However, juvenile fish quickly became the dominant life stage in downstream reaches composing almost the entire catch for this species by Reach 2. This trend was reflected by a marked decline in mean TL and mean biomass for collected channel catfish in more downstream reaches. However, in Reach 1 channel catfish mean TL actually showed an increase from adjacent Reach 2 in July 1993 and June 1996. The increase in mean TL in June 1996 may indicate that large channel catfish had invaded the lower river from Lake Powell and had remained resident. Unfortunately this explanation will not work for July 1993 in Reach 1, as adult channel catfish in Lake Powell would have been unable to move upstream past the waterfall that was present from the late 1980's to spring 1995.

An analysis of mean K over the study period showed that after significant increase during the middle of the study period, condition factors in 1997 showed no significant difference between 1991 and 1997 in May, but had decreased significantly between 1991 and 1997 in October in the core sampling area.

Taken together, the rising catch rates, lack of significant differences in mean TL and mean biomass and rather ambiguous mean condition factor trends, it does not appear that channel catfish have demonstrated a marked negative response to mimicry of a natural hydrograph. This finding agrees with analysis by Buntjer (1999). Instead, it appears that all the trends we have seen in channel catfish data may be as much a part of a cyclical population fluctuation as a reaction to manipulated river flows. At present, it appears that there is probably not enough water available in the San Juan River to suppress or reduce numbers of existing juvenile and adult channel catfish by flows alone. Additionally, spawning season for channel catfish in the Green and Colorado Rivers (and thus, likely, the San Juan) overlaps that of Colorado pikeminnow. Thus, using flow scenarios to control or adversely affect channel catfish spawning would likely also adversely impact Colorado pikeminnow spawning.

The decline in CPUE between October 1996 and 1997 in the core sampling area may be due to mechanical removal efforts beginning to take a toll on larger size-class channel catfish. Despite fluctuations throughout our study, there were no significant declines in either channel catfish mean TL or mean biomass in the core sampling area (RM 158.6-53.0) between 1991 and 1997 that would indicate a serious reduction in numbers of large channel catfish due to mechanical removal efforts. However, given the extremely high numbers of channel catfish in the San Juan River it may take several (i.e., 5-10) years of intensive efforts before significant changes in the channel catfish population can be detected.

Even though vigorous mechanical removal efforts have, as yet, failed to show dramatic positive results in reducing numbers of channel catfish in the San Juan River, this may be the only way to realistically reduce numbers of this species. Channel catfish tie up a huge amount of biomass in the San Juan River. In addition, they have been documented to prey on native fishes and their diet strongly suggests that they compete for food resources with many native fishes as well. Given these facts and the mission of the SJRIP to promote the health of the San Juan River native fish community and recover endangered native fishes, it would seem wise to pursue any course of action that would reduce numbers of channel catfish present in the river.

Common Carp

Common carp were the only nonnative fish species that was commonly collected throughout the entire study area. In Reach 6 common carp were generally more common than channel catfish, but less so than the native suckers. In Reach 6 as throughout the entire river, common carp collected by electrofishing were almost all adult fish. Though not statistically significant, numbers of common carp collected fell in May, July, and October collections in Reach 6 between 1996 and 1997, possibly indicating that their numbers were being effected by nonnative fish removal efforts. Like the native suckers, mean K of common carp (also a spring spawner) decreased consistently between May, July, and October collections in Reach 6.

In the core sampling area, catch rates for common carp in the core sampling area showed a steady decline between 1991 and 1994, then rose steadily between 1994 and 1997, to the point where they were as common in the catch in 1997 as they were in 1991. This pattern was very similar to the decreases and increases seen in channel catfish CPUE in the core sampling area. Like channel catfish, the highs and lows in common carp CPUE seen in the core sampling area during our study, when compared to 1988 and 1989 collections, appear that they may be nothing more than fluctuations in three- to five-year cycle.

Common carp were the only common nonnative species that demonstrated a consistent, steadily declining CPUE with increasing distance downstream from RM 180.0-53.0. Adult common carp (> 250 mm TL) accounted for 95.9% of the total catch for this species between 1994 and 1997 (the only four years fish were recorded by age class on all RM). This same phenomenon was noted for common carp collections in the Platte River, Nebraska, where 96% of common carp collected were greater than 300 mm TL (Conklin et al. 1995). A small number of age-1 common carp were consistently collected on October trips in the core sampling area, then disappeared from the catch until they had reached lengths exceeding 325 mm TL. The only other trip in which large numbers of juvenile common carp were collected was the July 1993 trip in the lower river when juveniles were by far the dominant life stage collected. Possible reasons for the lack of juvenile common carp collections include the fact that young common carp grow very quickly, with males reaching sexual maturity at about age 2 (250-305 mm TL) and females becoming sexually mature at about age 3 (435 mm TL; Panek 1987). Second, juvenile common carp (< 250 mm TL) seek warm, protected areas (i.e., backwaters, shallow embayments) that are hard to sample via boat-mounted electrofishing units.

Although common carp collected were always dominated by adult fish, beginning in 1993, there was a declining trend in mean TL proceeding downstream in the core sampling area, from Reach 5 through the upper part of

Reach 2 (RM 68-53). This was especially apparent in October 1993, May 1994, October 1994, and May 1995. It is not known exactly what caused this phenomenon, but the occurrence of this pattern in four consecutive May and October trips may reflect an increase in common carp spawning success associated with the consistently high, overbank flows (> 8,000 CFS) which began in 1992 (SJR-RIP 1999). Before 1992, flows of this magnitude had not occurred in the San Juan River since 1987. Common carp spawn in flooded, vegetated areas along the rivers banks and in flooded bottomland areas (Panek 1987). The lifespan of common carp in the wild is thought to be 9-15 years (Panek 1987). Young common carp spawned in 1987 would already have been large adult fish by the time our study started in 1991. High, overbank flows which began during our study in 1992 would have made warm, shallow vegetated areas along the river's edges, and in isolated side channels, backwaters, and bottomlands available to common carp for spawning that had not been available to this species since 1987. The ability to access and use these areas would increase common carp spawning success (Ryden and Pfeifer 1994a). A large influx of young fish in years after 1992 would cause mean TL's for this species to decline. It is the opinion of this author that overbank flows associated with spring runoff events in the San Juan River, at the flow range that they occurred between 1992 and 1997, actually increase common carp spawning success.

In late spring 1995, the waterfall at the confluence of Lake Powell and the San Juan River was inundated by rising lake levels and the lower San Juan River was invaded by nonnative lacustrine fishes moving upstream out of Lake Powell (Ryden and Pfeifer 1996a, Ryden and Ahlm 1996). This occurrence was paralleled by the highest catch rate for common carp in the lower river observed during our study. In June 1996 and August 1997 CPUE declined slightly from those observed in August 1995 in the lower river, yet still remained higher than in July 1993. The mean TL of common carp collected in the lower river also showed a significant increase between 1993 and 1995 and stayed high between 1995 and 1997. Variation in flows certainly has an effect on these observed trends. However, it appears that large adult common carp, like lacustrine predatory fishes and channel catfish are invading the lower river from Lake Powell when the waterfall is absent. The virtual disappearance of juvenile common carp in the lower river after 1993 is probably an artifact of this invasion phenomenon as well. Juvenile common carp did not truly disappear from the catch, but the relative percent of the catch for this species comprised by juvenile fish declined drastically with the influx of numerous adult fish from Lake Powell.

Common carp CPUE in the lower part of Reach 2 (RM 53.0-17.0) and Reach 1 (RM 17.0-2.9) was almost always identical, indicating an even distribution of habitat and fish between reaches. Furthermore, it indicates that common carp are not being adversely effected by the “lake effect” found in Reach 1 that causes numbers of other common species to either decline drastically in numbers or disappear altogether in this reach.

Given all the data presented above, the analysis presented by Buntjer (1999), and the amounts of water left in the San Juan River that can be used to mimic a natural hydrograph, it does not appear that numbers of adult common carp can be adversely effected by flows alone.

Since control of common carp populations does not appear to feasible by flows alone, mechanical removal may be the only feasible method for controlling common carp populations in the San Juan River. Declines in total

CPUE of common carp between 1996 and 1997 in both Reach 6 and on October trips in the core sampling areas may or may not be indications that this method of population control is working. Given the large numbers of common carp in the river, it may well take several years (i.e., 5-10) before definite, positive results from this effort are observed. Only further monitoring will tell.

Common carp, are truly omnivorous, feeding on detritus, aquatic vegetation, algae, aquatic invertebrates, and fish eggs (Panek 1987, Buntjer 1999). Because of their sheer numbers and quick growth, they quickly progress past the predation threshold and compete with native fishes for resources throughout their lifetime. Common carp tend to occupy the same types of flooded, vegetated areas (when they are available) as razorback sucker (Panek 1987, Mourning 1995, Modde 1996, Ryden and Pfeifer 1996b) and adversely impact these habitats via their vigorous feeding and spawning behaviors (Panek 1987). Common carp have also been documented to feed upon razorback sucker eggs (Tyus and Saunders 1996). Given these behaviors and very large amount of biomass in the San Juan River that is tied up by common carp, any effort to reduce their relative numbers could be nothing but beneficial to native fishes in the San Juan River.

Red Shiner

It is important not to put too much emphasis on numbers or trends associated with red shiner in main channel electrofishing collections. As with speckled dace, electrofishing cannot representatively sample red shiner, due to their small body size and the habitats which they occupy (e.g., very shallow, near shore habitats, brush and debris piles in low velocity areas, backwaters, embayments, slackwaters formed on the downstream side of mid-channel cobble bars). However, the relatively high of this species collected via electrofishing as well as seining collections made by other researchers (Buntjer et al. 1993, 1994, Propst and Hobbes 1993, 1994, 1995, 1996, Archer et al. 1995, 1996, Gido and Propst 1995, 1996), in both main and secondary channel habitats, attests to the fact that red shiner is both widespread and abundant in the San Juan River.

The relatively high CPUE observed for red shiner on June trips may possibly be explained by large numbers of red shiners being forced from the low-velocity, main channel and secondary channel habitats they usually occupy by high spring flows, forcing them to move to more protected, near-shore, low-velocity habitats. This concentration of red shiner along the river's edge would result in their being more readily collected on sampling trips that occur during high water periods (i.e., June trips).

Data from the 7-year research period suggests that red shiner density in all habitats in the San Juan River fluctuates over time, but overall, is not well correlated with flow events (Propst et al. 1999). Data collected during studies by Propst and Hobbes (1993-1996) have suggested that summer flow spikes can greatly reduce numbers of red shiner in secondary channel habitats and that artificial flow spikes from Navajo Reservoir might be successfully employed as a management tool for suppressing numbers of this species in secondary channels. However, artificial flow spikes for red shiner control would need to occur during the time of year when adult Colorado pikeminnow are spawning and larval Colorado pikeminnow are hatching and drifting thus causing adverse impacts to reproduction and recruitment of this endangered species (D. Propst pers. comm.). Thus, this potential management option for red shiner has not been explored in any detail to date.

Red shiner is a mobile, aggressive, generalist species that adapts well to new habitats (e.g., Minckley 1973, Matthews and Hill 1977, Tyus et al. 1982, Woodling 1985, Moyle and Cech 1988, Lentsch et al. 1996) like the shifting, ephemeral habitats in Reach 1, and is capable of numerically dominating fish assemblages (Matthews and Hill 1977). Red shiner is omnivorous, feeding on smaller fish, insects, algae, crustaceans, a variety of microorganisms, and plant material and (Table 13; Minckley 1973, Greger and Deacon 1988, Ruppert et al. 1993). High diet overlap was demonstrated between red shiner and speckled dace in the Virgin River (Greger and Deacon 1988). Red shiner has been documented to prey on larval bluehead sucker in the wild (Ruppert et al. 1993) and larval razorback sucker in predation experiments (Tyus and Saunders 1996). Because red shiner occupy nursery habitats used by YOY native fishes, including Colorado pikeminnow and razorback sucker, predation by red shiner may have a significant effect on survival of larval fish (Ruppert et al. 1993). Red shiner has been described as an opportunistic drift feeder and may prey on drifting fish larvae (Ruppert et al. 1993).

White Sucker

Notable among nonnative fish collections were the capture of both white sucker and two white sucker hybrid forms (flannelmouth X white sucker and bluehead X white sucker). Previous to 1993, there was only one documented collection of a white sucker from the mainstem San Juan River downstream of Farmington, NM (Platania 1990). White sucker had also been collected in small numbers from the area between Navajo Dam and Farmington (Brooks et al. 1994). By 1994, white sucker had been collected during tributary surveys from the Animas, Florida, Piedra, Navajo, and Los Pinos rivers and the San Juan River upstream of Navajo Reservoir (Miller and Rees 2000), while white sucker hybrids had been collected from the Animas and Florida rivers as well as the San Juan River upstream of Navajo reservoir. Miller and Rees (2000) also indicated that while the white sucker had become established in tributaries of the San Juan River upstream of Navajo Reservoir, it was rarely collected in other streams in the 1970's. However, sampling during the 1990's indicated that white sucker had become common in the Animas and Florida Rivers. These collections combined with the collection of white sucker and white sucker hybrids during adult monitoring trips as far downstream as RM 96.0 indicates a slow downstream expansion of range by this species, albeit in low numbers.

In 1994, Brooks et al. conducted a literature search to determine possible detrimental effects the presence of white sucker may have on the native fish community of the San Juan River. The single greatest threat they identified was hybridization between white sucker and native catostomids. Previous to 1994 there were no records of native suckers hybridizing with white sucker in the mainstem San Juan River below Navajo Reservoir (Ryden and Pfeifer 1995a). However, the collection of 11 flannelmouth X white sucker and 7 bluehead X white sucker hybrids between 1994 and 1997 documented that hybridization was indeed taking place in the San Juan River between introduced white sucker and native catostomids (Tables 12 and 58). Almost double the number of white sucker hybrids (18) were collected during adult monitoring trips as that of white suckers (10). Additionally, of the eight (out of 10) white suckers for which a total length or age class was recorded, only three were adult fish of spawning age (Table 58). Thus, it would appear, that spawning nonnative white suckers may be having a greater effect on the native catostomid gene pool than their low numbers alone would suggest.

Lacustrine Species

Walleye, striped bass, and threadfin shad invaded the lower San Juan River from Lake Powell after the inundation of the waterfall at RM 0.0 in late spring 1995. The movement of walleye and striped bass upstream into the river may be related to spawning movements. Both walleye and striped bass are documented to migrate up rivers and streams to spawn in spring as temperatures increase (Sigler and Miller 1963, Minckley 1973, McGinnis 1984). In fact, walleye have been documented to make long-distance movements (70-100 miles) in a matter of only a few months (Sigler and Miller 1963, Sigler and Sigler 1987). Both walleye and striped bass are voracious predators, and feed extensively on threadfin shad (Minckley 1973, Brooks et al. 2000), thus it is likely that both of these species may also have been following and feeding upon groups of threadfin shad that were abundant in the lower San Juan River after the inundation of the waterfall in spring 1995. In the San Juan River, both walleye and striped bass have been documented to prey upon native flannelmouth sucker (Brooks et al. 2000) up to half their body length (TL in mm).

For threadfin shad, it appears that Government Rapid may preclude further upstream distribution of this species. The dramatic decline in numbers of threadfin shad collected in June 1996, and their subsequent absence in collections in the lower river in 1997 indicates that this species is probably incapable of establishing a resident population in the river due to the high turbidity, highly variable flows, and seasonal temperature differences present in the river (Minckley 1973).

Largemouth bass, while always few in number, were consistently collected throughout our study. The presence of small, juvenile largemouth bass below irrigation return channels in Reach indicate that these channels may be a feeder source for largemouth bass escaping from ponds and other offstream impoundments in the vicinity of Farmington, NM. The relatively large number of largemouth bass collected in the lower river on the August and October 1995 trips (the same time that both walleye and striped bass were collected for the first time during our study) indicates that largemouth bass were also invading the lower San Juan River from Lake Powell at this time. A Stomach contents of a largemouth bass sampled in the San Juan River contained the remains of “small cyprinids” (possibly speckled dace; Brooks et al. 2000).

Like largemouth bass, smallmouth bass are probably entering the river via canals from offstream ponds and impoundments in the vicinity of Farmington, NM. It is also possible that these fish have found their way downstream from Navajo Reservoir. Unlike largemouth bass however, there is no evidence that smallmouth bass are entering the lower San Juan River from Lake Powell, although this species is resident there.

CONCLUSIONS/MANAGEMENT IMPLICATIONS

- Study Objective met? Yes
- Only trip flows significantly effect CPUE, sampling speeds do not
- October data sets determined to be most representative of trends in examining changes in fish community
- Flannelmouth sucker:
  - Occurs throughout entire study area, but numbers low in Reach 1
  - Numbers declining in the core sampling area over the study period
  - Still most abundant large-bodied species collected
  - CPUE actually increasing in Reach 6 over study period
  - Decreased numbers may be part of a fluctuating cycle
  - Mean K improved since beginning of study period
  - Mimicry of natural hydrograph good for San Juan River adult flannelmouth sucker population? Still unknown. Longer period of monitoring needed to make sense of trends
- Bluehead sucker:
  - Numbers declining in core sampling area over study period, but to a much lesser degree than flannelmouth sucker
  - CPUE increasing in Reach 6 over study period
  - Numbers low in canyon-bound reaches (< RM 68.0), disappearing from catch altogether by RM 17.0
  - Over half of the bluehead sucker population located in Reach 6
  - Decreased numbers may be part of a fluctuating cycle
  - Mean K improved since beginning of study period
  - Mimicry of natural hydrograph good for San Juan River adult bluehead sucker population? Probably yes. Increased numbers in Reach 6 likely indicate a positive response to “natural” flows
  - Future monitoring needs to include Reach 6 on every trip
- Speckled dace:
  - Common in San Juan River upstream of RM 68.0
  - Rare in canyon-bound reaches (< RM 68.0), disappearing from catch altogether by RM 13.0
  - Can’t be representatively sampled via electrofishing
- Roundtail chub:
  - Rare in study area
  - No resident population
  - Individuals collected in mainstem river believed to have originated in tributaries
- Razorback sucker:
  - No wild razorback sucker collected during study
  - Stocked razorback sucker collected fairly regularly after 1994

- Colorado pikeminnow:
  - Small extant adult population still residing in San Juan River in New Mexico, with a single adult fish being collected in Utah
  - Early life stages occur downstream of adults
  - Stocked juveniles collected fairly regularly after 1995

- Other natives:
  - Mottled sculpin rare in river downstream of PNM Weir (RM 166.6), disappearing form catch altogether by RM 155.0
  - Flannelmouth sucker X bluehead sucker hybrids present in low numbers on all trips

- Channel catfish:
  - Abundant between PNM Weir (RM 166.6) and Reach 1
  - Very rare upstream of PNM Weir
  - Increased numbers between 1994 and 1997 may be part of a fluctuating cycle
  - Mean K
    - did not change significantly between 1991 and 1997 on May trips (RM 158.6-53.0)
    - decreased significantly between 1991 and 1997 on October trips (RM 158.6-53.0)
  - Mimicry of natural hydrograph bad for San Juan River adult channel catfish population? No. Increased numbers in last half of study period indicate no negative response to “natural” flows
  - Further monitoring needed to examine impacts of mechanical removal efforts to San Juan River channel catfish population

- Common carp:
  - Abundant throughout entire study area
  - Very few juvenile common carp collected during study period
  - Increased numbers between 1994 and 1997 may be part of a fluctuating cycle
  - Mean K
    - increased significantly between 1991 and 1997 on May trips (RM 158.6-53.0)
    - not significantly different between 1991 and 1997 on October trips (RM 158.6-53.0)
  - Mimicry of natural hydrograph bad for San Juan River adult common carp population? No. Increased numbers in last half of study period indicate no negative response to “natural” flows
  - Overbank flows associated with mimicry of natural hydrograph beneficial to common carp
  - Further monitoring needed to examine impacts of mechanical removal efforts to San Juan River common carp population

- Red shiner:
  - Common in San Juan River downstream of RM 163.0
  - Not collected upstream of RM 163.0
  - Can’t be representatively sampled via electrofishing

- White sucker:
  - Have expanded their range in the San Juan River and its tributaries since the 1970's
  - Collected in low numbers during our study, mostly upstream of Shiprock, NM (RM 147.9)
  - Are hybridizing with native flannelmouth and bluehead sucker

- Lacustrine species:
  - Low numbers of largemouth and smallmouth bass collected throughout the study period
  - Largemouth bass present throughout the study area, may be preying on speckled dace, may have invaded the lower river from Lake Powell in 1995 after inundation of waterfall
  - Smallmouth bass limited to river upstream of Mexican Hat
  - Walleye, striped bass, and threadfin shad invaded lower river from Lake Powell in 1995 after inundation of waterfall
  - Walleye and striped bass documented to prey on native flannelmouth sucker

- Other nonnative species rare in adult monitoring collections

- Reach 1 (RM 17.0-0.0) is dominated by nonnative fish species with many being highly predacious game fish. Any nonnatives removed from this reach are likely quickly replaced by others from Lake Powell. Problematic for YOY Colorado pikeminnow that are known to occupy low velocity habitats in this reach of the river

CHAPTER 2: HABITAT USE AND NEEDS AND POPULATION TRENDS OF RARE FISH SPECIES

< Objective 2: Determine habitat use and needs and monitor population trends of rare fish species (Colorado pikeminnow, razorback sucker, and roundtail chub).

METHODS

Radio Telemetry

Between 1991 and 1994, 13 adult Colorado pikeminnow were surgically implanted with radio tags and monitored via radiotelemetry until their radio tags expired. Before implantation of a radio tag, adult Colorado pikeminnow were anesthetized with 200 mg/L (Tyus and McAda 1984) of tricaine methanesulfonate (MS-222). Radio-tagged fish were released as near their capture location as possible, within 0.5 hr. of capture. Radio tags implanted in Colorado pikeminnow were either Advanced Telemetry Systems (ATS) or AVM brand tags, and had battery lives of 9-, 12-, or 24-months. All radio tags operated at 40 (40.010-40.990) megahertz (mhz). Expired, or nearly expired, radio tags were removed from four recaptured Colorado pikeminnow and each fish was reimplanted with a new tag.

Experimentally-stocked razorback sucker (Ryden and Pfeifer 1995b, 1996b) equipped with radio tags were also monitored via radiotelemetry. Internal radio tags implanted in razorback sucker were AVM brand and had either 9- or 24-month battery life. No roundtail chub were implanted with radio tags between 1991 and 1997.

Radiotelemetry ("tracking") trips occurred monthly except during suspected spawning seasons when they occurred every other week, or weekly. Radiotelemetry also occurred during electrofishing trips. Tracking was done continually using an ATS brand receiver on either a 2- or 4-second scan cycle and a whip antenna. Tracking was performed from fixed-wing aircraft, an aluminum jon boat powered by a jet shoe-equipped 30 horsepower (h.p.) motor, or oar-powered raft. All active radio tags were scanned for on each tracking trip. When a radio tag was contacted, tag number, date, RM, and time of contact were noted. On ground trips, triangulation of specific habitats being used by radiotelemetered fish would take place from the river bank using a directional (paddle) antenna. Data recorded during radio tracking trips included tag number, date, RM, habitat type the fish was located in, and water temperature. More in-depth data were taken during contacts with radiotelemetered razorback sucker for another study (Ryden and Pfeifer 1995b and 1996b).

Movements and Habitat Use

Capture and recapture RM, as well as size classes of individual roundtail chub captured were used to make some basic assumptions about the roundtail chub population of the San Juan River.

No wild razorback sucker were captured between 1991 and 1994. In 1994, an experimental-stocking program was begun for this species. The results of this experimental-stocking program are reported in a separate reports (Ryden and Pfeifer 1995b, 1996b, and Ryden 2000). Thus, razorback sucker will not be dealt with in this report under this objective.

Colorado pikeminnow tracking data were examined to determine: 1) total number of RM fish moved, from the most upstream contact to the most downstream contact (total longitudinal movement); 2) maximum distance and direction moved from point of release (maximum displacement); 3) distance and direction from point of release to point of last contact (final displacement); 4) habitat types utilized; and 5) generalized movement patterns.

Movements and habitat use of rare species were determined by examining both electrofishing and radio telemetry data as explained above.

Population Trends

A Schnabel multiple-census population estimate (Van Den Avyle 1993) was used to arrive at a population estimate for the adult Colorado pikeminnow population between "Stump Camp" (RM 136.6) and Four Corners bridge (RM 119.2), for the period of June 1991 to October 1995 (a total of 15 sampling trips {3/yr} in this river section). Confidence intervals, both 95% and 99%, were determined using tables of Poisson distribution (Ricker 1975) to correct for the small number of fish being used in the population estimate. The reason for limiting the population estimate to this particular section of river and time frame was that this was the area of the river and time window in which the large majority, 15 of 17, adult Colorado pikeminnow were captured during our study. This particular section of the river was the only area that was commonly sampled on both standardized monitoring trips (spring and fall 1991-1995, and summer 1991-1992) and Colorado pikeminnow "hunts" (1993-1994). Limiting our population estimate to this section of the river allowed us to use the captures and recaptures of adult Colorado pikeminnow that occurred during Colorado pikeminnow "hunts" (1993-1994), thus bolstering our data set.

Petersen index (alternately known as Lincoln index) population estimates with the Bailey’s modification (Van Den Avyle 1993) were also performed for the fourteen sampling intervals to validate the numbers obtained using the Schnabel population estimate. Bailey’s modification essentially corrects for using small numbers of individual fish that are returned to the population after being captured and marked (Van Den Avyle 1993)

RESULTS

As stated under Objective 1, no wild razorback sucker were collected during our study. Therefore this objective could not be accomplished for razorback sucker. Habitat use and needs of stocked razorback sucker were studied (Ryden and Pfeifer 1994b, 1995b, 1996b) however. The results of those studies are presented in a separate report (Ryden 2000).

Likewise, no resident population of roundtail chub was identified during our studies. So as is the case for razorback sucker this objective could not be accomplished for roundtail chub.

Colorado pikeminnow were the only one of the three rare species for which data on habitat use and needs, and population trends could be obtained.

Radio Telemetry

Thirteen Colorado pikeminnow (8 females, 5 males) collected between 8 June 1991 and 15 April 1994 were surgically implanted with radio tags. These fish were monitored between 8 June 1991 and 8 July 1995 for year-round movements. A total of 236 radio telemetry contacts were made with these fish. Eighty-six of these contacts were "on-the-ground" contacts that occurred during 20 ground trips. An additional 150 contacts occurred during 48 fixed-wing aerial flights.

Movements

Of the 236 radiotelemetry contacts, 220 (93.2%) occurred between RM 141.8 and 109.0 (Figure 72). The other 16 radiotelemetry contacts all occurred with the Bluff fish. Examination of capture, recapture, observation, and radiotelemetry data reveal that the majority of contacts, 254 of 278 (91.4%), with wild adult Colorado pikeminnow in the San Juan River between 1991 and 1997 occurred in a 33-mile section of river, between RM 142.0 and 109.0 (Figure 72). These 254 contacts include 16 of 19 initial captures, 9 of 11 recaptures, 9 of 12 observations, and 220 of 236 radiotelemetry contacts (Tables 36 and 37, Figure 72).

Of the 24 remaining contacts with Colorado pikeminnow between 1991 and 1997, 19 (79.2%) occurred with the "Bluff fish." These 19 contacts included the initial capture of this fish, two recaptures, and 16 radiotelemetry contacts. Of the 16 radiotelemetry contacts with the "Bluff fish" (tag number 910), nine (56.3%) occurred between RM 73.7 to 76.0 over a period between October 1993 and January 1995 (Figure 72). Three other radiotelemetry contacts with the Bluff fish occurred during the up- and downstream legs of a probable spawning migration between 9 June 1994 and 9 October 1994 (Figure 72). After remaining within 1.2 RM of its initial capture location for 8 months, this fish moved upstream 57.5 RM upstream to the Mixer between 9 and 30 June 1994 (Figure 72). After spending approximately 2 months (4 radiotelemetry contacts) in the Mixer during the presumed 1994 spawning season, this fish moved downstream 54.2 RM in 8 days (25 August-2 September

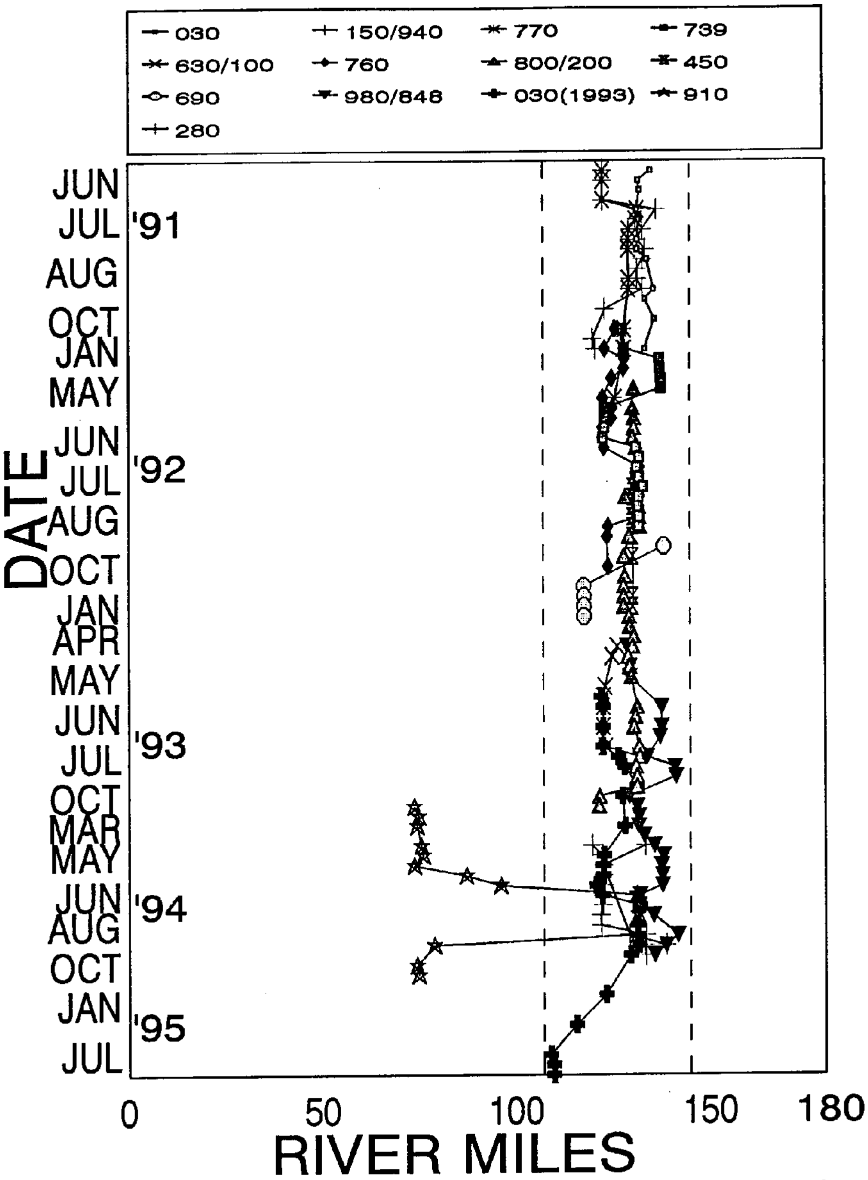


Figure 72. Riverwide movements of thirteen radiotelemetered adult Colorado pikeminnow in the San Juan River, 1991-1995. Dashed lines indicate the borders of the "preferred" reach (RM 109.0-142.0) utilized by the majority of radiotelemetered adult Colorado pikeminnow during our study.

1994). A month later, it was contacted within 0.4 RM of its original capture location, remaining there for the duration of its tag life (Figure 72; Ryden and Pfeifer 1995a).

On two occasions, a Colorado pikeminnow was observed, but not collected in this same area of the San Juan River. The first was observed at RM 79.5 on 11 June 1987 (Table 37; Platania 1990), and the second at RM 65.6 in June 1991 during our study (Table 37; Ryden and Pfeifer 1993). In addition, an adult Colorado pikeminnow that had originally been tagged at RM 0.0 in April 1987 (615 mm TL) was subsequently recaptured at RM 79.0 on 8 September 1987 (632 mm TL; Table 36; Platania 1990).

As a group, radiotelemetered Colorado pikeminnow tracked during our study moved only short distances, despite being large, sexually mature fish (as defined by Tyus and McAda 1984). All radiotelemetered Colorado pikeminnow that were captured in NM (n = 12) displayed sedentary behavior (mean total longitudinal movement [TLM] = 11.9 miles, mean maximum displacement [MD] = 9.6 miles), remaining in the "preferred" reach of river (RM 142.0-109.0) throughout their respective tracking periods (Tables 60 and 61, Figure 72). The Bluff fish (tag number 910) was the only individual during our study that displayed migratory behavior (Tables 60 and 61, Figure 72).

San Juan River Colorado pikeminnow appear to have small home ranges (Tables 60 and 61, Figure 72; Ryden and Pfeifer 1996a, Ryden and Ahlm 1996). This is demonstrated by the figures for final displacement (FD) for all five years (1991 FD = 2.20 miles, 1992 FD = 7.57 miles, 1993 FD = 6.84 miles, 1994 FD = 3.37 miles, 1995 FD = 6.58; Ryden and Pfeifer 1993, 1994a, 1995a, 1996a).

Habitat Use

Observations of specific habitat use were made during 83 ground radiotelemetry contacts with Colorado pikeminnow between 1991 and 1995. Habitat use varied by season, with the greatest number of habitat types being used during the summer months (i.e., June, July, and August; Figure 73). The highest percentage of ground radiotelemetry contacts (51.8%) were made with fish using runs, regardless of season (Figures 73 and 74). However, runs were less frequented during summer radiotelemetry observations than during radiotelemetry observations at other times of the year. Other habitats used were eddy, shoreline, pool, riffle, debris pile, and backwater in descending order of occurrence (Figure 74).

Population Trends

Between 1991 and 1997 the population of Colorado pikeminnow in the San Juan River appeared to be fairly static. Low numbers of YOY Colorado pikeminnow captured between 1991 and 1997 indicated that some small level of successful reproduction was taking place in the San Juan River (Table A-2 in Appendix A; Buntjer et al. 1993, 1994, Lashmett 1993, 1994, Archer et al. 1995, 1996). Recruitment, however, was not documented until the capture of two wild, juvenile Colorado pikeminnow (363 and 432 mm TL) in the lower San Juan River at RM 7.9 and 12.9, respectively, in summer 1996 (Table 36).

Table 60. Total longitudinal movement, maximum displacement, and final displacement of radio-tagged Colorado pikeminnow in the San Juan River, New Mexico, Colorado, and Utah, 1991 to 1995. Note: all contacts with fish in or at the Mancos River are considered as being at San Juan RM 122.6.

Tag Number	Release RM	Number of Contacts	Number of Days Contact with Fish was Maintained	Total[a] Longitudinal Movement (RM)	Maximum[b] Displacement in RM	Final[c] Displacement in RM
030('91)	134.95	12	227	4.45	3.05(-)	1.10(-)
150/940	122.60	20	369	16.70	13.80(+)	1.30(-)
770	122.60	13	340	8.85	8.85(+)	3.10(+)
739	127.50	18	312	14.90	10.00(+)	4.40(+)
630/100	127.00	12	266	9.20	4.80(+)	2.20(+)
760	125.70	20	356	9.40	6.30(+)	1.80(-)
800/200	130.10	36	513	10.50	9.60(-)	9.60(-)
450	130.10	10	166	1.10	1.10(+)	0.20(+)
690	138.00	5	140	20.40	20.40(-)	20.30(-)
980/848	128.60	25	538	13.20	13.20(+)	7.20(+)
030('93)	121.95	24	786	22.90	12.95(-)	12.95(-)
910	74.70	17	468	57.80	56.80(+)	0.20(+)
280	133.00	12	172	11.70	11.10(-)	0.50(+)
Total 13 Fish				201.10	171.95	64.85
Mean				15.47	13.23	4.99
Standard Deviation				14.04	14.05	6.06
Standard Error				3.89	3.90	1.68

[a] Total number of river miles moved, from the most upstream contact to the most downstream.

[b] Maximum distance moved from point of release after surgery during entire monitoring period, (+) represents upstream movement, (-) represents downstream movement.

[c] Distance from point of release after surgery to point of last contact, (+) represents upstream movement, (-) represents downstream movement.

Table 61. Rivers used and movement patterns of thirteen radiotelemetered Colorado pikeminnow in the San Juan River 1991-1995.

Fish Number	Radio Tag	Sex[1]	Total Length at last Contact (mm)	Rivers Used[2]	Contacted In Mixer During Spawning	Movement Pattern
1	030(1991)	M	571	S	yes	sedentary
2	150/940	F	754	M(x2)/S[3]	yes	sedentary
3	770	M	610	M/S	yes	sedentary
4	739	F	630	M/S	yes	sedentary
5	100/630	F	948	M/S	yes	sedentary
6	760	F	647	M/S	yes	sedentary
7	200/800	M	521	S	yes(x2)[3]	sedentary
8	450	M	595	S	yes	sedentary
9	690	F	705	S	no	sedentary
10	848/980	F	820	S	yes	sedentary
11	030(1993)	F	764	M(x2)/S[3]	yes(x2)[3]	sedentary
12	910	F	762	S	yes	migratory
13	280	M	617	M/S	no	sedentary

[1] M = Male, F = Female

[2] S = San Juan, M = Mancos

[3] (x2) = A fish used this area during two separate staging or spawning seasons.

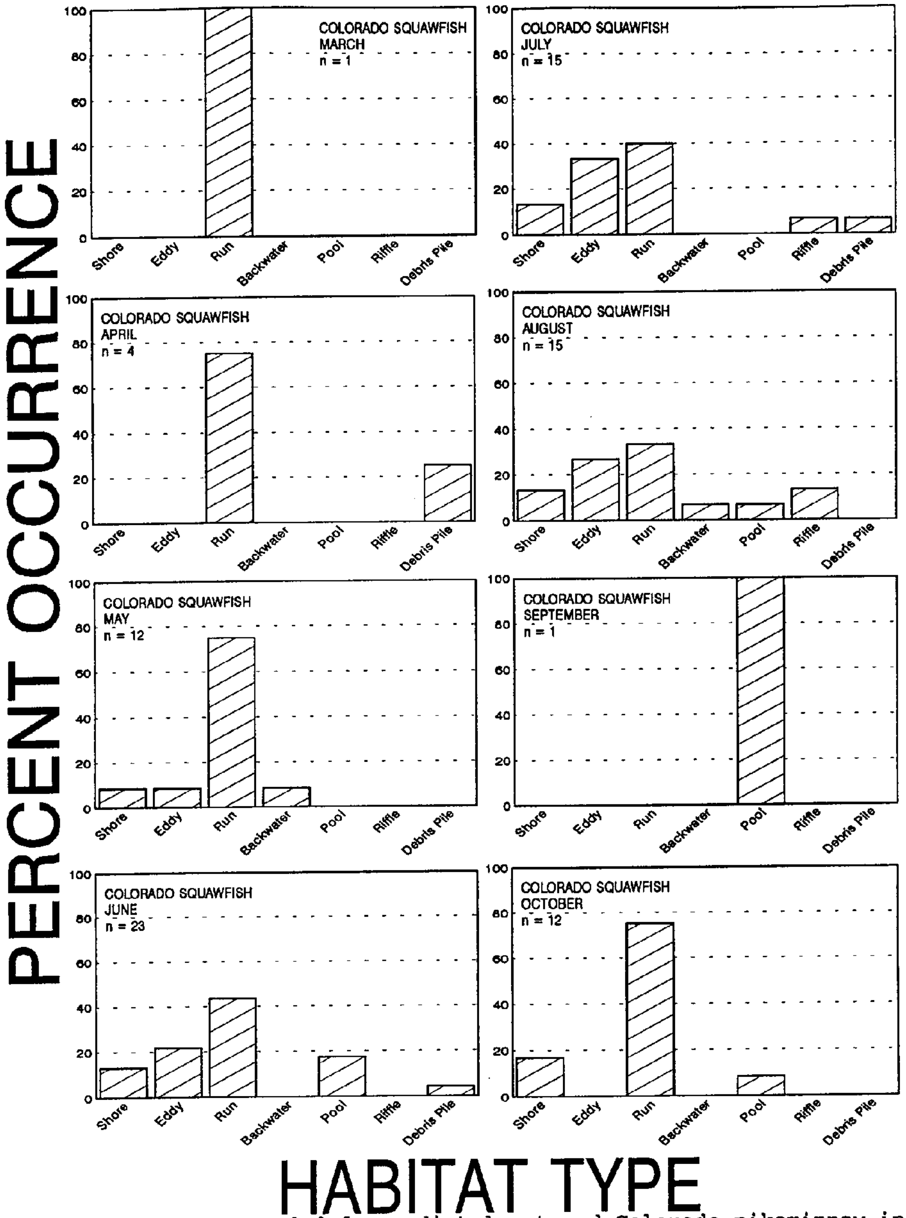


Figure 73. Habitat use recorded for radiotelemetered Colorado pikeminnow in the San Juan River, 1991-1995. n = total number of radiotelemetry observations during the specified calendar month.

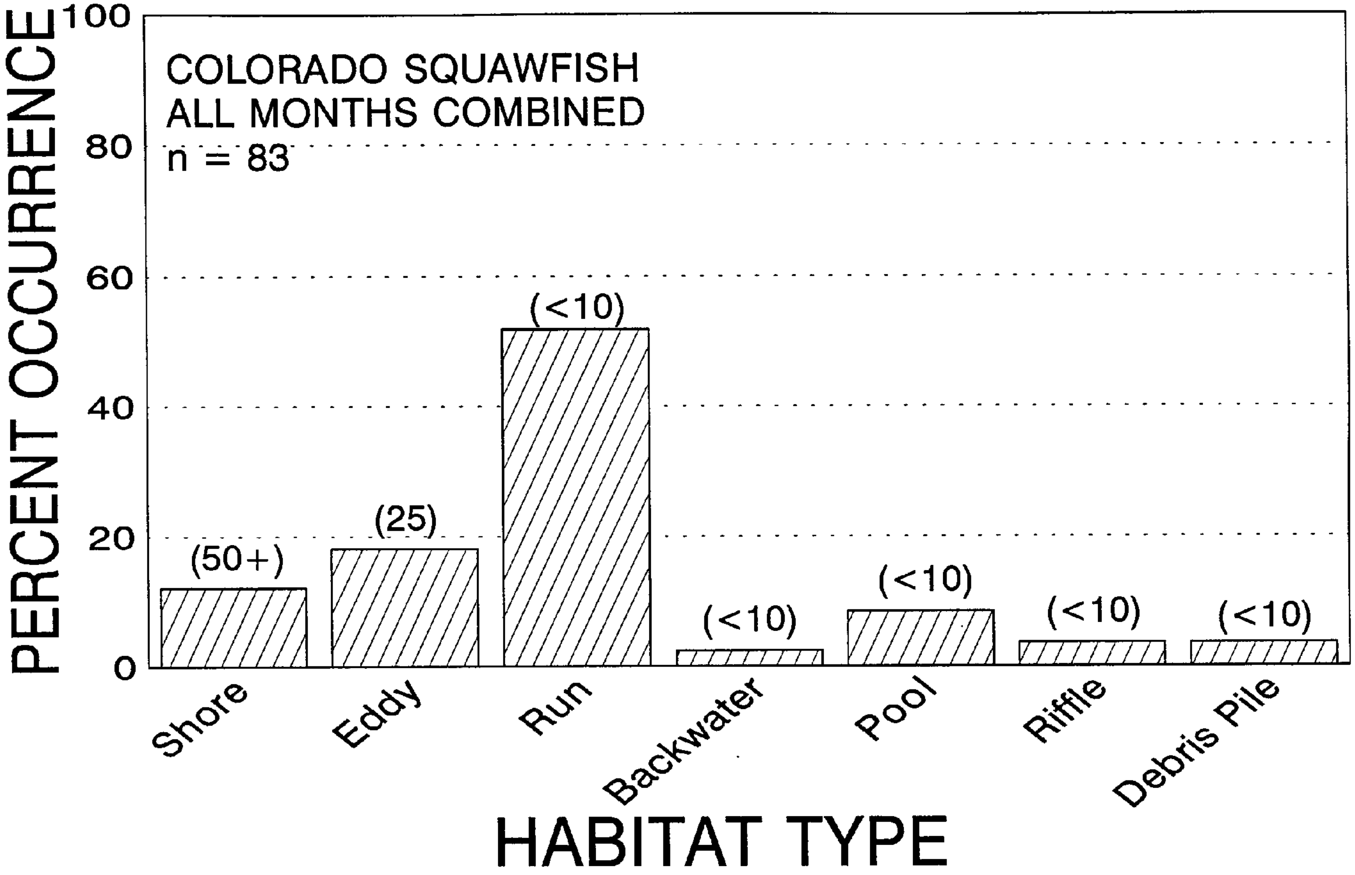


Figure 74. Habitat use recorded for radiotelemetered Colorado pikeminnow in the San Juan River, 1991-1995, all months combined. Numbers in parentheses are values obtained in a similar radiotelemetry study done on Colorado pikeminnow in the Green and Yampa Rivers in 1984 (Tyus and McAda 1984). n = the total number of radiotelemetry observations during our study, 1991-1995.

Numbers of wild, adult Colorado pikeminnow in the San Juan River have remained low throughout our study (Table 36). In fact, no adult Colorado pikeminnow have been captured in the San Juan River since two fish were collected on a channel catfish removal trip on 26 and 27 April 1995 (Table 36). No adult Colorado pikeminnow were captured on adult fish community trips after October 1994 (Table 36).

This lack of collections after spring 1995 may be due to adult Colorado pikeminnow becoming conditioned to avoid electrofishing fields and the sounds made by rafts as they are rowed downstream. During our study, seven adult Colorado pikeminnow were recaptured a total of 11 times. Four of these fish were recaptured twice each. This indicates that Colorado pikeminnow were surviving capture and handling and were remaining in about the same areas of the San Juan River as where they were initially captured. In two specific instances radiotelemetered Colorado pikeminnow were observed to avoid electrofishing rafts. Tag number 800 (9 October 1992), contacted at RM 128.8, swam ahead of two electrofishing rafts for 0.8 RM, swimming from its original position on the river right shoreline to the river left shoreline. The researcher tracking the fish directed electrofishing crews to the fish's position where it was captured (RM 128.0) when it swam back upstream, apparently to avoid crossing downstream over a shallow riffle-sand bar complex, into the path of the two electrofishing rafts working together. This fish was captured in the narrowest part of the river channel at which point the two electrofishing rafts working together were able to shock the entire channel. Tag number 100 (14 May 1993), contacted at RM 122.7, avoided an electrofishing raft, swimming downstream along the river right shoreline ahead of the electrofishing raft for 0.2 RM, at which point the fish moved to middle of the main channel, let the raft pass downstream, and then returned to the river right shoreline and swam back upstream to its previous position. In another instance (19 October 1991), a previously uncaptured Colorado pikeminnow (tagged with radio tag number 739 after its capture) was visually observed swimming ahead of an electrofishing raft for approximately a hundred yards before being captured at RM 127.7. Again, this fish was captured just above a shallow riffle-sand bar complex in a very narrow part of the river channel by two electrofishing rafts working in tandem, thus shocking the entire channel.

Colorado pikeminnow have also been observed to avoid non-electrofishing rafts. On 14 May 1992, a radiotelemetered Colorado pikeminnow (tag number 739) continually swam downstream ahead of a raft for several miles, with the signal for this fish eventually being lost at RM 137.5. No electrofishing rafts were in the area while this tracking was taking place. Adult Colorado pikeminnow were also documented to actively avoid splashing produced by crews setting trammel nets in low-velocity habitats. On 15 May 1992, a radiotelemetered Colorado pikeminnow (tag number 760) was located, via radiotelemetry, approximately 100 yards upstream in the Mancos River. As a crew attempted to set a trammel net across the mouth of the Mancos River, the fish swam quickly towards the river's mouth, actually hitting the net, before escaping and swimming across the main channel of the San Juan River to a point directly across the river from the Mancos River confluence. On 13 April 1993, another radiotelemetered Colorado pikeminnow (tag number 800) was located, via radiotelemetry, in a narrow (about 10-ft. wide) secondary channel near its confluence with the main channel at RM 130.6 (river right). After setting a trammel net across the mouth of this channel, three researchers entered the secondary channel approximately 30 yards above the fish and walked side by side downstream, disturbing the water in an attempt to scare the fish into the trammel net. This fish avoided both the researchers and the net on three consecutive attempts. Eventually, a second trammel net was dragged from upstream of the fish's location toward the channel's mouth, forcing the fish to become entangled in the first net, where it was captured.

Using the Schnabel multiple-census population formula (Van Den Avyle 1993), the number of Colorado pikeminnow in the river reach between RM 136.6 and 119.2, for the period of June 1991 to October 1995, was estimated at 19 fish. Ninety-five percent confidence interval (C.I.) calculations (Ricker 1975, Van Den Avyle 1993) performed for this estimate place the population in this river reach from 10-42 Colorado pikeminnow (99% C.I.'s = 8-54 Colorado pikeminnow), for the specified time period. Petersen index calculations (Van Den Avyle 1993) for the 14 sampling intervals used to validate the Schnabel population estimate placed the Colorado pikeminnow population between 9 and 20 fish for the specified river reach and time period.

DISCUSSION

Movements

Given the large number of contacts with Colorado pikeminnow in this 33-mile section of river and the dearth of adult fish collected and observed elsewhere in the river, it appears that the reach of river from RM 142.0-109.0 has qualities and characteristics that make it a "preferred" reach for adult Colorado pikeminnow (Ryden and Ahlm 1996). The spawning areas in this river section may be natal spawning areas to which San Juan River Colorado pikeminnow have an affinity (see Chapter 3). Likewise, the Mancos River which is seasonally used for staging prior to spawning (see Chapter 3) may also be a natally-imprinted feature. The relative stability of the Mixer area over time may also be a factor. While the location of specific spawning bars within the Mixer may change over time, the general features of the Mixer which cause the formation of these bars to occur remain (R. Bliesner pers. comm.). The presence of Cudei Diversion at the upstream end of this river section may also be a factor. Radiotelemetered Colorado pikeminnow did not show a strong desire to move upstream of this diversion during this study, although they are physically capable. Forage fishes are also very abundant in this river section. Some researchers have also suggested that the accumulation of annual thermal units (ATU’s) necessary for adult Colorado pikeminnow to establish year-round home feeding ranges may not be possible in the San Juan River upstream of Cudei Diversion, due to the colder water temperatures upstream of this point, thus limiting the distribution of this species (Osmundson 1999, D. Osmundson and V. Lamarra pers. comm.). Whatever the case, the fact that five of the eight Colorado pikeminnow captures and one of the two Colorado pikeminnow observations during the 1987 to 1989 study occurred in this same section of river lends further credence to the importance of this area (Platania 1990, Platania et al. 1991, Ryden and Ahlm 1996). Two other

Colorado pikeminnow captures during the 1987 to 1989 study occurred just outside this "preferred" reach at approximate RM's 103.74 and 144.74 (Platania 1990).

The contacts with the Bluff fish demonstrate the affinity of this fish for a short section the San Juan River just downstream below Bluff, UT. This individual appears to have migrated only long enough to spawn, returning to its home range within a very short period of time (Ryden and Ahlm 1996). The sightings of Colorado pikeminnow in the area of the river downstream of Bluff, coupled with the affinity of the Bluff fish for the area just downstream of Bluff, suggest that a small number of Colorado pikeminnow may also reside in the San Juan River between Bluff and Mexican Hat, UT.

With the exception of the Bluff fish, San Juan River Colorado pikeminnow display sedentary behavior, except during spawning season, and even then only make short distance migrations to local spawning areas. The migration of the Bluff fish, as well as the aforementioned Colorado pikeminnow captured and tagged in Lake Powell (RM 0.0; April 1987) and recaptured at RM 79.0 (September 1987) demonstrates that a small minority of San Juan River Colorado pikeminnow population does display migratory behavior (Platania 1990, Ryden and Pfeifer 1995a, Ryden and Ahlm 1996). Yet, even the Bluff fish showed a high fidelity to a short, 2.3-mile, section of river downstream of Bluff, UT (RM 73.7-76.0), with the exception of its spawning migration (Ryden and Pfeifer 1995a, Ryden and Ahlm 1996).

San Juan River Colorado pikeminnow appear to have small home ranges. The fidelity of San Juan River Colorado pikeminnow adults to a small home range, with the exception of spawning, was similar to behavior noted in other UCRB pikeminnow populations (Wick et al. 1983, Tyus 1985, McAda and Kaeding 1991).

For the period 1991-1995, mean MD and mean FD were close to that of Colorado pikeminnow in the "15-mile reach" of the Colorado River near Grand Junction, CO, but lower than other reaches of the Colorado River (McAda and Kaeding 1991) or Green and Yampa rivers (e.g., Tyus 1990).

Habitat Use

Habitat use data for San Juan River Colorado pikeminnow adults contradict those from an earlier study when more than 50% of contacts were with fish using shoreline habitat, followed by eddy (25%), pool (<10%), run (<10%), backwater (<10%), and other habitats (<10%) in the Green, White, and Yampa rivers (Figure 73; Tyus and McAda 1984). Tyus and McAda (1984) stated that habitat use varied between river system and time of year. This seasonal variation in habitat use was also apparent in observations with Colorado pikeminnow in the San Juan (Figure 73) and Colorado Rivers (Osmundson and Kaeding 1989). Comparisons between rivers show that mean depths at observation locations were deepest in the Green River (4.6 ft.) followed by the Colorado (4.0 ft.), San Juan (3.9 ft.), Yampa (3.0 ft.), and White rivers (2.3 ft.). In contrast, velocities at observation locations were fastest in the White River (1.6 ft/sec) followed by the Green (0.6 ft/sec) and Yampa rivers (0.3 ft/sec). No mean velocity was given for all Colorado pikeminnow contacts on the Colorado River, but Osmundson and Kaeding (1989) did state that velocity at fish locations was low (<0.35 ft/sec) over 50% of the time, with the only use of swift-water areas (i.e., runs, riffles, and rapids >1.0

ft/sec) occurring between July and September during spawning season. No velocities were taken at San Juan River Colorado pikeminnow locations. It is important to note that sample sizes were much larger in Tyus and McAda’s study (total radiotelemetry contacts {n} = 2,329) and Osmundson and Kaeding’s study (n = 452) than in this study (n = 83). However, despite the differences in sample sizes, it is still apparent that Colorado pikeminnow utilize a large number of different habitats in different rivers, but habitat use is not necessarily consistent between rivers. What is consistent is that Colorado pikeminnow show seasonal variation in their habitat use in all rivers. The relative size, depth, and swiftness of a given river undoubtedly effects which habitats Colorado pikeminnow will select and utilize in that river.

Population Trends

Between 1991 and 1997 the population of Colorado pikeminnow in the San Juan River appeared to be fairly static with a small amount of successful reproduction and an even smaller amount of recruitment taking place.

Performing a population estimate on adult Colorado pikeminnow in the San Juan River is somewhat problematic, given several factors. First is the aforementioned propensity of adult Colorado pikeminnow to actively avoid even the most effective of collection techniques. Second, is the small number of individual Colorado pikeminnow captured during our study. The third factor is the lack of a consistently sampled group of RM's on all adult fish community trips. With these factors in mind, data was partitioned to include only trips that sampled RM 136.6-119.2. This was the only common sampled area between both standardized adult fish community monitoring trips and Colorado pikeminnow "hunts." This was also the area of the river where the large majority of adult Colorado pikeminnow were collected and recaptured between 1991 and 1995. Data after 1995 were not used in making this estimate due to the lack of adult Colorado pikeminnow collections after 1995. Thus, this population estimate indicates the number of Colorado pikeminnow estimated to be in this reach of river as of October 1995.

This method of estimating populations assumes that there is no mortality in the sampled population after a fish is marked and released. In June 1991, a single female Colorado pikeminnow, captured at the Mancos River confluence (RM 122.6), died during surgery to implant a radio tag. This fish was not included in the population estimate calculations. Mortality (or lack thereof) of other tagged Colorado pikeminnow, between June 1991 and October 1995, could not be definitively established via radiotelemetry and electrofishing. However, electrofishing recaptures of seven different adult Colorado pikeminnow (four of them twice each), and upstream movements of several radiotelemetered fish during that time period indicates a high survival rate of sampled fish. No evidence (e. g., finding fish carcasses associated with an unmoving tag or finding a radio tag on dry land out of the river channel) was collected via radiotelemetry that would indicate mortality of any of the remaining radio-implanted Colorado pikeminnow post-release.

Recruitment of Colorado pikeminnow in the upper San Juan River (upstream of RM 109.0) is, presently, probably occurring (albeit at very low numbers) almost entirely from colonization of younger fish from the lower river reaches. This idea is supported by three pieces of evidence from the UCRB.

First, the general distribution of earlier life stage Colorado pikeminnow downstream of adult fish, a pattern similar to that reported for other UCRB rivers (Tyus 1986). Second, the general distribution of various life stages of Colorado pikeminnow in the San Juan River closely resembles that of Colorado pikeminnow in the Colorado River where this same phenomenon of smaller Colorado pikeminnow from downstream river reaches moving upstream to a preferred reach as they enter adulthood was documented in the late 1980's and early 1990's (Osmundson and Burnham 1996). In addition, the mean MD and mean FD of adult radiotelemetered Colorado pikeminnow in the San Juan River closely resembles that of Colorado pikeminnow in the "15-mile reach" near Grand Junction, CO. The "15-mile reach" is roughly the Colorado's River's equivalent of the San Juan River's "preferred" reach (RM 109.0-142.0). Third, the general lack of larger (>450 mm TL) Colorado pikeminnow in the river downstream of RM 109.0 which mirrors the trend observed in the Colorado River (Osmundson and Burnham 1996).

The large majority of adult Colorado pikeminnow collected in the Colorado River in the last ten years have been concentrated in the "15-mile reach" (CO RM 186-171), the adjacent "18-mile reach" (CO RM 171-153), or the lower 3.1 RM of the Gunnison River, which enters the Colorado River at RM 171.0 (the division point for "15-mile reach" and "18-mile reach"). In the Colorado River downstream of Moab, large numbers of juvenile Colorado pikeminnow have been collected from Courthouse Wash (CO) RM 63.9, downstream to (CO) RM 1.1 (Osmundson et al. 1997). So, essentially young Colorado pikeminnow in the Colorado River have at least 168 RM below the "15-mile reach" (150 RM below the "18-mile reach") in which to select suitable habitat or eddy out of the drift, and rear. At (CO) RM 0.0, the Green River joins the Colorado River, which then flows approximately 16 RM miles through Cataract Canyon, a high-gradient, rapid-filled canyon, before entering Lake Powell (Belknap and Belknap 1981). Surprisingly, Cataract Canyon provides suitable nursery habitat for YOY Colorado pikeminnow with up to 32 fish per 100 square meters being collected there (Valdez 1990). The fact that early life stage Colorado pikeminnow are collected as far downstream as Cataract Canyon means that almost certainly, some of these fish are moving downstream into Lake Powell.

In contrast to the San Juan and Colorado Rivers, the largest and healthiest remaining population of Colorado pikeminnow in the UCRB is in the Green River. Spawning areas for Colorado pikeminnow at the Yampa River confluence are over 300 RM upstream of the confluence of the Green and Colorado Rivers, while spawning areas for Colorado pikeminnow in Desolation Canyon are over 150 RM upstream of the confluence (e. g., Tyus et al. 1981; C. McAda pers. comm.). Early life stage Colorado pikeminnow have been collected as far downstream as the confluence of the Green and Colorado Rivers and into Cataract Canyon (Valdez 1990, McAda et al. 1994).

The concentration of adult Colorado pikeminnow between RM 142 and 109 in the San Juan River leaves larval Colorado pikeminnow only 41 RM in which to select suitable habitat or eddy out of the larval drift, before the river enters its canyon-bound reach (RM 68.0-17.0) where low-velocity habitats suitable for early life stage Colorado pikeminnow are rare. Downstream of this canyon-bound reach, Reach 1 (RM 17.0-0.0) may or may not provide suitable habitat for early life stage Colorado pikeminnow, depending upon the flows in the river at any given time and their effect on the ephemeral low-velocity habitats therein. The movement of early life stage Colorado pikeminnow into Lake Powell (documented by Lashmett 1993, 1994) due to lack of suitable downstream nursery habitats and length of the San Juan River being insufficient to retain young fish has almost certainly been a contributing factor to the decline of wild Colorado pikeminnow in this system since the construction of both Navajo Dam and Glen Canyon Dam in the early 1960's.

Successful reproduction of the San Juan River Colorado pikeminnow population has been documented throughout the late 1980's and early 1990's (Platania 1990, Lashmett 1993, 1994, Buntjer et al. 1993, 1994, Archer et al. 1995, 1996). However, the low numbers of larval Colorado pikeminnow being produced in concert with the movement of early life stage Colorado pikeminnow into Lake Powell, likely predation on young Colorado pikeminnow by predatory nonnative fishes, and other factors does not bode well for the long-term success of the San Juan River Colorado pikeminnow population. However, the recent success of experimentally-stocked juvenile Colorado pikeminnow may provide a much-needed boost to Colorado pikeminnow numbers in the San Juan River. These juvenile fish are surviving and growing, and should recruit into the adult (i.e., reproducing) population. These stocked juveniles have acted as two strong, albeit artificial, cohorts (i.e., year-classes). The success of these stocked fish seem to indicate that the bottlenecks for Colorado pikeminnow in the San Juan River occur at the life stages smaller than 100 mm TL.

CONCLUSIONS/MANAGEMENT IMPLICATIONS

- Study Objective met?
  - Partially for roundtail chub and razorback sucker
    - Only population trends (i.e., status) able to be determined for these two species
  - Yes for Colorado pikeminnow

- Movement:
  - Adult Colorado pikeminnow have small home ranges
  - Majority of adult Colorado pikeminnow were captured between RM 142.0 and 109.0 and remained throughout our study
  - Majority of San Juan River Colorado pikeminnow adults display sedentary behavior staying in home ranges except to make short distance migrations to local spawning areas
  - Even the Bluff fish showed fidelity to a home range, migrating only to spawn
  - Displacement values show movement patterns for Colorado pikeminnow in the San Juan River are very like those of Colorado pikeminnow in the “15-mile reach” of the Colorado river

- Habitat use:
  - Adult Colorado pikeminnow use a variety of habitats, with main channel runs being the most heavily utilized during our observations
  - This contrasts with habitat use data recorded for Colorado pikeminnow in the Green and Yampa rivers
  - The number of habitat use observations during our study was low

- Population trends:
    - Small number of successfully reproducing adult Colorado pikeminnow remain in the San Juan River
    - Schnabel population estimate indicated that 19 adult Colorado pikeminnow resided in the San Juan River between RM 136.6 and 119.2 between 1991 and 1995 (95% C.I. = 10-42 adults)
    - young Colorado pikeminnow stocked by the UDWR in 1996 and 1997 are surviving and represent two strong, albeit artificial, year classes

CHAPTER 3: SPAWNING AREAS OF RARE FISH SPECIES

< Objective 3: Locate potential spawning areas of rare fish species.

METHODS

Radiotelemetry contacts between June and September were examined to see if radiotelemetered Colorado pikeminnow were gathering in specific areas of the San Juan River to spawn. Tracking trips (both ground and aerial) were more frequent during these months than at other time of the year. Contacts with radiotelemetered Colorado pikeminnow in 1992 led to the initiation of intensive radiotelemetry studies during suspected spawning seasons (Miller 1994a, 1995), habitat studies to characterize suspected spawning bars (Bliesner and Lamarra 1993-1996), and the addition of a third drift netting station below the Mixer to try to capture newly-spawned Colorado pikeminnow (Buntjer et al. 1994).

RESULTS

Spawning Areas

Based on data from 1991-1994, a fairly strong pattern emerged that probably represents Colorado pikeminnow staging and spawning activities in connection with the Mancos River and the Mixer. Forty-nine radiotelemetry contacts were made with Colorado pikeminnow during pre-spawning periods (15 May-30 June) from 1991 through 1994 (Figure 72). Seven radiotelemetered Colorado pikeminnow, five females and two males, aggregated during pre-spawning periods in or near the mouth of the Mancos River, prior to moving to presumed spawning areas (Table 61, Figure 72; Ryden and Ahlm 1996). Two fish in each of the first three years (1991-1993), and three fish in 1994 exhibited this behavior (Table 61). Two of the seven Colorado pikeminnow were females that aggregated at the Mancos in more than one year (tag number 150/940 in 1991 and 1994 and tag number 030{1993} in 1993 and 1994) and subsequently moved to the presumed spawning areas (Table 61). These seven fish accounted for 21 (42.9%) of 49 radio contacts with Colorado pikeminnow during pre-spawning periods. Nine radiotelemetry contacts occurred in the Mixer and 19 radiotelemetry contacts occurred elsewhere in the river during pre-spawning periods. Eight of the contacts elsewhere in the river were with five of the seven fish that aggregated in the Mancos River. Their radiotelemetry contact locations ranged from 1.9 RM downstream to 3.1 RM upstream the Mancos River. Another large Colorado pikeminnow female (687 mm TL), that was gravid and freely expressing eggs, was captured at the mouth of the Mancos River in a trammel net on 9 June 1991 with two other Colorado pikeminnow. This female was not radio-tagged, although the two Colorado pikeminnow captured with her (one female and one male) both were.

Of the remaining six radiotelemetered Colorado pikeminnow, only four had active radio tags during pre-spawning periods. These four fish accounted for 11 of the 19 contacts elsewhere in the river and all nine radio contacts within the Mixer during pre-spawning periods. Three of these fish remained upstream of the Mancos River and the fourth was located downstream near Bluff, UT (i.e., the Bluff fish). The Bluff fish moved upstream past the Mancos to the presumed spawning area and was not documented to have used the Mancos River confluence.

Thus, of 11 Colorado pikeminnow with active radio tags during pre-spawning periods (1991-1994), seven (63.6%) used the Mancos River confluence. Including the large, gravid female captured there, eight (47%) of the 17 adult Colorado pikeminnow captured during our study are known to have used the Mancos River confluence during pre-spawning periods. No radio-tagged individuals were found at the Mancos River confluence at any other time of year.

Between 1991 and 1994, 11 (84.6%) of 13 radiotelemetered Colorado pikeminnow, including six of the seven that staged at the mouth of the Mancos River, moved to Mixer (RM 133.4 to 129.8) during presumed spawning periods (Table 61, Figure 72). Seven were female and four were male. One male was ripe, tuberculate, and releasing milt when captured on 28 June 1992. This ripe male was later located, based on ground triangulation, in close proximity to two female Colorado pikeminnow (739 and 760) and a second male (800/200) near a suspected spawning bar (10 July 1992). Two of five individuals tracked in multiple years were contacted in the Mixer in two consecutive years. Tag number 800/200, a male, was contacted in the Mixer in 1992 and 1993, and tag number 030{1993}, a female, was contacted in the Mixer in 1993 and 1994 (Table 17, Figure 29). Of the 72 radiotelemetry contacts made with Colorado pikeminnow during presumed spawning periods, 50 (69.4%) occurred in the Mixer (Figure 72; Ryden and Pfeifer 1993, 1994a, 1995a, 1996a, Ryden and Ahlm 1996). Fifteen of the remaining 22 contacts were with fish that spent part, but not all of their time in the Mixer during a given spawning season. The other seven contacts were split between one female fish (tag number 848/980) that used the Mixer during the second of two spawning seasons in which she was tracked (three contacts), and one male (tag number 280) that utilized the Mancos River, but did not move upstream to the Mixer during the spawning period. This male (tag number 280), was the only radiotelemetered Colorado pikeminnow that had an active radio tag during a presumed spawning period that did not use the Mixer during our radiotelemetry observations.

DISCUSSION

In the Green and Yampa Rivers, adult Colorado pikeminnow make repeated long distance migrations to a few known spawning areas (Tyus et al. 1981, Tyus 1986, 1990), much like the movement of San Juan River Colorado pikeminnow to the Mixer. However, unlike Colorado pikeminnow in the Green and Yampa Rivers, the majority of San Juan River Colorado pikeminnow do not move long distances but reside in the area in which they spawn, as do Colorado pikeminnow in the Colorado River (McAda and Kaeding 1991).

Physical habitat studies verified that suitable spawning habitat existed within the Mixer during the 1991-1994 time period (Bliesner and Lamarra 1993, 1994, and 1995). These probable spawning bar complexes were located at RM 132.1-132.0 and RM 131.3-131.25. However, because this area of the San Juan River is very dynamic, the specific location of suitable spawning bars in a localized area changes from year to year, depending on flows. For more information on specific spawning bars locations, channel dynamics, and the specific use of these areas by Colorado pikeminnow during spawning see Miller (1993 and 1994) and Bliesner and Lamarra (1993, 1994, 1995, 1996).

For the remainder of the year radiotelemetered Colorado pikeminnow remained spatially separated from one another, with some being upstream and some downstream of the presumed spawning areas (Ryden and Pfeifer 1993, 1994a, 1995a, 1996a, Ryden and Ahlm 1996).

The data suggests a seasonally-repeated behavior of staging at the Mancos River and spawning in the Mixer. This pattern of a pre-spawning aggregation of Colorado pikeminnow at the mouth of a tributary (the Mancos River) before moving to a probable spawning area has not been apparent in other Upper Basin rivers (Ryden and Ahlm 1996). Perhaps the Mancos serves to replace warm backwater habitats (which are generally absent in the San Juan River) that are frequented by Colorado pikeminnow in other UCRB rivers at this time of year (D. Osmundson, pers. comm.). Currently, the Mancos and Mixer are the only known staging and spawning areas for Colorado pikeminnow in the San Juan River. Indeed, the migration of the Bluff fish from its home range downstream of Bluff, UT to the Mixer in 1994 may be the most compelling evidence for the importance of this river reach to Colorado pikeminnow. However, not all Colorado pikeminnow appear to stage or spawn every year, at least not at these locations. This was evidenced by a large female (tag number 848/980) Colorado pikeminnow tracked in two consecutive years. This fish was never contacted in the Mancos and moved to the Mixer during only one spawning season. In addition, a male Colorado pikeminnow (tag number 280) contacted in and near the Mancos River in 1994 did not move to the Mixer during that spawning season. Other staging and spawning areas may exist in the San Juan River that have not been located. Captures and observations of Colorado pikeminnow near Bluff, UT, both during this study (one capture and one observation) and in the 1987-1989 study (one capture and one observation; Platania 1990, Platania et al. 1991) suggest that a group of Colorado pikeminnow may reside there. The availability of suitable spawning habitat in this section of the San Juan River is, at present, unknown. Yet, if there are truly other localized populations of Colorado pikeminnow in the San Juan River and if spawning of this species is taking place in other areas, why would the "Bluff fish" make the relatively long migration to the Mixer observed in 1994? Back-calculated dates of collected YOY Colorado pikeminnow place the spawning dates for these early life stage fish on the descending limb of the hydrograph (i.e., July; Platania et al. 2000). In addition, the collection of a larval Colorado pikeminnow (8.6 mm TL) on 2 August 1996 at the Mixer drift netting station (RM 128.0; Platania 1997) documents that successful reproduction by Colorado pikeminnow was occurring upstream of this site, again probably in the Mixer, despite the lack of adult Colorado pikeminnow seen on adult monitoring trips.

CONCLUSIONS/MANAGEMENT IMPLICATIONS

- Study Objective met? Yes
- Adult Colorado pikeminnow are staging in the Mancos River in May and early June and moving to the Mixer (RM 133.4-129.8) to spawn in July and August
- This pattern of staging and spawning was a seasonally repeated behavior for many, but not all Colorado pikeminnow during tracked during successive years of our study

CHAPTER 4: THE EFFECT OF INSTREAM DIVERSION STRUCTURES ON FISH MOVEMENTS

< Objective 4: Determine the extent to which current instream diversion structures (dams, weirs, etc.) impede movement of San Juan River fishes, with emphasis on rare fish species.

INTRODUCTION

Five major instream diversion structures (located between RM 178.5-142.0) occur within the boundaries of designated Critical Habitat for Colorado pikeminnow and razorback sucker (Maddux et al. 1993, United States Department of the Interior 1994). Four of these major instream diversion structures--Fruitland Diversion (RM 178.5), PNM Weir (RM 166.6), APS Weir (RM 163.3), and Hogback Diversion (RM 158.6) are in Reach 6. In addition, three minor instream diversion structures are also located in Reach 6. The fifth major instream diversion structure in our study area (Cudei Diversion at RM 142.0) is located in Reach 5. For detailed descriptions of these five structures, see Masslich and Holden (1996). A sixth major instream diversion structure, the Hammond Diversion (at RM 205.0 in Reach 7), may also be an impediment to fish movement (M. Wethington pers. comm.), but is upstream of designated Critical Habitat and out of our study area. There are no water diversion structures on the San Juan River in CO or UT.

This conglomeration of eight major and minor instream water diversion structures within such a short, 36.5-RM (RM 178.5-142.0), section of river is unprecedented among major rivers in the Upper Colorado River Basin (UCRB) in which populations of endangered fish reside. Platania (1990) speculated that the five diversion structures (Figure 1) may impede the movements of San Juan River fishes.

Instream diversion structures can effect fish communities in three ways. The first way is by impeding fish movement, or passage, up- or downstream past a structure. Instream diversion structures can act as either physical or behavioral barriers (or both) to fish passage (Kynard 1993).

The second way instream diversion structures effect fish communities is by entraining fish. All of the aforementioned diversion structures are potential fish entrainment hazards. Fish moving downstream along the shoreline on the same side of the river as the intake structure for a canal or pump are subject to entrainment. Two types of intake structures are used on instream diversions in the San Juan River, canals and pumps. Both represent entrainment dangers. Pumps tend to entrain only early life stage fish, while canals have the potential to entrain fishes of all life stages.

Documentation that endangered fish species become entrained in canals, ponds, and other off-channel features already exists. In central AZ, adult Colorado pikeminnow were once abundant enough in irrigation canals to be harvested using pitch forks (Miller 1961). In the San Juan River, two razorback sucker were collected from an irrigation pond near Bluff, UT that connected to the river via a canal in 1976 (VTN Consolidated Inc. and Museum of Northern Arizona 1978, and Platania 1990). Hendrickson (1993) noted that stocked juvenile Colorado pikeminnow had been found in a diversion canal and gravel pits connected to the river by ditches. More recently, the UDWR documented that juvenile Colorado pikeminnow stocked in the San Juan River at the Hwy. 64 bridge (RM 147.9; 19 August 1997) were becoming entrained in the Cudei Canal at RM 142.0 (Converse 1997), shortly after stocking.

The third way instream diversion structures effect fish communities is by disturbing the benthic and fish communities during repair and reconstruction efforts. Because of the materials from which they are made, namely rock and earth, three of the major instream diversion structures (Fruitland, Hogback, and Cudei Diversions) are regularly damaged by high river flows and need to be periodically rebuilt or repaired. During repair operations, heavy equipment enter the river channel, pushing large amounts of river bed material onto the diversion berms. This causes major disturbances, if not complete destruction, of the benthic community in the area immediately around the diversion structure, as well as displacing fish from the immediate area. In addition, large amounts of silt and bottom sediments are transported downstream, degrading the quality of downstream benthic habitats for an undetermined distance. This destruction of the benthic community near the diversion structure would tend to displace native speckled dace, whose habitat would be destroyed, and would detrimentally effect feeding of native suckers in the degraded areas due to loss of food items.

Data collected during the adult monitoring study concentrated only on the impacts of instream diversion structures to fish movements.

METHODS

Evaluation of the extent to which current instream water diversion structures impeded endangered fish movement was initially intended to be done by examining electrofishing and radiotelemetry data in combination. However the absence of Colorado pikeminnow from electrofishing collections upstream of Cudei Diversion, the overall lack of movement of radiotelemetered Colorado pikeminnow upstream past Cudei and other diversion structures, the recapture of only a single PIT-tagged roundtail chub marked between diversion structures, and the failure to capture any wild razorback sucker during our study frustrated early attempts to address this objective.

Due to the difficulties in obtaining movement data for rare fish species relating to instream diversion structures, it was decided to use native sucker species as surrogates to study the effects of these structures on native fish movement. Beginning in April 1996 native suckers captured while electrofishing between RM 180.0 and 158.0 were tagged with yellow or red, FLOY brand, dangler tags bearing a "USFWS" prefix followed by a six-digit number (e.g., USFWS 035751). Fish captured between RM 180.0 and 166.6 (the Animas River confluence to just upstream of the PNM weir) were tagged with yellow FLOY tags. Those fish captured between RM 166.5 and 158.0 (below the PNM weir to just below Hogback Diversion) were tagged with red FLOY tags. The vast majority of the fish FLOY-tagged during our study were native bluehead and flannelmouth suckers. However, during a single trip (14 October 1996) all nonnative fishes captured were FLOY-tagged as well. Data from recaptured, FLOY-tagged fish were then examined to assess movement around instream diversion structures. Additional, movement data were obtained from recaptured channel catfish and common carp that had been FLOY-tagged as part of another study (Brooks and Williams 1993, Brooks et al. 1994, Buntjer and Brooks 1995, 1996). Fish tagged during this study were all implanted with blue, FLOY brand, dangler tags bearing an "SJR" or "FWS" prefix followed by a five-digit number (e.g., SJR 04321). Movement data were also examined for recaptured, experimentally-stocked razorback sucker (Ryden and Pfeifer 1995b, 1996b, and 2000) and Colorado pikeminnow (Archer et al. 2000) that were recaptured during our electrofishing efforts, as well as the single radiotelemetered Colorado pikeminnow that was contacted above Cudei Diversion (RM 142.0) in late July 1994 (Miller 1995).

RESULTS

Between 16 April 1996 and 29 September 1997, 4,427 fish representing eight species were implanted with red and yellow FLOY-tags. Yellow FLOY tags were implanted in fish upstream of the PNM Weir, RM 166.6, while red FLOY tags were implanted downstream of RM 166.6 (Table 62, Figure 75). In addition, 6,023 blue FLOY-tags were implanted in channel catfish and common carp between 1992 and 1995, as part of a study to obtain a population estimate on and study the movements of nonnative fishes (Table 62, Figure 75; Brooks and Williams 1993, Brooks et al. 1994, Buntjer and Brooks 1995 and 1996). Data were reexamined to assess the movement of FLOY-tagged nonnatives in relation to diversion structures.

Of the eight FLOY-tagged species, four (channel catfish, common carp, flannelmouth sucker, and bluehead sucker) moved either up- or downstream over at least one instream diversion structure (Table 63). Of 2,649 FLOY-tagged flannelmouth sucker, 90 (3.4%) were recaptured. Of those 90 recaptured flannelmouth sucker, 18 (20.0%), moved either up- or downstream over at least one diversion structure (Tables 63-65). Of the 1,303 FLOY-tagged bluehead sucker, 31 (2.4%) were recaptured. Of those 31 recaptured bluehead sucker, 8 (25.8%), moved either up- or downstream over at least one diversion structure (Tables 63-65). Of 3,706 FLOY-tagged channel catfish, 186 (5.0%) were recaptured. Of those 186 recaptured channel catfish, 35 (18.9%), moved either up- or downstream over at least one diversion structure (Tables 63-65). Of the 2,778 FLOY-tagged common carp, 61 (2.2%) were recaptured. Of those 61 recaptured common carp, six (9.8%), moved either up- or downstream over at least one diversion structure (Tables 63-65).

All FLOY-tagged native suckers were tagged within ten miles either up- or downstream of a major diversion structure (Table 62). Of the 3,706 channel catfish FLOY-tagged, 2,178 (58.8%) were tagged downstream of RM 132.0, ten miles downstream of the Cudei Diversion, the most downstream of the major diversion structures. Likewise, of the 2,778 common carp FLOY-tagged, 1,434 (51.6%) were tagged downstream of RM 132.0. The remaining 1,528 FLOY-tagged channel catfish (41.2%) and 1,344 FLOY-tagged common carp (48.4%), were tagged within ten miles either up- or downstream of one of the five major diversion structures (Table 62; J. Brooks, unpublished data). All FLOY-tagged fish representing the other four species were tagged within ten miles up- or downstream of a major instream diversion structure (Table 62). No FLOY-tagged individuals of the other four species were recaptured during our study (Table 62).

Table 62. Numbers and size distributions of fish species FLOY-tagged in the San Juan River, 1992-1997. The number of recaptured, FLOY-tagged fish of each species is shown in parentheses.

Species	Upstream of Fruitland Diversion Above RM 178.5	Between Fruitland Diversion and PNM Weir RM 178.5-166.6	Between PNM and APS Weirs RM 166.6-163.3	Between APS Weir and Hogback Diversion RM 163.3-158.6	Between Hogback and Cudei Diversions RM 158.6-142.0	Downstream of Cudei Diversion RM 142.0 and below
Channel catfish:	1(0)	0(0)	131(4)	163(10)	647(38)	2,764(134)
Statistics:						
mean TL =	505 mm	N/A	471 mm	414 mm	421 mm	359 mm
range =	N/A	N/A	272-764 mm	254-611 mm	220-655 mm	64-810 mm
Common carp:	34(1)	128(8)	113(9)	146(4)	493(21)	1,864(18)
Statistics:						
mean TL =	507 mm	510 mm	475 mm	464 mm	426 mm	431 mm
range =	195-625 mm	346-656 mm	376-580 mm	380-594 mm	113-562 mm	114-633 mm
Black bullhead:	0(0)	2(0)	0(0)	0(0)	0(0)	1(0)
Statistics:						
mean TL =	N/A	200 mm	N/A	N/A	N/A	309 mm
range =	N/A	185-215 mm	N/A	N/A	N/A	N/A
Rainbow trout:	2(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Statistics:						
mean TL =	340 mm	N/A	N/A	N/A	N/A	N/A
range =	340-340 mm	N/A	N/A	N/A	N/A	N/A
Largemouth bass:	0(0)	0(0)	0(0)	0(0)	1(0)	1(0)
Statistics:						
mean TL =	N/A	N/A	N/A	N/A	250 mm	236 mm
range =	N/A	N/A	N/A	N/A	N/A	N/A
Flannelmouth sucker:	379(10)	563(12)	983(36)	709(31)	14(0)	1(1)
Statistics:						
mean TL =	459 mm	452 mm	432 mm	421 mm	395 mm	311 mm
range =	230-592 mm	240-590 mm	242-589 mm	240-575 mm	268-524 mm	N/A
Bluehead sucker:	299(5)	407(12)	294(7)	297(6)	6(1)	0(0)
Statistics:						
mean TL =	353 mm	344 mm	318 mm	340 mm	366 mm	N/A
range =	135-445 mm	202-558 mm	233-431 mm	208-504 mm	306-420 mm	N/A
Flannelmouth X bluehead sucker:	2(0)	1(0)	2(0)	2(0)	0(0)	0(0)
Statistics:						
mean TL =	433 mm	343 mm	326 mm	313 mm	N/A	N/A
range =	391-475 mm	N/A	267-384 mm	305-320 mm	N/A	N/A

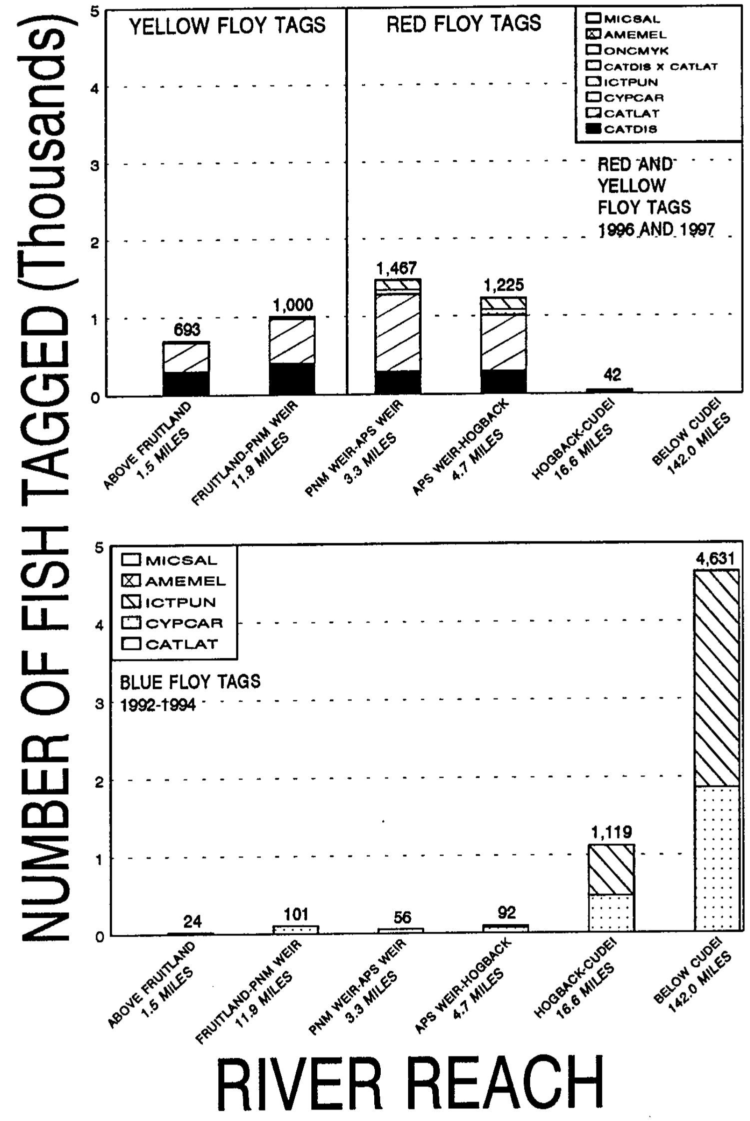


Figure 75. Numbers of fish FLOY-tagged, by species and tag color, in the San Juan River during the adult fish community monitoring study, 1996-1997 (top) and during nonnative fish studies, 1992-1995 (bottom).

Table 63. Total numbers of recaptured, FLOY-tagged fish (by species) that demonstrated either up- or downstream passage[a] over the five major instream diversion structures in the San Juan River, 1992-1997. Numbers of individual recaptured FLOY-tagged fish (by species) that demonstrated either up- or downstream passage are indicated in parentheses after the species code.

	UPSTREAM PASSAGE:[a]				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Ictpun(18)[b]	0	0	0	4	15
Cypcar (1)	0	0	0	0	1
Catlat(15)	5	10	7	1	1
Catdis (4)	1	0	3	0	0

	DOWNSTREAM PASSAGE:[a]				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Ictpun(18)[b]	0	0	2	4	12
Cypcar (5)	0	0	2	1	4
Catlat(13)	3	2	6	4	1
Catdis (4)	2	0	2	1	1

[a]: If an individual fish passed over more than one diversion structure, it was included in the total count for the number of fish for every diversion it passed. For example one Catlat tagged at RM 132.0 passed upstream over four of the five instream diversion structures. Therefore it was included as one fish in the total count for each of the four diversion structures it passed.

[b]: These two totals for Ictpun include a single individual that passed downstream over Cudei Diversion, then back upstream over Cudei Diversion. This is the only recaptured, FLOY-tagged individual that was documented passing a diversion structure in both directions. Thus the total number of recaptured FLOY-tagged Ictpun that demonstrated passage was 35, not 36. All other recaptured, FLOY-tagged fish represented here were documented moving only upstream or only downstream.

Table 64. Numbers and percentages of recaptured, FLOY-tagged fish, by species, that moved upstream past one or more of the five major instream diversion structures, in relation to various groupings of FLOY-tagged fish, San Juan River, New Mexico, 1992-1997.

	UPSTREAM PASSAGE:			
	Riverwide Downstream of this Diversion:		Between this Diversion and the Next Diversion Downstream:	
Diversion Structure and Species	Versus All Fish FLOY-tagged and released	Versus All FLOY-tagged Recaptures	Versus All Fish FLOY-tagged and Released	Versus All FLOY-tagged Recaptures
Fruitland Diversion				
Ictpun	No Data	No Data	No Data	No Data
Cypcar	No Data	No Data	No Data	No Data
Catlat	5 of 2,270 (0.2%)	5 of 80 (6.3%)	2 of 563 (0.4%)	2 of 12 (16.7%)
Catdis	1 of 1,004 (0.09%)	1 of 26 (3.8%)	1 of 407 (0.2%)	1 of 12 (8.3%)
All 4 Species	6 of 9,733 (0.06%)	6 of 352 (1.7%)	3 of 1,101 (0.3%)	3 of 32 (9.4%)
PNM Weir				
Ictpun	No Data	No Data	No Data	No Data
Cypcar	No Data	No Data	No Data	No Data
Catlat	10 of 1,707 (0.6%)	10 of 68 (14.7%)	8 of 983 (0.8%)	8 of 36 (22.2%)
Catdis	No Data	No Data	No Data	No Data
All 4 Species	10 of 8,632 (0.1%)	10 of 320 (4.3%)	8 of 1,523 (0.5%)	8 of 56 (14.3%)
APS Weir				
Ictpun	No Data	No Data	No Data	No Data
Cypcar	No Data	No Data	No Data	No Data
Catlat	7 of 724 (1.0%)	7 of 32 (21.9%)	6 of 709 (0.8%)	6 of 31 (19.4%)
Catdis	3 of 303 (1.0%)	3 of 7 (42.9%)	3 of 297 (1.0%)	3 of 6 (50.0%)
All 4 Species	10 of 7,109 (0.1%)	10 of 264 (3.8%)	9 of 1,317 (0.7%)	9 of 51 (17.6%)
Hogback Diversion				
Ictpun	4 of 3,411 (0.1%)	4 of 172 (2.3%)	3 of 647 (0.5%)	3 of 38 (7.9%)
Cypcar	No Data	No Data	No Data	No Data
Catlat	1 of 15 (6.7%)	1 of 1 (100%)	No Data	No Data
Catdis	No Data	No Data	No Data	No Data
All 4 Species	5 of 5,792 (0.08%)	5 of 213 (2.3%)	3 of 1,161 (0.3%)	3 of 60 (5.0%)
Cudei Diversion				
Ictpun	15 of 2,764 (0.5%)	15 of 134 (11.2%)	14 of 2,764 (0.5%)	14 of 134 (7.9%)
Cypcar	1 of 1,864 (0.05%)	1 of 18 (5.6%)	1 of 1,864 (0.05%)	1 of 18 (5.6%)
Catlat	1 of 1 (100%)	1 of 1 (100%)	1 of 1 (100%)	1 of 1 (100%)
Catdis	No Data	No Data	No Data	No Data
All 4 Species	17 of 4,631 (0.4%)	17 of 153 (11.1%)	16 of 4,631 (0.3%)	16 of 153 (10.5%)

Table 65. Numbers and percentages of recaptured, FLOY-tagged fish, by species, that moved downstream past one or more of the five major instream diversion structures, in relation to various groupings of FLOY-tagged fish, San Juan River, New Mexico, 1992-1997.

	DOWNSTREAM PASSAGE:			
	Riverwide Upstream of this Diversion:		Between this Diversion and the Next Diversion Upstream:	
Diversion Structure and Species	Versus All Fish FLOY-tagged and released	Versus All FLOY-tagged Recaptures	Versus All Fish FLOY-tagged and Released	Versus All FLOY-tagged Recaptures
Fruitland Diversion				
Ictpun	No Data	No Data	No Data	No Data
Cypcar	No Data	No Data	No Data	No Data
Catlat	3 of 379 (0.8%)	3 of 10 (30.0%)	3 of 379 (0.8%)	3 of 10 (30.0%)
Catdis	2 of 299 (0.7%)	2 of 5 (40.0%)	2 of 299 (0.7%)	2 of 5 (40.0%)
All 4 Species	5 of 717 (0.7%)	5 of 16 (31.3%)	5 of 717 (0.7%)	5 of 16 (31.3%)
PNM Weir				
Ictpun	No Data	No Data	No Data	No Data
Cypcar	No Data	No Data	No Data	No Data
Catlat	2 of 942 (0.2%)	2 of 22 (9.1%)	2 of 563 (0.4%)	2 of 12 (16.7%)
Catdis	No Data	No Data	No Data	No Data
All 4 Species	2 of 1,818 (0.1%)	2 of 48 (4.2%)	2 of 1,101 (0.2%)	2 of 32 (6.3%)
APS Weir				
Ictpun	2 of 132 (1.5%)	2 of 4 (50.0%)	2 of 131 (1.5%)	2 of 4 (50.0%)
Cypcar	2 of 275 (0.7%)	2 of 18 (11.1%)	2 of 113 (1.8%)	2 of 9 (22.2%)
Catlat	6 of 1,925 (0.3%)	6 of 58 (10.3%)	5 of 983 (0.5%)	5 of 36 (13.9%)
Catdis	2 of 1,000 (0.2%)	2 of 24 (8.3%)	2 of 294 (0.7%)	2 of 7 (28.6%)
All 4 Species	12 of 3,341 (0.4%)	12 of 104 (11.5%)	11 of 1,523 (0.7%)	11 of 56 (19.6%)
Hogback Diversion				
Ictpun	4 of 295 (1.4%)	4 of 14 (28.6%)	4 of 163 (2.5%)	4 of 10 (40.0%)
Cypcar	1 of 421 (0.2%)	1 of 22 (4.5%)	No Data	No Data
Catlat	4 of 2,634 (0.2%)	4 of 89 (4.5%)	3 of 709 (0.4%)	3 of 31 (9.7%)
Catdis	1 of 1,297 (0.07%)	1 of 30 (3.3%)	No Data	No Data
All 4 Species	10 of 4,658 (0.2%)	10 of 155 (6.5%)	7 of 1,317 (0.5%)	7 of 51 (13.7%)
Cudei Diversion				
Ictpun	12 of 942 (1.3%)	12 of 52 (23.1%)	12 of 647 (1.9%)	12 of 38 (31.6%)
Cypcar	4 of 914 (0.4%)	4 of 43 (9.3%)	3 of 493 (0.6%)	3 of 21 (14.3%)
Catlat	1 of 2,648 (0.04%)	1 of 89 (1.1%)	No Data	No Data
Catdis	1 of 1,303 (0.08%)	1 of 31 (3.2%)	No Data	No Data
All 4 Species	18 of 5,819 (0.3%)	18 of 215 (8.4%)	15 of 1,161 (1.3%)	15 of 60 (25.0%)

Flows at which individual fish passed diversion structures varied widely (Table 66). This wide range of flows precluded identifying a range of flows at which a certain structure might be successfully negotiated by a given species. The wide range of possible flows at which a structure was passed was usually an artifact of a given fish not being recaptured until several sampling trips after it had been tagged and released.

Documented instances of rare fish passing instream diversion structures were also rare (Table 67). Twenty-two individual rare fish, including one radiotelemetered Colorado pikeminnow (this fish moved first upstream, then back downstream over Cudei Diversion), one PIT-tagged roundtail chub, and 20 stocked razorback sucker made either up- or downstream movements past instream diversion structures between 13 May 1992 and 6 October 1997. Instances of rare fish passing upstream over a diversion (3 total) were far outnumbered by downstream passage events (20 total; Table 67). As with common species, flows for both up- and downstream passage events for rare fishes varied widely (Table 66).

In general, fish that were documented to have moved upstream past a diversion were larger than those that moved downstream past a diversion (Tables 68 and 69). Only one fish (a 193 mm TL razorback sucker) smaller than 320 mm TL moved upstream past any diversion (Table 68). In contrast, several fish smaller than 320 mm TL were documented to have moved downstream past various diversions.

Examination of CPUE data in the two RM immediately up- and downstream of the five major diversion structures showed evidence that fish are "stacking-up" (i.e., exhibiting noticeably higher CPUE) downstream of the PNM Weir, Hogback Diversion, and Cudei Diversion at certain times of the year (Figures 76 and 77). Of these three diversions, the stacking-up phenomenon was most evident at the PNM Weir where it occurred on all May and July trips, but not on the October 1996 trip (Figure 76). No such evidence was evident for the Fruitland Diversion or the APS Weir where CPUE in the first RM upstream of the diversion was almost always higher than that in the first RM downstream of the structure (Figure 76).

Electrofishing data revealed that the PNM Weir acts as a barrier to the colonization of upstream areas by common nonnative fish species (Figure 78). The three common native species were all present in relatively equal numbers both up- and downstream of the PNM Weir (Figures 78 and 79). In contrast, nonnative channel catfish were rare, at best, upstream of the PNM Weir. Of 1,712 channel catfish collected in Reach 6 between 1991 and 1997, only ten (0.6%) were collected upstream of the PNM Weir (Figure 78). Common carp were only ever half as abundant upstream of this structure as downstream (Figure 78). Red shiner were never collected upstream the PNM Weir during our study (Table 12).

DISCUSSION

Looking strictly at the numbers, it would appear that native suckers more readily moved past instream diversion structures than did nonnative channel catfish and common carp. However, since FLOY-tagged native suckers were tagged within ten miles either up- or downstream of a major diversion structure, but only about 40-50% of channel catfish and common carp were

Table 66. Flows (in CFS) present in the San Juan River during time periods when various fish species were documented passing either up- or downstream over the five major instream diversion structures in the San Juan River, 1992-1997.

	UPSTREAM PASSAGE:				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Ictpun	No Data	No Data	No Data	140-11,800	140-11,800
Cypcar	No Data	No Data	No Data	No Data	326- 3,300
Catlat	140-11,800	140-11,800	140-11,800	265-11,700	265-11,700
Catdis	514-11,800	No Data	140-11,800	No Data	No Data
Xyrtex	No Data	No Data	No Data	1,050- 5,360	265-11,700
Ptyluc	No Data	No Data	No Data	No Data	280- 1,920

	DOWNSTREAM PASSAGE:				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Ictpun	No Data	No Data	265-11,800	514-11,800	140-11,700
Cypcar	No Data	No Data	514-11,700	330-11,700	140-11,700
Catlat	140-11,800	514-11,800	140-11,800	140- 3,710	514- 3,710
Catdis	140-11,800	No Data	514- 6,430	514- 3,710	514- 3,710
Gilrob	No Data	No Data	No Data	No Data	326- 9,290
Xyrtex	No Data	No Data	No Data	No Data	140-11,700
Ptyluc	No Data	No Data	No Data	No Data	280- 1,920

Table 67. Total numbers of rare fish (by species) that demonstrated either up- or downstream passage[a] over the five major instream diversion structures in the San Juan River, 1992-1997. Numbers of individual rare fish (by species) that demonstrated either up- or downstream passage are indicated in parentheses after the species code.

	UPSTREAM PASSAGE:[a]				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Xyrtex (2)	0	0	0	1	1
Ptyluc (1)[a]	0	0	0	0	1

	DOWNSTREAM PASSAGE:[a]				
Species	Over Fruitland Diversion RM 178.5	Over PNM Weir RM 166.6	Over APS Weir RM 163.3	Over Hogback Diversion RM 158.6	Over Cudei Diversion RM 142.0
Gilrob (1)	0	0	0	0	1
Xyrtex(18)	0	0	0	0	18
Ptyluc (1)[a]	0	0	0	0	1

[a]: If an individual fish passed over more than one diversion structure, it was included in the total count for the number of fish for every diversion it passed. For example the Ptyluc tagged at RM 122.6 passed upstream over Cudei Diversion then downstream over Cudei Diversion. Therefore it was included as one fish in the total count for both the upstream and downstream passage counts for this structure.

Table 68. Number, mean total length (TL) and range in millimeters (mm), and sex, by species, of fish that moved upstream past one of the five major instream diversion structures, San Juan River, 1992-1997.

Diversion and Species	UPSTREAM PASSAGE:			
	Number	Sex	Mean TL (in mm)	TL Range (in mm)
Fruitland Diversion				
Ictpun	No Data			
Cypcar	No Data			
Catlat	3	Male	464	434-503
"	2	Indeterminate	504	475-532
Catdis	1	Indeterminate	377	
PNM Weir				
Ictpun	No Data			
Cypcar	No Data			
Catlat	2	Male	444	434-454
"	2	Female	436	416-456
"	4	Indeterminate	445	387-532
Catdis	No Data			
APS Weir				
Ictpun	No Data			
Cypcar	No Data			
Catlat	2	Male	452	450-454
"	1	Female	416	
"	4	Indeterminate	393	320-472
Catdis	1	Female	360	
	2	Indeterminate	359	352-365
Hogback Diversion				
Ictpun	3	Indeterminate	492	412-554
Cypcar	No Data			
Catlat	1	Female	416	
Catdis	No Data			
Xyrtex	1	Indeterminate	193	
Cudei Diversion				
Ictpun	15	Indeterminate	564	336-670
Cypcar	1	Female	409	
Catlat	1	Female	416	
Catdis	No Data			
Xyrtex	1	Indeterminate	397	
Ptyluc	1	Female	754	

Table 69. Number, mean total length (TL) and range in millimeters (mm), and sex, by species, of fish that moved downstream past one of the five major instream diversion structures, San Juan River, 1992-1997.

Diversion and Species	DOWNSTREAM PASSAGE: Number	Sex	Mean TL (in mm)	TL Range (in mm)
Fruitland Diversion				
Ictpun	No Data			
Cypcar	No Data			
Catlat	1	Male	550	
"	2	Indeterminate	442	412-471
Catdis	1	Male	311	
"	1	Indeterminate	235	
PNM Weir				
Ictpun	No Data			
Cypcar	No Data			
Catlat	2	Indeterminate	332	282-382
Catdis	No Data			
APS Weir				
Ictpun	2	Indeterminate	419	358-480
Cypcar	2	Indeterminate	449	441-457
Catlat	6	Indeterminate	411	282-520
Catdis	2	Indeterminate	342	280-403
Hogback Diversion				
Ictpun	4	Indeterminate	367	303-438
Cypcar	1	Indeterminate	457	
Catlat	1	Male	378	
"	1	Female	548	
"	2	Indeterminate	506	459-552
Catdis	1	Indeterminate	280	
Cudei Diversion				
Ictpun	12	Indeterminate	487	363-661
Cypcar	4	Indeterminate	461	450-485
Catlat	1	Indeterminate	552	
Catdis	1	Indeterminate	280	
Gilrob	1	Indeterminate	294	
Xyrtex	6	Male	413	397-430
"	2	Female	406	372-439
"	10	Indeterminate	334	200-463
Ptyluc	1	Female	754	

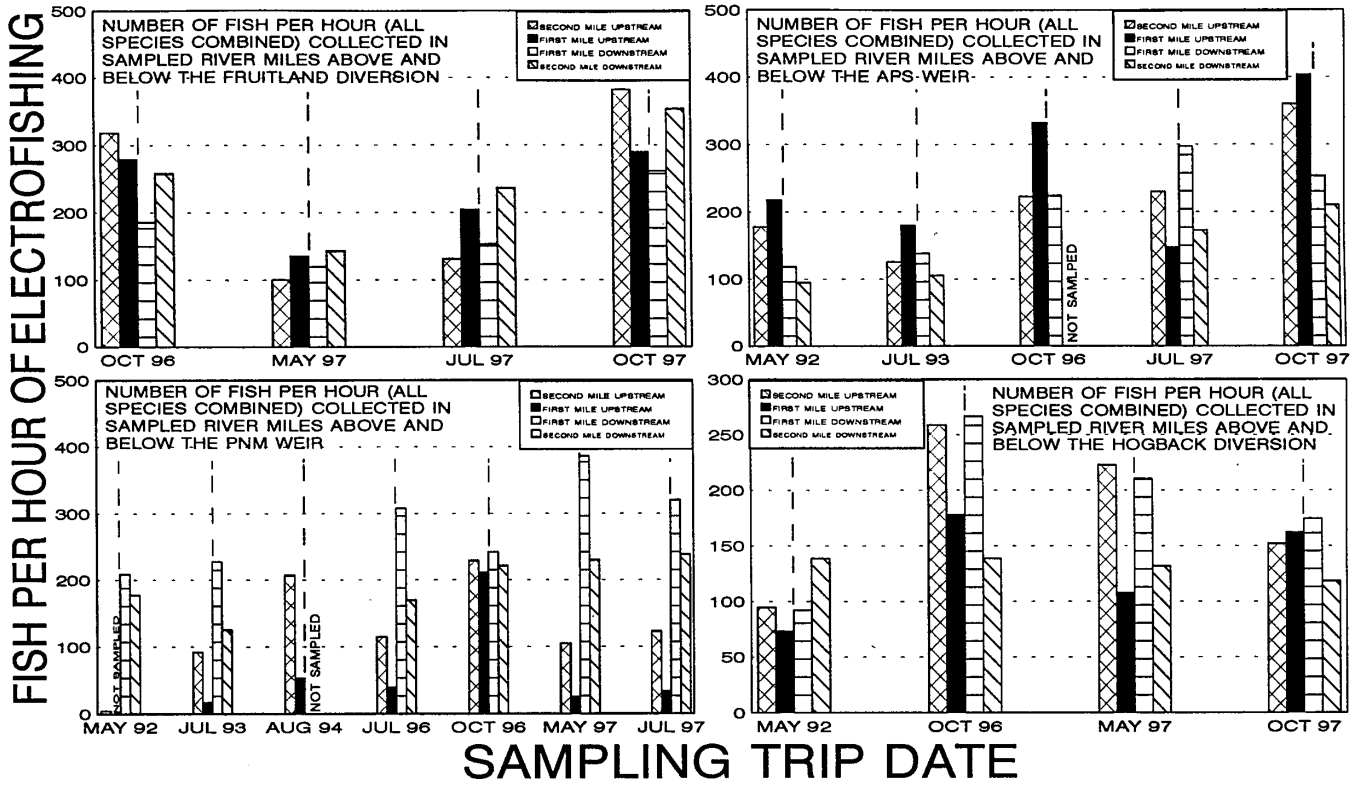


Figure 76. Number of fish per hour of electrofishing, all species combined, collected in the two river miles immediately upstream and immediately downstream of four of the five major instream diversion structures in the San Juan River, for all adult fish community monitoring trips, 1992-1997, on which the given four-mile sections of river were sampled. Dashed lines indicate the location of the diversion structure.

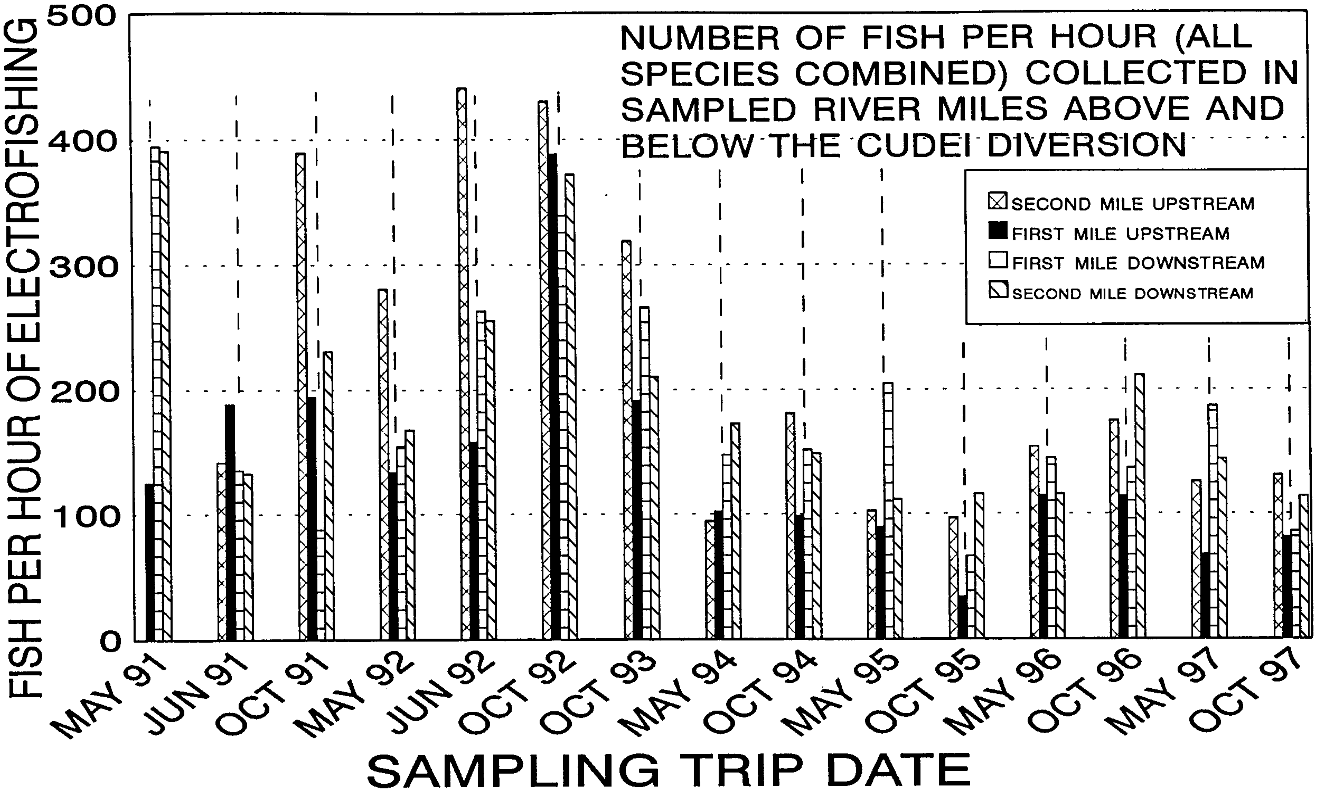


Figure 77. Number of fish per hour of electrofishing, all species combined, collected in the two river miles immediately upstream and immediately downstream of the Cudei Diversion (RM 142.0), for all adult fish community monitoring trips on which this four-mile section of river was sampled. Dashed lines indicate the location of Cudei Diversion.

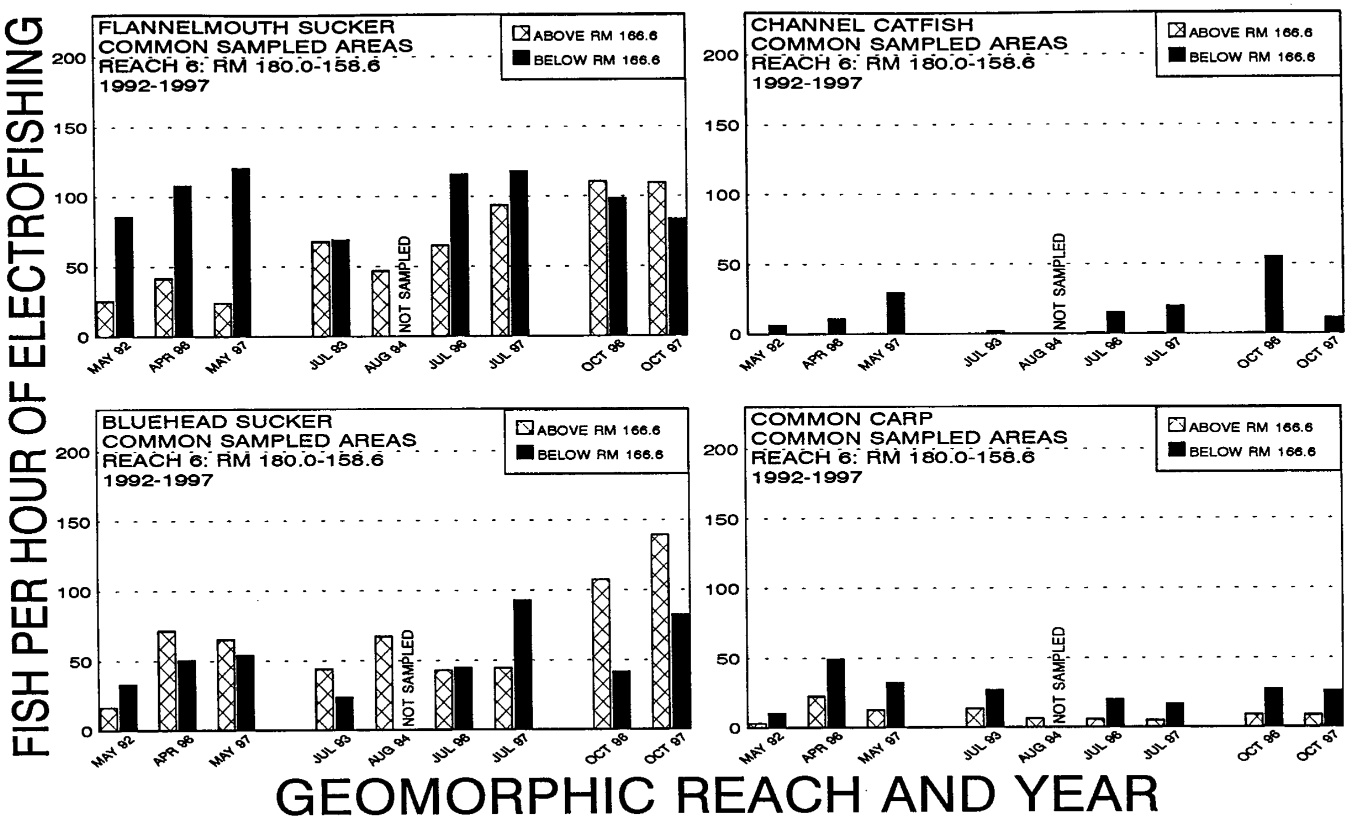


Figure 78. Number of fish per hour of electrofishing in Reach 6, up- and downstream of the PNM Weir (RM 166.6), for four of the six most abundant fish species collected on adult fish community monitoring trips, 1992-1997.

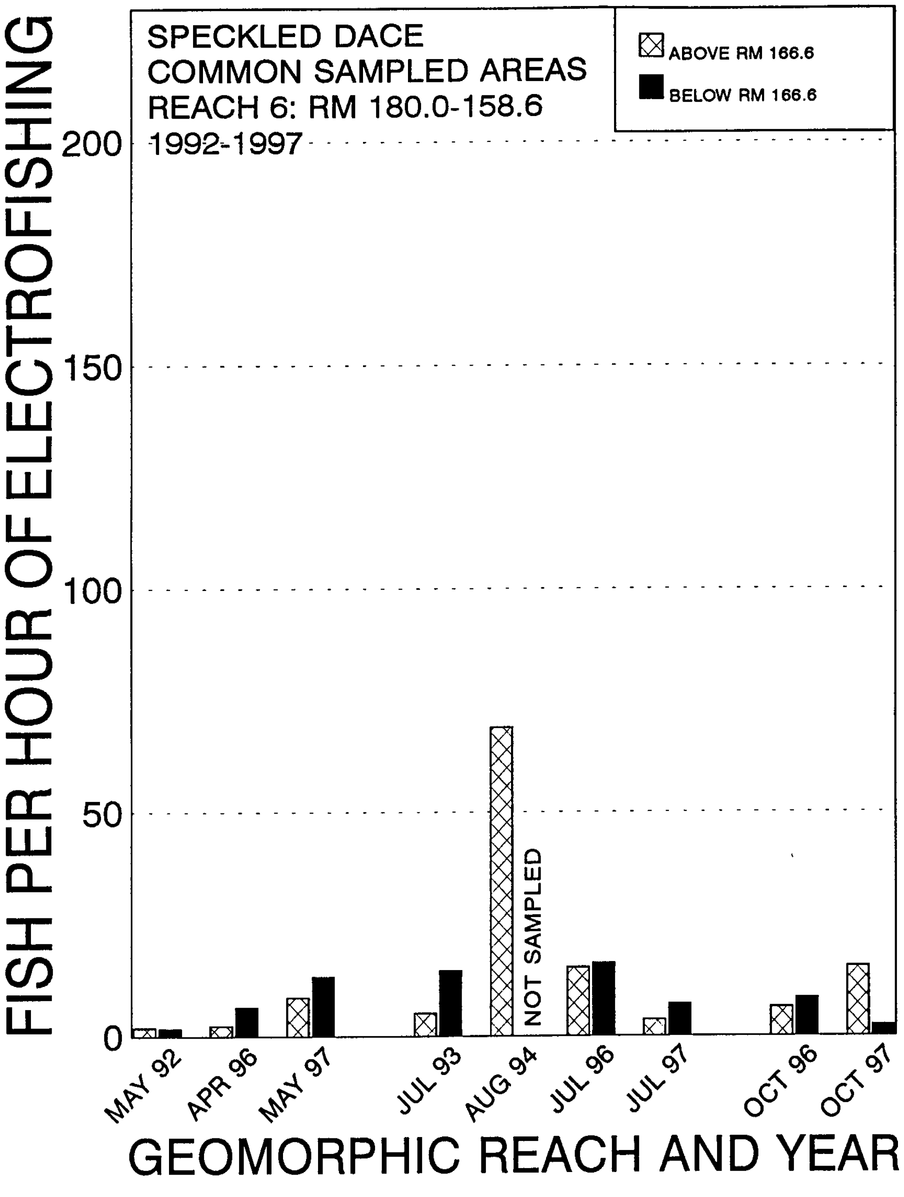


Figure 79. Number of fish per hour of electrofishing in Reach 6,up- and downstream of the PNM Weir (RM 166.6), for speckled dace collected on adult fish community monitoring trips, 1992-1997.

tagged in this same relative location to instream diversions, it is not surprising that more tagged native suckers would have passed these structures.

Very low numbers of recaptures with FLOY-tagged fish make any definite statements about the relative ability of one species to pass a certain diversion as opposed to other species impossible to make. Downstream of RM 166.6, where all four common large-bodied fishes coexist in large numbers, passage of the three diversion structures (both up- and downstream) by large adults of all four species appears to be possible, at least at ceratin flows and operational scenarios. Likewise, upstream of RM 166.6, where predominately native suckers exist, passage of the Fruitland Diversion (both up- and downstream) by large adult suckers also appears to be possible, at least at certain flows and operational scenarios. The PNM Weir appears to be a different story, however. Only flannelmouth sucker have been documented to successfully negotiate the PNM Weir, either up- or downstream during our study. The PNM Weir acts as a barrier to large-scale colonization of upstream reaches by common nonnative fish species.

The stacking-up phenomenon observed at the PNM, Hogback, and Cudei diversions is, at least in part, due to the presence of a “dead zone” immediately upstream of these three structures. Due to either their positions in the river channel (i.e., being on the inside bends in the river channel; Hogback and Cudei) or the sheer volume of water they back up (PNM Weir), these three structures have large sediment deposits immediately upstream of them that cause the river to be very nonproductive and CPUE of fish species to be very low. In the case of the PNM Weir, this dead zone stretches for almost a mile upstream of the structure. In addition, the PNM Weir appears to act as a movement barrier to upstream fish passage. Upstream movements of native suckers during spawning seasons (late spring through early summer) would cause higher numbers of these species to appear downstream of the structure, while native suckers in the dead zone immediately upstream of the diversion would tend to move upstream in search of clean cobble substrates over which to spawn. This same stacking-up phenomenon has been observed during the spring and summer at two sites in the Gunnison River: 1) downstream of the Hartland Diversion (approximately 3 RM upstream of Delta, CO; B. Burdick pers. comm.), and 2) downstream of the Redlands Diversion Dam and the recently-opened Redlands Fishway that provides selective upstream passage around this structure (2.3 RM upstream of the Gunnison-Colorado River confluence in Grand Junction, CO; Burdick In Prep.).

At present, the effect of instream diversions on wild endangered fishes appears to be negligible. There are no wild populations of either razorback sucker or roundtail chub presently in the river and wild Colorado pikeminnow generally occur downstream of all five major diversions. However, with the recent augmentation efforts of both razorback sucker and Colorado pikeminnow in reaches farther upstream, the impact of these diversions becomes more of a concern. Data already exist that juvenile Colorado pikeminnow become entrained in Cudei canal shortly after stocking. However, this is the only diversion that has been studied to date. Entrainment of stocked, early life stage fish would almost undoubtedly occur in other diversion canals (and possibly pumps) if hatchery fish were stocked upstream of them. The issue of instream diversions and their effect on endangered fish (particularly stocked fish) will become more of an issue as augmentation efforts and efforts to expand the range of these species into upstream areas increase.

While adult monitoring did provide some preliminary data about fish passage related to San Juan River instream diversions, the data was of limited usefulness. By trying to answer questions about all diversions over a wide range of trips, the amount of information gained on any particular diversion was very limited. The broad-based sampling approach used on adult monitoring trips was, simply, not intensive enough. In the future, to truly understand the relationships between a given structure and the surrounding fish community, diversion structures should be studied individually with many more sampling trips taking place in a much shorter amount of time. This would allow for more recaptures of tagged fish and a tighter determination of what flows and operational scenarios allow successful passage of a structure. In addition, questions such as whether or not fish are being entrained in canals and pumps associated with diversions, whether or not passage through headgates structures is possible, and the effect that diversion repair operations (on non-permanent structures such as Fruitland and Hogback diversions) have on the surrounding fish and benthic communities could be addressed.

CONCLUSIONS/MANAGEMENT IMPLICATIONS

- Study Objective met? Partially

- All diversions passed, both up- and downstream by flannelmouth sucker, and most diversions by other species as well
  - Only flannelmouth sucker passed PNM Weir in either direction
  - Fish moving upstream past diversion structures are generally larger than those moving downstream past diversions

- PNM Weir acts as a barrier to large-scale upstream colonization by common nonnative fish species
  - Common nonnative fishes greatly reduced in number or absent upstream of the PNM Weir
    - Of 1,712 channel catfish collected in Reach 6 between 1991 and 1997, only ten (0.6%) were collected upstream of the PNM Weir
    - Common carp CPUE was always at least 50% less upstream of the PNM Weir than it was downstream of this structure
    - Red shiner were never collected upstream of the PNM Weir during this study
  - Common native fishes abundant in Reach 6 both up- and downstream of PNM Weir

- At present, effect of instream diversions on populations of wild, endangered fishes appears to be minimal, because they mostly exist downstream of these structures
  - As augmentation and efforts to expand range of endangered fishes move farther upstream, the effects of instream diversions will have to be more closely examined

- Adult monitoring studies are too broad-based to answer specific questions about any given diversion or its effects on the fish community
  - Very few FLOY-tagged fish were recaptured
  - Impossible to determine specific flows or operational scenarios at which any given diversion was passable by a given fish species

- Future studies should be much more intensive and specific to a particular diversion

- By the finalization of this report, plans to modify or improve fish passage at the following diversion structures will be underway:
  - Selective fish passage structure to be designed and installed at the PNM Weir
  - Hogback Diversion to be fitted with a permanent diversion structure which includes a fish ladder on the face of the dam
  - Cudei Diversion to be removed from river and water for areas currently irrigated by the Cudei Canal to be piped under the river from the existing Hogback Canal
  - It is recommended that future evaluation of fish passage at instream diversions should concentrate on:
    - Evaluating the effectiveness of changes made to PNM Weir and Hogback Diversion
    - Determining whether fish passage at the APS Weir and Fruitland Diversion are a problem
    - Entrainment of native fishes in diversion canals

CHAPTER 5: UPSTREAM MOVEMENTS OF LACUSTRINE PREDATORY FISHES AND RARE FISHES FROM LAKE POWELL

- Objective 5: Monitor the upstream movement of lacustrine predatory fish species and rare fish species from Lake Powell. Determine potential negative impacts of lacustrine predatory fish species on the native fish community in the San Juan River.

INTRODUCTION

By the early 1990's, the lower San Juan River had been identified as a very important nursery area for young Colorado pikeminnow (Buntjer et al. 1993, 1994, Lashmett 1993, 1994, and 1995, Archer et al. 1995, 1996, Platania 1996). The immigration of large, predatory, lacustrine fish from Lake Powell in this section of river combined with the already high numbers of red shiner, common carp, and channel catfish already present in the river was a point of great concern, because the presence of large numbers of these nonnative predatory fishes can literally turn nursery habitats into lethal traps for larval and juvenile native fish (Mueller et al. 1998).

Adult Colorado pikeminnow and razorback sucker were also known to occupy the San Juan River-Lake Powell interface area (Platania 1990). With the formation of the waterfall at RM 0.0 in the late 1980's adult endangered fish in the San Juan River Arm of Lake Powell were precluded from moving back upstream into the river. Stocked razorback sucker had also been documented to move downstream into Lake Powell after being stocked in upstream areas of the river. It was unknown whether these rare fishes in Lake Powell would move back upstream into the San Juan River once the waterfall was inundated.

METHODS

Electrofishing was used to monitor the movement of lacustrine predatory fish species from Lake Powell into the lower San Juan River. Stomach samples were taken from nonnative predatory fish to establish the food habits of these species in riverine environments and try to assess their impact on the native fish community in the lower San Juan River.

Electrofishing, radio telemetry (Ryden 2000), and sonic telemetry (G. Mueller, pers. comm.; Mueller and Marsh 1998) were also used to examine the movements of stocked razorback sucker between the San Juan River and Lake Powell.

RESULTS

Lacustrine Predators

Before 1995, no predatory lacustrine fishes (i.e., walleye and striped bass) were collected during adult monitoring trips. After the inundation of the waterfall at RM 0.0 in spring 1995, three lacustrine fishes were collected that hadn’t previously been seen during our study. These included 65 walleye and 51 striped bass (Table 12). The most upstream collection of walleye during our study was at RM 108.3, while striped bass were collected as far upstream as RM 91.2. However, the large majority of both of these species were collected in the canyon-bound reaches downstream of Mexican Hat, UT (RM 53.0; Table 59).

In 1995 and 1996, all walleye and striped bass collected were large fish (Table 59, Figure 80). Walleye averaged 521 mm TL (n = 13 of 26 measured) in 1995 and 517 mm TL (n = 28 of 30 measured) in 1996. Striped bass averaged 561 mm TL (n = 7 of 34 measured) in 1995 and 566 mm TL (n = 16 of 17 measured) in 1996. Numbers of walleye collected in 1997 dropped to only nine fish. Walleye collected in 1997 were smaller (mean TL = 362 mm, range 220-505 mm) than in 1995 and 1996 (mean TL = 521, range 407-646 mm; and 517 mm, range 420-634 mm, respectively; Table 59, Figure 80). No striped bass were observed or collected in 1997 (Table 59). Both walleye and striped bass have been documented to prey upon native flannelmouth sucker as well as early life stage nonnative channel catfish (Brooks et al. 2000).

The lower San Juan River ($\leq$ RM 53.0) showed an increase in the number of nonnative fish collected relative to the number of native fishes collected there in 1995 and 1996 (Figure 81). In addition, the number of different nonnative species present in the lower river has increased since the inundation of the waterfall at RM 0.0 in 1995. The influx of lacustrine species from Lake Powell in 1995 was accompanied by a rise in abundance of common nonnative species in the lower river (Figure 81). Numbers of largemouth bass in the lower San Juan River (below RM 53.0) were higher during the August 1995 and June 1996 sampling than at any other time when the lower river was sampled (Table 59, Figure 82). In addition, in August and October 1995, the largest number of largemouth bass captured during any two consecutive trips (30) were collected (Table 59). Over half of these (16) were collected from RM 52-11. Channel catfish, common carp, and red shiner abundance also showed a spike in the Reach 1 and the lower portion of Reach 2 in August 1995 compared to previous years (Figures 41, 56, and 71).

Native fishes of any species were far less abundant in electrofishing collections downstream of Slickhorn Canyon (RM 17.7) in 1996 and 1997 collections, than in previous years (Figure 81).

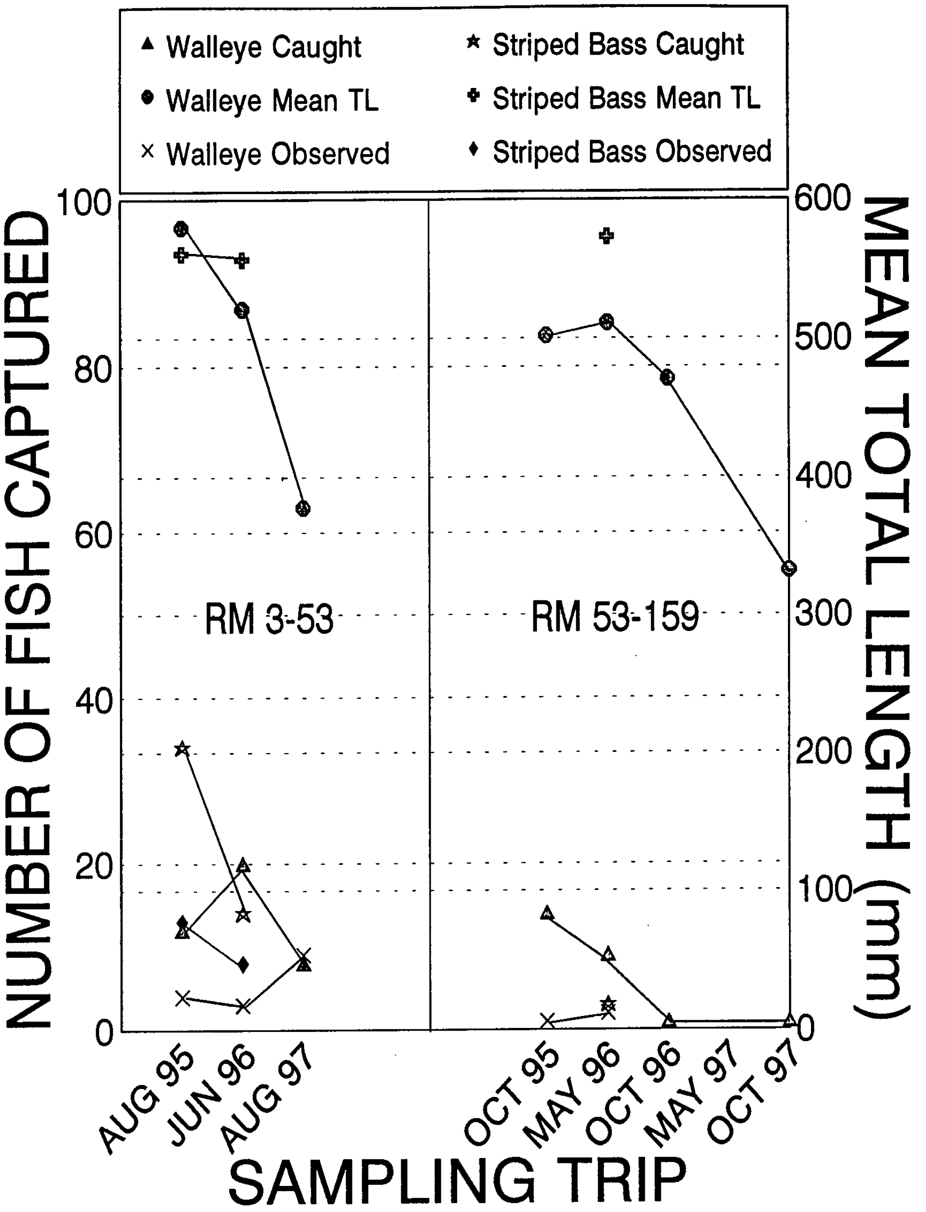


Figure 80. Total numbers and total lengths (in millimeters) of walleye and striped bass collected from the San Juan River between August 1995 and October 1997. Data are partitioned to show river miles that were sampled during each adult fish community monitoring trip.

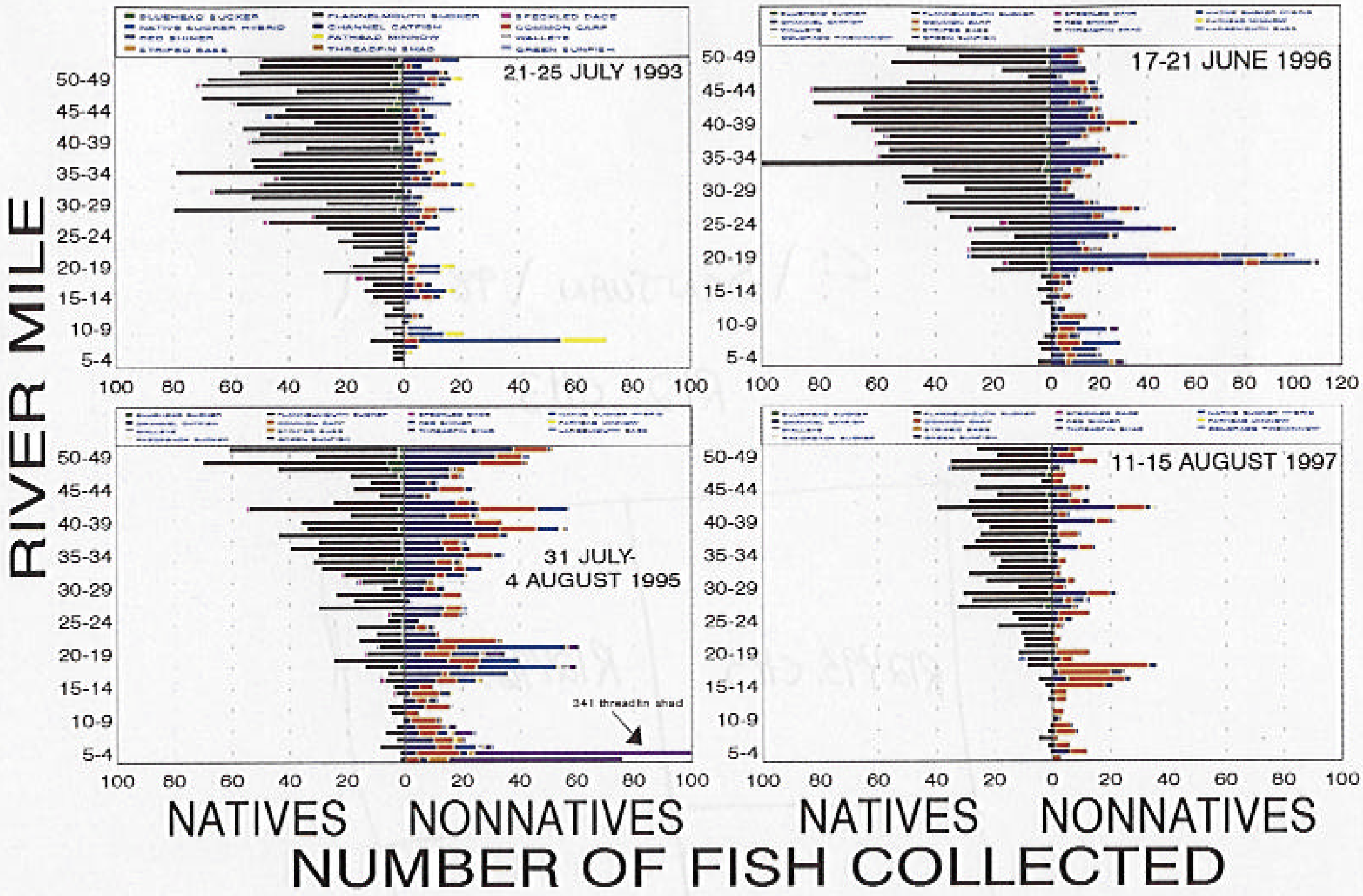


Figure 81. Number of native vs. nonnative fish, by species, on four adult fish community monitoring trips in the lower San Juan River (RM 53.0-3.0), 1993-1997.

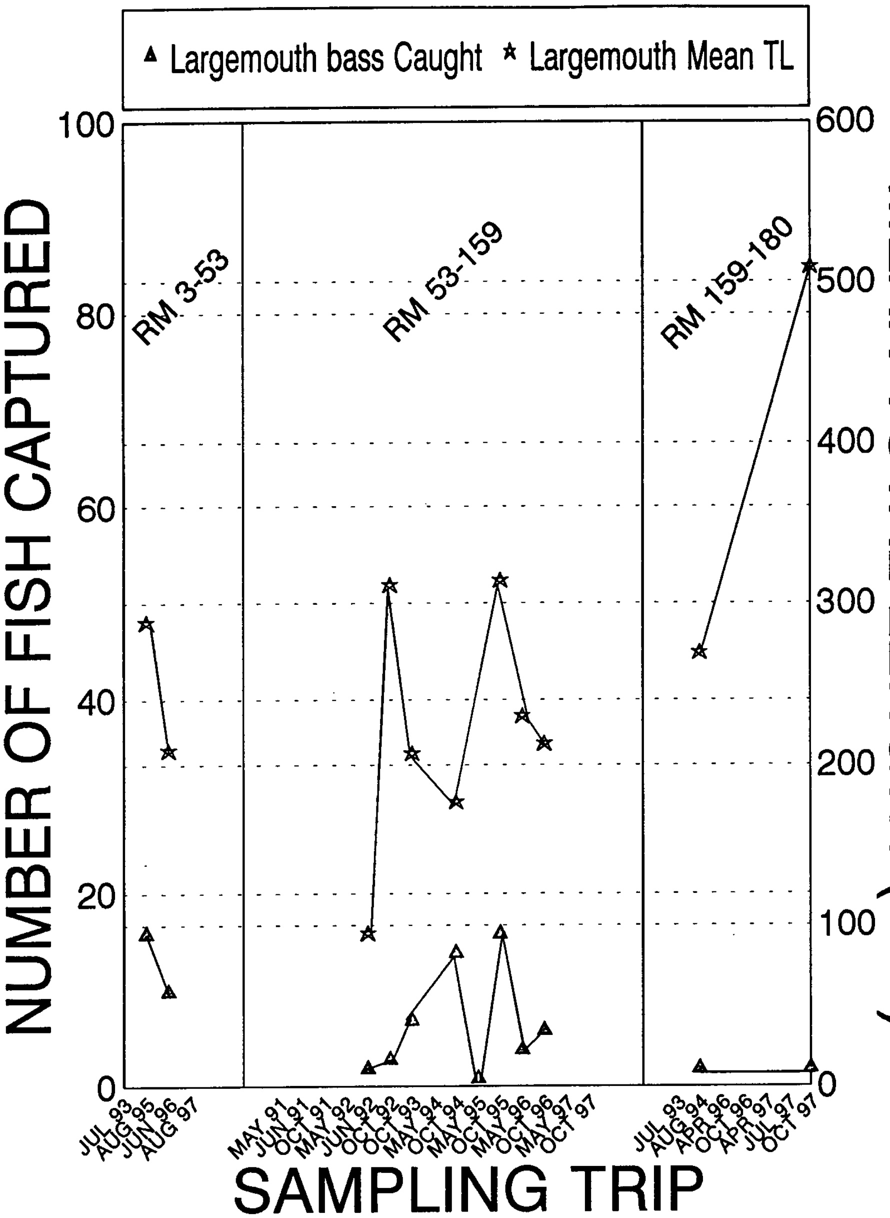


Figure 82. Total numbers and total lengths (in millimeters) of largemouth bass collected from the San Juan River between May 1991 and October 1997. Data are partitioned to show river miles that were sampled during each adult fish community monitoring trip.

Rare Native Fish

Little direct evidence of rare native fish movement, either to or from Lake Powell, was gathered during the adult monitoring study. The UDWR (Lake Powell-Wahweap office) stocked a total of 130 razorback sucker into Lake Powell at Piute Farms Marina (RM 0.0) on 8 and 15 August 1995, 65 each day (Ryden 1997). One of these fish (417 mm TL; sex indeterminate), stocked 8 August 1995, was recaptured 287 days later (21 May 1996; 456 mm TL) at RM 58.0. In addition, several razorback sucker that had been equipped with sonic tags and released in the San Juan River arm of Lake Powell as part of another study were contacted in the lower San Juan River (G. Mueller pers. comm.). One of these was contacted on an adult monitoring trip on 20 June 1996, at RM 20.9.

DISCUSSION

Lacustrine Predators

Between 1991 and May 1995, no predatory lacustrine fishes were collected during adult monitoring trips. The presence of a large ($\geq$ 10 meters high at some flows) waterfall where the San Juan River entered Lake Powell created an impassable barrier and kept lacustrine predators from moving upstream into the river and impacting populations of native fishes. In spring 1995, the water level in Lake Powell rose enough that the waterfall became completely inundated. In response to the inundation of this waterfall walleye, striped bass, and threadfin shad along with numerous species already present in the river (i.e., common carp, largemouth bass, channel catfish, and red shiner) moved upstream from the inflow area and invaded the lower San Juan River.

Walleye and striped bass may have invaded the San Juan River in search of spawning areas. Walleye and striped bass both spawn from late winter through late spring and prefer areas with current and sufficient oxygenation (Pflieger 1975, McGinnis 1984). Such habitats can be found in the lower San Juan River, especially upstream of RM 17.7, and it is conceivable that these species migrated upstream to spawn in the spring of 1995 after the waterfall was inundated. Another explanation would be that these two species followed schools of threadfin shad up the river. During our study, the upstream limit of threadfin shad distribution was Government Rapid (RM 20.2). Therefore, walleye and striped bass moving upstream past Government Rapid would need to find an alternate food source other than threadfin shad. The small size-class native suckers and channel catfish in the lower San Juan River provided an ample food supply. Stomach samples taken from these lacustrine predators in the San Juan River documented that both walleye and striped bass are preying on native flannelmouth suckers, and walleye are also preying upon immature channel catfish (Brooks et al. 2000).

The presence of only large, sexually mature adult fish in 1995 and 1996 indicates that spawning may be the primary reason for the presence of these two fish species in the river. The decline in numbers of walleye collected to nine fish in 1997 may be somewhat deceiving. Flows during the August 1997 sampling trip were almost three times as high as during the previous year's sampling trip. This would have almost certainly made fish harder to collect during the 1997 trip. In addition, during this trip numerous walleye were observed that were not netted, so it is clear that electrofishing crews were not netting all the walleye that were in the river at the time. Thus, numbers of walleye in the lower river may well have been as high in 1997 as in 1996. No striped bass were observed or collected in 1997. The absence of this species in 1997 collections may be due to the inherent high turbidity in the San Juan River which may have caused adult stripers to retreat to Lake Powell, or killed them outright.

Walleye collected in 1997 were considerably smaller than those collected in 1995 and 1996. Comparing the size of walleye collected in the San Juan River in 1997 with growth rates reported for walleye in Utah Lake (Sigler and Miller 1963), it seems possible that at least the smaller individuals (≤ 220 mm TL) collected in 1997 may have been spawned in the San Juan River. Although the San Juan River does not constitute prime walleye habitat, a few of these individuals, if they were indeed spawned in the river, may become resident. Striped bass (n = 27) were collected in the San Juan River in Utah (most upstream collection = RM 100.3) as late as 1989, but were concentrated mostly in the lower 14.5 RM (Platania 1990). Walleye (n = 3) were also collected in the lower 14.5 RM of the San Juan River after the waterfall was present (Platania 1990).

Nonnative predatory fish species greatly outnumber even the common native fishes in the lower river and prey on the most abundant of these, flannelmouth sucker. The large concentration of nonnative predators and competitors in the river downstream of Mexican Hat is problematic for early life stages of Colorado pikeminnow, which are spawned in much smaller numbers than other native species, and are known to use the ephemeral backwaters in the lower San Juan River and upper few miles of Lake Powell. If nonnative fish species in the lower San Juan River are having an impact on native fish species that are abundant (i.e., flannelmouth sucker) then they are almost certainly having more of an impact on rare fish species in this section of the river. The two juvenile Colorado pikeminnow collected in the lower river in the summer of 1996 (Table 36) were both collected in main channel habitats in the lower river identical to those from which both walleye and striped bass have been collected (i.e., shoreline habitats near vegetated banks with sand substrates, up to 3 ft. deep). Additionally, stocked juvenile Colorado pikeminnow have been also recaptured from these same types of habitats. The use of these types of habitats places juvenile Colorado pikeminnow, both wild and stocked, in harms way when lacustrine predators are present. Given the rarity of Colorado pikeminnow in the San Juan River, the loss of even a single individual to predation would have more impact on the Colorado pikeminnow population than the loss of numerous common fish such as flannelmouth sucker would have to that population.

It may be that the presence of the waterfall where the San Juan River enters Lake Powell is actually a boon to native fishes in this heavily modified river system. While early life stage native fish that moved over the waterfall and into the lake ran a high risk of being eaten by predatory lake fishes, the waterfall, when it was present, protected native fishes in the San Juan River from the nonnative predators and competitors currently invading the river from Lake Powell.

Rare Native Fish

Ryden and Ahlm (1996) stated that while the waterfall at the San Juan River-Lake Powell confluence keeps lacustrine predators from invading the river, it also keeps rare native fishes in Lake Powell (either resident individuals or those that have moved downstream from the San Juan River into Lake Powell) from moving upstream into the San Juan River. Evidence from several studies indicate that there are rare native fishes residing in the Lake Powell inflow area and that they will move upstream into the San Juan River when the waterfall is not present. An adult Colorado pikeminnow (615 mm TL) captured in the San Juan River arm of Lake Powell (RM 0.0) and implanted with a Carlin tag on 7 April 1987 was recaptured 154 days later (8 September 1987; 632 mm TL) at RM 79.0, near Bluff, UT (Platania 1990). Two large, juvenile Colorado pikeminnow (363 and 432 mm TL) were captured in the lower 12.9 RM of the San Juan River in the summer of 1996, after the inundation of the waterfall. These two Colorado pikeminnow had not been seen before this time despite intensive sampling in the lower river for five years, and have not been recaptured since. While it can't be proven these fish had an association with Lake Powell, the close proximity of these fish to Lake Powell at the time of their capture suggests that they may have moved upstream from the lake after the inundation of the falls and may, once again, be residing in the lake inflow area.

Adult razorback sucker were reported to occur in the San Juan River arm of Lake Powell prior to 1987 (Platania 1990). However, the first verified collections of razorback sucker in the San Juan River arm of Lake Powell occurred between 20 March and 3 April 1987. During that time, 12 individual adult razorback sucker (8 ripe males, and 4 gravid females) were collected along the south shore of Lake Powell near the concrete boat ramp at Piute Farms Marina (Platania 1990). Six of these fish were subsequently recaptured at this site despite being transported up to one mile away from their initial point of capture (Platania 1990). From 28 to 30 March 1988, ten adult razorback sucker (5 of which were reproductively active) were collected at this same site. Six of these ten fish were recaptures from 1987 sampling (Platania 1990). This annual concentration of reproductively active adult razorback sucker at this site suggests a spawning aggregation or staging prior to moving to another spawning site (Platania 1990). Only a single wild razorback sucker, a tuberculate male (571 mm TL; 25 April 1988), was captured in the San Juan River near Bluff, UT prior to the stockings of razorback sucker which began in 1994 (Platania 1990, Ryden 1997). This fish may have been an individual from the Lake Powell inflow area that had moved upstream.

Since the late 1980's only one razorback sucker has been collected in the San Juan River arm of Lake Powell. This fish, a 427 mm TL male, originally stocked at RM 79.6 on 27 October 1994, was recaptured by a U.S. Bureau of Reclamation crew 140 days later, at RM (-)8.5 in Lake Powell. This fish had moved 88.1 RM downstream, over the waterfall (Table 12; Mueller and Wydoski 1995).

The contact with a sonic tagged fish and the electrofishing collection during the adult monitoring study prove that stocked razorback sucker will move upstream from Lake Powell into the San Juan River, as well as downstream from river to lake.

Another razorback sucker, stocked at RM 79.6 (251 mm TL) on 29 March 1994 was recaptured on 12 August 1997 at RM 38.7 (502 mm TL). This fish was subsequently recaptured 51 days later at RM 130.8, 91.1 miles upstream (Ryden 2000). While this particular individual was not associated with Lake Powell in any way, its long upstream movement in a very short amount of time, coupled with the migration of the stocked individuals from Lake Powell upstream into the San Juan River indicates that adult razorback sucker are capable of moving upstream from Lake Powell into the San Juan River at will. However, it is unknown whether any of the adult razorback sucker captured in Lake Powell in the early 1980's would be compelled to make such an upstream migration. Perhaps the wild male razorback sucker captured near Bluff, UT in 1988 was an adult that had moved upstream from the San Juan River arm of Lake Powell.

It is important to reiterate here that the waterfall at RM 0.0 is not a natural feature. It was formed by the filling to capacity (early 1980's) and subsequent drop in lake level (ca. 1987) of Lake Powell. During the filling of Lake Powell, huge sediment deposits (approximately 60 ft. deep in some places) were laid down in the lower 14 RM of the San Juan River (Ryden and Ahlm 1996). The drop in lake level caused the river to cut a new course through the sediment accumulation and flow over a sandstone outcrop creating the waterfall (> 10 m at some flows).

At present, it is unknown whether the waterfall will reappear the next time Lake Powell recedes. Depending on where the new channel forms in such a situation, the waterfall may never reappear. More likely however, is that the waterfall will be an unpredictable feature that is present at times and absent at others. Lake levels from year to year, the amount of sediment deposited between periods when Lake Powell recedes, and the exact location of the new river channel when the lake again recedes are all unpredictable factors that will effect the future influence of this unique feature on the San Juan River fish community. Due to its very nature, the presence of the waterfall cannot truly be managed for in a selective manner and, thus, used to reliably deter the upstream movement of lacustrine predatory fishes. The greatest benefit to both wild and stocked razorback sucker and Colorado pikeminnow entering or already present in the San Juan River arm of Lake Powell can be achieved by keeping the waterfall inundated, allowing free access to the San Juan River. Keeping the level of Lake Powell high enough to inundate this feature is the only possible management option available (i.e., you cannot manage for the presence of the waterfall, only for its absence).

CONCLUSIONS/MANAGEMENT IMPLICATIONS

- Study Objective met? Yes

- Lacustrine predators are invading the San Juan River from Lake Powell when the waterfall at RM 0.0 is not present
  - Walleye and Striped bass documented to prey on juvenile native flannelmouth sucker and YOY nonnative channel catfish
  - Common nonnative species (channel catfish, common carp, red shiner, largemouth bass) also invading river from Lake Powell when waterfall is absent
  - Nonnative predators and competitors greatly outnumber even common native species in Reach 1
    - Gauntlet of nonnative fishes likely detrimental to survival of YOY Colorado pikeminnow in Reach 1

- Very little direct evidence of the movement of rare fishes to or from Lake Powell during our study
  - Two razorback sucker from other studies contacted in lower river during our study
    - One recaptured electrofishing
    - One contacted via sonic telemetry
  - Evidence from other studies indicates both wild Colorado pikeminnow and wild and stocked razorback sucker will move upstream from Lake Powell into the San Juan River. Stocked razorback sucker also documented moving from the San Juan River into Lake Powell

- Waterfall at RM 0.0, when it is present, represents a management conundrum
  - Keeps nonnative predators and competitors from entering Lake Powell, thus somewhat protecting early life stage Colorado pikeminnow found in Reach 1
  - Keeps any rare native fishes already in Lake Powell isolated from riverine populations
  - When Lake Powell recedes again, the waterfall may or may not be present, depending on where the new channel is cut. The presence of the waterfall cannot be managed for in a selective manner (i.e., you cannot manage for the presence of the waterfall, only for its absence). The greatest benefit to rare fishes entering or already in Lake Powell would come from keeping the waterfall inundated.

RELATIONSHIP OF THE ADULT MONITORING STUDY TO THE SAN JUAN RIVER RECOVERY IMPLEMENTATION PROGRAM

The adult monitoring study was begun before the development and inception of the LRP. Therefore, the adult monitoring study does not specifically address one task or section of the LRP. However, this study does address, at least in part, several tasks and milestones identified in the LRP. Sections of the LRP addressed by information collected during the adult monitoring study include:

Task 5.2.5.1-Determine habitat requirements for different life stages of endangered and other native fishes: Radio telemetry of captured Colorado pikeminnow adults identified spawning areas and led to in-depth studies by other researchers (see Bliesner and Lamarra 2000, Miller 2000) that determined the parameters of utilized spawning areas. Electrofishing data for flannelmouth sucker, bluehead sucker, and speckled dace was coupled with habitat mapping data (Holden 1999) to identify associations between peaks in species distribution and availability of specific habitat types (i.e., riffles, runs). This information was used during the development of flow recommendations.

Task 5.2.5.2-Identify subreaches that provide habitats for the different life stages of endangered and other native fishes: Electrofishing and radio telemetry data identified a specific sub-reach being utilized by adult Colorado pikeminnow, as well as determining that roundtail chub were probably not a viable component of the San Juan River fish community. In addition, electrofishing data identified the distribution by life stage of flannelmouth sucker and bluehead sucker as well as indicating the downstream limits of occurrence for both bluehead sucker and speckled dace.

Task 5.2.9.1 (Milestone)-Identify actions designed to accomplish non-flow physical habitat modification for endangered fish species: Electrofishing and radio telemetry data identified instream diversion structures as probable barriers to upstream movements by Colorado pikeminnow (and other native fishes), suggesting that alteration or removal of these features would be beneficial to Colorado pikeminnow.

Task 5.3.1-Identify and characterize the historic and current fish species community structure: Electrofishing data characterized the main-channel fish community that currently exists in the San Juan River.

Task 5.3.2-Determine the status and trends of resident fish species: Seven years of adult monitoring helped identify the relative status and trends of both common and rare native and nonnative fishes in the San Juan River.

Task 5.3.5-Characterize the fish species community response to different annual flow regimes: Data collected on the four common large-bodied fishes over the seven-year research period allowed conclusions to be drawn about the effects of research flows on the San Juan River fish community. This information was used in the development of flow recommendations.

Task 5.4.1-Characterize the distribution and abundance of nonnative fish species: Electrofishing data identified the distribution and abundance by life stage of channel catfish, common carp, and other less common large-bodied nonnative fishes in the river's main channel habitats. In addition, it identified the upstream distribution limits of channel catfish and red shiner, the downstream distribution limit of white sucker, and the extent to which nonnative predatory fishes from Lake Powell had invaded the San Juan River.

Task 5.4.2-Identify and characterize habitats used by nonnative fish species and effects on native fish species habitat use: Electrofishing data for channel catfish and common carp was coupled with habitat mapping data (Holden 1999) to identify associations between peaks in species distribution and availability of specific habitat types (i.e., riffles, runs). This information was used during the development of flow recommendations. Examination of dietary overlap between native and nonnative species and the sheer amount of biomass represented by nonnative fish species strongly suggest that their impact on native fish species habitat use through competition and predation is considerable.

Task 5.4.4-Characterize the response of nonnative fish species to varying flow regimes and recommend flows that minimize or eliminate interactions with native fish species: Data collected on the four common large-bodied fishes over the seven-year research period allowed conclusions to be drawn about the effects of research flows on the San Juan River fish community. This information was used in the development of flow recommendations.

In addition, the information gathered on adult monitoring trips was used, in part, to help develop flow recommendations (Task 5.2.7 {Milestone}), fish collected on adult monitoring trips provided the samples used by crews addressing fish health issues (Task 5.3.4), tissue samples collected from Colorado pikeminnow and roundtail chub by adult monitoring crews were used to address genetic questions (Task 5.3.7.1), sampling methods developed during adult monitoring trips were used to develop sampling protocols for the long term monitoring program (Task 5.3.9), fish collected on adult monitoring trips provided a large percentage of the samples used to ascertain the impact of nonnative fishes on their native counterparts (Task 5.4.3), and information collected over the seven years of adult monitoring studies is archived in the San Juan River standardized database (Task 5.7.2).

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APPENDIX A. Summary data for all life stages of roundtail chub and YOY and age-1 Colorado pikeminnow collected on other research projects in the San Juan River between 1987 and 1997. These fish were used in conjunction with collections from adult monitoring trips to draw conclusions about the distribution and abundance of these species in the San Juan River. Therefore, they are included here for reference purposes.

Table A-1. Summary data for roundtail chub collected in the San Juan River during other studies between 1987 and 1997.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1987							
05/20/87	Platania 1990	--[a]	--	---	Seine	90.50[b]	BA[c]
08/06/87	UNM Unpublished Data	--	--	---	Unknown	162.80	--
08/09/87	Platania 1990	65.8	--	---	Seine	139.95[b]	BA
08/12/87	Platania 1990	41	--	---	Seine	126.55[b]	BA
09/09/87	Platania 1990	--	--	---	Seine	88.15[b]	MC
10/05/87	Platania 1990	31	--	---	Seine	176.00[b]	SC
10/07/87	Platania 1990	41	--	---	Seine	152.80[b]	BA
10/08/87	Platania 1990	47.5	--	---	Seine	141.80[b]	SC
10/09/87	UNM Unpublished Data	--	--	---	Unknown	138.70	--
10/09/87	UNM Unpublished Data	--	--	---	Unknown	135.10	--
10/11/87	Platania 1990	163	--	---	EL[d]	121.80[b]	MC/RU
1988							
08/01/88	Platania 1990	42.7	32.2	---	Seine	121.20[b]	SC
1989							
03/28/89	Platania 1990	183.2	--	---	EL	142.01[b]	MC/SH
05/07/89	Platania 1990	129.4	96.5	---	EL	176.00[b]	MC/SH
05/09/89	Platania 1990	208.5	--	---	EL	132.69[b]	MC/ED
1990							
No roundtail chub collected							
1991							
08/02/91	UNM Unpublished Data	--	7	---	Seine	118.90	--
08/03/91	UNM Unpublished Data	--	19	---	Seine	107.30	--
08/03/91	UNM Unpublished Data	--	12	---	Seine	105.10	--
09/18/91	Buntjer et al. 1993	59	43	---	Seine	123.10	BA
09/18/91	UNM Unpublished Data	--	42	---	Seine	122.20	--
09/18/91	UNM Unpublished Data	--	40	---	Seine	114.70	--
09/19/91	Buntjer et al. 1993	62	42	---	Seine	108.30	BA
09/19/91	Buntjer et al. 1993	40	--	---	Seine	108.30	BA
09/19/91	Buntjer et al. 1993	35	25	---	Seine	108.30	BA

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[a] Data not recorded

[b] These RM's are calculated approximations converted from the old system of RM reported in Platania (1990) to the new system of RM adopted by the SJR-RIP in 1992. Mancos = collected in the Mancos River within 0.8 miles of the San Juan River confluence (RM 122.6).

[c] BA = Backwater, MC = Main channel, SC = side channel, RU = Run, SH = Shoreline, ED = Eddy, FT = Flow-through (a "trickle"-fed side channel), EM = Embayment, PO = Pool

[d] EL = collected by electrofishing

Table A-1, continued. Summary data for roundtail chub collected in the San Juan River during other studies between 1987 and 1997.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1991, continued							
09/19/91	Buntjer et al. 1993	35	--	---	Seine	108.30	BA
09/19/91	UNM Unpublished Data	--	--	---	Seine	108.30	BA
1992							
03/27/92	UNM Unpublished Data	--	--	---	Unknown	186.50	--
07/16/92	Buntjer et al. 1993	22	19	---	Seine	120.70	BA
07/16/92	Buntjer et al. 1993	--	14	---	Seine	120.70	BA
07/29/92	Buntjer et al. 1993	34	30	---	Seine	122.10	FT
07/29/92	Buntjer et al. 1993	23	20	---	Seine	122.10	FT
07/29/92	Buntjer et al. 1993	23	21	---	Seine	122.10	FT
07/29/92	Buntjer et al. 1993	26	--	---	Seine	122.10	FT
08/13/92	Buntjer et al. 1993	39	29	---	Seine	121.80	BA
08/13/92	Buntjer et al. 1993	39	28	---	Seine	120.30	BA
08/13/92	Buntjer et al. 1993	28	21	---	Seine	117.90	FT
08/13/92	Buntjer et al. 1993	28	20	---	Seine	114.60	BA
08/13/92	Buntjer et al. 1993	23	18	---	Seine	114.60	BA
08/13/92	Buntjer et al. 1993	31	--	---	Seine	114.60	BA
08/13/92	Buntjer et al. 1993	31	--	---	Seine	114.60	BA
08/13/92	Buntjer et al. 1993	34	26	---	Seine	114.60	BA
08/13/92	Buntjer et al. 1993	27	21	---	Seine	113.40	BA
08/13/92	Buntjer et al. 1993	35	25	---	Seine	113.40	BA
09/16/92	Buntjer et al. 1993	108	81	---	Seine	129.50	RU
09/16/92	Buntjer et al. 1993	132	--	---	Seine	127.20	EM
1993							
03/31/93	Buntjer et al. 1994	43	35	---	Seine	130.20	PO
08/04/93	Buntjer et al. 1994	--	12	---	Seine	129.20	--
08/05/93	Buntjer et al. 1994	--	11	---	Seine	119.80	--
08/05/93	Buntjer et al. 1994	--	13	---	Seine	107.50	BA
08/06/93	Buntjer et al. 1994	--	10	---	Seine	90.00	--
08/06/93	Buntjer et al. 1994	15	12	---	Seine	79.20	BA
08/06/93	Buntjer et al. 1994	15	11	---	Seine	79.20	BA
08/06/93	Buntjer et al. 1994	--	11	---	Seine	74.70	--
08/06/93	Buntjer et al. 1994	24	18	---	Seine	73.90	BA
08/07/93	Buntjer et al. 1994	--	10	---	Seine	67.70	--
08/07/93	Buntjer et al. 1994	--	11	---	Seine	67.70	--
08/07/93	Buntjer et al. 1994	13	11	---	Seine	40.00	BA
08/08/93	Buntjer et al. 1994	15	12	---	Seine	38.70	BA
08/08/93	Buntjer et al. 1994	13	11	---	Seine	12.80	BA
09/08/93	Gido and Propst 1994	--	--	---	Seine	128.60	SC
09/08/93	Gido and Propst 1994	--	--	---	Seine	128.60	SC
09/15/93	Buntjer et al. 1994	32	27	---	Seine	120.80	PO
09/16/93	Buntjer et al. 1994	--	41	---	Seine	113.50	--
09/16/93	Buntjer et al. 1994	--	24	---	Seine	113.50	--
09/16/93	Buntjer et al. 1994	--	22	---	Seine	110.00	--
09/16/93	Buntjer et al. 1994	--	34	---	Seine	103.80	--
09/16/93	Buntjer et al. 1994	25	19	---	Seine	100.40	BA

Table A-1, continued. Summary data for roundtail chub collected in the San Juan River during other studies between 1987 and 1997.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1993, continued							
09/16/93	Buntjer et al. 1994	(4 fish @ 21-25 mm SL)			Seine	97.80	BA
09/16/93	Buntjer et al. 1994	30	25	---	Seine	97.80	BA
09/17/93	Buntjer et al. 1994	33	26	---	Seine	87.80	BA
09/17/93	Buntjer et al. 1994	37	28	---	Seine	82.80	BA
09/17/93	Buntjer et al. 1994	--	25	---	Seine	74.50	--
09/18/93	Buntjer et al. 1994	--	23	---	Seine	53.10	--
09/18/93	Buntjer et al. 1994	26	19	---	Seine	44.20	BA
09/20/93	Buntjer et al. 1994	28	22	---	Seine	11.80	BA
09/28/93	Gido and Propst 1994	--	--	---	Seine	87.40	SC
11/02/93	Gido and Propst 1994	--	--	---	Seine	134.90	SC
11/02/93	Gido and Propst 1994	--	--	---	Seine	134.90	SC
11/02/93	Gido and Propst 1994	--	--	---	Seine	87.40	SC
11/02/93	Gido and Propst 1994	--	--	---	Seine	87.40	SC
11/02/93	Gido and Propst 1994	--	--	---	Seine	87.40	SC
1994							
04/02/94	Gido and Propst 1995	--	--	---	Seine	87.40	SC
07/19/94	Archer et al. 1995	83	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	75	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	80	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	68	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	87	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	77	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	74	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	73	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	60	--	---	Seine	122.70	BA
07/19/94	Archer et al. 1995	86	--	---	Seine	119.40	BA
07/19/94	Archer et al. 1995	78	--	---	Seine	119.40	BA
07/27/94	Gido and Propst 1995	--	--	---	Seine	134.90	SC
07/28/94	Archer et al. 1995	141	--	---	Seine	122.70	MC
07/28/94	Archer et al. 1995	95	--	---	Seine	122.70	MC
07/28/94	Archer et al. 1995	100	--	---	Seine	122.70	MC
07/28/94	Archer et al. 1995	90	--	---	Seine	122.70	MC
08/04/94	Archer et al. 1995	101	--	---	Seine	122.70	MC
08/04/94	Archer et al. 1995	78	--	---	Seine	122.70	MC
09/01/94	Gido and Propst 1995	--	--	---	Seine	134.90	SC
09/07/94	Archer et al. 1995	117	--	---	Seine	142.90	BA
09/07/94	Archer et al. 1995	104	--	---	Seine	122.70	BA
11/05/94	Gido and Propst 1995	--	--	---	Seine	134.90	SC
1995							
08/28/95	Buntjer & Brooks 1996	--	--	---	Hoop Net	128.20	SC
09/13/95	UNM Unpublished Data	--	24	---	Seine	115.10	--
09/13/95	UNM Unpublished Data	--	29	---	Seine	114.00	--
09/14/95	Archer et al. 1996	55	--	---	Seine	114.90	BA
09/16/95	Archer et al. 1996	30	--	---	Seine	68.60	BA
10/ /95	Propst Unpublished	--	--	---	Seine	Unknown	MC/SH

Table A-1, continued. Summary data for roundtail chub collected in the San Juan River during other studies between 1987 and 1997.

Date	Source Report	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1997							
07/26/97	UNM Unpublished Data	--	21	---	Drift Net	55.00	--
08/14/97	NMGF Unpublished Data	--	18	---	Seine	120.85	MC/SH
08/14/97	NMGF Unpublished Data	--	16	---	Seine	120.60	SC
08/14/97	NMGF Unpublished Data	--	19	---	Seine	117.50	MC/SH
08/14/97	NMGF Unpublished Data	--	15	---	Seine	117.20	SC
08/14/97	NMGF Unpublished Data	--	19	---	Seine	117.20	SC
08/14/97	NMGF Unpublished Data	--	--	---	Seine	117.20	SC
08/14/97	NMGF Unpublished Data	--	--	---	Seine	117.20	SC
08/15/97	NMGF Unpublished Data	--	18	---	Seine	117.20	MC/SH
08/15/97	NMGF Unpublished Data	--	15	---	Seine	117.20	MC/SH
08/15/97	NMGF Unpublished Data	--	21	---	Seine	110.30	SC
08/15/97	NMGF Unpublished Data	--	30	---	Seine	110.30	SC
08/15/97	NMGF Unpublished Data	--	--	---	Seine	110.30	SC
08/15/97	NMGF Unpublished Data	--	22	---	Seine	109.10	MC/SH
08/15/97	NMGF Unpublished Data	--	24	---	Seine	109.05	SC
08/15/97	NMGF Unpublished Data	--	20	---	Seine	107.30	MC/SH
08/15/97	NMGF Unpublished Data	--	26	---	Seine	107.30	MC/SH
08/16/97	NMGF Unpublished Data	--	19	---	Seine	99.05	SC
08/16/97	NMGF Unpublished Data	--	21	---	Seine	99.05	SC
08/16/97	NMGF Unpublished Data	--	18	---	Seine	96.95	SC
08/17/97	NMGF Unpublished Data	--	21	---	Seine	83.80	SC
08/17/97	NMGF Unpublished Data	--	18	---	Seine	83.80	SC
08/18/97	NMGF Unpublished Data	--	26	---	Seine	71.40	MC/SH
09/30/97	NMGF Unpublished Data	--	33	---	Seine	148.30	SC
10/01/97	NMGF Unpublished Data	--	44	---	Seine	134.60	SC
10/02/97	NMGF Unpublished Data	--	41	---	Seine	127.65	MC/SH
10/02/97	NMGF Unpublished Data	--	36	---	Seine	126.60	SC
10/03/97	NMGF Unpublished Data	--	28	---	Seine	122.10	SC
10/03/97	NMGF Unpublished Data	--	28	---	Seine	120.70	SC
10/03/97	NMGF Unpublished Data	--	38	---	Seine	120.70	SC
10/03/97	NMGF Unpublished Data	--	--	---	Seine	120.70	SC
10/03/97	NMGF Unpublished Data	--	43	---	Seine	120.70	MC/SH
10/03/97	NMGF Unpublished Data	--	37	---	Seine	120.70	MC/SH
10/04/97	NMGF Unpublished Data	--	24	---	Seine	111.10	MC/SH
10/04/97	NMGF Unpublished Data	--	34	---	Seine	111.10	MC/SH
10/04/97	NMGF Unpublished Data	--	--	---	Seine	111.10	MC/SH
10/04/97	NMGF Unpublished Data	--	--	---	Seine	111.10	MC/SH
10/04/97	NMGF Unpublished Data	--	--	---	Seine	111.10	MC/SH
10/05/97	NMGF Unpublished Data	--	26	---	Seine	103.20	SC
10/05/97	NMGF Unpublished Data	--	38	---	Seine	103.20	SC
10/05/97	NMGF Unpublished Data	--	--	---	Seine	103.20	SC
10/06/97	NMGF Unpublished Data	--	26	---	Seine	83.80	SC

Table A-2. Summary data for young-of-the-year and age-1 Colorado pikeminnow collected in the San Juan River between 1987 and 1997.

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

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

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

Table A-2, continued.

Date	Source Report	Year Class	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1990								
09/09/90	Buntjer et al. 1993	1990	34	--	---	Seine	8.3	Backwater
1991								
No young-of-the-year Colorado pikeminnow collected								
1992								
09/22/92	Lashmett 1993	1992	--	20	---	Seine	-6.3	Backwater/LP[b]
1993								
07/26/93	Buntjer et al. 1994	1993	--	9.2	---	Drift Net	53.0	Shoreline/MC
07/27/93	Buntjer et al. 1994	1993	--	9.2	---	Drift Net	53.0	Shoreline/MC
08/30/93	Lashmett 1994	1993	--	17	---	Seine	2.9	Backwater
08/31/93	Lashmett 1994	1993	24.4	19	---	Seine	-0.4	Backwater/LP
09/01/93	Lashmett 1994	1993	18.5	18	---	Seine	1.8	Backwater
09/01/93	Lashmett 1994	1993	32.6	26	---	Seine	1.2	Backwater
09/02/93	Lashmett 1994	1993	18.5	15	---	Seine	-0.2	Backwater/LP
09/02/93	Lashmett 1994	1993	19.4	15	---	Seine	-0.1	Backwater/LP
09/02/93	Lashmett 1994	1993	21.4	17	---	Seine	-0.1	Backwater/LP
10/10/93	Lashmett 1994	1993	--	26	---	Seine	0.0	Backwater
10/12/93	Lashmett 1994	1993	--	24	---	Seine	3.0	Backwater
10/12/93	Lashmett 1994	1993	--	23	---	Seine	1.0	Backwater
10/12/93	Lashmett 1994	1993	--	29	---	Seine	1.0	Backwater
1994								
04/07/94	Archer et al. 1995	1993	59	--	---	Seine	11.6	Backwater
04/07/94	Archer et al. 1995	1993	49	--	---	Seine	11.6	Backwater
08/04/94	Archer et al. 1995	1994	14	--	---	Seine	122.6	Backwater
08/12/94	Archer et al. 1995	1994	19	--	---	Seine	25.2	Backwater
08/13/94	Archer et al. 1995	1994	17	--	---	Seine	9.8	Backwater
08/13/94	Archer et al. 1995	1994	21	--	---	Seine	9.8	Backwater
09/24/94	Archer et al. 1995	1994	24	--	---	Seine	8.0	Backwater

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

Table A-2, continued.

Date	Source Report	Year Class	TL (mm)	SL (mm)	WT (grams)	Gear	River Mile	Habitat
1995								
08/02/95	Platania 1996	1995	9.5	8.9	---	Drift Net	53.0	Shoreline/MC
08/03/95	Platania 1996	1995	9	8.1	---	Drift Net	53.0	Shoreline/MC
08/14/95	Archer et al. 1996[c]	1995	--	14	---	Seine	23.8	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	12	---	Seine	22.3	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	12	---	Seine	22.2	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	14	---	Seine	21.0	Backwater
08/15/95	Archer et al. 1996[c]	1995	--	11	---	Seine	12.8	Backwater
1996								
08/02/96	Platania 1997	1996	8.6	8.1	---	Drift Net	128.0	Shoreline/MC
1997								
No young-of-the-year Colorado pikeminnow collected								

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

APPENDIX B. Sample sizes used for various statistical tests performed on the four common, large-bodied fishes. Results of statistical tests are presented in the body of this report.

Table B-1. Sample sizes (n =) used for various statistical tests on flannelmouth sucker, bluehead sucker, channel catfish, and common carp collected in Reach 6 (RM 180.0-158.6).

	Statistical Test For:			
Trip/Species	CPUE	MEAN TL	MEAN WT	CONDITION FACTOR
May 1992:				
flannelmouth sucker	456	192	192	192
bluehead sucker	214	84	84	84
channel catfish	22	11	11	11
common carp	58	22	21	21
April 1996:				
flannelmouth sucker	1214	647	202	201
bluehead sucker	1324	352	213	213
channel catfish	60	9	9	9
common carp	599	116	117	116
May 1997:				
flannelmouth sucker	818	521	152	152
bluehead sucker	833	356	143	143
channel catfish	152	24	19	19
common carp	271	69	63	63
July 1993:				
flannelmouth sucker	881	143	128	128
bluehead sucker	469	97	89	89
channel catfish	9	6	6	6
common carp	237	235	232	232
July 1996:				
flannelmouth sucker	1263	234	233	233
bluehead sucker	649	140	138	138
channel catfish	93	14	14	14
common carp	168	28	28	28
July 1997:				
flannelmouth sucker	1118	601	234	233
bluehead sucker	663	242	144	144
channel catfish	72	29	28	28
common carp	99	13	13	13
October 1996:				
flannelmouth sucker	1021	779	no fish were weighed this trip	
bluehead sucker	738	453	“	”
channel catfish	276	272	“	”
common carp	181	172	“	”
October 1997:				
flannelmouth sucker	1132	348	244	244
bluehead sucker	1318	469	421	420
channel catfish	56	17	16	16
common carp	189	19	18	18

Table B-2. Sample sizes (n =) used for various statistical tests on flannelmouth sucker, bluehead sucker, channel catfish, and common carp collected on May trips in the core sampling area (RM 158.6-53.0).

	Statistical Test For:			
Trip/Species	CPUE	MEAN TL	MEAN WT	CONDITION FACTOR
May 1991:				
flannelmouth sucker	2556	639	633	623
bluehead sucker	401	93	92	89
channel catfish	479	112	111	108
common carp	768	83	83	83
May 1992:				
flannelmouth sucker	7461	1557	1546	1546
bluehead sucker	1334	377	377	377
channel catfish	1028	636	629	629
common carp	678	141	138	138
May 1994:				
flannelmouth sucker	9982	1846	1826	1824
bluehead sucker	806	160	158	158
channel catfish	642	84	84	84
common carp	447	119	119	117
May 1995:				
flannelmouth sucker	6837	1245	1238	1238
bluehead sucker	599	118	117	117
channel catfish	1110	326	323	321
common carp	572	192	191	191
May 1996:				
flannelmouth sucker	10157	1936	1928	1925
bluehead sucker	1364	236	232	231
channel catfish	1436	257	258	256
common carp	1637	292	290	290
May 1997:				
flannelmouth sucker	4393	1379	1007	1007
bluehead sucker	887	501	287	287
channel catfish	2732	522	515	514
common carp	2337	507	501	289

Table B-3. Sample sizes (n =) used for various statistical tests on flannelmouth sucker, bluehead sucker, channel catfish, and common carp collected on October trips in the core sampling area (RM 158.6-53.0).

	Statistical Test For:			
Trip/Species	CPUE	MEAN TL	MEAN WT	CONDITION FACTOR
October 1991:				
flannelmouth sucker	11461	2204	2185	2183
bluehead sucker	2186	421	414	413
channel catfish	2289	479	476	475
common carp	1871	290	283	283
October 1992:				
flannelmouth sucker	15423	2997	2967	2960
bluehead sucker	2882	575	570	569
channel catfish	4058	825	815	814
common carp	1441	279	276	276
October 1993:				
flannelmouth sucker	11720	2611	2585	2582
bluehead sucker	2305	469	465	464
channel catfish	1565	407	404	402
common carp	1211	256	254	253
October 1994:				
flannelmouth sucker	11803	2283	2266	2264
bluehead sucker	1696	322	317	316
channel catfish	2096	432	430	429
common carp	755	225	224	224
October 1995				
flannelmouth sucker	10419	1910	1901	1897
bluehead sucker	1964	341	339	339
channel catfish	3471	893	890	888
common carp	1448	504	505	503
October 1996:				
flannelmouth sucker	7567	2323	1542	1542
bluehead sucker	1405	795	340	340
channel catfish	3596	963	690	688
common carp	2277	638	468	467
October 1997:				
flannelmouth sucker	6211	1715	1608	1608
bluehead sucker	1307	819	768	766
channel catfish	2651	556	554	553
common carp	1689	353	351	351

Table B-4. Sample sizes (n =) used for various statistical tests on flannelmouth sucker, bluehead sucker, channel catfish, and common carp collected on June sampling trips (RM 158.6-76.4) and summer sampling trips (RM 53.0-2.9).

	Statistical Test For:			
Trip/Species	CPUE	MEAN TL	MEAN WT	CONDITION FACTOR
JUNE TRIPS (RM 158.6-76.4)				
June 1991:				
flannelmouth sucker	3664	706	695	695
bluehead sucker	726	154	151	151
channel catfish	637	143	142	142
common carp	1157	133	133	133
June 1992:				
flannelmouth sucker	10521	2866	2827	2826
bluehead sucker	2352	617	612	611
channel catfish	1326	699	688	688
common carp	1161	507	499	499
SUMMER TRIPS (RM 53.0-2.9)				
July 1993:				
flannelmouth sucker	1608	322	313	313
bluehead sucker	37	10	10	10
channel catfish	186	165	165	165
common carp	89	26	22	22
August 1995:				
flannelmouth sucker	1006	171	169	169
bluehead sucker	51	6	6	6
channel catfish	702	128	128	128
common carp	345	55	53	53
June 1996:				
flannelmouth sucker	1636	311	309	309
bluehead sucker	28	12	11	11
channel catfish	671	196	192	191
common carp	176	146	143	143
August 1997:				
flannelmouth sucker	772	136	136	136
bluehead sucker	24	6	6	6
channel catfish	156	32	32	32
common carp	272	41	41	41

APPENDIX C. Regression of CPUE (for the four most abundant large-bodied fish species combined) versus river flows (in CFS) on all standardized adult monitoring trips between 1991 and 1997.

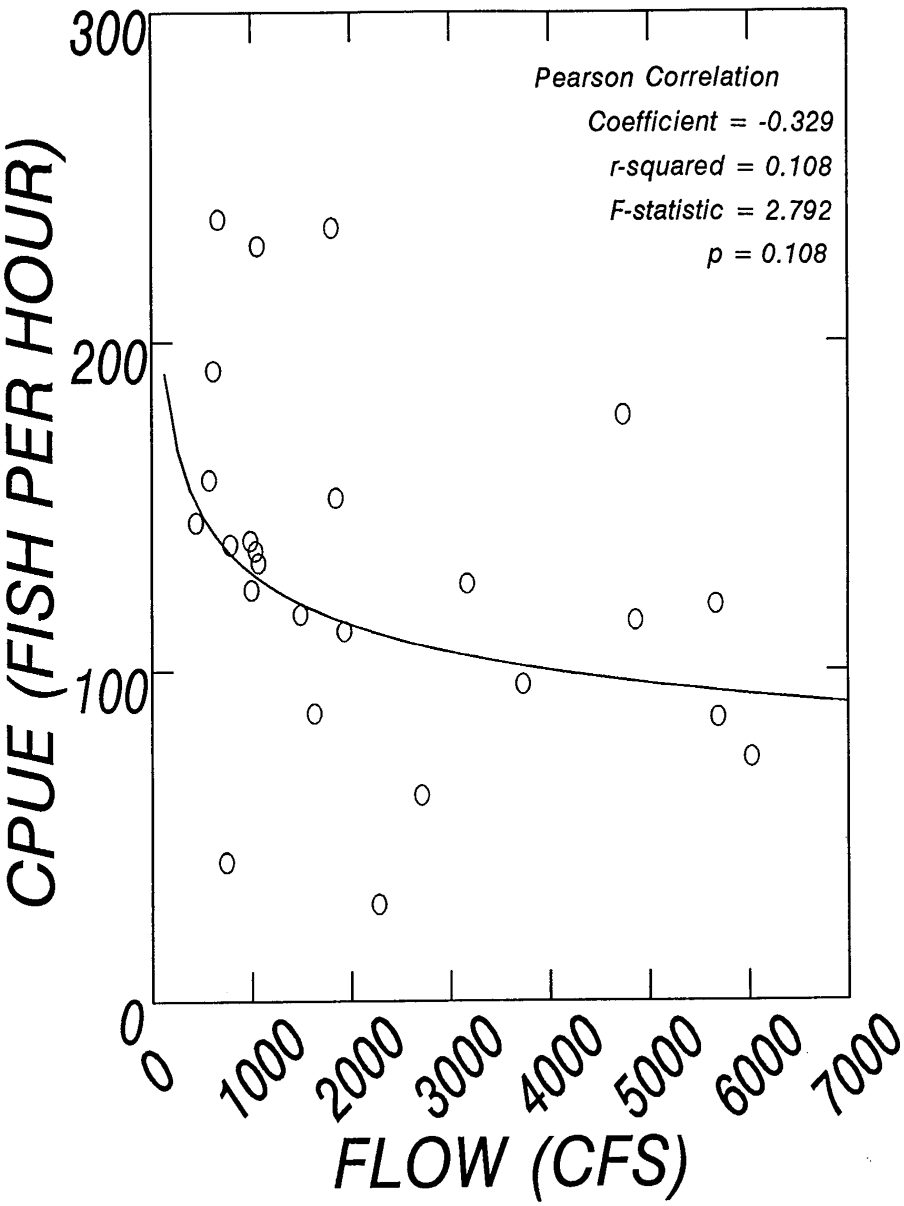

Figure C-1. Regression of CPUE (for flannelmouth sucker, bluehead sucker, channel catfish, and common carp combined) versus river flows (in CFS) for all standardized adult monitoring trips between 1991 and 1997. Each circle represents one trip.