DISTRIBUTION, ABUNDANCE, AND COMPOSITION OF FISHES IN BRIGHT ANGEL AND KANAB CREEKS, GRAND CANYON NATIONAL PARK, ARIZONA

by

Edward (Ted) Osgood Otis IV

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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ABSTRACT

Brown and rainbow trout perennially dominated Bright Angel Creek; native species (flannelmouth and bluehead suckers) generally occurred only during spawning (March and April-May, respectively) and initial rearing of juveniles (bluehead sucker only). Flannelmouth suckers spawned at depths between 20-40 cm, currents between 0.4-0.8 m/sec, and over loosely compacted substrates (gravel, rock). Speckled dace abundance had markedly decreased since previous investigations, possibly due to brown trout becoming the dominant predator in the stream.

Four native and 6 non-native species were taken in Kanab Creek; spawning was documented for bluehead sucker and speckled dace. Small bluehead suckers (<160 mm) were perennial residents below a barrier 6.2 km above the mouth. Larger individuals (>200 mm) were absent in winter, but spawned in the lower 3.2 km of the stream in April and early May. Bluehead suckers spawned in shallow waters (<25 cm), slow currents (<0.25 m/sec), and over loosely compacted substrates (pebble, gravel).

CHAPTER 1. INTRODUCTION

Justification

The Colorado River's native ichthyofauna is mostly endemic (Miller 1959, Minckley 1991), having adapted to the unique circumstances that made up the historic Colorado River ecosystem. The 438 kilometer (km) stretch of the Colorado River that flows through the Grand Canyon was once typical of the conditions that created this assemblage of "big river fishes." However, many physical and biological changes to the river since the turn of the century have severely impacted the canyon's native aquatic biota.

Miller (1959) reported 35 native fish species once inhabited the Colorado River drainage, 8 of these were indigenous to the Grand Canyon (Minckley 1991). Suttkus and Clemmer (1976) took 19 species from the Grand Canyon during 1970-1976; only 4 of these were native. Presently, only 5 native species remain in the Grand Canyon between Lakes Powell and Mead: humpback chub, *Gila cypha*; speckled dace, *Rhinichthys osculus*; flannelmouth sucker, *Catostomus latipinnis*; bluehead sucker, *Catostomus discobolus*; and razorback sucker, *Xyrauchen texanus* (Carothers and Brown 1991). The humpback chub and razorback sucker are federally listed as endangered. The status of the razorback sucker in the Grand Canyon is questionable; only a handful of relict individuals have been caught in the last 10 years.

The decline of native fish populations in the Colorado River system has been thoroughly documented (Holden and Stalnaker 1975, Carothers and Johnson 1983, Minckley 1991). Changes in habitat associated with the construction of hydroelectric dams is widely considered to be the primary cause of the decline (Minckley and Deacon 1968, Vanicek et al. 1970, Spofford et al. 1980). Since the closure of Glen Canyon dam in 1963, 3 of the canyon's 8 native species (Colorado River squawfish, *Ptychocheilus lucius*; roundtail chub, *Gila robusta*; and bonytail chub, *Gila elegans)* have been extirpated from the middle Colorado River in the Grand Canyon (Carothers and Brown 1991). Hamman (1982) and Marsh (1985) reported that water temperatures in the range currently prevalent below Glen Canyon dam may be unsuitable for successful incubation of the eggs from several native species (humpback chub, razorback sucker, bonytail chub, and Colorado squawfish).

Considerable effort has been extended to define the impacts on aquatic resources that have been caused by the Glen Canyon Dam. Field studies have focused primarily on the mainstem Colorado River (Holden and Stalnaker 1975, Minckley and Blinn 1976, Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987) and the Little Colorado River (Kaeding and Zimmerman 1983). These investigations continue under Glen Canyon Environmental Studies (GCES)- Phase II. Relatively little effort has been made to understand the dynamics of the small tributaries that enter the Colorado River in the Grand Canyon (but see Minckley 1978, Carothers and Minckley 1981, Usher et al. 1984). Aside from the Little Colorado River (LCR), which may offer the only spawning habitat for humpback chub in Grand Canyon (Kaeding and Zimmerman 1983, Maddux et al. 1987), the ecology of the tributaries is poorly understood.

Several major tributaries enter the Colorado River during its passage through the Grand Canyon. Some of these tributaries have been developed (e.g., Bright Angel Creek), but most are relatively pristine. One of these tributaries (the LCR) is essential to the preservation of the canyon's population of humpback chub (Suttkus and Clemmer 1976, Kaeding and Zimmerman 1983, Maddux et al. 1987, USFWS 1990); others also provide spawning habitats for native species (Maddux and Kepner 1988, Weiss 1993). Holden and Stalnaker (1975) concluded about the native fishes of the Colorado River- "Only those native species adapted to tributary streams (speckled dace, bluehead and flannelmouth suckers) are likely to survive."

My study was designed to collect baseline information on the seasonal abundance, distribution, and composition of fishes inhabiting 2 dissimilar tributaries in Grand Canyon (Bright Angel and Kanab Creeks). I conducted fish surveys in a quantitative and repeatable manner to facilitate comparison with future long term monitoring. A quantitative understanding of the fish populations occupying tributaries is essential to the goal of managing for the persistence of the canyon's native aquatic resources. These data should also facilitate management decisions, particularly on Bright Angel Creek which sustains high visitor use and an active sport fishery.

Field Schedule

Three planned surveys of fish populations on Bright Angel Creek were precluded by high flows and associated turbidity (Table 1). Limited access, bureaucracy, and the relative remoteness of my study sites made it difficult to schedule additional trips or to reschedule those that were compromised by weather.

Table 1. Summary of dates of surveys of fish population and aquatic habitat surveys in Bright Angel and Kanab Creeks, Grand Canyon National Park, January 1992-July 1993.

Creek	Date(s)	Trip Length	Activities
Bright Angel	1/7-9/92[1]	3	fish/habitat
Bright Angel	6/14-7/4/92	21	fish/habitat
Bright Angel	9/8-19/92[2]	12	fish/habitat
Bright Angel	10/27-30/92[2]	4	fish
Bright Angel	11/30-12/14/92	15	fish/habitat
Bright Angel	3/16-28/93[2]	13	fish/habitat
Bright Angel	6/12-21/93	10	fish/habitat
		Total 78	
Kanab	8/6-8/92	3	fish/habitat
Kanab	11/6-8/92	3	fish/habitat
Kanab	1/14-16/93[3]	3	fish/habitat
Kanab	4/21-5/7/93	17	fish/habitat
Kanab	6/25-27/93	3	fish/habitat
		Total 29	

[1] Electrofishing was used for fish sampling; all other periods on Bright Angel Creek I used underwater observation (snorkeling).

[2] Poor visibility precluded snorkel censusing of fish populations.

[3] High flows prevented seining of blocked reaches, as was done in all other periods.

Site Descriptions

Bright Angel Creek

Bright Angel Creek originates on the Kaibab Plateau of the north rim and drains an area of 262 km^2 (USGS 1989). It flows about 28 km before meeting the Colorado River near river mile (rm) 87 (Lat 36° 06' 11", Long 112° 05' 44"; Stevens 1983, USGS 1989; Figure 1). The creek has moderately high gradient, dropping an average of 80 m/km (USGS 1989). Numerous springs contribute to perennial flow, but Angel and Roaring Springs are the largest (Johnson and Sanderson 1968). Four perennial tributaries (Phantom, Ribbon, Wall, and Transept creeks) and 1 intermittent tributary (Manzanita Creek) also contribute to flow. The discharge from Bright Angel Creek averages 35 cubic feet/sec (cfs) (based on 49 years of records) and ranges from 13 - 501 cfs (USGS 1989).

My study area included the lower 14.3 km of stream below a 3-m waterfall that occurs about 500 m downstream of the bridge below B. Aikens residence (NPS pumphouse operator). This reach averaged about 5.4 m wide. Typically, more than 75% of available depths were < 40 cm, and few deep holes (> 1 m) were available. Current velocities were moderately high (> 50% were > 0.3 m/sec). Substrates were largely boulder, cobble, and gravel throughout the system, with cobble dominating (unpubl. data). Bright Angel Creek is 1 of 8 dolomitic tributaries on the Kaibab plateau that are characterized by high levels of calcium and magnesium and low amounts of sulfate, chlorides, and sodium (Cole and Kubly 1976). Water temperatures ranged from 5-21 C during this study.

Shoreline vegetation is relatively sparse near the confluence and is dominated by salt cedar, *Tamarix chinensis*; coyote willow, *Salix exigua*; arrow-weed, *Tessaria sericea;* and alkali golden bush, *Haplopappus acredenius* (Carothers and Minckley 1981). A few hundred meters upstream of the confluence, in the vicinity of the campground, low densities of cottonwood trees, *Populus fremontii* contribute to the riparian vegetation. About 7 km upstream, the canyon widens and dense vegetation (willows dominating) overhangs the stream in many places.

Kanab Creek

Kanab Creek originates on the Pausagunt Plateau in Kane County, Utah, and drains an area of 6,013 km^2 (Webb et al. 1991). It flows 105 km southward before entering the Colorado River at rm 143.5 (Lat 36 23' 40.2", Long 112 37' 43.6") in the Grand Canyon, Arizona (Stevens 1983, Figure 1). Kanab Creek averages about 16 m drop per km. Typical of many drainages, the greatest elevation change occurs in the headwaters; the lower 10 km can be characterized as low gradient and slow moving. Mean monthly discharge averages 6.8 cfs (Fredonia, AZ gauge 09403780), but flows can exceed 4,000 cfs during summer floods (USGS 1989).

I studied Kanab Creek from the confluence with the Colorado River to 10.0 km upstream. This portion averages about 5.2 m wide, and has a near equal ratio of pools (inclusive of runs and glides) to riffles. Typically, current velocities are < 0.3 m/sec, and more than 70% of the available depths are < 30 cm.

The sparse vegetation of the confluence area is mainly salt cedar and seep willow, *Baccharis salicifolia*. These species co-occur with Arizona grape, *Vitis arizonica*; and cattails, *Typha spp.* in upstream areas (Carothers and Minckley 1981). Kanab Creek has slow shallow waters and little riparian shading. These characteristics contribute to high summer water temperatures; temperatures ranged from 9 C in winter to 30 C in summer during this study. Kanab Creek is high in sulfate, low in nitrogen and phosphorous, and moderately high in silica (Cole and Kubly 1976).

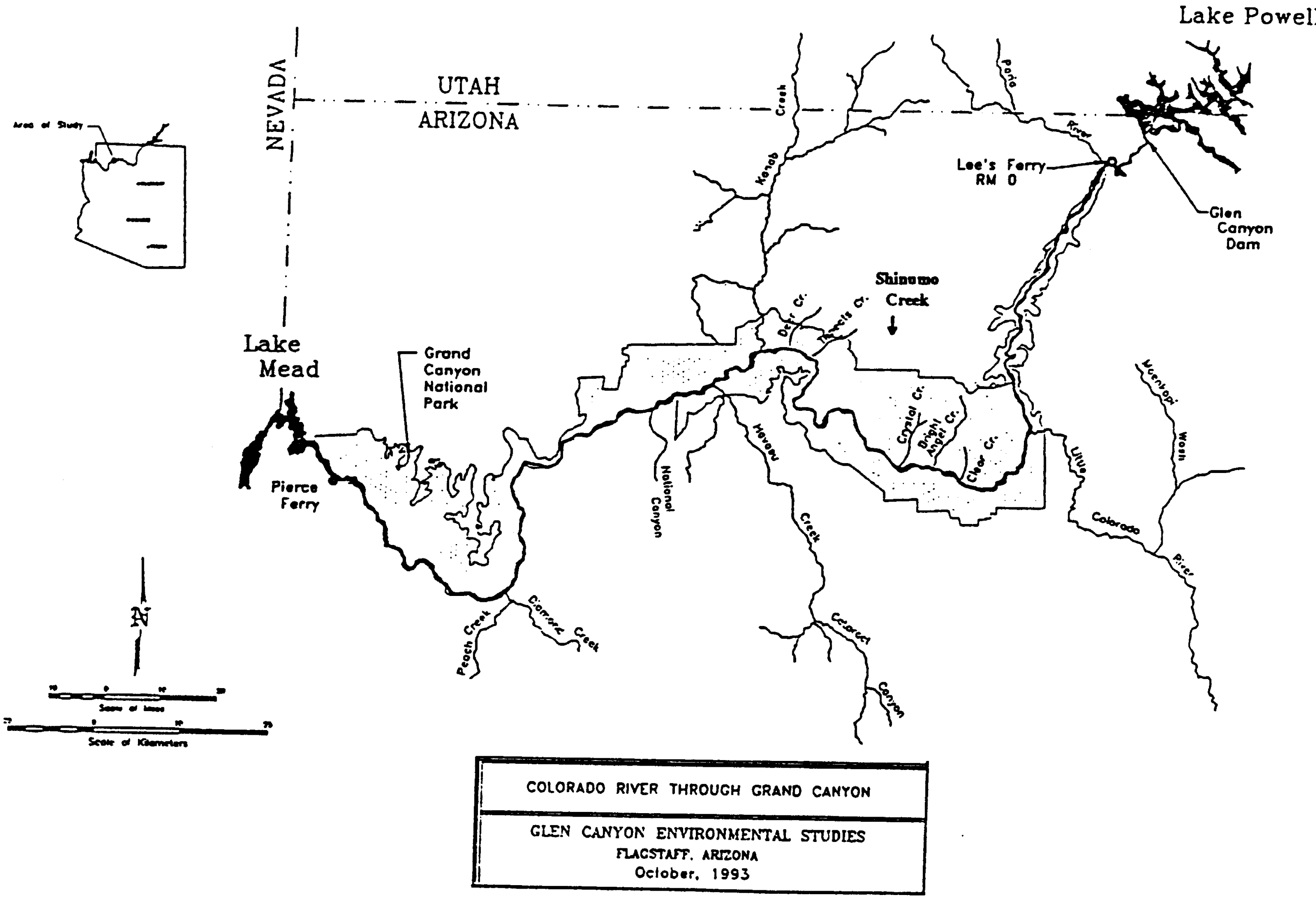


Figure 1. The Colorado River through the Grand Canyon (with Bright Angel and Kanab creeks).

CHAPTER 2. DISTRIBUTION, ABUNDANCE, AND COMPOSITION OF FISHES IN BRIGHT ANGEL AND KANAB CREEKS

INTRODUCTION

How the operation of Glen Canyon Dam has impacted the aquatic communities of the tributaries is not fully understood. At the least, decreased temperatures in the mainstem have made it easier for trout to establish themselves throughout the Grand Canyon and to repopulate tributaries after floods. Another impact of the dam on tributaries involves the elimination of high magnitude floods in the Colorado River; historically, high mainstem flows in spring may have facilitated access for native fishes to some tributaries for spawning (Maddux et al. 1987, Allan 1993).

Despite recognition that the tributaries are important for maintaining native species, there is little historical information on the fishery resources in Grand Canyon tributaries. Early reports by NPS naturalists rarely included any reference to aquatic vertebrates. Most of the existing reports on fish in the tributaries (McKee 1930, 1933, Brooks 1931, Markley 1931, Patraw 1931, Brooks 1932, Williamson and Tyler 1932) were informal and focused on the success of early efforts to introduce trout to the cooler side streams (e.g., Clear, Bright Angel, Tapeats, Shinumo, and Havasu creeks). Native fishes were generally mentioned only as an aside in these reports. Williamson and Tyler (1932) mention finding "suckers, fingerling size to eight inches" during a survey of Shinumo Creek in August 1930 and "a few suckers" in Bright Angel Creek during March

1931. They did not identify the species of suckers. I found only 1 other reference to native fishes from sidestreams, an observation of an 8- inch long "sucker" caught by youngsters on Bright Angel Creek about 1 mile above Phantom Ranch (Bryant 1942).

A biological inventory of 5 tributaries (Clear, Bright Angel, Shinumo, Tapeats, and Havasu creeks), presumably conducted in the late 1940's, reported that no "non-food" species were found (Schellbach 1949). It is very unlikely that native species were completely absent from tributaries at the time of Schellbach's writing. In a letter written to Mr. Schellbach in 1944, R.R. Miller presented a list of species that he had identified from collections made in Grand Canyon National Park (Miller 1944). The list included 2 *Pantosteus delphinus* (*C. discobolus* [Smith 1966]) collected from Bright Angel Creek, 1 large adult *Gila elegans* from Phantom Creek, and 63 *Rhinichthys osculus* from Garden Creek. The *G. elegans* reported from Phantom Creek was more likely *G. cypha*, which Miller did not describe until 1946 (Miller 1946). Alternatively, the reported capture location of the *Gila spp.* may have been incorrect. *Gila elegans* and *G. cypha* generally inhabit large rivers, and adults have not been found above the confluence (inclusive of the lower 200 m) in any of the canyon's tributaries except the LCR.

Since the closure of Glen Canyon dam several mainstem studies have examined fish populations at the mouths of tributaries (Minckley and Blinn 1976, Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987). Minckley (1978), Carothers and Minckley (1981), and Usher et al. (1984) provided the first studies of fish communities upstream of the confluences of selected tributaries of the Colorado River.

Of these, only Minckley (1978) and Carothers and Minckley (1981) actively sampled streams to assess fish populations. However, neither of these investigations penetrated more than 3.2 km upstream of the mouths of the tributaries surveyed. Furthermore, reported fish densities were tenuous due to the inherent difficulties of sampling these side-streams.

I attempted to describe seasonal distributions and relative abundances of fishes within portions of Bright Angel and Kanab creeks not blocked by physical barriers. Obstacles currently prevent the upstream movement of most fishes at 14.3 km and 6.2 km up Bright Angel and Kanab creeks, respectively (speckled dace were regularly found above the barrier on Kanab Creek). Bright Angel and Kanab creeks are dissimilar in their physical characteristics, but each one may be representative of a subset of the other tributaries occurring in the Grand Canyon. The Paria and Little Colorado rivers and Kanab Creek have been described as warm water tributaries that are important to native fishes (Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987, Maddux and Kepner 1988, Mattes 1993, Weiss 1993). Clear, Bright Angel, Tapeats, and Shinumo creeks have been described as high gradient, cool water tributaries that support resident populations of introduced trout (Holden and Stalnaker 1975, Carothers and Minckley 1981, Maddux et al. 1987, Allan 1993). The patterns of use of Bright Angel and Kanab creeks by native and introduced fishes may be representative of streams in their respective categories; at the least, describing their use should enhance our understanding of the ecology of two Grand Canyon tributaries.

Objectives

My objectives were to describe the:

1. seasonal composition, abundance, and distribution of fishes in Bright Angel and Kanab creeks;
2. temporal and spatial overlap of native and nonnative species in Bright Angel and Kanab Creeks.

METHODS

Size Class Categories

I stratified each fish taxon into 3 "ecological species" (Polis 1984) based on size classes [young-of-year (Y-O-Y), juvenile, adult] as recommended by Gorman (1988) and Pearsons et al. (1992). The dividing line between adults and juveniles (Table 2) was sometimes arbitrary. For instance, I was interested in investigating the effects of predation by introduced trout on native species in Bright Angel Creek. Sizes at which trout become piscivorous have been reported to be in the range from 250-300 mm (Brynildson et al. 1963, Garman and Nielsen 1982). Thus I defined adult trout as fish $\geq$ 250 mm. For species other than trout, adult size classes were generally based upon approximate lengths at sexual maturity reported in the literature (e.g., Minckley 1973, Kaeding and Zimmerman 1983) or personally observed. The upper size limit for Y-O-Y was either the reported length at age 1 (Carothers and Minckley 1981, Maddux et al.

Table 2. Fish species and size classes observed in Bright Angel and Kanab Creeks, Grand Canyon National Park, Arizona, during 1992 and 1993. W,Sp,S,F represent Winter, Spring, Summer, and Fall respectively.

			Size class (mm TL)			Period(s) of observation	
Family and species	Common name	Species Code	Young of year	Juvenile	Adult	Bright Angel Ck.	Kanab Ck.
Cyprinidae							
Rhinicthys osculus	Speckled dace	SPD	<25	25-65	>65	W,Sp,F	W,Sp,S,F
Gila cypha	Humpback chub	HBC	<100	100-250	>250		S,F
Pimephales promelas	Fathead minnow	FHM	<25	25-50	>50		W,Sp,S,F
Cyprinus carpio	Common carp	CRP	<100	100-350	>350		Sp,S
Catostomidae							
Catostomus lattipinnis	Flannelmouth sucker	FMS	<120	120-450	>450	Sp	W,Sp,S,F
Catostomus discobolus	Bluehead sucker	BHS	<30	30-160	>160	W,Sp	W,Sp,S,F
Salmonidae							
Salmo trutta	Brown trout	BRT	<100	100-250	>250	W,Sp,S,F	
Oncorhynchus mykiss	Rainbow trout	RBT	<100	100-250	>250	W,Sp,S,F	S
Salvelinus fontinalis	Brook trout	BKT	<100	100-250	>250	W	
Oncorhynchus clarki	Cutthroat trout	CTT	<100	100-250	>250	W,Sp	
Cyprinodontidae							
Fundulus zebrinus	Plains killifish	RGK	<25	25-60	>60		W,Sp
Centrarchidae							
Lepomis cyanellus	Green sunfish	GSF	<25	25-150	>150		Sp,S
Ictaluridae							
Ictaluris punctatus	Channel catfish	CCF	<100	100-350	>350		S,F

1987), length of apparent age 1 fish (length frequency histograms), or the size at which fish could no longer be considered larvae (Snyder and Muth 1990). This last criterion was used for species that apparently reach sexual maturity at age 1+ (speckled dace, bluehead sucker) that otherwise would not have been represented by a juvenile size class. Young of year trout (< 100 mm TL) were not identified to species during snorkel surveys.

Fish Surveys

Bright Angel Creek

Three different fish sampling procedures were used on Bright Angel Creek. During my initial visit in January 1992, I electrofished 5 sites in the lower 8.0 km to estimate species composition and relative abundance of fishes. These sites were located at 2.0-km intervals (0.0, 2.0, 4.0, 6.0, and 8.0 km). A single pass was made in each reach in the upstream direction. The upper boundary of each site was blocked (6.35-mm mesh seine, 7.62 m x 1.22 m) to prevent fish from leaving the station. Fish were collected with a Smith-Root (Type IV) battery powered backpack electroshocker using pulsed DC current (200-400 volts) and were placed in live boxes until measured.

Grand Canyon National Park (GCNP) would not allow me to use electrofishing to obtain subsequent samples from Bright Angel Creek in 1992 due to concerns over aesthetics and public safety. As a result, I used snorkeling to visually assess fish populations. This restriction limited fish surveys to periods of clear water. I was unable to perform multiple snorkel surveys of randomly selected (blocked) sites in June 1992 because sections of the 100-m reaches were sometimes too shallow or current velocities were too high. Therefore, I selected 23 snorkelable sites in the lower 14.3 km for fish surveys (Table 3).

In September 1992, I calculated the pool/riffle ratio for Bright Angel Creek and established 40 permanent fish sampling sites within the lower 14.3 km of the creek. These sites encompassed pools and riffles in equal number.

I modified a method developed by Hankin and Reeves (1988) to select fish survey sites on Bright Angel Creek in September 1992. Hankin and Reeves (1988) recommended systematically selecting non-standard sized homogeneous habitat units to decrease first stage sampling errors (Hankin 1984). I did not sample entire homogeneous riffle areas as recommended by Hankin and Reeves (1988) but instead sampled 20-m sections of riffles. Entire pools were sampled; they never exceeded 20 m in length. I adjusted reach wide fish densities based on the calculated pool/riffle ratios within the stream.

I designated every 10th riffle and every 10th pool beginning at the mouth as fish survey sites. The upper and lower boundaries of each site were marked with coded aluminum surveyor's tags affixed to perennial vegetation above recent high water marks. A drawing of each site was made, its length was recorded, and a photograph was taken. There were 40 survey sites (20 riffles, 20 pools) on Bright Angel Creek between the mouth and the waterfall at rk 14.3 (Table 4). The mean width of each site was determined by averaging widths along 3 transects within the site each time it was

Table 3. Physical characteristics of fish survey sites on Bright Angel Creek in June 1992.

Stream Reach	Site ID	Stream Location (rk)	Site Length (m)	Mean Width	Site Area (sq. meters)
	FS-1	0.12	23.5	7.23	170
	FS-2	1.24	23.0	7.67	176
1	FS-3	1.60	19.0	4.45	85
	FS-4	2.02	17.3	4.15	72
	FS-5	2.96	15.5	4.43	69
2	FS-6	3.15	18.0	4.13	74
	FS-7	5.67	23.2	4.47	104
	FS-8	7.02	13.2	4.55	60
3	FS-9	7.35	12.0	4.50	54
	FS-10	7.40	13.0	4.15	54
	FS-11	8.80	14.4	3.53	51
	FS-12	9.22	12.0	4.07	49
	FS-13	9.98	10.0	4.55	46
4	FS-14	10.55	31.8	5.27	168
	FS-15	11.15	16.8	3.40	57
	FS-16	11.55	16.2	3.40	55
	FS-17	12.00	20.0	4.48	90
	FS-18	12.90	20.1	4.62	93
	FS-19	12.77	13.0	5.43	71
5	FS-20	13.26	17.5	5.03	88
	FS-21	13.84	11.3	4.20	47
	FS-22	14.01	16.4	4.37	72
	FS-23	14.26	19.7	7.10	140

Table 4. Physical characteristics of fish survey sites established on Bright Angel Creek in September 1992 and sampled during December 1992 and June 1993.

Stream Reach	Site ID	Location (rk)	Initial Designation	Site Length (m)	Mean Width	Site Area (sq. meters)	Subsequent Dec '92
	R1	0.02	Riffle	10.7	4.92	53	Pool*
	P1	0.32	Pool	14.3	5.50	79	Pool
	R2	0.65	Riffle	20.0	6.17	123	Riffle
1	P2	0.72	Pool	20.0	5.70	114	Pool
	R3	1.80	Riffle	20.0	4.87	97	Riffle
	P3	1.82	Pool	12.4	4.47	55	Riffle*
	R4	2.24	Riffle	13.0	4.75	62	Riffle
	P4	2.25	Pool	7.0	4.97	35	Pool
	R5	3.04	Riffle	20.0	5.33	107	Riffle
	P5	3.15	Pool	14.0	2.65	37	Pool
	R6	3.84	Riffle	20.0	6.25	125	Riffle
2	P6	3.86	Pool	11.5	4.08	47	Pool
	R7	4.83	Riffle	20.0	4.27	85	Pool*
	P7	4.93	Pool	10.0	3.38	34	Pool
	R8	5.50	Riffle	14.8	4.07	60	Riffle
	P8	5.52	Pool	20.0	3.50	70	Pool
	R9	6.21	Riffle	17.7	3.92	69	Riffle
	P9	6.23	Pool	9.6	4.87	47	Riffle*
	R10	7.00	Riffle	20.0	3.77	75	Riffle
3	P10	7.02	Pool	13.2	4.30	57	Riffle*
	R11	7.65	Riffle	16.0	4.37	70	Riffle
	P11	7.69	Pool	7.5	5.32	40	Pool
	R12	8.34	Riffle	10.0	4.85	49	Riffle
	P12	8.42	Pool	8.2	3.22	26	Riffle*
	R13	9.34	Riffle	19.0	4.57	87	Riffle
	P13	9.39	Pool	7.8	4.48	35	Pool
	R14	10.27	Riffle	12.2	3.32	41	Riffle
4	P14	10.30	Pool	7.0	4.85	34	Pool
	R15	10.61	Riffle	11.0	3.40	37	Riffle
	P15	10.63	Pool	9.7	4.02	39	Riffle*
	R16	11.02	Riffle	9.5	5.53	53	Riffle
	P16	11.04	Pool	7.7	4.10	32	Pool
	R17	12.01	Riffle	20.0	4.38	88	Riffle
	P17	12.05	Pool	9.5	3.22	31	Pool
	R18	12.77	Riffle	13.0	3.87	50	Riffle
5	P18	12.79	Pool	9.0	3.52	32	Pool
	R19	13.46	Riffle	9.7	3.60	35	Riffle
	P19	13.50	Pool	9.0	4.85	44	Pool
	R20	14.23	Riffle	10.7	7.32	78	Riffle
	P20	14.26	Pool	19.7	8.83	147	Pool
	P/R		20/20				17/23

* Denotes a change in habitat type since the previous survey.
NS = Site was not sampled during this period.

surveyed. I calculated areas sampled by multiplying the length (nearest 10 cm) of each site by its mean width (nearest 5 cm). Surface areas sampled were calculated during every sample period to adjust for changes following high flow events.

I initially attempted to set block nets at the upper and lower ends of each survey site but found that fish left the area while I placed nets. Therefore, surveys were performed in unblocked sites. Prior to the surveys, divers were trained to estimate the size of fish by estimating sizes of underwater objects and subsequently measuring them (Griffith 1981); observers were trained to adjust for the 1.33x magnification that occurs underwater. Two divers entered the creek far enough below the downstream end of the site to avoid disturbing fish in the site. They then slowly pulled themselves upstream over the substrate and counted fish by species and size class. Divers stayed in lanes to avoid double counts on fish, except where water clarity and narrow stream widths allowed bank to bank visibility. Under these conditions, both divers made total counts of fish. Snorkel surveys were performed between 0900-1600 hr while direct sunlight was on the survey site and when there was a minimum of 2 m visibility.

Kanab Creek

Because of the inaccessibility of Kanab Creek, I generally had to limit sampling visits to 3 days to conform with rafting schedules. I sampled fish in the lower 10.0 km of stream. Fish survey sites were selected on the basis of their suitability for seining; high turbidity and conductivity precluded the consistent use of snorkeling or electrofishing. I selected seineable sites at 1.0-km intervals beginning at the mouth (0.0 km) and extending 10.0 km upstream (11 sites). Each site was marked with coded aluminum surveyors tags, photographed, and a detailed drawing was made. A minimum of 3 transects were established in each survey site to determine mean stream-widths for each site. Surface areas sampled were calculated in the same manner as described for survey sites on Bright Angel Creek. All survey sites except one (FS-3) remained seineable throughout the study. An alternative site (FS-3A) 50 m above the original site was chosen to replace FS-3.

Seines (3.2-mm mesh, 9.14 m x 1.22 m) were used to block the upper and lower boundaries of sample sites on Kanab Creek. Multiple passes were then made downstream with a bag-seine (3.2-mm mesh, 9.14 m x 1.22 m; 1.22 x 1.22 m bag). Fish from each seining effort were counted and placed into live boxes until sampling was complete.

I generally recorded total length (TL, nearest mm), weight (nearest 2 g), sex, and sexual condition for each fish captured (weight was not recorded for speckled dace). All fish also were examined for external parasites. A Passive Integrated Transponder (PIT) tag was implanted in the lower abdomen of native fish >150 mm TL. The tag contains a unique 12 digit alpha-numeric code that can be read by an electronic scanning device (Biosonics Inc.). Tags were inserted into the peritoneal cavity to the right of the ventral midline and anterior to the pelvic girdle using a custom designed 12 gauge hypodermic needle. A 10% Betadine solution was used to sterilize the needle, tag, and wound. Each fish was handled for less than 1 minute and then released near the site of capture.

Emigration of Larval Catostomids

On 20 June 1992 and 6 May 1993, respectively, I used drift nets at the mouths of Bright Angel and Kanab creeks to sample for large scale emigrations of native larval fishes. In Bright Angel Creek, nets were placed 20 m upstream of the mouth in the thalweg of the stream. Two nets were stacked so that the whole water column was sampled. In Kanab Creek, 2 nets were placed side by side in the main channel of the stream, 80 m above the mouth; each net fished the entire depth of the water column. The nets were set for 15 min every 2 hr for a 24-hr period on Bright Angel Creek and for a 16-hr period (1800-1000 hr) on Kanab Creek. Larval fish were preserved in 10% formalin for later identification in the lab.

Trout Predation on Native Fish

The stomach contents of 11 trout taken from Bright Angel Creek were examined using a nonlethal stomach flushing device modeled after Seaburg (1957). Most of these trout were captured by angling in June 1992 while larval bluehead suckers and speckled dace (10-18 mm TL) were present in the stream. Trout were not anesthetized because of the possibility that they might be recaptured and eaten by other anglers shortly after release (Schnick et al. 1979). I measured the total length (mm) and weight (nearest 2 g) of each trout sampled for stomach contents in Bright Angel Creek. Five trout were killed, and the contents of their stomachs were examined to determine the efficiency of the flushing device in dislodging stomach contents.

Standard Density Estimates

I calculated Standard Density Estimates (SDE) for each species and size class for every sample site during each sample period on both streams. Due to differences in fish sampling methods, SDE's were calculated differently for Bright Angel and Kanab creeks. On Bright Angel Creek, SDE's were defined as:

$$SDE_{BRTA,i} = \frac{N_{BRTA,i}}{\text{Site Area,i}} \times 100$$

where:

$SDE_{BRTA,i}$ = Standard Density Estimate for brown trout adults in site i.
$N_{BRTA,i}$ = Total number of brown trout adults observed in site i.
Site Area,i = Mean width x total length of site i.

Thus, on Bright Angel Creek, SDE reflects the actual density of fish observed in each sample site, standardized to a 100-m^2 area. Separate SDE's were calculated for individual riffles and pools sampled within stream reaches. A reach mean was determined for each habitat type by adding all SDE_{pool}'s from a reach, and dividing by the number of pool sites in that reach. The same was done for riffle sites (SDE_{riffle}) within reaches. A grand reach mean was then determined by multiplying the respective habitat means by the proportional availabilities of those habitats, and then adding pool and riffle means together as follows:

$$SDE_{x,1} = [SDE_{Xriffle,1} \times (0.76)] + [SDE_{Xpool,1} \times (0.24)]$$

where: $SDE_{X,1}$ = Mean SDE for species/size class X in reach 1.

$SDE_{Xriffle,1}$ =Mean SDE for species/size class X observed in riffle sites in reach 1.

$SDE_{Xpool,1}$ = Mean SDE for species/size class X observed in pool sites in reach 1.

I used multiple seine hauls within blocked survey sites on Kanab Creek to minimize second stage sampling errors (estimating fish abundance within sites-Hankin 1984). I then used the Program CAPTURE (Removal Estimator, Rexstad and Burnham 1991) to estimate the abundance of large fishes (Otis et al. 1978, White et al. 1982). CAPTURE-generated population estimates were not calculable for all species or size classes for every site because of inadequate sample sizes (Appendix I). Therefore, I needed a modified SDE that was relevant for all species and size classes so that direct comparisons could be made between reaches and across periods. This SDE had to be standardized to account for differing efforts (i.e., number of seine hauls) between events. Accordingly, I used the sum of the catch from the top 2 seine hauls (those yielding the greatest number of fish) from each site. By using the catch from the top 2 seine hauls, I could adjust for inefficient trials that hung up on rocks.

I calculated the SDE's for Kanab Creek fishes as follows:

$$SDE_{BHSA,i} = \frac{N_{Top2,i}}{Site\ Area,i} \times 100$$

where:

$SDE_{BHSA,i}$ = Standard Density Estimate for adult bluehead suckers in site i.

$N_{Top2,i}$ = Sum of adult bluehead suckers caught in the top 2 seine hauls in site i.

Site Area,i = Mean width x total length of site i.

Data Analyses

I used linear regression (SPSS/PC+ V2.0) to compare the SDE's derived from 2 methods of estimating fish numbers (Top 2 seine hauls and CAPTURE population estimate) on Kanab Creek (Ott 1988). These comparisons were made only for bluehead sucker and speckled dace (adults and juveniles combined), because these were the only categories with adequate samples for CAPTURE to estimate populations. By treating $SDE_{CAPTURE}$ as the true density of fishes present, I evaluated the relative efficiency of $SDE_{Top\ 2}$ for each species and estimated its consistency as an index of fish abundances.

For evaluating stream-wide distribution of fish, I stratified each stream into separate reaches. Physical obstacles 3.2 km and 6.2 km up Kanab Creek naturally divided that stream into 3 reaches (reach 1 = 0.0-3.2 km, reach 2 = 3.2 - 6.2 km, and reach 3 = 6.2 - 10.0 km). I arbitrarily divided Bright Angel Creek into five 3-km stream reaches (reach 5 [12.0 - 14.3 km] was shortened by a waterfall). To determine differences in the distribution of speckled dace in Kanab Creek, I compared their SDE's across stream reaches 1-3 within sample periods (for each species/size class) using a Kruskal-Wallis (K-W) one-way analysis of variance (ANOVA) (Gibbons 1985).

My test hypotheses were:

H_o: Median SDE_{X1} = Median SDE_{X2} = Median SDE_{X3} (where x = a given species/size class).

H_a: Not all of the median SDE_X's are equal between reaches 1-3.

When significant values ($p < 0.05$, corrected for ties) resulted from the ANOVA, I performed Dunn's multiple comparisons test (Dunn 1964) to determine which pairs were significantly different from one another ($p < 0.05$). Because bluehead suckers did not occur above reach 2, I used the Mann-Whitney-Wilcoxon test (M-W) to compare SDE's between reaches 1and 2 for that species (Gibbons 1985). To evaluate stream-wide changes in SDE's between sample periods, I used the K-W one-way ANOVA (Gibbons 1985).

My test hypotheses were:

H_o: Median SDE_{Xaug} = Median SDE_{Xnov} = Median SDE_{Xmay} = Median SDE_{Xjun} (where x = a given species/size class)

H_a: Not all of the median SDE_X's are equal between periods.

Dunn's (1964) test was used to determine which pairs were significantly different from one another when the ANOVA showed significant differences across periods ($p < 0.05$, corrected for ties). Data for January 1993 were excluded from this analysis, because high flows prevented multiple seines hauls of blocked reaches.

I used the Mann-Whitney-Wilcoxon test for pair-wise comparisons of total lengths of bluehead suckers during each sample period. I used the Bonferroni correction factor (Miller 1981) to determine the appropriate significance level for these comparisons ($p < 0.005$ for 10 pair-wise comparisons).

The necessity to change sample locations and sampling methods on Bright Angel Creek made the SDE's from January and June 1992 uncomparable to other periods. Therefore, these data were used only to evaluate species composition and distribution.

I used the K-W one-way ANOVA to compare SDE's from December 1992 and June 1993. Brown and rainbow trout were the only species occurring frequently enough to be analyzed. Comparisons were made across sample reaches within periods and also across periods. Test hypotheses were similar to those illustrated above. Dunn's (1964) multiple comparisons test was performed when K-W indicated significant differences between samples.

I generated length-frequency histograms for bluehead suckers and speckled dace from Kanab Creek for each sampling period. Length-frequency histograms were not possible from Bright Angel Creek because fish were not actually measured. I used bar graphs to summarize SDE's for various species and size classes of fish observed during each sample period in both streams. Comprehensive presentations of SDE data for Bright Angel and Kanab creeks are tabled in Appendices II and III, respectively.

RESULTS

Tagging of Native Fishes

Native species were tagged at the request of GCES to benefit long-term monitoring. I did not use these data directly, but they are reported in Appendix IV.

Standard Density Estimates

The SDE's based on the 2 most effective seine hauls and SDE's based on CAPTURE generated population estimates for bluehead suckers and speckled dace in Kanab Creek showed a strong correlation ($r^2 = 0.94$, $F_{1,11} = 184.4$, $p < 0.0001$; and $r^2 = 0.97$, $F_{1,8} = 328.2$, $p < 0.0001$, respectively, for bluehead suckers and speckled dace). The regression equations indicated that about 72% and 75% of the CAPTURE estimated populations of bluehead suckers and speckled dace, respectively, were consistently caught in the 2 most effective seine hauls ($y = 1.38541X_{two}$ and $y = 1.34184X_{two}$, respectively).

Pool/Riffle Ratios

There were no significant differences in pool/riffle ratios between reaches on Bright Angel Creek ($p > 0.10$, K-W one-way ANOVA) or Kanab Creek ($p = 0.29$, M-W rank sum test). Therefore, I used the stream-wide mean pool/riffle ratio (0.24:1.00) when adjusting reach mean SDE's to reflect the relative proportions of stream environments that were sampled on Bright Angel Creek. The stream-wide mean pool/riffle ratio for Kanab Creek was 1:1; this value was not used to adjust SDE's, because only pool sites (including runs and glides) were seined.

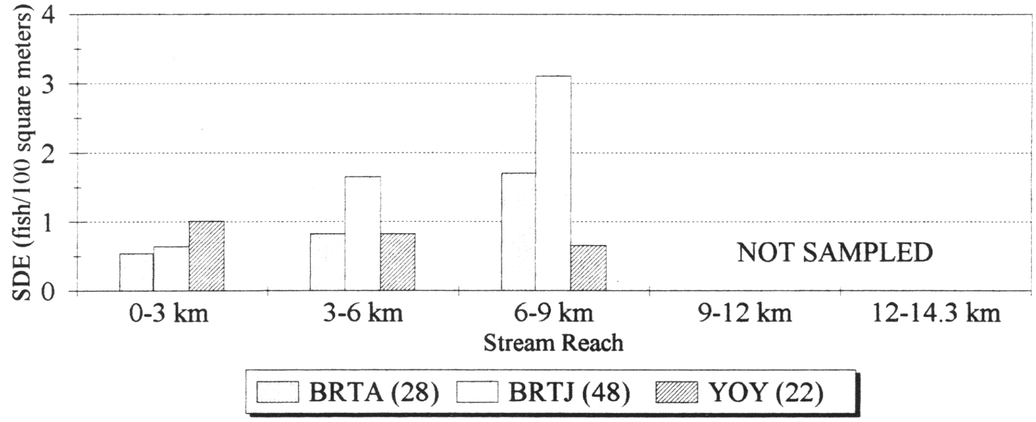
Fish Surveys

Bright Angel Creek

7-9 January 1992 (Period 1)

Stream reaches 1-3 were sampled with electrofishing during 7-9 January 1992. I caught 28 adult and 48 juvenile brown trout, *Salmo trutta*, and 2 adult and 18 juvenile rainbow trout, *Oncorhynchus mykiss*. About 79% of the total catch of trout >100 mm TL were brown trout and 21% were rainbow trout. I also caught 2 Y-O-Y trout (both species combined). A single adult bluehead sucker (330 mm TL) was caught at rk 6.0, and 2 speckled dace were caught (57 and 85mm TL), 1 at the confluence and 1 at the 2.0-km site. A putative cutthroat trout x rainbow trout hybrid (378 mm TL) was caught in reach 1 just upstream from the confluence of Bright Angel Creek and the Colorado River. The densities of adult and juvenile brown trout increased upstream (Figure 2), whereas densities of rainbow trout adults and juveniles generally decreased slightly upstream (Figure 3). The number of Y-O-Y trout (browns and rainbows combined) was relatively consistent in the lower 8.0 km of the stream (Figure 2).

January 1992



June 1992

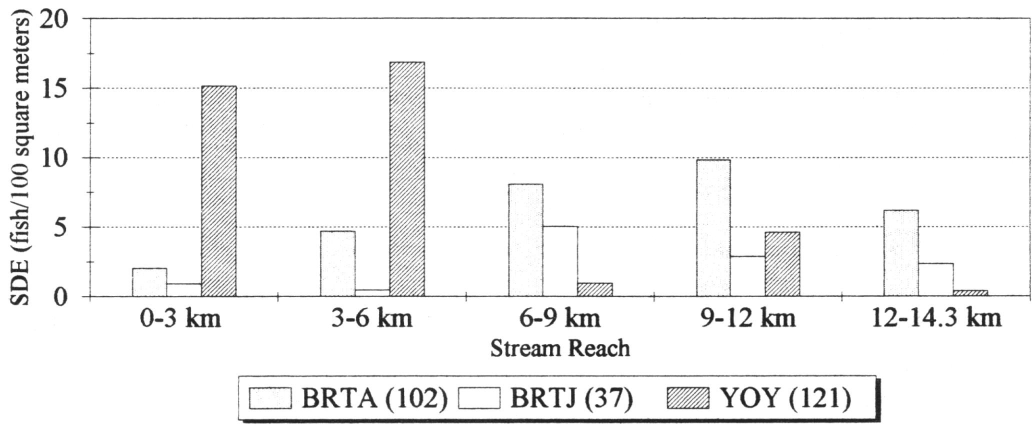
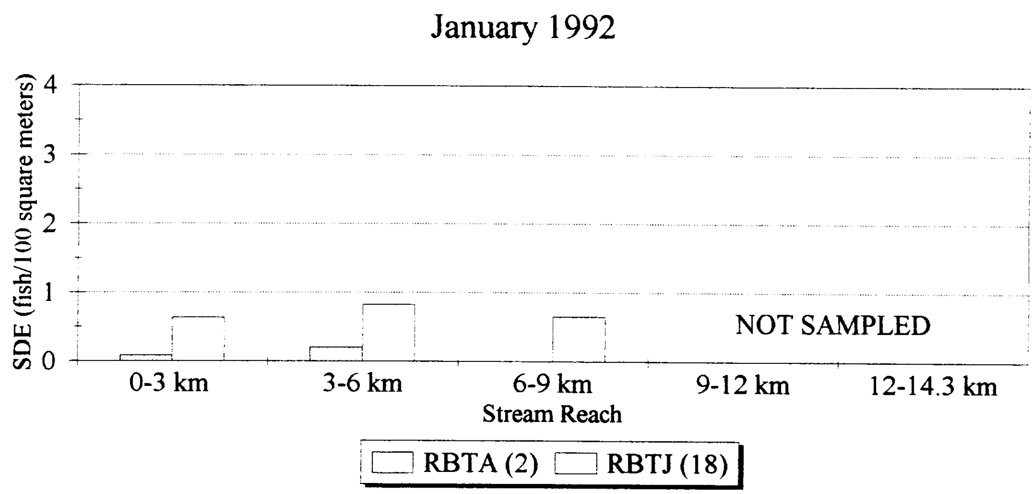


Figure 2. Standard Density Estimates (SDE) for adult (BRTA), juvenile (BRTJ), and Y-O-Y (browns and rainbows combined) brown trout in Bright Angel Creek during January and June 1992.



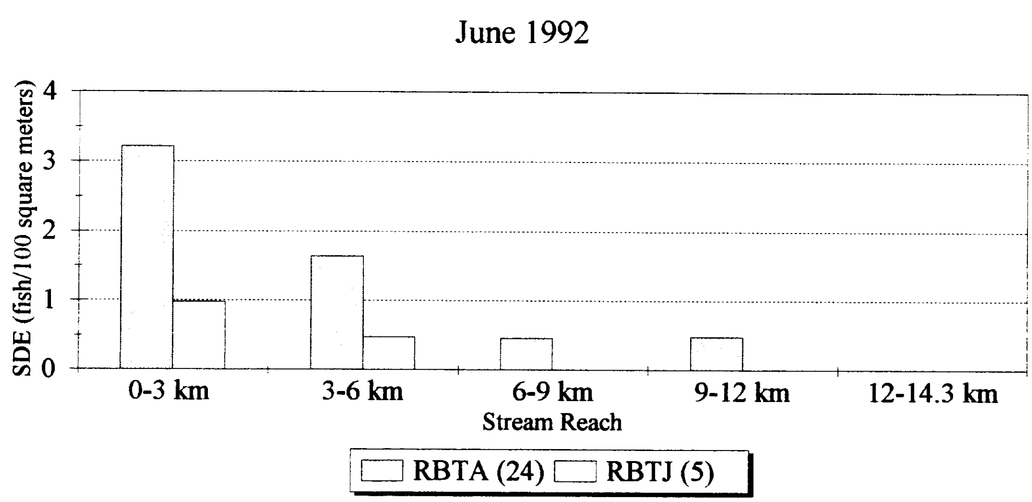


Figure 3. Standard Density Estimates (SDE) for adult (RBTA) and juvenile (RBTJ) rainbow trout in Bright Angel Creek during January and June 1992.

June 1992 (Period 2)

Twenty-three pools were snorkeled in the lower 14.3 km of Bright Angel Creek between 14 June - 4 July, 1992 (Table 3). Brown trout (102 adults and 37 juveniles) represented 83% of all trout > 100 mm TL, and rainbow trout (24 adults and 5 juveniles) made up 17%. The number of Y-O-Y trout (121 total) was highest in reaches 1 and 2, though some Y-O-Y were observed in all reaches (Figure 2). The relative densities of adult and juvenile brown trout were highest in upstream areas (reaches 3, 4 and 5; Figure 2), while densities of adult and juvenile rainbow trout were highest in downstream areas (reaches 1 and 2; Figure 3). In fact, only a few adults and no juvenile rainbow trout were observed above reach 2. No rainbow trout were observed in the uppermost reach (Figure 3). One putative cutthroat trout x rainbow trout hybrid (285 mm TL) was taken by angling from a pool 11.5 km upstream.

Twenty adult speckled dace were observed at a single site 120 m above the confluence of Bright Angel Creek and the Colorado River. A rock dam built by hikers caused Bright Angel Creek to back up and inundate the riparian area. The middle of the large pool created by the dam contained 6 adult rainbow trout, whereas the speckled dace occupied the flooded vegetation of the riparian area. No other adult or juvenile speckled dace (excluding Y-O-Y) were observed in the lower 14.3 km of Bright Angel Creek. However, many dace representing all size classes were observed in an isolated spring (known locally as Willow Spring) located 7.7 km upstream from the mouth of Bright Angel Creek. Willow Spring flows from the ground just a few feet off the North Kaibab

Trail creating a boggy section characterized by cattails and high grasses. The spring then flows across the trail and into a small, densely vegetated marsh. This marsh is adjacent, but unconnected, to Bright Angel Creek, except possibly during floods when the stream crests its banks. Speckled dace were the only fish observed in Willow Spring.

I observed several groups of larval fishes in shallow, quiet areas along the stream bank in the lower 3.0 km of Bright Angel Creek and within Phantom Creek below the falls. I collected a few specimens and later identified them as speckled dace and bluehead suckers. The 20 speckled dace near the confluence and these larvae were the only native fishes observed in Bright Angel Creek.

The drift nets set at the mouth of Bright Angel Creek caught 1 larval speckled dace. Stream discharge and drift rates were not calculated due to the low catch of drifting larval fishes.

Several tributaries flow into Bright Angel Creek within my study area: Phantom Creek enters from the west near rk 3.1, Ribbon Falls Creek enters from the west near rk 10.25, Wall Creek enters from the east near rk 11.29, and Transept Creek enters from the west near rk 12.44. I surveyed the lower 200-800 m of these streams and found several Y-O-Y and juvenile brown trout in small pools (particularly in Wall and Transept creeks). No native fishes were observed.

Though my study area ended at the 2-m waterfall located about 0.5 km downstream from the bridge below B. Aiken's residence (NPS Roaring Springs pumphouse operator), I snorkeled several reaches above the bridge to look for native fishes. None were found; however, brown and rainbow trout were present in proportions roughly equal to those downstream (80% brown trout [41 fish], 20% rainbow trout [10 fish]). Both species were observed as far up Bright Angel Creek as I surveyed, about 200 m beyond where Roaring Springs Creek joins Bright Angel Creek.

I found no evidence of vertebrate remains in the stomachs of 10 trout > 250 mm TL (8 brown, 2 rainbow) caught primarily in reaches 4 and 5. The efficiency of the flushing device was high; virtually no organic material remained in the stomachs of 5 trout dissected following flushing. However, many of the trout stomachs that I examined (these 5 and others from trout harvested by anglers on the stream) contained high numbers of nematodes. The parasites occurred most frequently in the posterior (pyloric) section of the stomach. Accurate records of infection rates were not made; however, I estimate that 25-50% of all trout examined contained nematodes.

Daily water temperatures ranged from 16.0 - 21.0 C (mean = 19.4) during surveys in June 1992.

September 1992

No snorkel surveys were possible during this period due to low water clarity resulting from 2 large floods. The first flood occurred near the end of August, and the second occurred on 15 September. The east side tributaries (Manzanita and Wall creeks) exhibited the most riparian damage and bank erosion following the flood. Rangers at Phantom Ranch indicated the stream gauge read about 3-4 feet above normal (Shores, NPS, pers. comm.). Rangers judged the flood on 15 September to be at least as large as the preceding one, and concluded that both floods may have been the largest in many years. Bright Angel Creek had crested its banks in several locations near Cottonwood Campground and Wall Creek. I found 21 dead brown trout along 1 side of the creek in a 500-m stretch. The fish were partially buried in silt, impaled in bushes, and stranded in puddles. Trout could also be seen "gasping" at the surface of many pools. The water was red with suspended solids, and fish may have had difficulty obtaining sufficient oxygen.

I surveyed the tributaries flowing into Bright Angel Creek following the 15 September flood. Transept Creek still contained a few Y-O-Y trout in its lower reaches but the other tributaries appeared devoid of fish. The sidestreams and Bright Angel Creek proper experienced tremendous bedload movement that greatly diminished the periphyton communities that had previously colonized the larger substrates.

December 1992 (Period 3)

Forty sites (17 pools, 23 riffles, Table 4) were snorkeled in the lower 14.3 km of Bright Angel Creek between 30 November - 14 December 1992. Brown trout composed 86.4% of all trout observed > 100 mm TL (66 adults, 23 juveniles). About 70% (62 fish) of these fish were from pools (Figure 4). Rainbow trout represented 11.7% of all trout >100 mm TL, with 10 adult and 2 juvenile fish observed in reaches 1 - 4. Eight of these 12 fish were observed in pools (66%, Figure 5). Brook trout, *Salvelinus fontinalis,* made up 1.9%; 2 adult brook trout were observed in the uppermost pool at rk 14.3. Only 13 Y-

O-Y trout were observed throughout the stream; most of these occurred in pools (Figure 6). No Y-O-Y trout were observed in reach 5, and all but 1 of the 13 Y-O-Y fish occurred in reaches 1-3 (Figure 7).

One adult bluehead sucker (> 300 mm TL) was observed in a crevice created by 2 large (>30 cm) rocks at the 0.65 km snorkel site. I captured the sucker by hand and examined it for spawning condition and parasites. No gametes were expelled with gentle posterio-lateral pressure and no external parasites were found. The fish was listless and lesions occurred along its torso; the upper lobe of its caudal fin was almost completely missing.

There were no significant differences in densities of either adult or juvenile brown trout between stream reaches ($p > 0.25$ and $p > 0.30$, respectively, Table 5), but the absolute density of adult brown trout generally increased upstream (Figure 8). The density of juvenile brown trout was greatest in reach 3 (Figure 8).

There were no significant differences in densities of adult or juvenile rainbow trout between stream reaches ($p > 0.25$ and $p > 0.08$, respectively, Table 6). However, rainbow trout densities were lowest in upstream areas; no rainbow trout were observed in reach 5, and only adults were observed above reach 2 (Figure 9).

Trout were not yet spawning. Large adult browns and some rainbows had begun to pair up, but only 1 redd was seen. Fish showed no post-spawning characteristics (e.g. worn caudal fins, flaccid abdomens, or discoloration. Brown trout in particular exhibited

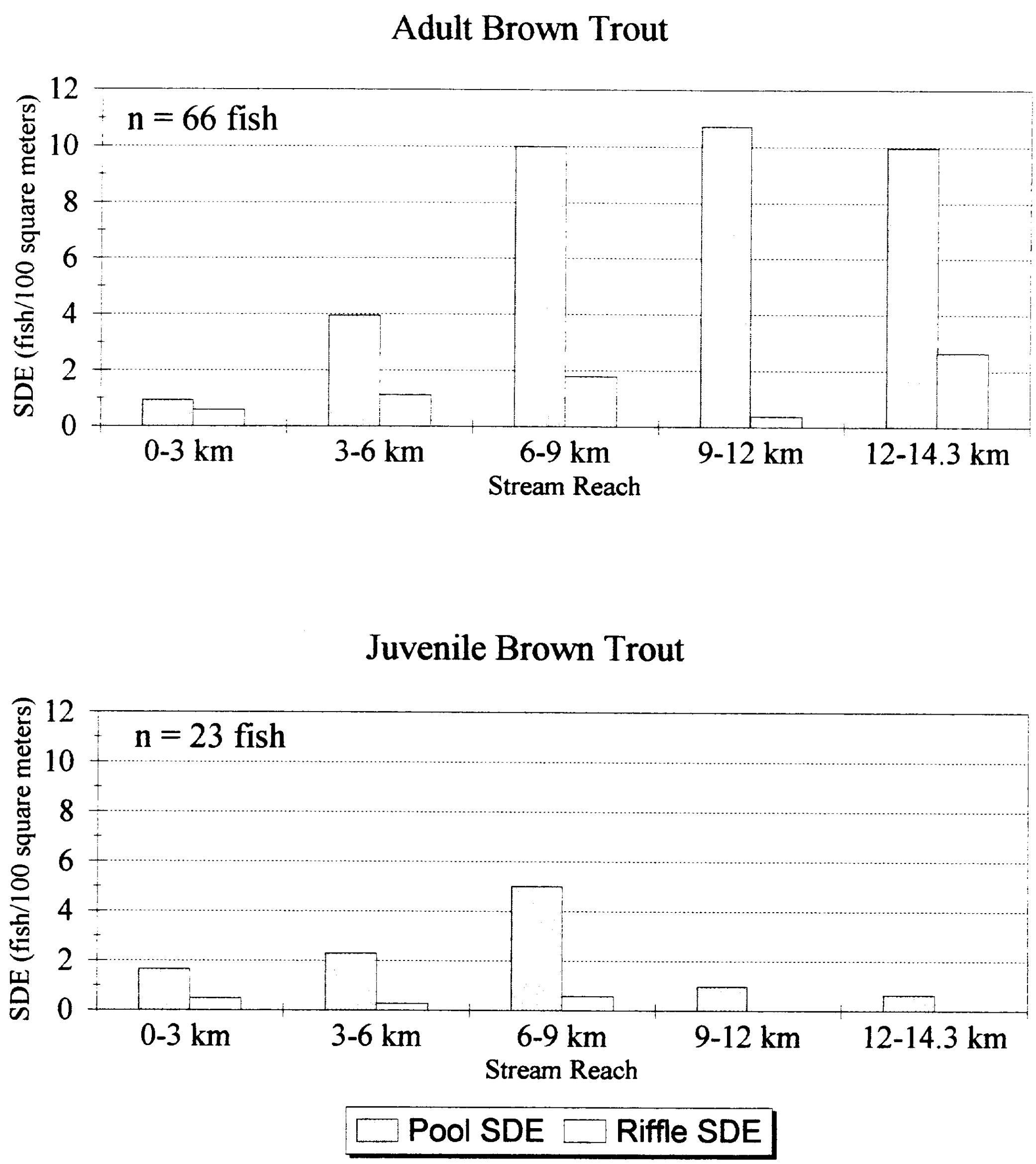


Figure 4. Standard Density Estimates (SDE's) for adult and juvenile brown trout observed along two habitat gradients during snorkel surveys on Bright Angel Creek in December 1992.

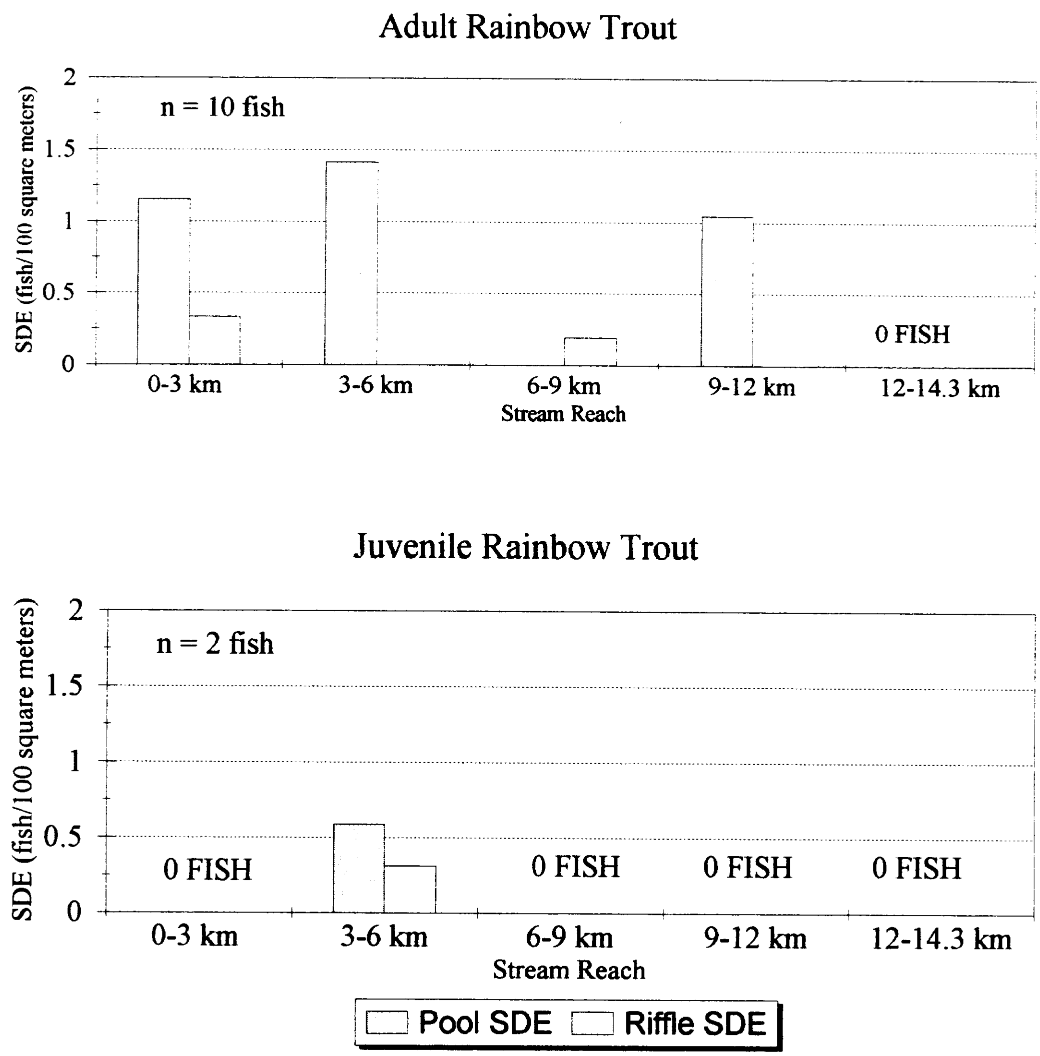


Figure 5. Standard Density Estimates (SDE's) for adult and juvenile rainbow trout observed along two habitat gradients during snorkel surveys on Bright Angel Creek in December 1992.

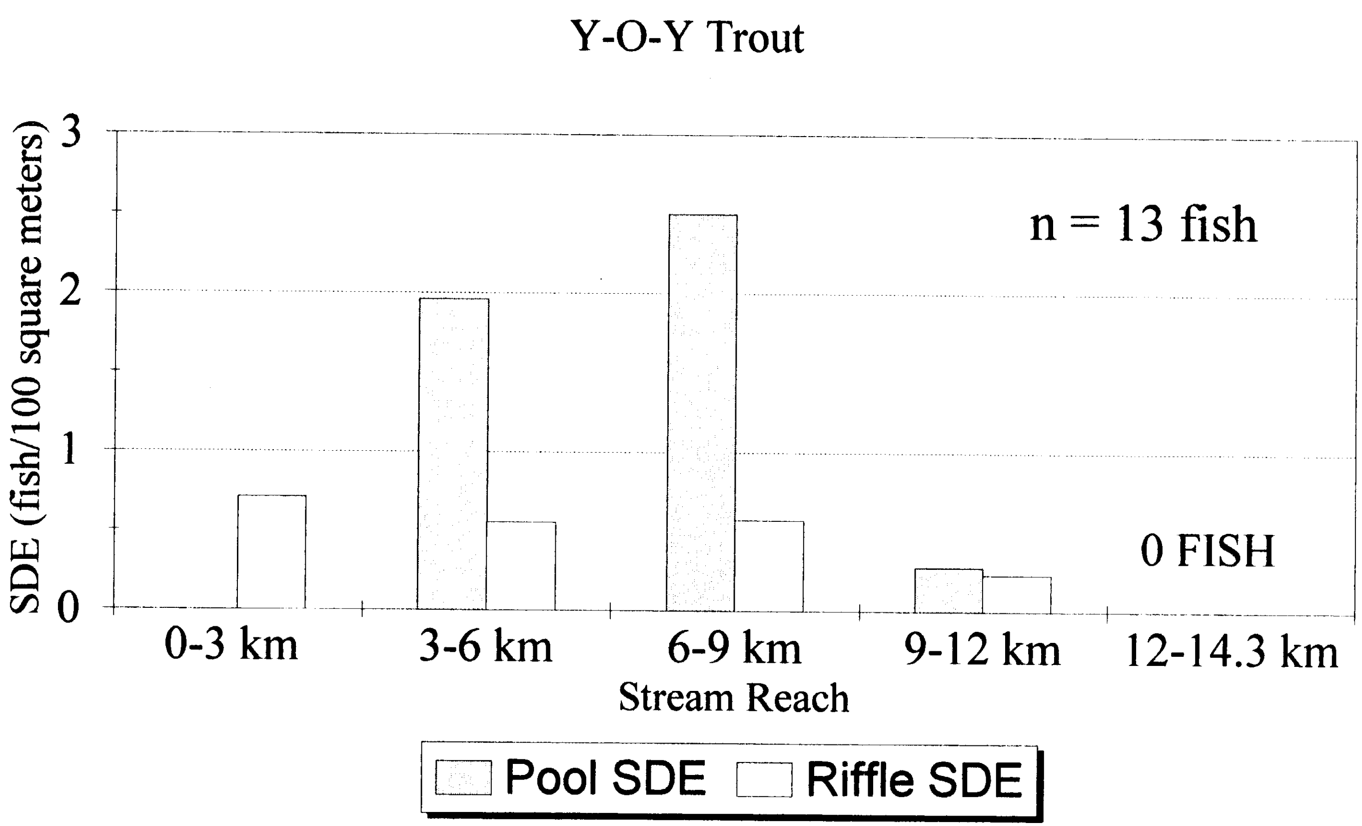


Figure 6. Standard Density Estimates (SDE's) for Y-O-Y trout (browns and rainbows combined) observed along two habitat gradients during snorkel surveys on Bright Angel Creek in December 1992.

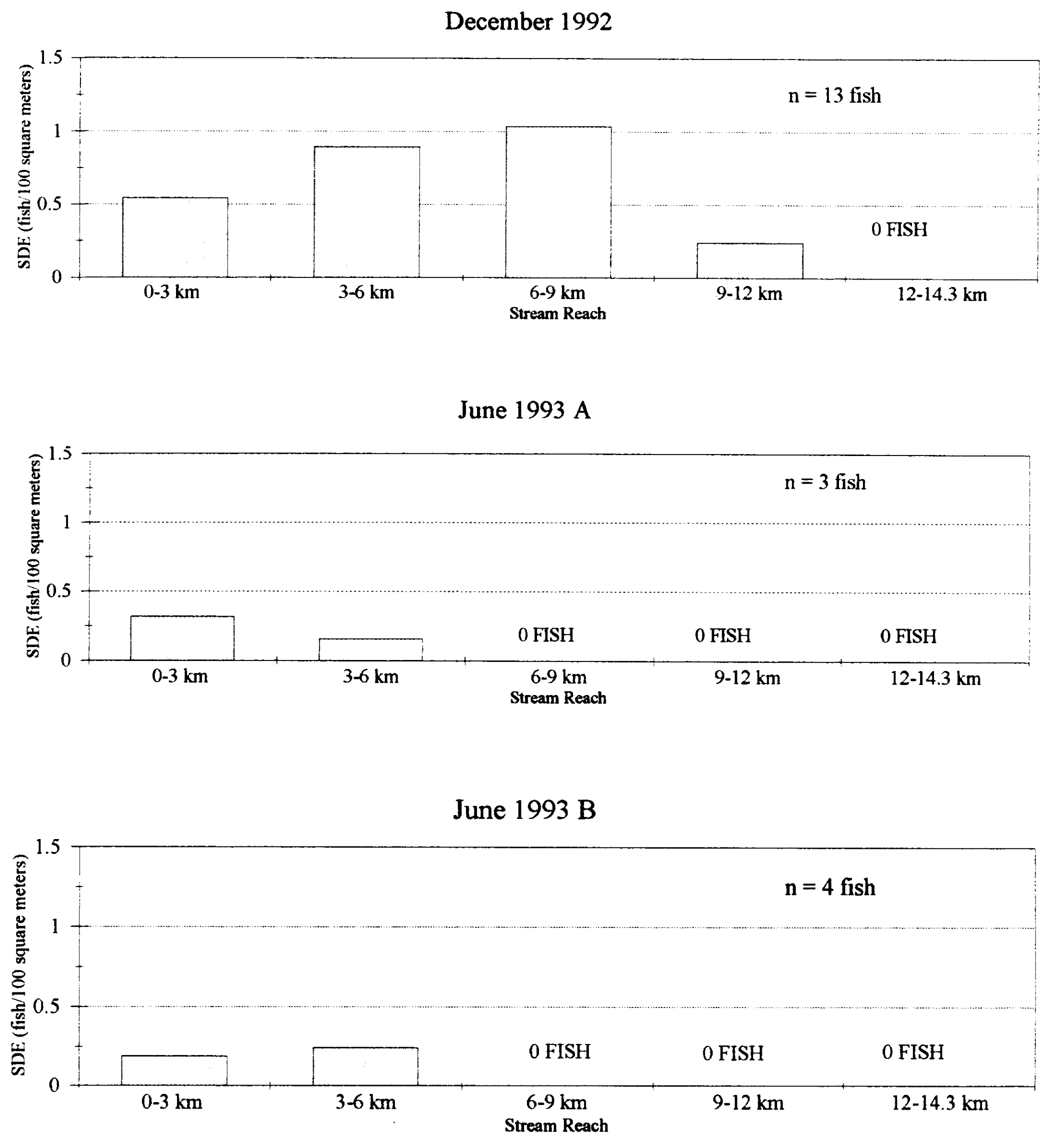


Figure 7. Standard Density Estimates (SDE's) for Y-O-Y trout (browns and rainbows combined) observed during snorkel surveys on Bright Angel Creek, December 1992 - June 1993 (2 surveys were done 5 days apart in June [A and B] to determine short term variability in distribution and abundance of fish).

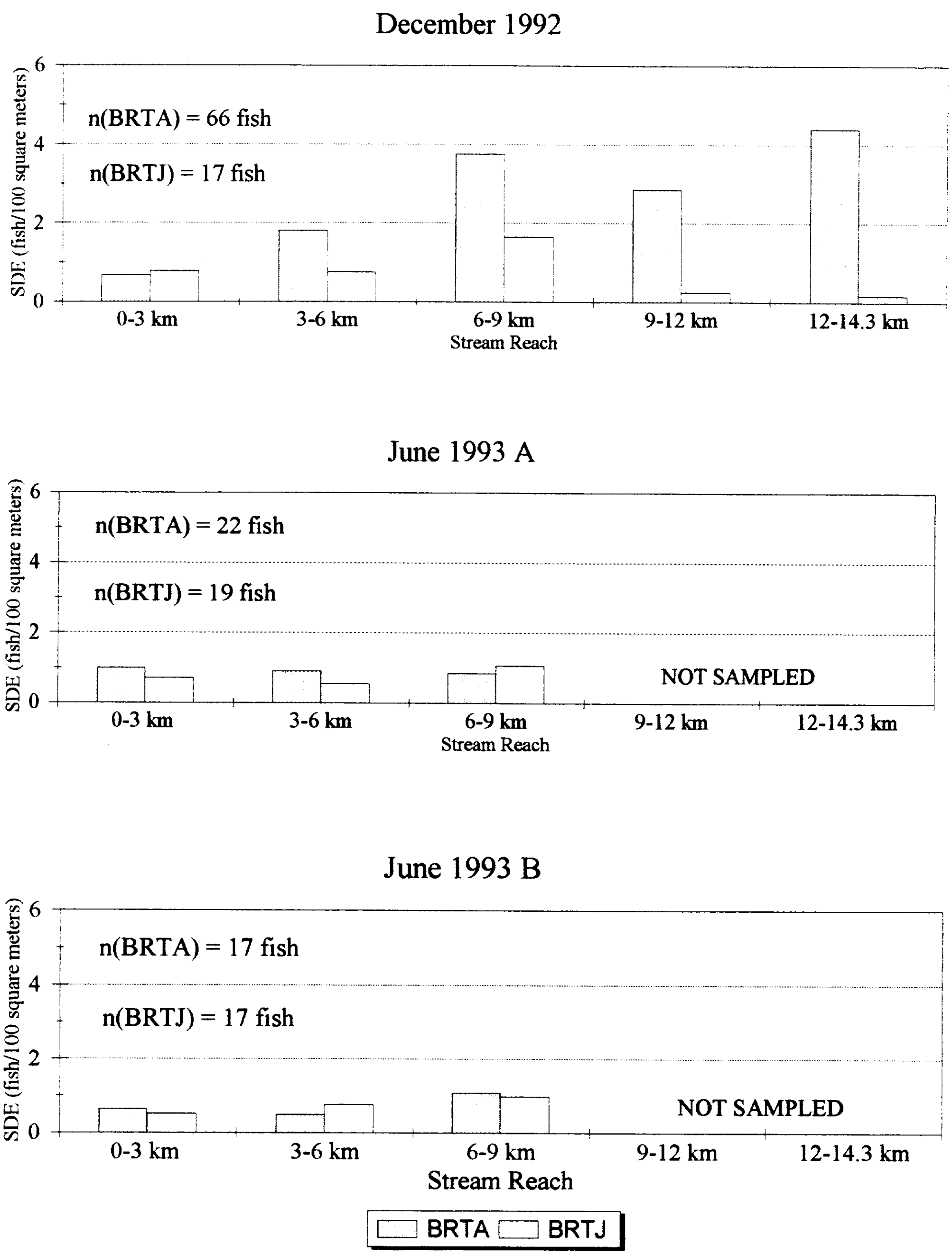


Figure 8. Standard Density Estimates (SDE) for adult (BRTA) and juvenile (BRTJ) brown trout observed during snorkel surveys on Bright Angel Creek, December 1992 - June 1993 (2 surveys were done 5 days apart in June [A and B] to determine short term variability in distribution and abundance of fish).

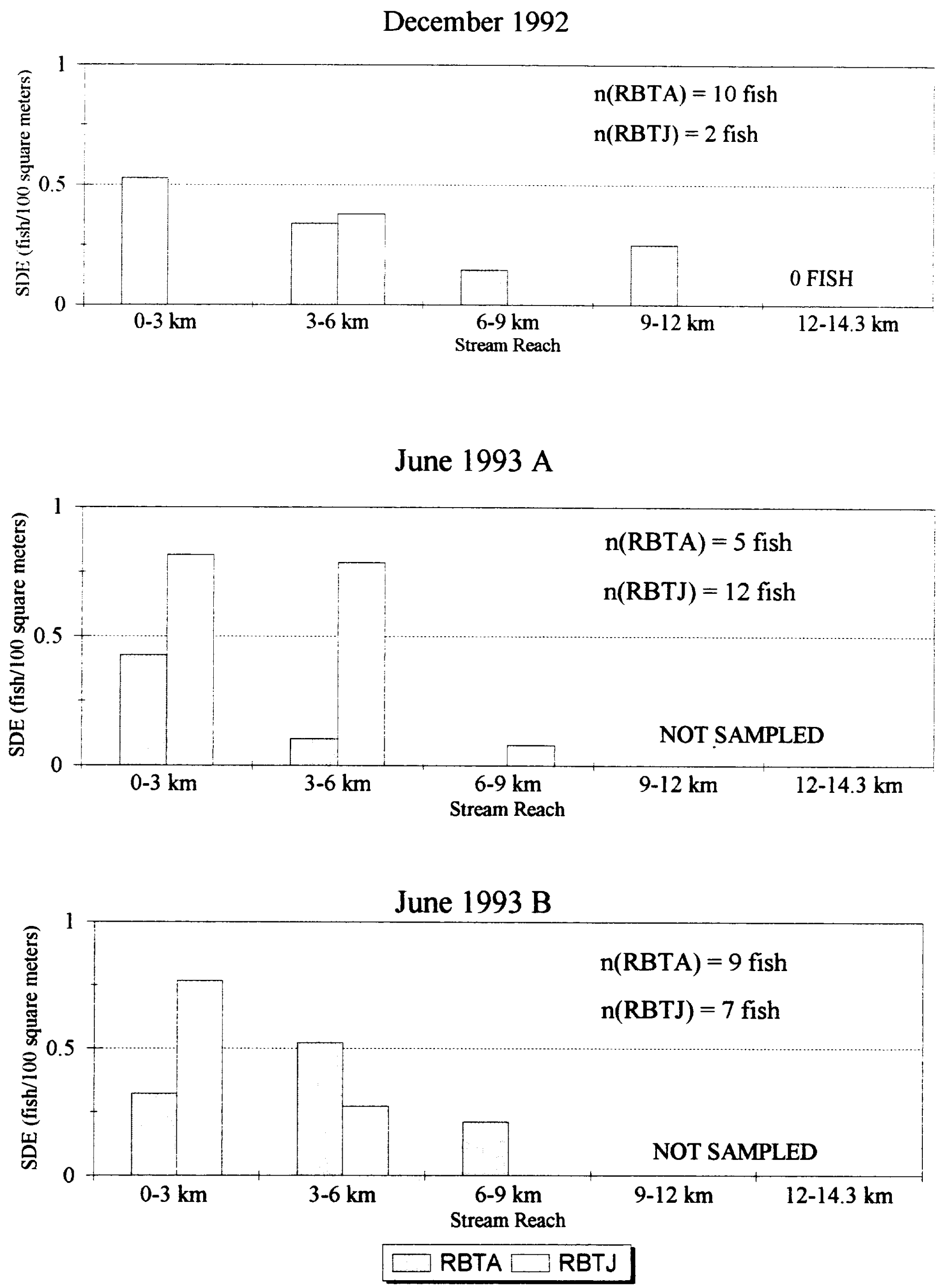


Figure 9. Standard Density Estimates (SDE) for adult (RBTA) and juvenile (RBTJ) rainbow trout observed during snorkel surveys on Bright Angel Creek, December 1992 - June 1993 (2 surveys were done 5 days apart in June [A and B] to determine short term variability in fish distribution and abundance).

Table 5. Comparisons (Kruskal-Wallis one-way ANOVA test) of brown trout densities across stream reaches in Bright Angel Creek, December 1992 - June 1993; NS = not sampled.

Brown Trout		Median Value					Critical Values	
		Stream Reach (# of sites)					(Corrected for ties)	
Period	Size Class	0-3 km (8)	3-6 km (8)	6-9 km (8)	9-12 km (8)	12-14.3 km (8)	Chi-square	p value
	Adult	0.439	1.667	2.354	0.943	3.555	5.311	0.257
Dec 1992	Juvenile	0.000	1.464	0.000	0.000	0.000	4.871	0.301
	Adult/Juvenile comb.	1.944	3.431	2.762	0.943	4.139	2.833	0.586
	Adult	0.926	0.888	0.617	0.485	NS	0.433	0.933
Jun 1993 A	Juvenile	0.490	0.410	0.463	1.951	NS	4.495	0.213
	Adult/Juvenile comb.	1.841	1.560	1.364	2.437	NS	1.030	0.794
	Adult	0.370	0.336	0.000	2.437	NS	4.786	0.188
Jun 1993 B	Juvenile	0.000	0.472	0.463	0.980	NS	0.502	0.919
	Adult/Juvenile comb.	1.148	1.328	1.747	3.417	NS	3.284	0.350

Table 6. Comparisons (Kruskal-Wallis one-way ANOVA) of rainbow trout densities across stream reaches in Bright Angel Creek, December 1992 - June 1993; NS = not sampled.

Rainbow Trout		Median Value					Critical Values	
		Stream Reach (# of sites)					(Corrected for ties)	
Period	Size Class	0-3 km (8)	3-6 km (8)	6-9 km (8)	9-12 km (8)	12-14.3 km (8)	Chi-square	p value
	Adult	0.000	0.000	0.000	0.000	0.000	5.297	0.258
Dec 1992	Juvenile	0.000	0.000	0.000	0.000	0.000	8.205	0.084
	Adult/Juvenile comb.	0.000	1.182	0.000	0.000	0.000	8.903	0.064
	Adult	0.000	0.000	0.000	0.000	NS	5.094	0.165
Jun 1993 A	Juvenile	0.490	0.882	0.000	0.000	NS	4.695	0.196
	Adult/Juvenile comb.	1.046	0.882	0.000	0.000	NS	7.979	0.046
	Adult	0.000	0.000	0.000	0.000	NS	1.942	0.585
Jun 1993 B	Juvenile	0.000	0.000	0.000	0.000	NS	2.730	0.435
	Adult/Juvenile comb.	0.847	0.000	0.000	0.000	NS	4.118	0.249

bright spawning coloration and males were developing slightly kiped jaws. Fish captured by angling were not yet running ripe.

Many of the adult trout (>250mm TL) observed in December were considerably larger than those observed in June 1992. These large fish may have recently entered the stream from the Colorado River to spawn.

A survey of the tributaries to Bright Angel Creek indicated that trout were still absent from Wall Creek; the flood in September had created a 1-m plunge just 10 m up Wall Creek above its confluence with Bright Angel Creek. Ribbon Creek also contained no trout. Several trout (Y-O-Y and juveniles) were observed in the lower portions of both Transept and Phantom creeks.

Speckled dace were not seen in Willow Spring, however thick vegetation made searching for fish difficult. The water temperature at the spring was 12.5 C at 1300 hr.

Daily water temperatures ranged from 5.2 - 8.7 C (mean = 6.9) during surveys of Bright Angel Creek during December 1992. The water temperatures in the tributaries to Bright Angel Creek were comparable (range 5.2 - 9.8 C).

16-28 March 1993

This trip coincided with a spawning run of flannelmouth suckers from the Colorado River into the lower reach of Bright Angel Creek. Underwater visibility was 1-2 m during the first few days, and I was able to make observations of spawning and determine the distribution of spawning flannelmouth suckers in the creek (chapter 4).

Following the observations of the first 3 days, rising flows and turbidity made it impossible to conduct snorkel surveys. However, 4 minnow traps were set in the lower 0.8 km of the stream. Traps were frequently moved over a 7 day period. Only 1 speckled dace was caught in 500 trap hours (CPUE= 0.002 fish/hour).

Daily water temperatures ranged from 13.5 - 14.5 C (mean = 14.2 C) on Bright Angel Creek in March 1993.

12-21 June 1993 A (Period 4)

Twenty-six survey sites were snorkeled in the lower 9.4 km (2 sites above 9.0 km were pooled with reach 3). Brown trout made up 73.2% of all trout > 100 mm TL (22 adults, 19 juveniles), and rainbow trout comprised 26.8% of all trout >100 mm TL (3 adults and 12 juveniles). Densities of juvenile and adult brown trout were relatively consistent across reaches 1-3 (Figure 8, Table 5). There were no significant differences in the densities of adult or juvenile rainbow trout (Table 6), but the absolute density decreased from downstream to upstream (Figure 9). Only 3 Y-O-Y trout were observed in the stream, 1 in reach 1 and 2 in reach 2 (Figure 7). Three adult bluehead suckers were observed, 1 at each of the 1.8, 6.2, and 7.0 km survey sites. One fish that I hand captured was "spent" (flaccid abdomen, no gametes expressible). A pair of flannelmouth suckers was observed at the 3.84 km survey site. Both fish lay together over small boulder substrate ($\geq$ 25 cm) and had flaccid abdomens indicative of post-spawning.

Many quiet, shallow areas along the stream banks contained small groups of larval fishes (12-20 mm TL). Many larval fishes also were observed in Phantom Creek below the falls (about 100 m above its confluence with Bright Angel Creek). Several collections were made, and speckled dace and bluehead sucker were subsequently identified. I set 10 minnow traps in the lower 3.2 km of Bright Angel Creek and in Phantom Creek below the falls. Only 12 speckled dace were caught in over 520 trap hours (CPUE = 0.023 fish/hour). No speckled dace were observed during surveys of established sites, but 3 adult dace were seen in the lower 2.0 km during training surveys.

Willow Spring marsh contained many juvenile and Y-O-Y speckled dace (15-40 mm TL), but only a few adults were seen. The water temperature at the spring was 18.0 C at 0845 hrs. Daytime water temperatures in Bright Angel Creek ranged from 13.5 - 21.0 C (mean = 17.0) in June 1993.

June 1993 B (Period 5)

I snorkeled the 26 survey sites (in the lower 9.4 km) in Bright Angel Creek twice in June 1993. The second survey, begun 3 days after the first was completed, was done to determine whether there was short term temporal variability (abundance, distribution, composition) of fishes (Decker and Erman 1992). There were no significant differences in fish densities between the 2 surveys (p's > 0.05, M-W U rank sum test), and general trends (distribution, composition) were consistent (Figures 7-9).

Variations Across Seasons

There was a significantly higher density of adult brown trout in the stream in December 1992 than in June 1993 (Table 7). Conversely, there was a higher density of juvenile rainbow trout in the stream in June 1993 than in December 1992 (Table 8).

Brown trout densities (adult and juveniles combined) tended to be higher in upstream areas, whereas rainbow trout densities (adult and juvenile combined) were generally highest in downstream areas (Figure 10). Y-O-Y trout often were absent from the uppermost stream reach; however, their densities were consistent across downstream reaches except during June 1992, when densities were considerably higher in reaches 1 and 2 (Figure 10). A complete summary of SDE's for various species/size classes of trout in Bright Angel Creek is presented in Appendix II.

Kanab Creek

SDE_{Top2} is reported here to facilitate direct comparisons of relative fish densities across stream reaches and periods. However, SDE's based upon total catch and CAPTURE-generated population estimates (where possible) are available (Appendix III) for comparison with future monitoring efforts.

6-8 August 1992 (Period 1)

Juvenile bluehead suckers were the numerically dominant native species/size class in Kanab Creek in August 1992 (100 fish, Figure 11). They were followed by

Table 7. Comparisons (Kruskal-Wallis one-way ANOVA) of brown trout densities across sample periods in Bright Angel Creek, December 1992 - June 1993; * denotes significance ($p < 0.05$).

Brown Trout	Median SDE			Critical Values	
	Sample Period (number of sites sampled)			(Corrected for ties)	
Size Class	Dec '92 (40)	Jun '93 A (26)	Jun '93 B (26)	Chi-Square	p value
Adult	1.237	0.741	0.000	6.247	0.044*
Juvenile	0.000	0.000	0.000	0.499	0.779

Table 8. Comparisons (Kruskal-Wallis one-way ANOVA) of rainbow trout densities across sample periods in Bright Angel Creek, December 1992 - June 1993; *denotes significance ($p < 0.05$).

Rainbow Trout	Median SDE			Critical Values	
	Sample Period (number of sites sampled)			(Corrected for ties)	
Size Class	Dec '92 (40)	Jun '93 A (26)	Jun '93 B (26)	Chi-Square	p value
Adult	0.000	0.000	0.000	0.792	0.673
Juvenile	0.000	0.000	0.000	12.067	0.002*

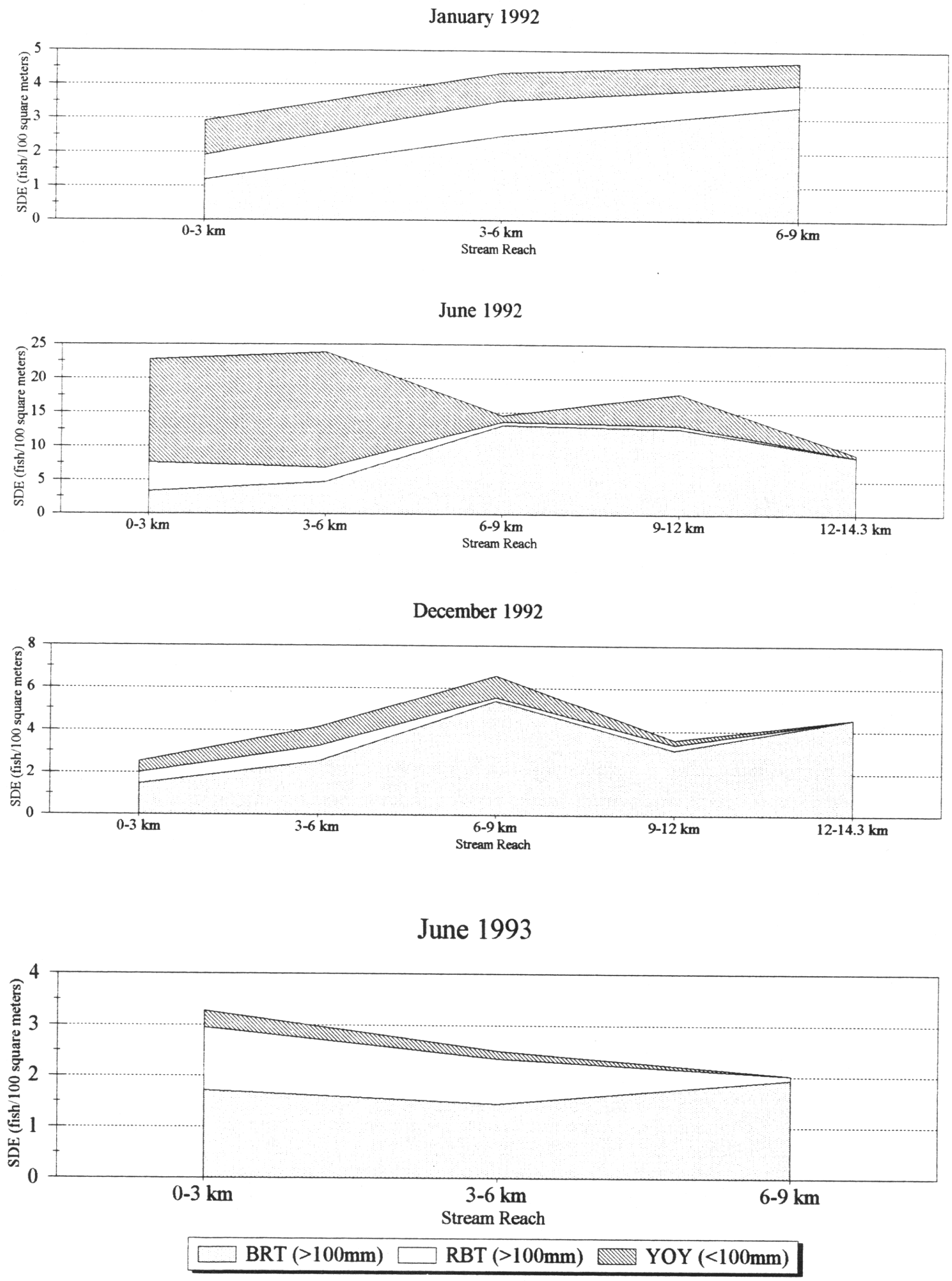


Figure 10. Composition of brown (BRT), rainbow (RBT), and Y-O-Y (both species combined) trout in Bright Angel Creek by stream reach, January 1992 - June 1993.

juvenile speckled dace (88 fish, Figure 12), adult speckled dace (8 fish), juvenile flannelmouth sucker (4 fish, Figure 13), and adult bluehead sucker (1 fish, Figure 11).

Flannelmouth suckers occurred at the confluence and 1.8 km up Kanab Creek (2 at each site). Bluehead suckers were distributed throughout the lower 6.0 km, with the highest density at the 6.0 km site (SDE_{BHSAJ2} = 27.2 fish/100 m^2, Figure 11). A small waterfall about 1-m in height prevented movement of bluehead suckers above rk 6.2. The mean length of bluehead suckers caught in August 1992 was 96 mm TL. Most bluehead suckers were in the 80 to100-mm size class; however, individuals as large as 179 mm TL were taken (Figure 14). There were no significant differences in bluehead sucker densities between reaches 1 and 2 (Table 9).

Speckled dace were found at all locations in the lower 10.0 km; the falls at rk 6.2 apparently did not act as a barrier to their upstream distribution. Speckled dace were most abundant at the 5.23 km site (SDE_{SPDAJ2} = 27.5 fish/100 m^2, Figure 12). The mean length of speckled dace was 52 mm TL, and most individuals were in the 50 to 60-mm size class (Figure 15). There were no significant differences in the densities of speckled dace by reach (Table 10).

Channel catfish, *Ictaluris punctatus* (3 adults); common carp, *Cyprinus carpio* (2 adults); fathead minnows, *Pimephales promelas* (15 fish); and rainbow trout (1 juvenile) were taken at the confluence site on Kanab Creek. No other non-native species were observed in the creek. The largest catfish (650 mm TL) contained a partially digested adult bluehead sucker (identification made by M. Douglas and W.L. Minckley, Arizona State University).

Four hoopnets and 4 minnow traps set (over 500 trap hours) in the lower 60 m of Kanab Creek captured 1 rainbow trout, 1 speckled dace, and 2 flannelmouth suckers. Daytime water temperatures in Kanab Creek ranged from 21.0-28.5 C (mean = 24.5) during this sampling period.

6-8 November 1992 (Period 2)

Juvenile bluehead suckers (87 fish) were the most abundant native species/size class in Kanab Creek in November 1992. I also captured 61 Y-O-Y, 37 juvenile, and 14 adult speckled dace, 6 adult bluehead suckers, 4 juvenile flannelmouth sucker, and 3 Y-O-Y bluehead sucker. No adult or Y-O-Y flannelmouth suckers were caught.

Bluehead suckers were most numerous at the 4.0 km site (SDE_{BHSAJ2} = 44.0 fish/100 m^2); however, they were distributed throughout the lower 6.0 km (Figure 11). The mean length of bluehead suckers was 109 mm TL, and most individuals were in the 100 to 120-mm size class (Figure 14). The largest bluehead sucker was 251mm TL and was taken at the confluence. Three Y-O-Y bluehead suckers caught at the mouth of the creek ranged from 18 to 20 mm TL. There were no significant differences in SDE's between reaches 1 and 2 for any size class of bluehead sucker (Table 9).

The density of Y-O-Y speckled dace was highest at the 7.2 km site, and juveniles were most abundant at 4.0 km (Figure 12). No speckled dace were taken at the confluence or at the 10.0 km sites; however, they were found at all other sites. The mean length of speckled dace was 38 mm TL, but the length frequency histogram was bimodal with peaks at 10 to 20 mm and 60 to 70 mm (Figure 15). Y-O-Y dace ranged from 17 to 24 mm TL. There were no significant differences in SDE's across reaches 1-3 for any size class of speckled dace (Table 10).

Two juvenile flannelmouth suckers were taken at the confluence (269 mm, 264 mm TL), and 2 at the 1.8 km site (169 mm, 178 mm TL) (Figure 13). One juvenile channel catfish (103 mm TL) and 18 fathead minnows (26-55 mm TL) were taken at the confluence site. No non-native fishes were caught above the confluence in November 1992.

The November trip to Kanab Creek was made in conjunction with Arizona Game and Fish (AGF). AGF made several seine hauls in the lower 200 m of Kanab Creek, 1 of which yielded a Y-O-Y humpback chub (G. Doster, AGF, pers. comm.).

Daytime water temperatures ranged from 9.7-11.9 C (mean = 10.4).

14-16 January 1993 (Period 3)

The discharge of Kanab Creek was higher in January 1993 than it had been in previous periods, and I could not completely block some sites. Therefore, I blocked the downstream end of each sample reach and made 1-3 seine hauls downstream into this net. Consequently, SDE's from January cannot be compared directly to those from other periods.

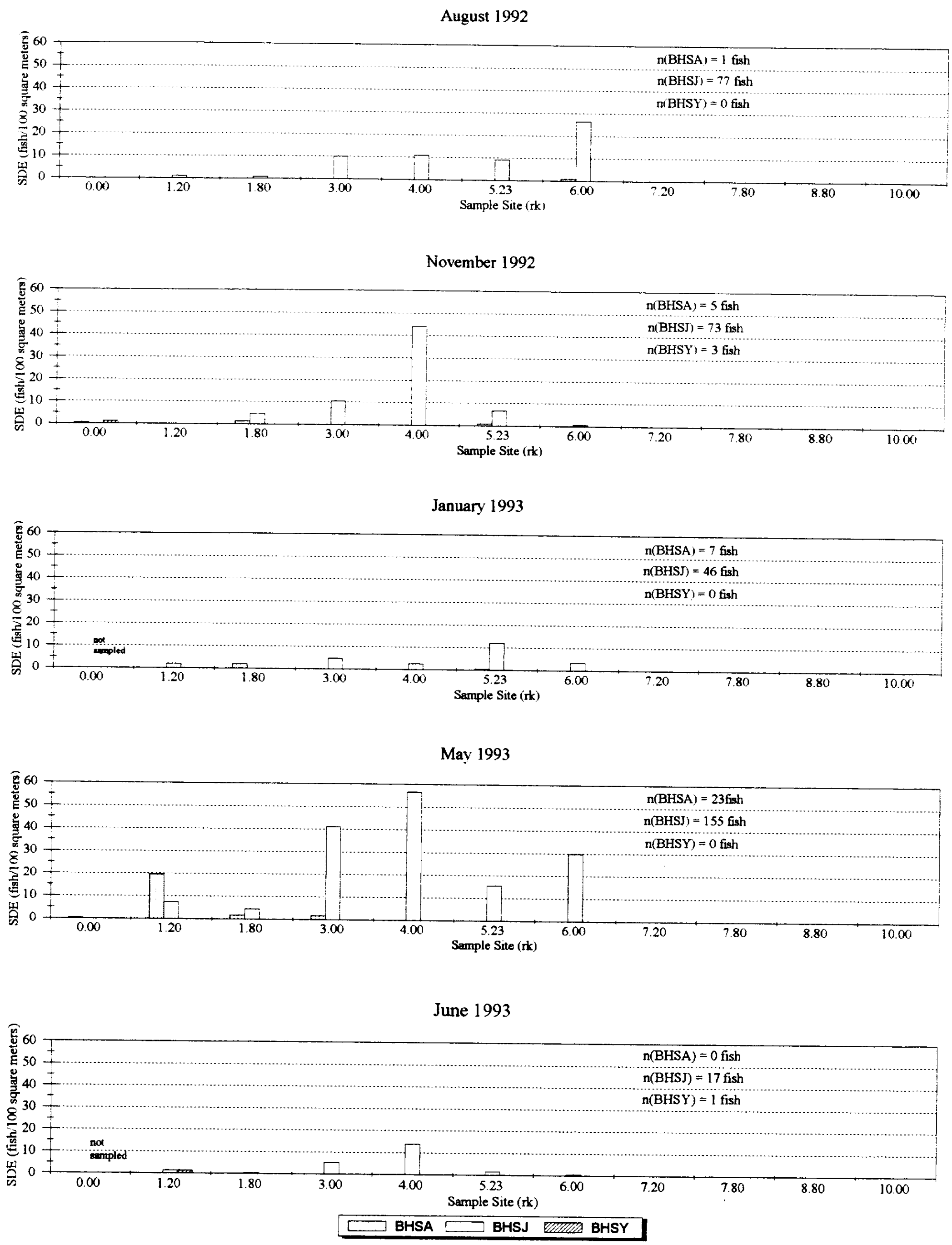


Figure 11. Standard Density Estimates (SDE- Top 2 seine hauls) for adult (BHSA), juvenile (BHSJ), and Y-O-Y (BHSY) bluehead suckers caught by seining in Kanab Creek, August 1992-June 1993.

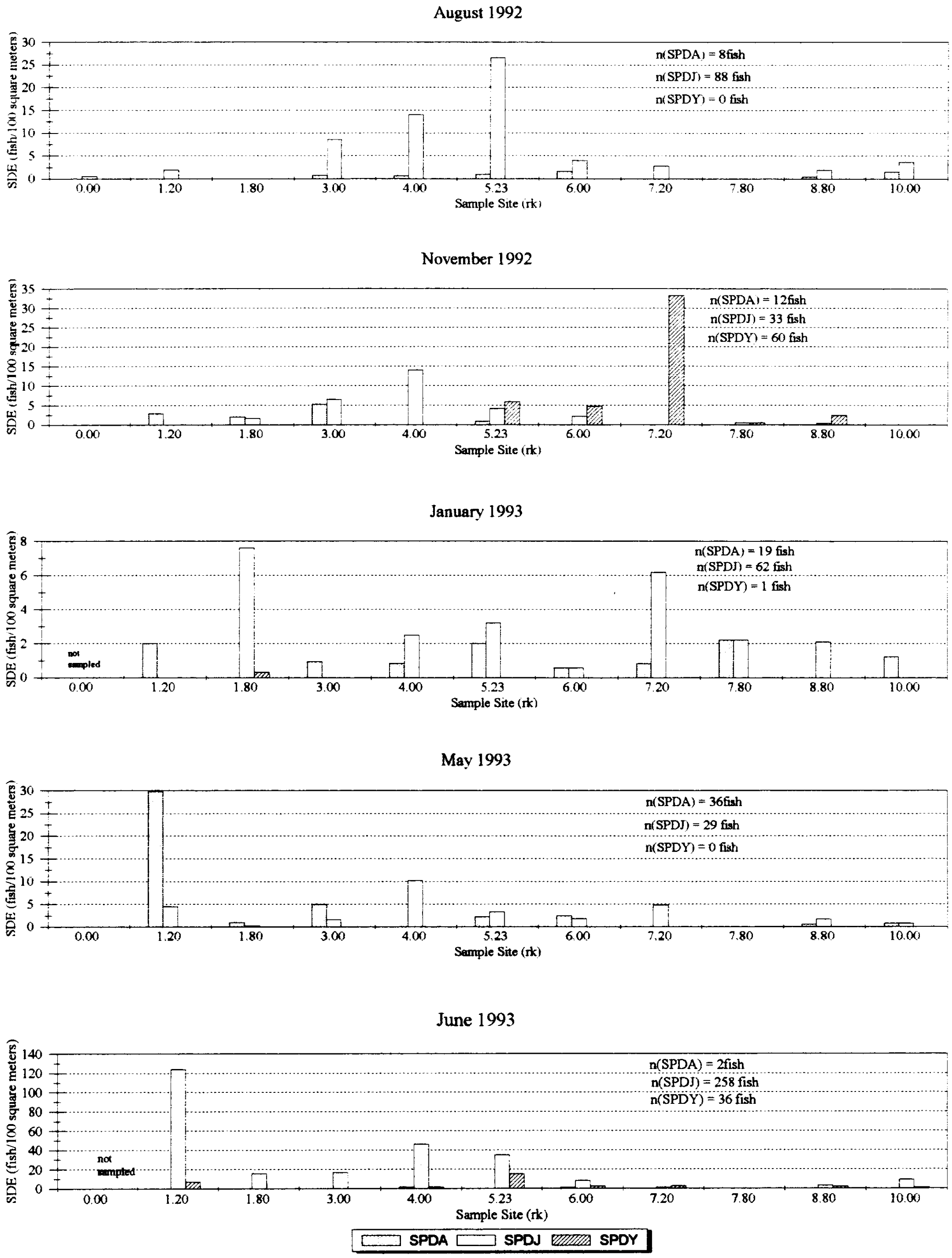


Figure 12. Standard Density Estimates (SDE- Top 2 seine hauls) for adult (SPDA), juvenile (SPDJ), and young of year (SPDY) speckled dace caught by seining in Kanab Creek, August 1992-June 1993; (note Y-axis scales).

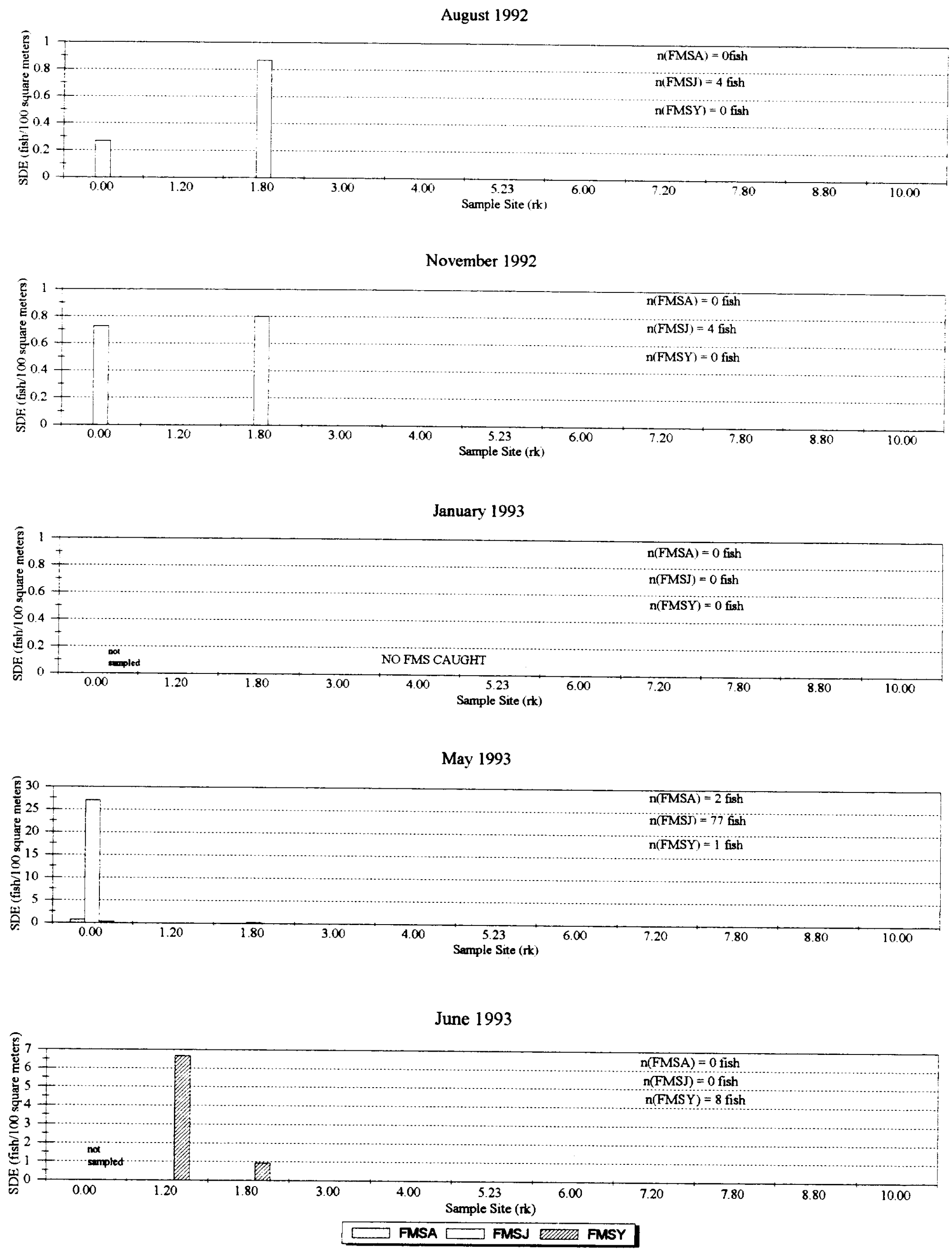


Figure 13. Standard Density Estimates (SDE-Top 2 seine hauls) for adult (FMSA), juvenile (FMSJ), and Y-O-Y (FMSY) flannelmouth suckers caught by seining in Kanab Creek, August 1992-June 1993; (note Y-axis scales).

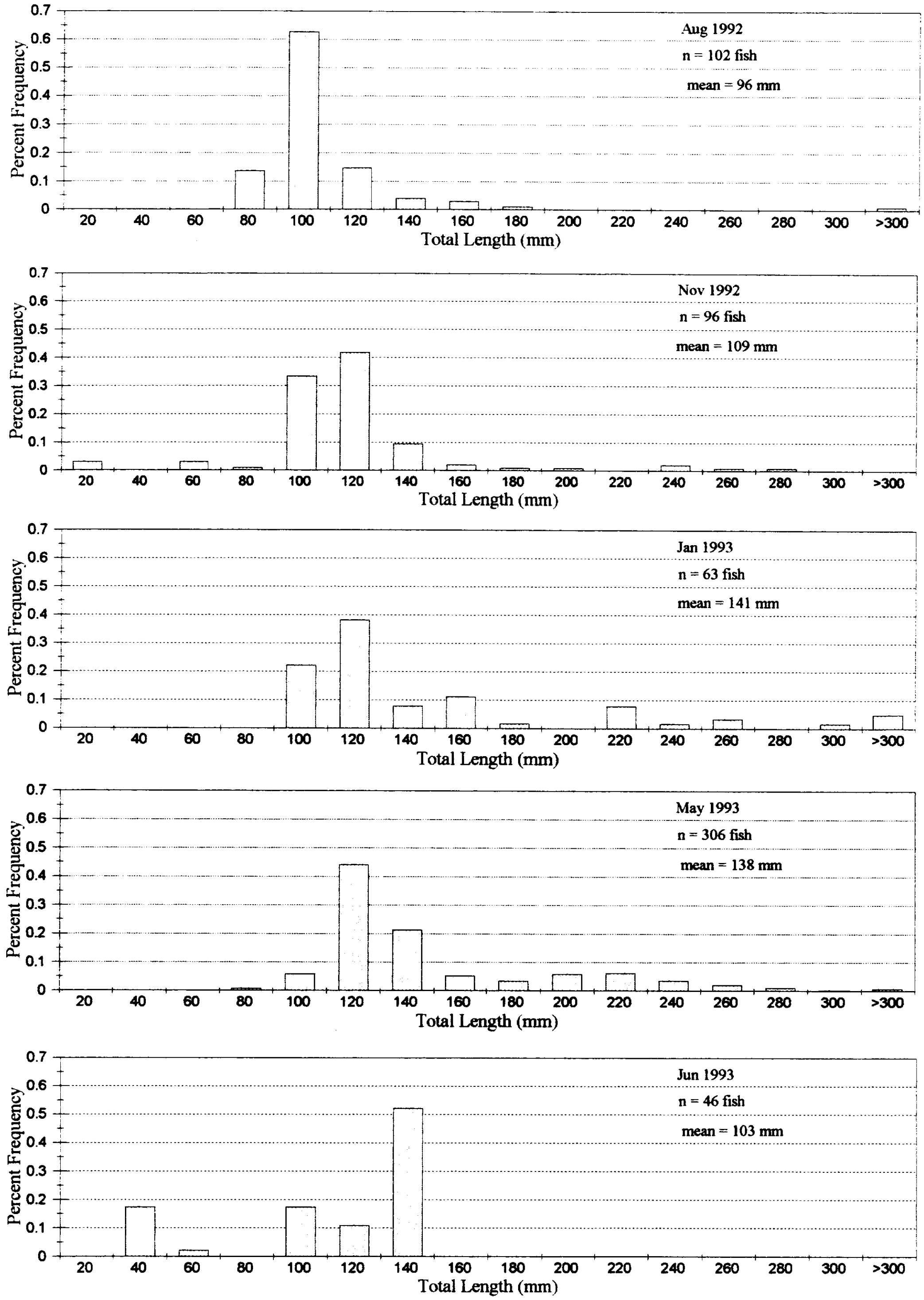


Figure 14. Length-frequency histograms for bluehead suckers caught in Kanab Creek during each sample period in 1992-1993.

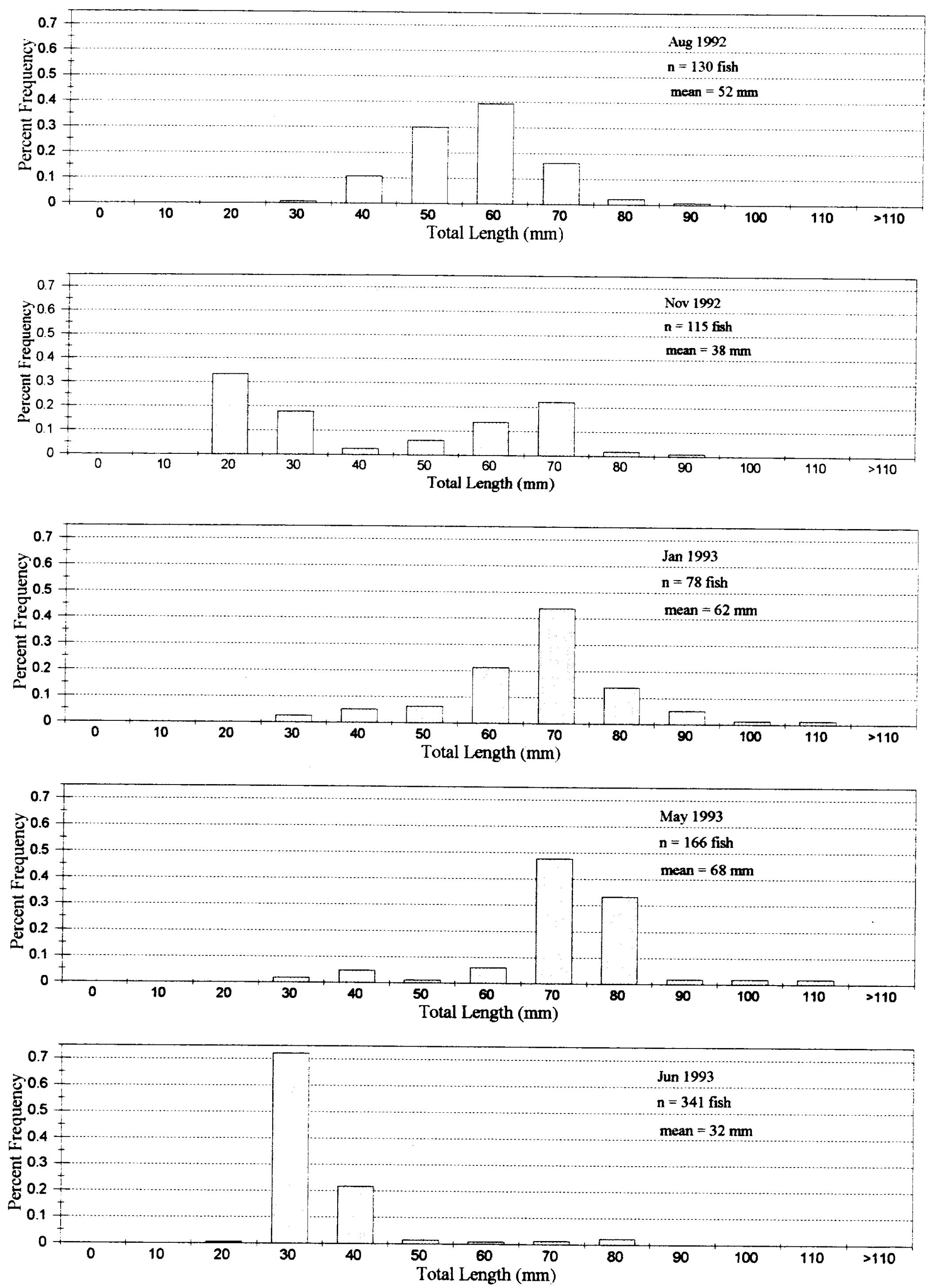


Figure 15. Length-frequency histograms for speckled dace caught in Kanab Creek during each sample period in 1992-1993.

Table 9. Comparisons (Mann-Whitney-Wilcoxon Test) of bluehead sucker densities across stream reaches 1 and 2 in Kanab Creek, August 1992 - June 1993; *denotes significance ($p < 0.05$).

Bluehead sucker		Median SDE		Critical Values	
		Stream Reach (# of sites)		(Corrected for ties)	
Period	Size Class	0-3 km (4)	3-6 km (3)	Z- value	p value
	Adult	0.000	0.000	-1.155	0.248
Aug 1992	Juvenile	0.920	10.976	-1.768	0.077
	Young-of-year	0.000	0.000	0.000	1.000
	Adult/Juvenile comb.	0.920	10.976	-1.760	0.077
	Adult	0.181	0.000	-0.390	0.697
Nov 1992	Juvenile	2.400	6.667	-1.070	0.285
	Young-of-year	0.000	0.000	-0.866	0.387
	Adult/Juvenile comb.	3.181	7.500	-1.061	0.289
	Adult	1.590	0.000	-2.201	0.028*
May 1993	Juvenile	5.947	29.697	-1.414	0.157
	Young-of-year	0.000	0.000	0.000	1.000
	Adult/Juvenile comb.	16.419	29.697	-1.061	0.289
	Adult	0.000	0.000	0.000	1.000
Jun 1993	Juvenile	0.821	1.587	-0.655	0.513
	Young-of-year	0.000	0.000	-1.000	0.317
	Adult/Juvenile comb.	0.821	1.587	-0.655	0.513

Table 10. Comparisons (Kruskal-Wallis one-way ANOVA) of speckled dace densities across stream reaches in Kanab Creek, August 1992 - June 1993.

Speckled dace		Median SDE			Critical Vaues	
		Stream Reach (# of sites)			(Corrected for ties)	
Period	Size Class	0-3 km (4)	3-6 km (3)	6-10 km (4)	Chi-Square	p value
Aug 1992	Adult	0.000	0.917	0.198	4.025	0.134
	Juvenile	1.237	14.024	2.358	5.110	0.078
	Young-of-year	14.024	0.000	0.000	0.000	1.000
	Adult/Juvenile comb.	2.358	14.634	2.556	5.110	0.078
Nov 1992	Adult	2.408	0.000	0.000	5.163	0.076
	Juvenile	0.800	4.167	0.172	4.794	0.091
	Young-of-year	0.000	4.795	1.449	0.425	0.119
	Adult/Juvenile comb.	3.208	5.000	0.172	4.985	0.083
May 1993	Adult	2.941	2.198	0.284	0.260	0.272
	Juvenile	0.916	3.297	1.204	2.782	0.249
	Young-of-year	0.000	0.000	0.000	0.000	1.000
	Adult/Juvenile comb.	3.857	5.495	1.841	2.066	0.356
Jun 1993	Adult	0.000	0.578	0.000	5.185	0.075
	Juvenile	16.028	34.921	1.928	5.573	0.062
	Young-of-year	0.000	2.312	1.311	1.696	0.428
	Adult/Juvenile comb.	16.028	34.921	1.928	5.573	0.062

The numerical rank order of native fishes by abundance in January 1993 was: speckled dace juveniles (62), bluehead sucker juveniles (47), speckled dace adults (19), bluehead sucker adults (7), and Y-O-Y speckled dace (1). No flannelmouth suckers were caught in established seine reaches in January 1993, but 3 Y-O-Y flannelmouth suckers (66, 67, and 87 mm TL) were taken at a location 200 m upstream from the mouth of Kanab Creek. It was not possible to seine the confluence site due to high flows and deep water. I took 46 fathead minnows (2 of which were gravid) and 2 plains killifish, *Fundulus zebrinus* (34 and 56 mm TL) 200 m above the confluence.

The relative abundance of bluehead suckers was highest at the 5.23 km site (SDE_{BHSAJ} = 12.4 fish/100 m^2, Figure 11), but suckers were distributed throughout the lower 6.0 km. The mean total length of bluehead suckers was 141 mm, but most individuals were in the 100 to 120-mm size class (Figure 14). There were several adult bluehead suckers >200mm TL in reach 1.

The largest number of speckled dace were at the 1.8, 5.23, and 7.2 km sites (SDE_{SPDAJ} = 7.6, 5.2, and 7.0 fish/100 m^2, respectively, Figure 12). Dace were present in all sites sampled in January. The mean length of speckled dace was 62 mm TL, and most individuals were in the 60 to70-mm size class (Figure 15).

Four hoopnets and 9 minnow traps set in the lower 120 m of Kanab Creek captured 11 fish in over 800 trap-hours. These nets and traps were checked every 12 hours and moved to new locations every 24 hours. I captured 2 juvenile flannelmouth suckers (184 mm and 326mm TL), 1 adult bluehead sucker (220 mm TL), 1 juvenile speckled dace, and 7 fathead minnows (adults and juveniles combined). Supplemental seining at 21 locations in the lower 300 m of Kanab Creek captured fathead minnows (17 fish), speckled dace (15 fish), bluehead suckers (3 juveniles, 1 adult), and a flannelmouth sucker (juvenile).

Daytime water temperatures ranged from 8.9-9.8 C during seining efforts.

21 April - 7 May 1993 (Period 4)

I captured 230 juvenile bluehead suckers, 90 juvenile flannelmouth suckers, 42 adult speckled dace, 32 adult bluehead suckers, 30 juvenile speckled dace, 2 adult flannelmouth suckers, and 1 Y-O-Y flannelmouth sucker during this period.

Juvenile bluehead suckers were most abundant at the 4.0 km site (SDE_{BHSJ2} = 56.5 fish/100 m^2), but adults were most abundant at the 1.2 km site (SDE_{BHSA2} = 19.4 fish/100 m^2, Figure 11). The mean length of bluehead suckers stream-wide was 138 mm, but most individuals were in the 100 to 120-mm size class (Figure 14). There were significantly more adult bluehead suckers in reach 1 than in reach 2 ($p < 0.03$, Table 9). There were no other significant differences in the densities of bluehead suckers between reaches (Table 9). At rk 3.2, there was a barrier to bluehead sucker movement. The barrier occurred where large boulders confined the stream to a narrow channel with a high velocity plunge of about 50-70 cm. Several large adult bluehead suckers were observed in the pool below this barrier, but no adults were observed above it.

Speckled dace were most abundant at the 1.2 km site (SDE_{SPDAJ2} = 34.3 fish/100 m^2), but they also occurred at most other locations (Figure 12). The mean length of speckled dace was 68 mm TL, and most fish were in the 60 to70-mm size range (Figure 15). There were no significant differences in the SDE's for speckled dace between reaches (Table 10).

The confluence site was seined 3 times during this period, once during a day when Kanab Creek was turbid and the flow of the Colorado River did not affect the mouth of Kanab Creek (29 April at 1350 hr), once that same night when the Colorado River backed up Kanab Creek for almost 100 m (29 April at 2200 hr), and again during a day when Kanab Creek was clear (6 May at 1200 hr). I caught the most fish (92 flannelmouth suckers) during the day when Kanab Creek was turbid; no fish were caught when Kanab Creek was clear. I caught 17 flannelmouth suckers during the night seine haul. A winged hoopnet (opening downstream) set overnight 35 m above the mouth (with AGF) on 21 April caught 14 flannelmouth suckers (310-433 mm TL), 4 bluehead suckers (102-292 mm TL), and 4 speckled dace.

I made several "opportunistic" seine hauls and set hoopnets and minnow traps in the lower 200 m of Kanab Creek during this period to determine fish diversity in the confluence area. The five species captured were: 61 speckled dace, 21 flannelmouth suckers, 6 bluehead suckers, 1 carp, and 1 fathead minnow. Four hoop nets and 3 minnow traps (520 total trap-hours) captured 45 flannelmouth suckers (130-427 mm TL), 8 bluehead suckers (170-275 mm TL), 3 speckled dace (70-78 mm TL), and 1 green sunfish, *Lepomis cyanellus,* (97 mm TL).

I caught 11 bluehead sucker larvae in 2 drift nets set near the mouth of Kanab Creek on 6 and 7 May. Nine out of the 11 larvae were caught between 0200-0400 hr. Larvae were abundant throughout reach 1 of the creek beginning 5 May.

On 3 May, I again seined the 7 sites in the lower 6.0 km of Kanab Creek to confirm my observation that many bluehead suckers had recently left the creek. Without exception, fewer bluehead suckers were caught at each site during this second survey (mean % difference = 58.5% fewer fish); the largest difference occurred at sites in reach 1 (78.0% fewer fish). Most of the male bluehead suckers stream-wide still expressed milt, but many of the females were spent.

Daytime water temperatures ranged from 15.2-24.5 C (mean = 19.6 C) on Kanab Creek during this period.

26-28 June 1993 (Period 5)

The capture of fish in established seining sites in Kanab Creek in June 1993 was: juvenile speckled dace (299), Y-O-Y dace (36), juvenile bluehead suckers (18), Y-O-Y flannelmouth suckers (9), adult dace (2), and Y-O-Y bluehead suckers (1). Two green sunfish and several carp were observed during snorkel surveys in the lower 2.5 km of the stream.

The density of bluehead suckers was highest at the 4.0 km site (SDE_{BHSJ2} = 13.8 fish/100 m^2), but they occurred in low numbers at all sites in the lower 6.0 km (Figure 11). The mean length of bluehead suckers was 103 mm TL (Figure 14). Bluehead sucker SDE's for reaches 1 and 2 were not significantly different (Table 9). Water visibility exceeded 4 m in some locations. These conditions enabled the snorkeling of many reaches that were unseineable. Snorkel surveys of 6 sites in the lower 1.5 km indicated that bluehead suckers were concentrated in pools directly below plunges and in the faster flowing water of riffles.

The density of speckled dace was highest at the 1.2 km site (SDE_{SPDJ2} = 124.0 fish/100 m^2), but they were found throughout the lower 10.0 km (Figure 12). The mean length of speckled dace during this period was 32 mm TL, but most individuals were in the 20-30 mm size range (Figure 15). SDE's for speckled dace by stream reach in June were not significantly different (Table 10).

Only 9 flannelmouth suckers were observed in established seining sites on Kanab Creek in June 1993. All were Y-O-Y fish and were in the 1.2 and 1.8 km sites (Figure 13).

The confluence was not seined during this period because U.S. Fish and Wildlife Service (FWS) crews deployed hoopnets and minnow traps and conducted snorkel surveys in this area. A juvenile humpback chub, about 72 mm TL, was caught in a mini-hoopnet in the lower 500 m of Kanab Creek, and 2 adult chub were observed at night in a slow run near the shale bedrock on river left less than 100 m above the mouth of the creek (S. Leon and O. Gorman, FWS, pers. comm.).

Prior to the June trip, several weeks had passed since the last flood event. Sediments had settled and water clarity was high. Stream discharge and current velocities were low resulting in some stagnant water. Algae covered sections of the stream bed and water temperatures reached 30.0 C during the day. Many Y-O-Y and juvenile fishes in the lower 6.0 km were infected by the external parasite *Lernaea cyprinacea*. Several dozen fish were found dead in the lower 6.0 km with *Lernaea* still attached. The majority of dead fish were Y-O-Y and small juvenile speckled dace and bluehead suckers, but several bluehead suckers over 120 mm TL were also found dead. No dead fish or *Lernaea* were found above the 6.2 km barrier. Of 335 live fishes seined at sites in the lower 6.0 km, 35 (10.4%) were infected by *Lernaea*. These individuals contained from 1-4 *Lernaea*. *Lernaea* generally were attached to the torso near the origin of the pectoral and pelvic fins.

Daytime water temperatures on Kanab Creek ranged from 24.0 - 30.0 C (mean = 27.0 C) during this sampling period. Water quality measurements (temperature, dissolved oxygen, pH, conductivity) for this period are shown in Table 11.

Variation Across Seasons

There were significantly more adult bluehead suckers in reach 1 during April-May 1993 than during any other period ($p = 0.016$, Table 12). Bluehead suckers caught in April-May 1993 were significantly larger (median TL) than bluehead suckers caught during all other periods except January ($p < 0.001$ for all pairwise comparisons except January, where $p > 0.03$ Bonferroni correction required $p < 0.0125$ for significance).

There were significantly more juvenile dace in June than in November ($p < 0.033$, Table 13) and significantly more Y-O-Y dace in June than in either August or May ($p < 0.001$, Table 13).

DISCUSSION

Methodological Considerations

Standard Density Estimates

The reported SDE for Bright Angel Creek fish is based on the total number of fish observed at each site. The calculated $SDE_{Top\,2}$ for Kanab Creek fish is based on the total catch of the 2 most effective seine hauls at each survey site. Although this SDE may not precisely represent the true density of fishes it does result in a standardized index of fish abundance that can be used to make direct comparisons between stream reaches and sampling periods. The high correlation between $SDE_{Top\,2}$ and $SDE_{CAPTURE}$ suggests that $SDE_{Top\,2}$ was an effective index of fish density. I have not made direct comparisons of fish densities between Bright Angel and Kanab Creeks because their respective SDE's do not have the same basis. $SDE_{Total\,Catch}$ and $SDE_{CAPTURE}$ (where calculable) more closely approximate true densities in Kanab Creek (Appendix III).

Table 11. Summary of water quality conditions on Kanab Creek during 25 - 27 June 1993.

Date	Time of day	Stream Location (rk)	DO (ppm)	Water Temp. (C)	pH	Conductivity (micro-siemens)
25 June	0833	1.0	6.00	19.7	7.18	1242
	0933	1.5	6.90	19.4	7.90	1300
	1032	2.0	7.30	21.2	7.59	1240
	1145	2.5	8.20	22.5	7.69	1230
	1316	3.0	6.90	25.7	7.54	1250
	1424	3.5	6.40	27.9	7.53	1210
	1539	4.0	5.60	26.7	7.17	1230
	1633	4.5	4.50	27.4	7.48	1270
	1728	5.0	6.00	25.5	7.76	1270
26 June	1114	5.5	7.00	24.5	7.98	1240
	1259	6.0	6.10	25.6	7.96	1260
	1347	6.5	5.40	27.4	8.12	1090
	1451	7.0	5.50	27.5	7.94	1210
	1540	7.5	2.30	28.7	7.82	1280
	1632	8.0	4.20	28.5	7.52	1260
27 June	1038	8.0	6.00	22.9	7.23	1250
	1142	8.5	6.10	23.6	7.94	1260
	1237	9.0	6.80	25.8	8.07	1230
	1352	9.5	6.80	27.0	7.10	1200
	1443	10.0	5.10	26.8	7.77	1220

Table 12. Comparisons (Kruskal-Wallis one-way ANOVA) of bluehead sucker densities across sample periods on Kanab Creek, August 1992 - June 1993; *denotes significance ($p < 0.05$).

Bluehead sucker	Median SDE				Critical Values	
	Sample Period (number of sites sampled)				(Corrected for ties)	
Size Class	Aug '92 (7)	Nov '92 (7)	May '93 (7)	Jun '93 (6)	Chi-Square	p value
Adult	0.000	0.000	0.000	0.000	6.705	0.082
Juvenile	0.870	0.000	4.432	0.443	3.267	0.352
Young-of-year	0.000	0.000	0.000	0.000	2.293	0.514
Adult/Juvenile comb.	0.870	0.362	5.973	0.443	4.902	0.179
Adults (Reach 1 only)	0.000	0.181	1.590	0.000	10.389	0.016*

Table 13. Comparisons (Kruskal-Wallis one-way ANOVA) of speckled dace densities across sample periods on Kanab Creek, August 1992 - June 1993; *denotes significance ($p < 0.05$).

Speckled dace	Median SDE				Critical Vaues	
	Sample Period (number of sites sampled)				(Corrected for ties)	
Size Class	Aug '92 (11)	Nov '92 (11)	May '93 (11)	Jun '93 (10)	Chi-Square	p value
Adult	0.395	0.000	0.704	0.000	4.884	0.181
Juvenile	2.740	0.493	1.705	9.091	8.820	0.032*
Young-of-year	0.000	0.000	0.000	1.538	17.573	<0.001*
Adult/Juvenile comb.	6.351	2.055	4.242	9.091	6.098	0.107

Seining

Seining effectiveness has been related to the capturability of target species (Lyons 1986, Parsley et al. 1989), which is related to water clarity, water temperature, and substrate types (Hunter and Wisby 1964, Lyons 1986). Therefore variation between sample sites and periods can be related to seining efficiency rather than differences in fish abundance. Consequently, estimating the area covered by a non-blocked single pass seine and then calculating a Catch Per Unit of Effort (CPUE) is of limited use in directly comparing fish abundances across spatial and temporal zones. To minimize some of the variability inherent to seining, I blocked sites, made multiple seine hauls, accurately measured the sample area, and applied equal effort.

My seining efficiency results are not true capture efficiencies (CE) as defined by Parsley et al. (1989). Parsley et al. (1989) defined CE for each taxon as CE = C/areaT; where C is the catch in the first haul, T is the total number of that taxon removed from the enclosure, and area is the proportion of the enclosed area sampled by the first seine haul. These authors also emphasized that CE for a species can be greatly affected by substrate and should include data taken over a variety of substrates. Small sample sizes precluded me from making separate substrate comparisons. Therefore, my CE reflects the proportion of the estimated population (via CAPTURE) that was caught in the top 2 seine hauls.

Snorkel Surveys

Direct observation by snorkeling is an effective way to census fish populations (Keenleyside 1962, Northcote and Wilkie 1963, Whitworth and Schmidt 1980, Schill and Griffith 1984, Pearsons et al. 1992) with less fish disturbance than traditional practices (Hankin and Reeves 1988). However, the effectiveness of this technique can be limited by the depth, clarity, and turbulence of the water, and the reactions of fish to divers (pers. obs.). During my surveys, trout generally reacted to divers by either remaining motionless near cover, rushing downstream past them, or by staying slightly ahead of them; native fish generally did not react negatively to divers. Y-O-Y trout often hid under substrates when divers approached and may have been under-counted. Riffles generally offered less visibility than pools because of turbulence. Thus, the densities of fishes reported for Bright Angel Creek may be conservative.

Fish Sample Sites

Fish sample sites on Kanab Creek were not representative of available habitats on that stream; only seineable sites were selected. Therefore, reported densities for fishes in Kanab Creek may not be indicative of the overall density of fishes.

Both riffles and pools were surveyed on Bright Angel Creek, and fish densities were adjusted to account for the true proportions of pools (0.24) and riffles (0.76). Thus, reported densities for fishes in Bright Angel Creek should be representative of the overall density of fishes.

Species Distribution, Abundance, and Composition

Although there is danger in drawing conclusions from sample events that represent a "slice in time" (Decker and Erman 1992), my surveys of Kanab Creek were consistently spaced throughout the year and should represent typical patterns of use of that stream relative to native and introduced fish. Conclusions regarding Bright Angel Creek fish populations are more tentative, as effective surveys were accomplished only during winter (January and December 1992) and spring (June 1992 and 1993).

Bright Angel Creek

Brown trout were predominant in Bright Angel Creek during every period sampled. They reached their highest densities in upstream areas. Rainbow trout reached their highest densities in downstream areas. Rainbow trout in upstream areas tended to be large individuals; sub-adult rainbow trout were relatively abundant throughout the lower 6.0 km of Bright Angel Creek but were not observed above reach 3 (6-9 km).

Flannelmouth suckers were abundant in Bright Angel Creek only during spawning- an abbreviated period beginning as early as February and ending in late March or early April. No Y-O-Y flannelmouth suckers were observed in Bright Angel Creek. Aspects of the spawning ecology of flannelmouth suckers in Bright Angel Creek are discussed in chapter 4.

Minckley (1978) reported bluehead suckers spawning in Bright Angel and Phantom creeks during April-May. I never directly observed bluehead suckers spawning in Bright Angel Creek, but I saw several post spawning adult suckers in the creek during June 1993, and I observed low numbers of bluehead sucker larvae in the lower 3.0 km of the stream each June. Juvenile bluehead suckers were not observed in Bright Angel Creek; thus, the stream does not appear to be used for rearing, as is Kanab Creek.

Status of *Rhinichthys* in Bright Angel Creek

Several authors have implicated predation by introduced species as contributing to the decline of native fishes throughout the Southwest (Meffe 1985, Marsh and Langhorst 1988, Marsh and Brooks 1989, Rinne 1992) and within the Grand Canyon (Miller 1968, Minckley 1991, Haden 1992).

I found few adult and juvenile dace in Bright Angel Creek in 1992 and 1993. The low abundances that I observed are markedly different than those reported by Minckley (1978); speckled dace were the most common native species in Bright Angel Creek in the spring and summers of 1976 and 1977 and were easily obtainable in both Phantom and Bright Angel creeks. Minckley (1978) noted that numbers dropped dramatically during the fall and that dace were unobtainable during winter. Speckled dace were also abundant in 1978; Carothers and Minckley (1981) estimated densities of dace at 2,800 fish/hectare during the summer.

During the seasons (March - September) that Minckley (1978) reported the greatest abundances of speckled dace in Bright Angel Creek, I found very few. Dace may have avoided detection by snorkel surveys, but in Shinumo and Kanab creeks they showed no fear of divers and even "nibbled" at their skin (pers. obs.). Furthermore, dace are generally easy to trap; I caught over 150 speckled dace in a single unbaited minnow trap fished for less than 12 hr in the LCR, and Mattes (1993) also had high capture rates in that system. Yet in over 1,000 trap-hours on Bright Angel Creek I caught only 13 speckled dace.

The apparent change in the abundance of speckled dace between the 1970's and 1993 may be related to a change in the dominant predator in Bright Angel Creek. Rainbow trout were the predominant trout species during the mid-to-late 1970's (Minckley 1978). In fact, Minckley (1978) caught only 2 brown trout in Bright Angel Creek, and 1 in Phantom Creek, during the 2 years of his investigation. Similarly, a 1977-1979 creel census (Carothers and Minckley 1981) showed that 97% of the trout caught on Bright Angel Creek were rainbow trout. These 2 studies took place within the lower 3.2 km of Bright Angel Creek. Usher et al. (1984) conducted a creel census in the lower 3.2 km in 1980 and reported that rainbow trout represented 92.3% (brown trout 4.7%, and brook trout 3%) of the angler catch. In 1984 this picture had begun to change; a creel survey on Bright Angel Creek by GCNP and AGF showed that rainbow trout composed 84.5% of the catch, brown trout 11.8%, and brook trout 3.6% (Wintermute 1984). The most recent creel survey (1988) showed an additional increase in brown trout; rainbow trout comprised 76.5% of the catch, brown trout 22.5%, and brook trout 1.0% (B. Persons, AGF raw data).

may reach 120-140 mm at age 1, probably as a result of higher stream temperatures (relative to the Colorado River). Male bluehead suckers < 100 mm TL in Kanab Creek often expressed milt; and virtually all those > 110 mm TL expressed milt. I also found gravid females as small as 102 mm TL. While many individuals in Kanab Creek were sexually mature at small sizes, spawners I observed were rarely under 140 mm TL, and most were considerably larger (mean TL of spawners at the 1.35 km site = 198 mm).

Smith (1966) reported mature male bluehead suckers as small as 79 mm (SL) in the San Juan and Little Colorado rivers, but reported that Grand Canyon (Colorado River) populations did not reach maturity until they were 152 mm (SL). Many riverine populations of a species grow larger than conspecific populations inhabiting small streams (Smith 1981). Smith (1981) found this fish size/habitat size relationship to be true with bluehead suckers. It is unclear whether fish are smaller in small streams due to stunted growth or decreased longevity; however, it appears that small stream populations also reach sexual maturity at smaller sizes.

Larval Habitats

Slow backwaters and pools, and small pockets along the bank contained large numbers of larval bluehead suckers in May 1993. While larvae used a variety of depths and substrates, there was an obvious trend for larvae to select areas with low current velocities (< 0.1 m/sec, Figure 18). Banks (1964, as cited in Sublette 1990) and Snyder and Muth (1990) also reported larval bluehead suckers used quiet shoreline areas.

My data showed that brown trout made up a mean percent composition of 80.6% (± 5.77; n = 4 periods) stream-wide, and 57.4% (± 13.39; n = 4 periods) in the lower 3.0 km. During the winter months (when the previous creel surveys were conducted), brown trout comprised 66.3 % (± 6.15; n = 2 periods) of the trout in the lower 3.0 km. These data indicate that brown trout have replaced rainbow trout as the dominant predator in this stream. Maddux et al. (1987) provided an early indication of this increase in brown trout abundance in Bright Angel Creek; they reported that the abundance of brown trout had increased in the mainstem Colorado River since Carothers and Minckley's (1981) investigations and noted that most of the increase occurred around the confluence of Bright Angel Creek.

Rainbow trout (20,000 fingerlings) were first stocked in Bright Angel Creek in 1923 (Fish plantings in GCNP 1920-1956; Scientific Documents File, GCNP Library) and were periodically stocked (as eyed eggs or fingerlings) until 1964. In addition, rainbow trout that were stocked in other locations (Clear, Shinumo, Tapeats and Havasu creeks, and Lee's Ferry) have access to Bright Angel Creek via the perpetually cool Colorado River. Brown trout were stocked in Bright Angel Creek only 3 times, once in 1924 (50,000 eyed eggs) and twice in 1930 (100,000 and 45,000 eyed eggs respectively) (Table 14).

The shift from rainbow to brown trout may have several explanations. Several studies have shown brown trout outcompete other salmonids in some streams (Fausch and White 1981, Waters 1983). Elements in their success may be their aggressiveness

(Fausch and White 1981), their ability to feed at low light levels (Robinson 1978), their low vulnerability to exploitation by sport fishing (Cooper 1952), and their ability to use other fishes as food (Garman and Nielsen 1982).

Usher et al. (1984) casually observed in 1981 that brown trout abundances were higher in upstream areas than in downstream areas in Bright Angel Creek; thus it's possible that brown trout were already gaining dominance in upstream areas in the early 1980's. Rainbow trout may have maintained dominance in lower reaches until recently because of their continued stocking through the mid 1960's (Table 14).

In addition, fishing pressure on Bright Angel Creek has increased over the years, particularly after rainbow trout stockings ceased (Wintermute 1984). Most of the angling pressure on Bright Angel Creek occurs below Phantom Ranch (Carothers and Minckley 1981). This increased fishing pressure could have selectively removed more rainbows than browns from the lower stream.

In other tributaries where speckled dace currently occur (e.g., Paria and Little Colorado rivers, Shinumo and Kanab creeks), all size classes are present in the stream throughout the year (Allan 1993, Weiss 1993, Gorman 1994, pers. obs.). Minckley (1978) found all size classes in Bright Angel Creek during early spring (March) through fall (September) surveys. I consistently found only low numbers of larvae (10-18 mm TL) in June of 1992 and 1993. The only location along the stream where all size classes of dace were present was in Willow Spring. Their persistence in this spring, from which

Table 14. Summary of trout stocking records for the Colorado River and tributaries in Grand Canyon area through 1979; adapted from Carothers and Minckley (1981).

SPECIES	DATE	LOCALITY	# STOCKED	SIZE	SOURCE
Rainbow Trout	09\1923	Bright Angel Creek	20000	Fingerlings	NPS
Rainbow Trout	05\1923	Tapeats Creek	5000	Eyed Eggs	NPS
Rainbow Trout	09\1924	Bright Angel Creek	6000	Fingerlings	NPS
Rainbow Trout	02\1931	Havasu Creek	18000	Eyed Eggs	NPS
Rainbow Trout	01\1932	Bright Angel Creek	21000	Eyed Eggs	NPS
Rainbow Trout	12\1934	Bright Angel Creek	31000	Eyed Eggs	NPS
Rainbow Trout	09\1935	Bright Angel Creek	21000	Eyed Eggs	NPS
Rainbow Trout	05\1939	Bright Angel Creek	13800	Fingerlings	NPS
Rainbow Trout	06\1940	Bright Angel Creek	18000	Fingerlings	NPS
Rainbow Trout	06\1940	Tapeats Creek	2000	Fingerlings	NPS
Rainbow Trout	07\1940	Clear Creek	18000	Fry	NPS
Rainbow Trout	11\1941	Bright Angel Creek	32000	Fingerlings	NPS
Rainbow Trout	07\1942	Bright Angel Creek	28000	Fingerlings	NPS
Rainbow Trout	07\1942	Phantom Creek	14000	Fingerlings	NPS
Rainbow Trout	04\1944	Havasu Creek	4500	Fry	NPS
Rainbow Trout	06\1947	Bright Angel Creek	10394	Fingerlings	NPS
Rainbow Trout	04\1948	Havasu Creek	13000	Fingerlings	NPS
Rainbow Trout	03\1950	Bright Angel Creek	45240	Fingerlings	NPS
Rainbow Trout	04\1954	Havasu Creek	2000	Fingerlings	NPS
Rainbow Trout	07\1958	Bright Angel Creek	45000	Fingerlings	NPS
Rainbow Trout	06\1964	Bright Angel Creek	23900	Fingerlings	NPS
Rainbow Trout	1964	Lee's Ferry	10200	Adv. Fingerlings	AZG&F
Rainbow Trout	1964	Lee's Ferry	5000	Catchable	AZG&F
Rainbow Trout	1965	Lee's Ferry	10000	Fingerlings	AZG&F
Rainbow Trout	1965	Lee's Ferry	8830	Catchable	AZG&F
Rainbow Trout	1966	Lee's Ferry	10000	Fingerlings	AZG&F
Rainbow Trout	1966	Lee's Ferry	4500	Catchable	AZG&F
Rainbow Trout	1967	Lee's Ferry	3100	Catchable	AZG&F
Rainbow Trout	1968	Lee's Ferry	5500	Catchable	AZG&F
Rainbow Trout	1969	Lee's Ferry	20000	Adv. Fingerlings	AZG&F
Rainbow Trout	1969	Lee's Ferry	6545	Catchable	AZG&F
Rainbow Trout	1970	Lee's Ferry	20000	Adv. Fingerlings	AZG&F
Rainbow Trout	1970	Diamond Creek	6173	Fingerlings	USF&W
Rainbow Trout	1971	Lee's Ferry	5110	Catchable	AZG&F
Rainbow Trout	1971	Diamond Creek	11000	Fingerlings	USF&W
Rainbow Trout	1972	Lee's Ferry	4585	Catchable	AZG&F
Rainbow Trout	1973	Lee's Ferry	5075	Catchable	AZG&F
Rainbow Trout	1974	Lee's Ferry	3990	Fingerlings	AZG&F
Rainbow Trout	1975	Lee's Ferry	30000	Fingerlings	AZG&F
Rainbow Trout	1975	Lee's Ferry	4500	Catchable	AZG&F
Rainbow Trout	1976	Lee's Ferry	100000	Fingerlings	AZG&F
Rainbow Trout	1977	Lee's Ferry	100000	Fingerlings	AZG&F
Rainbow Trout	1978	Lee's Ferry	50000	Fingerlings	AZG&F

Table 14 (cont'd). Summary of trout stocking records for the Colorado River and tributaries in Grand Canyon area through 1979; adapted from Carothers and Minckley (1981).

SPECIES	DATE	LOCALITY	# STOCKED	SIZE	SOURCE
Brown Trout	1924	Bright Angel Creek	50000	Eggs	NPS
Brown Trout	07\1926	Shinumo Creek	50000	Eyed Eggs	NPS
Brown Trout	08\1930	Shinumo Creek	50000	Eyed Eggs	NPS
Brown Trout	12\1930	Garden Creek	4000	Eyed Eggs	NPS
Brown Trout	01\1930	Bright Angel Creek	100000	Eyed Eggs	NPS
Brown Trout	12\1930	Bright Angel Creek	45000	Eyed Eggs	NPS
Brook Trout	08\1920	Bright Angel Creek	5000	Fingerlings	NPS
Brook Trout	06\1927	Havasu Creek	10000	Fingerlings	NPS
Brook Trout	12\1928	Clear Creek	50000	Eyed Eggs	NPS
Brook Trout	01\1931	Clear Creek	25000	Eyed Eggs	NPS
Brook Trout	12\1934	Clear Creek	18000	Eyed Eggs	NPS
Brook Trout	1977	Lee's Ferry	47880	Fingerlings	AZG&F
Brook Trout	1978	Lee's Ferry	100000	Fingerlings	AZG&F
Brook Trout	12\1978	Lee's Ferry	?	Fingerlings	AZG&F
Cutthroat Trout	1979	Lee's Ferry	50000	Catchable	AZG&F

trout were excluded, provides circumstantial evidence for predation by brown trout affecting the abundance of speckled dace.

Rainbow trout and speckled dace coexisted in Bright Angel Creek for many years (as evidenced by their co-occurrence during Minckley's [1978] surveys); they continue to coexist in Shinumo Creek (Allan 1993). The apparent decline in speckled dace abundance in Bright Angel Creek is coincident with the increase in numbers of brown trout. Brown trout are highly piscivorous (Garman and Nielsen 1982); fish sometimes comprise 70% or more of their diet (McCraig 1960, Garman and Nielsen 1982).

Garman and Nielsen (1982) found the abundance of native torrent suckers, *Moxostoma rhothoecum,* declined in blocked stream reaches where large (>280 mm TL) brown trout had been stocked. They suggested that when brown trout establish reproducing populations in streams, there is generally a reduction in overall biomass of the non-game fish community. Other authors have shown that extirpation of prey species can result when predators are introduced (Johaness and Larkin 1961, Zaret and Paine 1973, Meffe 1985).

It is uncertain whether bluehead suckers are also being affected by the presence of brown trout in Bright Angel Creek. Adult bluehead suckers entered Bright Angel Creek each spring and spawned successfully (as evidenced by the presence of Y-O-Y suckers each June) but no juvenile bluehead suckers were observed. Juveniles are found throughout the year in other tributaries in Grand Canyon (e.g., Shinumo, Havasu and Kanab creeks, Allan 1993, pers. obs.), and Minckley (1978) collected them from Bright

Angel Creek in the summer of 1976. Thus, there is some circumstantial evidence that the dominance of brown trout may affect the successful rearing of juvenile bluehead suckers in Bright Angel Creek.

Kanab Creek

Ten species occurred at the confluence of Kanab Creek with the Colorado River (Table 2), but only speckled dace were found above a barrier at rk 6.2. Non-native fishes generally did not occur above the confluence area; thus, there was little temporal or spatial overlap of native and non-native fish.

Fathead minnows, carp, and channel catfish were the most common non-native species at the confluence. These 3 species have regularly been reported from this location (Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987, Maddux and Kepner 1988). Channel catfish and green sunfish prey upon native fishes (Marsh and Langhorst 1988, Marsh and Brooks 1989, Haden 1992, pers. obs.), however, their low abundance and limited distribution in Kanab Creek suggests that they currently have little impact on native fishes.

The fluctuating discharge of the Colorado River, in conjunction with varying turbidity levels in Kanab Creek, apparently creates a mosaic of use of the confluence by native and introduced fishes. During daytime periods of low mainstem flow and clear outflow from Kanab Creek few fish occupied the mouth of the creek. However, when outflow from Kanab Creek was turbid, or at night, fish readily occupied this area. Fish may avoid of the confluence area during periods of high light penetration. Chart and Bergersen (1992) reported flannelmouth sucker numbers declined in a tailwater following closure of Taylor Draw Dam. They suggested that flannelmouth suckers avoided the area partly because of reduced turbidity.

Two adult humpback chub were observed using the mouth of Kanab Creek at night in June 1993. To my knowledge, this is the first report of adult humpback chub in Kanab Creek; juvenile and Y-O-Y chub have occasionally been caught around the confluence (G. Doster, AGF, pers. comm., this study). The thermal conditions (warmer water) at the mouth of Kanab Creek occasionally may attract chub from the Colorado River; however, the infrequency of these collections suggest it is not a preferred habitat. Alternatively, the rare sightings of chub in Kanab Creek may be more a reflection of the limited distribution of chub in the mainstem Colorado River.

Ninety-two flannelmouth suckers were seined at the confluence of Kanab Creek with the Colorado River in May 1993; only 2 were adults. One adult female expressed eggs but appeared to be in post-spawning condition. No adult flannelmouth suckers were observed above the confluence (inclusive of the lower 100 m), and no spawning was observed in Kanab Creek. However, flannelmouth suckers may spawn in the mouth of Kanab Creek, since several Y-O-Y were present in the lower 1.8 km of the stream in June 1993. Y-O-Y flannelmouth suckers observed in upstream areas were at least 40-50 mm TL; thus, they may have hatched elsewhere and entered the creek from the Colorado River.

Speckled dace were found throughout the lower 10.0 km, apparently able to ascend barriers such as the one at rk 6.2. In May 1993 I watched several dace ascend a barrier similar to the one at 6.2 km. Water poured through a narrow chute and dropped 30-50 cm into a small pool. Dace leapt 10-20 cm out of the backwash of the plunge and onto the flat surface of a sloped boulder. They then flopped down into a thin stream of water (only enough to partially cover their gills) that ran down the boulder. The dace would move up the boulder in a series of swimming bursts followed by waiting periods. Fish were often flushed back over the plunge, but an occasional individual was able to gain the pool above the plunge. Speckled dace are known both for accessing even the uppermost reaches of streams and for their abilities to recolonize disturbed habitats, factors at least partially responsible for their widespread occurrence in the West (Minckley 1973, Pearsons et al. 1992).

Speckled dace apparently spawned throughout much of the year in Kanab Creek. Y-O-Y and small juveniles were present during most sampling periods. John (1963) reported that speckled dace spawning in the Chiricahua Mountains of Arizona was induced, in part, by flood events following torrential rains. He concluded that summer and fall spawning events were more dependent upon these rains than spring spawning was. Floods occurred on Kanab Creek throughout my study, but it was difficult to determine if spawning by speckled dace was triggered by these floods.

The distribution and abundance of bluehead suckers in Kanab Creek varied relative to physical barriers, spawning, and perhaps summer water quality conditions.

Bluehead suckers occurred throughout the year below a natural barrier at rk 6.2. A barrier at rk 3.2 (which is probably surmountable at higher water levels) appeared to prohibit the upstream movement of suckers entering the stream to spawn in April-May 1993; adult suckers (> 160 mm TL) were only taken in reach 1. The mean length of bluehead suckers taken in reach 2 (111.0 mm TL) was significantly smaller than the mean length of suckers taken in reach 1 (167.8 mm TL) ($p < 0.001$, Mann-Whitney U test).

It is possible that the bluehead suckers above the barrier at rk 3.2 represent a separate population, spawning at sizes smaller than 160 mm. I found ripe males and females and a few larvae above rk 3.2 in May 1993. Allan (1993) reported a stunted population of reproducing bluehead suckers (mean TL = 160 mm) in Shinumo Creek above a waterfall located 120 m above the mouth.

Adult bluehead suckers were most prevalent in Kanab Creek during the spawning period in April-May but were also present during the winter. They were virtually absent beyond the confluence area during summer. Summertime water temperatures often exceed 30 C in Kanab Creek (J. Rote, USGS raw data 1991-1993). The upper lethal temperature limits for native fishes in the Grand Canyon have not been determined, but the historic temperature regime of the Colorado River suggests mainstem fishes can tolerate temperatures ranging from 0-30 C (Valdez 1992). Those temperatures are extremes, however, and Colorado River fishes were probably rarely exposed to them. Thus, temperatures approaching or exceeding 30 C in Kanab Creek may cause adult bluehead suckers to exit the stream. However, larvae and juvenile bluehead suckers are probably more sensitive to temperature than adults (Valdez 1992) and they remain in Kanab Creek throughout the summer. Thus, temperature is probably not the only factor responsible for the emigration of adult suckers. Dissolved oxygen (DO) levels decrease as a function of warming water temperatures (Cole 1983). In June 1993 I found juvenile bluehead suckers primarily occupying riffles and plunge pools- habitats which provide increased aeration. It is possible that low DO levels associated with high water temperatures limit the summer distribution of adult bluehead suckers in Kanab Creek.

Previous surveys on Kanab Creek have investigated only the confluence area (Minckley and Blinn 1976, Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987) or the lower 1 km (Maddux and Kepner 1988). Therefore, comparing my data with previous surveys is difficult, and evaluation of changes in the status of fishes is tenuous.

Seasonal Variations in Community Structure

Brown trout dominated the fish community in Bright Angel Creek year round, but large adult browns occurred more frequently during winter spawning periods. Conversely, juvenile rainbow trout were less abundant during winter spawning periods. Bluehead suckers and speckled dace dominated the fish community of Kanab Creek during all seasons, but there were seasonal variations in length frequencies as adult suckers entered the stream to spawn. I observed no large-scale seasonal variations in fish community structure in either Bright Angel or Kanab Creek. Maddux et al. (1987) suggested that there were thermally induced transitions of fish communities in most tributaries; native fishes dominated in spring (89%) and summer (96%), and trout dominated in winter (68%). Autumn was a period of transition (Maddux et al. 1987). My data for Bright Angel and Kanab creeks do not show this pattern. I found no evidence that native species dominated Bright Angel Creek during any period (flannelmouth suckers may have predominated in the lower 1 km during a 3 week period in March), nor any indication that non-native species ever were predominate in Kanab Creek. The same species remained in the stream year round, albeit with some changes in their population structures related to spawning events.

The pattern that I have reported seems to be repeated in other tributaries. Weiss (1993) reported heavy use of the Paria River by spawning flannelmouth suckers in early spring, but year round use only by speckled dace; non-native species were never encountered above the confluence. Conversely, Tapeats Creek was perennially dominated by rainbow trout; no native fish were found during 3 surveys of that stream (August 1992, January and June 1993, unpubl. data). Shinumo Creek appears to represent a special case since it is isolated from mainstem river fishes. Allan (1993) reported that rainbow trout, bluehead suckers, and speckled dace perennially co-occurred above the lower falls.

Parasitism

The external parasite, *Lernaea cyprinacea,* infected 10.4% of the fishes handled in Kanab Creek in June 1993. Fish throughout the lower 6.2 km of the stream were infected and many Y-O-Y fishes (primarily speckled dace, but also bluehead suckers) were found dead on the stream bottom with 1 or more *Lernaea* still attached. No *Lernaea* or dead fish were found above the natural barrier at rk 6.2 . The absence of *Lernaea* above the barrier at rk 6.2 suggests that the barrier is relatively impermeable to fish. Water quality was similar above and below the 6.2 km barrier ($p > 0.05$ for temperature, DO, pH, and conductivity; two-sample T-test). The fact that virtually all the dead fish examined still had attached *Lernaea* indicates that infestation by *Lernaea* may be a principal factor in their deaths.

L. cyprinacea is a widely distributed copepod (Crustacea) parasite able to use a variety of taxa for hosts (Kapata 1979). It is known to cause mortality in confined areas, particularly in coincidence with high temperatures and high population densities (Uzman and Rayner 1958, as cited in Carothers and Minckley 1981). *Lernaea* is a thermophilic species, preferring temperatures above 21 C (Singhal et al. 1986). Carothers and Minckley (1981) reported *Lernaea* on large numbers of juvenile flannelmouth and bluehead suckers, speckled dace, and humpback chub in the LCR and Kanab Creek in the fall of 1978; adult fish and introduced species were not infected with the parasite. Infection rates were as high as 55% for bluehead suckers in Kanab Creek; however, no mortalities were reported. Carothers and Minckley (1981) reported that the incidence of *Lernaea* increased dramatically between August and October in Kanab Creek in 1978.

I did not observe *Lernaea* on fish in Kanab Creek in August 1992 or in May 1993. The mean daytime water temperature during the May survey was 19.6 C; it was 27.0 C when I first observed *Lernaea* in June 1993. A high incidence of *Lernaea* was observed on native fishes in Kanab Creek during late summer 1993 (G. Doster, AGF, pers. comm.); percent occurrence was not calculated but infection rates may have approached those observed by Carothers and Minckley (1981) in 1978. The fact that *Lernaea* occurred primarily on juvenile fish is likely a consequence of their being the only size class consistently present during the summer (Carothers and Minckley 1981). Few fish > 140 mm TL were observed upstream in Kanab Creek during the summer in 1993 (G. Doster, AGF, pers. comm.).

It appears *Lernaea* outbreaks do not occur annually in Kanab Creek; I did not observe them in 1992, and they have been infrequently reported in the past. Presumably, there are specific physical (high temperatures, low DO) and perhaps biological (high densities of fish) conditions that trigger the outbreaks. Valdez (1992) suggested that *Lernaea* infestation on fishes in the Upper Basin does not cause significant mortalities; however, he noted that impacts were not fully known. My observations on Kanab Creek suggest *Lernaea* can contribute to the mortality of Y-O-Y and juvenile native fishes.

CHAPTER 3. SPAWNING OF BLUEHEAD SUCKERS

INTRODUCTION

The bluehead sucker, *Catostomus discobolus* (Cope), is widely distributed throughout the Bear, Weber, and Upper Colorado River drainages (Holden and Minckley 1980). General descriptions of this species can be found in Smith (1966), Minckley (1973), Sigler and Sigler (1987), and Sublette et al. (1990). The bluehead sucker was previously known as *Pantosteus delphinus* and was given it's present taxonomic status by Smith (1966); some southwestern fish biologists prefer to retain the genus *Pantosteus* (*Pantosteus discobolus*: Minckley 1973, Maddux and Kepner 1988), while others prefer *Pantosteus* as a subgenus [*Catostomus* (*Pantosteus*) *discobolus*: Sublette et al. 1990].

The bluehead sucker is common within the Colorado River drainage and has been found in relative abundance during previous aquatic surveys of the Grand Canyon (Holden and Stalnaker 1975, Suttkus and Clemmer 1976, Carothers and Minckley 1981, Maddux et al. 1987). Despite it's abundance, published accounts of its life history are limited and incomplete. Andreasen and Barnes (1975) described the reproductive cycle of *C. discobolus* from the Weber River, Utah, by monitoring gonad indices throughout the year. McAda and Wydoski (1983) reported size at sexual maturity and length fecundity ratios for Upper Basin populations. Maddux and Kepner (1988) described the behavior of spawning bluehead suckers in Kanab Creek and gave a brief description of spawning habitat. Snyder and Muth (1990) described the early life history of several catostomids with an emphasis on larval identification. Smith (1966) provides the most complete account of the taxonomic status and ecology of the species. Detailed information on spawning habitat selection and size at sexual maturity for fish in tributaries in the lower drainage have not been published.

Objectives

The objectives of my study were to describe the:

1. timing and duration of spawning by bluehead suckers in Kanab Creek;
2. habitat used by spawning bluehead suckers in Kanab Creek;
3. locations of spawning areas used by bluehead suckers in Kanab Creek; and
4. length at sexual maturity for bluehead suckers.

METHODS

Timing and Duration of Spawning

I monitored the presence of Y-O-Y fish during seasonal sampling (Table 1) of Kanab Creek. I also monitored the reproductive status of individual fish during seasonal sampling. Gentle posterio-lateral pressure could generally induce expulsion of gametes from the uro-genital vent of ripe fish regardless of sex; little or no pressure induced gamete expulsion in running ripe individuals. Although not a definitive gauge of gamete maturation and sexual readiness, this method has been employed to indicate spawning condition in suckers (Tyus and Karp 1990). Morphologic characteristics such as tubercles appeared to be poor indicators of spawning readiness because males often had tubercles along their anal fins throughout most of the year, even when milt was not expressible.

Bluehead suckers have been observed spawning in the Canyon in early spring (Minckley 1978, Maddux et al. 1987) and in Kanab Creek in early May (Maddux and Kepner 1988). Therefore, I scheduled sampling in Kanab Creek from 21 April-7 May 1993 to gather data on aspects of the spawning ecology of bluehead suckers.

Spawning Areas, Behavior, and Length at Maturity

During 21 April-7 May, 1993 I identified spawning areas in the lower 10 km of Kanab Creek. I visually surveyed sections of the stream each day for spawning fish. Poor water clarity precluded effective visual surveys for the first 4 days; however, water clarity quickly increased thereafter (to > 2 m), allowing easy identification of groups of spawning suckers.

On 28 April, I observed fish spawning 1.35 km up Kanab Creek. I used an 8x8-m grid of colored rocks spaced 2 m apart to identify individual spawning sites and map habitat characteristics. Throughout the 6-hour period of observations, I recorded hourly readings of water temperature, relative shading over the spawning area, male to female sex ratio during spawning acts, duration of spawning acts, estimated length of spawning females, and specific locations of egg deposition. My methods largely followed those used by Maddux and Kepner (1988).

At the end of the observation period, I blocked (3.2-mm mesh seine, 9.14 m x 1.22 m) the lower end of the spawning area and made 2 seine hauls down-stream into the block net. Fish captured were held in a "live box" until individual total length (TL, nearest mm), weight (nearest 2 g), sex, and sexual condition were recorded. All fish also were examined for external parasites. Fish >150 mm TL were implanted with a Passive Integrated Transponder (PIT) tag in their lower abdomen. Each fish was handled for less than 1 minute and then released into the section of stream from which it was taken.

Length at sexual maturity was estimated either by measuring fishes that were observed spawning, or measuring fishes that extruded gametes. Samples of recently emerged larvae (< 50 fish) were collected on 5 May 1993 for identification. These larvae were taken from various locations throughout the lower 3.0 km of Kanab Creek. Specimens were fixed in 10% formalin and later transferred to 95% ETOH. Keys from Snyder and Muth (1990) were used for identification of larval catostomids.

Habitat Measurements

I measured several habitat characteristics at 24 documented spawning micro-sites. A micro-site is defined as the specific location at which eggs were deposited during the spawning act (suckers spawned over well defined sites). One point measurement of depth and water velocity was made at each micro-site. I used a labeled (1-cm increments) PVC pole to measure water depth and a Marsh-McBirney portable current meter (Model 201D) to measure water velocity. Since depths were under 75 cm at spawning sites, and no flow obstructions occurred in the water column, I measured velocities at mean column depth (Bovee and Milhous 1978, Baltz and Moyle 1984). Ten substrate particles were randomly chosen from each site, and the maximum diameter of each was recorded. In addition, substrate compactedness was subjectively categorized as either compact, moderately compact, loose, or very loose. I attempted to collect eggs from most spawning locations using a fine mesh aquarium net. Ova diameters (unpreserved eggs) were measured in the field.

To determine the stream-wide availability of various habitat characteristics (n = 54 transects), I made measurements along transects (perpendicular to flow, 200 m apart) beginning at the confluence (rk 0.00) and extending 10.0 km upstream. Point estimates of depth, current velocity, and substrate were recorded at 1-m intervals along these transects (Gorman and Karr 1978). To assure wetted points, the first and last points were 10-cm from each bank; measurements were always made from river left to right. If the far bank occurred less than 1 m from the last point, the measured distance to the edge was recorded. This procedure facilitated calculation of stream width at each transect location.

A habitat pole was used for all measurements of stream-wide habitat availability. The pole consisted of a 2-m length of 1.9-cm diameter PVC conduit, permanently marked in 1-cm increments to measure water depths. Substrates at each 1-m interval were characterized (into 1 of 12 categories [Cummins 1962, Gorman 1988]) by their size and composition (Table 15). Water velocity was stratified into 6 categories based on the turbulence of surface water flowing against the habitat pole (Gorman and Karr 1978, Gorman 1988). Each category represented a range of flows. Categories were correlated to mean column velocities measured with a Marsh-McBirney current meter (Table 15). The pole technique allows the collection of a greater number of velocity measurements than would be feasible using conventional flow meters (perhaps as much as 10x faster, Gorman 1994).

Beginning 5 May 1993, many larval bluehead suckers emerged in the lower 3.0 km of Kanab Creek. I measured depth, current (Marsh McBirney), and substrate conditions at 13 random sites inhabited by larval suckers to make comparisons of conditions used vs. those available stream-wide.

Data Analyses

I used SPSS/PC+ V2.0 to calculate the mean lengths of spawning males and females captured at the 1.35 km site and throughout the stream. I also calculated the mean sex ratio (males to female) observed during individual spawning acts and the mean duration of spawning acts.

Data on conditions at systematic transects (representing conditions available stream-wide) were compared to data on conditions at spawning micro-sites and larval habitats. Current velocity and substrate measurements from spawning sites and current velocities from larval habitats were converted to categories (Table 15) to facilitate this analysis. I compared the distributions of conditions at spawning micro-sites to those available stream-wide (depth, current, and substrate) using the Kolmogorov-Smirnov (K-S) two-sample test ($p < 0.05$ = significant). I used the Mann-Whitney-Wilcoxon (M-W) test (Gibbons 1985) to compare size distributions (TL) of spawning bluehead suckers to determine if there were significant differences between sexes.

RESULTS

Timing, Location, and Duration of Spawning

I observed bluehead suckers spawning in Kanab Creek from 25 April-5 May 1993. Spawning intensity was greatest during the last week of April; few spawners were observed after 3 May. Several ripe fish were handled on 22 April, so it is likely that fish were spawning prior to that date although water turbidity precluded observation. One "spent" female (uro-genital vent swollen and distended, abdomen flaccid, few or no eggs expelled with manual pressure) bluehead sucker was caught on 27 April, and another 3 days later.

Ripe bluehead suckers were found throughout Kanab Creek below the 6.2 km barrier; however, spawning activities were greatest downstream of the 3.2 km barrier at 5 locations: 0.18 km, 1.35 km, 2.0 km, 2.1 km, and 2.7 km. These sites had large clusters of spawning fish, but single pairs and small groups (4-5 fish) of spawning suckers were observed throughout reach 1.

Table 15. Current velocity and substrate categories used for habitat characterization on Bright Angel and Kanab creeks (modeled after Gorman and Karr [1978]).

	Category	Description	Range (m/sec)
	0	none	<0.02
	1	very slow	0.02-0.10
Current Velocity	2	slow	0.11-0.30
	3	moderate	0.31-0.70
	4	fast	0.71-1.20
	5	torrent	>1.20
			Particle size (mm)
	0	silt	<0.06
	1	silty-sand	0.06-0.10
	2	sand	0.10-2.0
	3	gravel	2.0-16.0
	4	pebble	16.0-32.0
Substrate sizes	5	rock	32.0-100
	6	cobble	100-256
	7	boulder	256-1m
	8	large boulder	1m-3m
	9	giant boulder	>3m
	10	travertine	travertine
	11	bedrock	bedrock

During November 6-8, I caught 2 bluehead sucker metalarva (18 and 20 mm TL) in the lower 100 m of the stream. No larval suckers were caught above the mouth of Kanab Creek. Water temperatures at that time ranged from 9.7-11.9 C during the day.

Spawning Behavior

On 28 April 1993, a large group of suckers (> 20 fish) was observed spawning in shallow water over loose gravel substrates 1.35 km above the mouth of Kanab Creek. Spawning activities (number of acts/hour) increased throughout the morning as water temperatures rose above 17 C. Spawning intensity declined briefly around mid-day as the spawning area was exposed to direct sunlight. Activity increased again as the area returned to shade (Figure 16). A total of 133 spawning acts was observed. As many as 29 suckers were seen over the 64-m^2 spawning area at one time.

Males held position in loose clusters or cruised randomly over the spawning area and along the vertical bedrock making up the right stream bank. Females either held position in the open or entered the spawning area from deeper water a few meters upstream. Once a female moved into the spawning area, she was immediately approached by 1-5 males. Females not ready to spawn swam upstream into deeper water, leaving the males to continue patrolling the area. If the female was ready to spawn, at least 1 male would position himself beside and slightly downstream of her. Males tried to induce the female to spawn by nudging her sides.

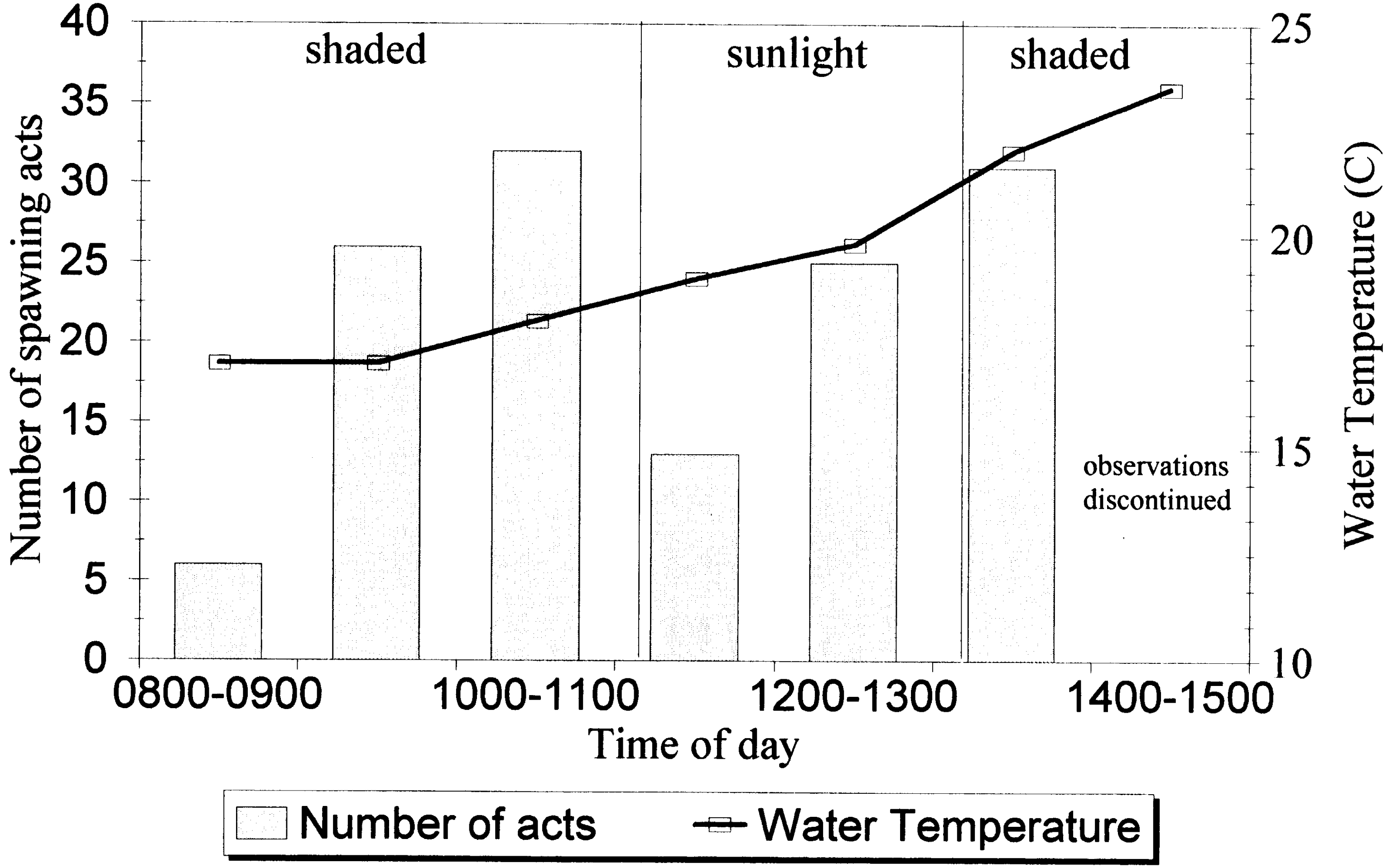


Figure 16. Bluehead sucker spawning activity relative to water temperature and direct sunlight; 28 April 1993, Kanab Creek (n = 132 spawning acts).

Rapid shuddering of the body, caudal fin, and anal fin occurred as spawning began. Males appeared to tilt their bodies slightly outward as they pressed themselves tightly to the female. Their anal fins were spread and angled toward the vent of the female. Only 2 males could effectively participate in spawning with 1 female (1 on either side); however, other males often tried to participate by swimming rapidly over the top of the spawning trio, seeking an opening. Rarely did these supernumerary individuals displace established males or release gametes. The mean ratio of males to females during a spawning act was 2.4:1 (range 1:1-5:1, mode = 2:1). The spawning act lasted an average of 2.5 seconds (range 1-6 sec).

At the completion of spawning, the female generally swam off, usually into deeper water. The males generally followed for only a short distance before returning to the spawning area. The action of spawning swept fine particles away from larger substrates, creating small depressions, and exposing interstitial spaces into which eggs were deposited. Spawning depressions ranged from 4.5-7.0 cm wide (mean = 5.6 $\pm$ 0.84; n = 7), 7.5-9.5 cm long (mean = 8.3 $\pm$ 0.75; n = 7), and 1.0-2.3 cm deep (mean = 1.6 $\pm$ 0.54; n = 7). Eggs recovered from depressions were demersal and adhesive and ranged in size from 2.4-3.1 mm in diameter (mean = 2.7 $\pm$ 0.2, n = 13).

Spawning Habitat Selection

Spawning areas were generally located at the head of riffles at the shallow tail end of deep runs or pools. Bluehead suckers spawned at depths ranging from 8.0-33.0

cm (mean = 16.0 ± 5.5; n = 24), current velocities ranging from 0.07-0.38 m/sec (mean = 0.20 ± 0.07; n = 24), and over substrates ranging from 6.0 - 80.0 mm in diameter (mean = 27.6 ± 14.6, median = 23, mode = 17; n = 240) (Figure 17). Substrates were always loosely compacted and made up of a mixture of particle sizes; however, most of the fines were swept away during the spawning act.

Spawning bluehead suckers selected slow-moderate currents and small substrates significantly out of proportion to their availabilities ($p < 0.001$, Table 16, Figure 17). The depth variable was borderline insignificant ($p = 0.053$), but frequency histograms (Figure 17) revealed that bluehead suckers spawned in relatively shallow (< 40 cm) waters. A Mann-Whitney-Wilcoxon test also showed an insignificant p-value ($p = 0.862$) for depth. However, the power of the test was low because the distributions of my samples (use, available) were not symmetrical (Gibbons 1985).

Larval Habitat Use

Larval bluehead suckers were abundant throughout the lower reaches of Kanab Creek beginning 5 May 1993; however, densities were greatest in the lower 2.0 km. Larvae most often occurred in quiet, shoreline areas, and backwaters. Use of depths and substrates varied considerably; however, only 1 group was observed in current velocities > 0.1 m/sec (Figure 18).

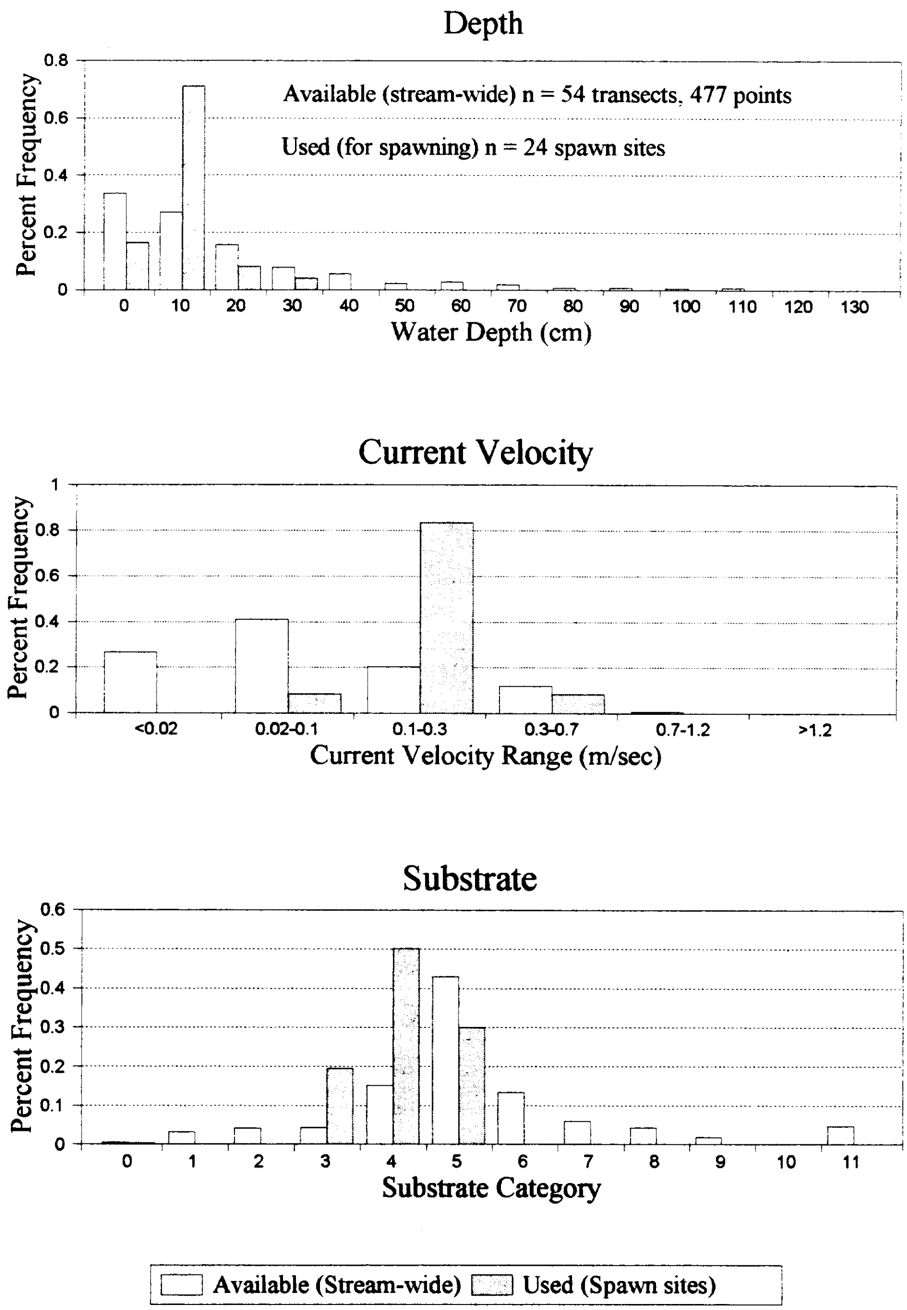


Figure 17. Relative frequency histograms of depths, currents, and substrates used by, and available to, spawning bluehead suckers in Kanab Creek, April-May, 1993.

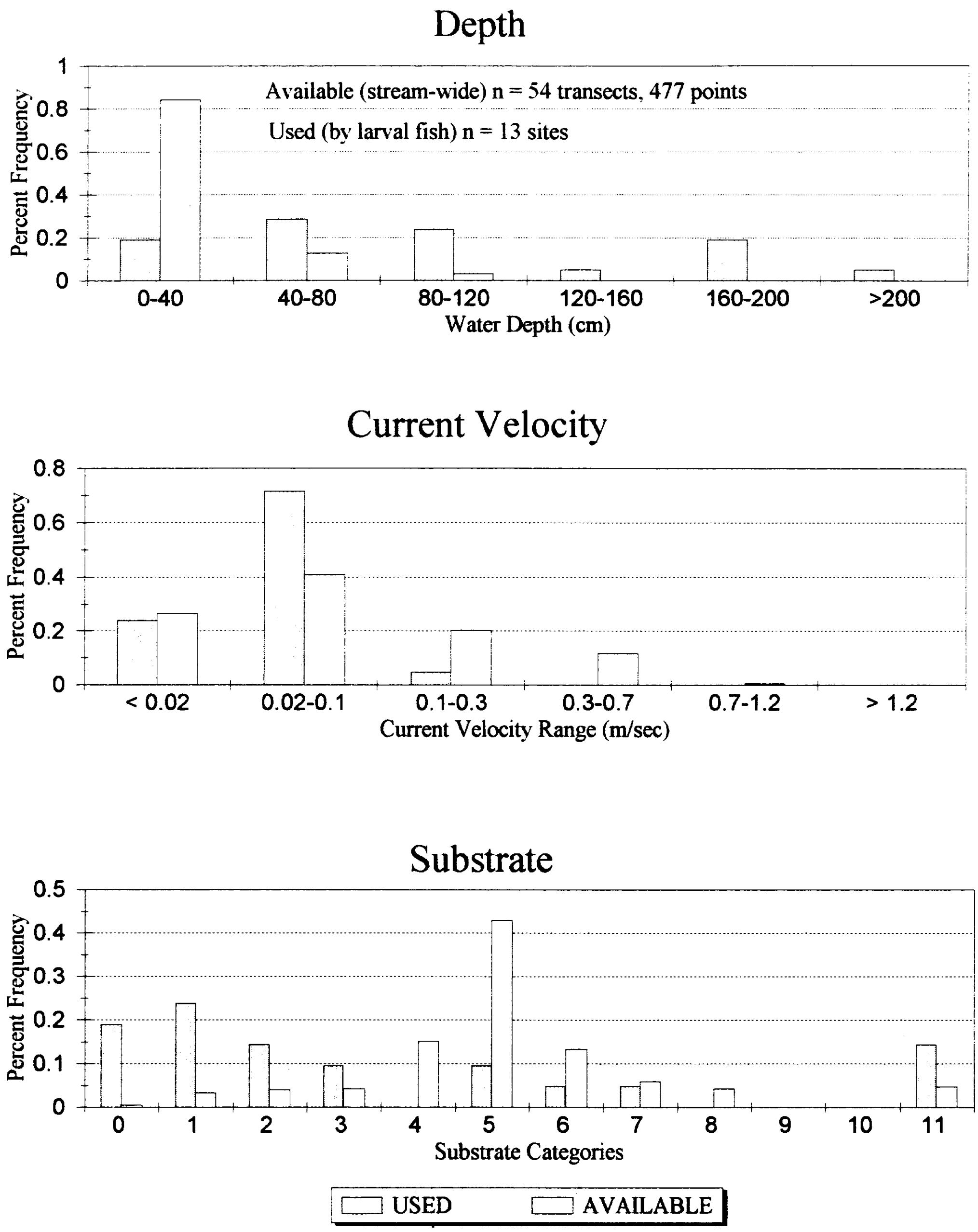


Figure 18. Relative frequency histograms of depths, currents, and substrates used by, and available to, recently emerged (10-13 mm) bluehead sucker protolarva in Kanab Creek, 5 May 1993.

Table 16. Comparisons (Kolmogorov-Smirnov two-sample test) of the distributions of depth, current, and substrate used by, and available to, spawning bluehead suckers in Kanab Creek, April-May 1993; *denotes significance ($p < 0.05$).

Variable	Test	n (avail)	n (used)	Max. Abs. Diff.	Z-value	p-value
Depth	available, used	477	24	0.28171	1.347	0.053
Current	available, used	477	24	0.58810	2.813	< 0.001*
Substrate	available, used	477	24	0.56208	2.689	< 0.001*

Length at Maturity

The lengths of suckers captured while spawning at the 1.35 km site ranged from 127-302 mm TL (mean = 198.4 ± 37; n = 23). There was no significant difference between length distributions of males and females spawning at the 1.35 km site (means = 196.7 ± 24.4 mm, n = 16; 202.4 ± 59.1 mm, n = 7, respectively; $p > 0.6$). Stream-wide, ripe males as small as 94 mm TL were found, and tubercles were observed on males as small as 77 mm TL. Virtually all male bluehead suckers > 110 mm TL expressed milt. Gravid females were as small as 102 mm TL, and several females in the 120-140 mm size class were observed spawning. Generally, however, females < 160 mm TL did not express eggs when examined. Stream-wide, lengths of males and females were not significantly different ($p > 0.07$) (means = 139.7 mm ± 41.3, and 158.6 mm ± 59.7 respectively).

DISCUSSION

Timing of Spawning

Bluehead suckers in the Colorado River Drainage have been reported to have a protracted spawning period (Andreasen and Barnes 1975, Maddux et al. 1987). However, Maddux and Kepner (1988) reported that bluehead suckers spawned in Kanab Creek in the spring only. My observations confirm an April-May spawning by bluehead suckers in Kanab Creek. By evaluating other data, I was able to estimate the time of peak spawning. Bluehead sucker protolarva (10-13 mm TL) first appeared throughout the lower 4.0 km of Kanab Creek on 5 May; many thousands of larvae appeared overnight. Assuming an incubation and swim-up period of 12-18 days, based on mean daily temperatures (15-18 C) and incubation and swim-up periods reported by Snyder and Muth (1990), I estimated that peak spawning probably occurred between April 17-23 in 1993.

The capture of bluehead sucker metalarva (18 and 20 mm TL) in November could also indicate the occurrence of a second spawning event some time in October or of some limited "opportunistic" spawning by recently matured residents of Kanab Creek who did not participate in the April-May spawn. However, the fact that larvae were not captured upstream of the mouth in November could also suggest that these metalarva were hatched some place other than Kanab Creek.

McAda (1977) reported bluehead suckers spawning in the upper Colorado River during June and July at temperatures greater than 15 C. Data from ongoing studies on the Little Colorado River (LCR) indicate that bluehead suckers spawn during May, with Y-O-Y fish first appearing in June. Mean daily temperatures during that period are about 18- 21 C (Gorman 1994).

The reported spawning temperatures from the upper drainage and the LCR are similar to those I observed during spawning in my study (Figure 19). Temperature and photoperiod are important cues regulating reproductive cycling in Cypriniform fishes (De Vlaming 1972), but in desert fishes, particularly those spawning in small streams, stream discharge may be an equally important factor (Weiss 1993). Historical records (there are only limited provisional flow data available from Kanab Creek during the period of my study) indicate that spawning generally occurs during a receding hydrograph (Figure 20). Following spawning, there is a period of stable flows through May and June, and sporadic late summer floods when the monsoons begin (Figure 20). Spawning on a receding hydrograph makes sense ecologically, because it would offer the greatest chance of a period of low stable flows for egg incubation and larval emergence.

I was unable to observe bluehead suckers spawning in Bright Angel Creek due to high flows in the Spring of 1993. However, I found bluehead sucker post-flexion mesolarva during mid-June surveys (1992 and 1993). The small size of these larvae (13-16 mm TL) indicates that they had been spawned some time during May. This timing would be consistent with the data reported by Minckley (1978), who found bluehead suckers spawning in Phantom and Bright Angel creeks in April and May. They are also consistent with my observations of spent fish; during snorkel surveys in June 1993, I observed a few post-spawning bluehead suckers throughout the lower 7.0 km of Bright Angel Creek.

There are obvious differences in the hydrographs of Bright Angel (Figure 21) and Kanab Creeks (Figure 20) relative to when bluehead suckers spawn. Bright Angel Creek is normally experiencing peak flows during the period of bluehead sucker spawning, while on Kanab Creek, bluehead suckers spawn on a falling hydrograph (Figures 20 and 21) near base flow. While this observation would seem to suggest that bluehead sucker spawning is not positively correlated with a receding hydrograph in Bright Angel Creek, there is an alternative possibility. Bluehead sucker spawning may be timed to provide favorable conditions for emerging fry. The mean daily temperature of Bright Angel Creek is generally a few degrees cooler than Kanab Creek during the respective spawning periods (Figures 19 and 22). Lower water temperatures in Bright Angel Creek would lengthen the incubation period in that stream (Snyder and Muth 1990). Thus, hatching and swim-up might be delayed until the end of May or beginning of June- a period approaching low stable flows in Bright Angel Creek. Therefore, although spawning may occur under different hydrologic and thermal conditions in the 2 creeks, emergence in both systems may be timed to occur during periods of receding, stable flows.

Variation in thermal regimes of natal streams has been suggested as a principal factor influencing differential spawning times in conspecific populations of migratory species (Leggett and Carscadden 1978, Burger et al. 1985). Burger et al. (1985) suggested that spawning of chinook salmon, *Oncorhynchus tshawytscha*, in the Kenai River Alaska is timed so that emergence occurs during conditions optimal for young. Timing of emergence is directly related to timing of spawning and the water temperatures prevalent throughout incubation. Thus, water temperature may influence the timing of spawning of bluehead suckers in part because it dictates when emergence occurs.

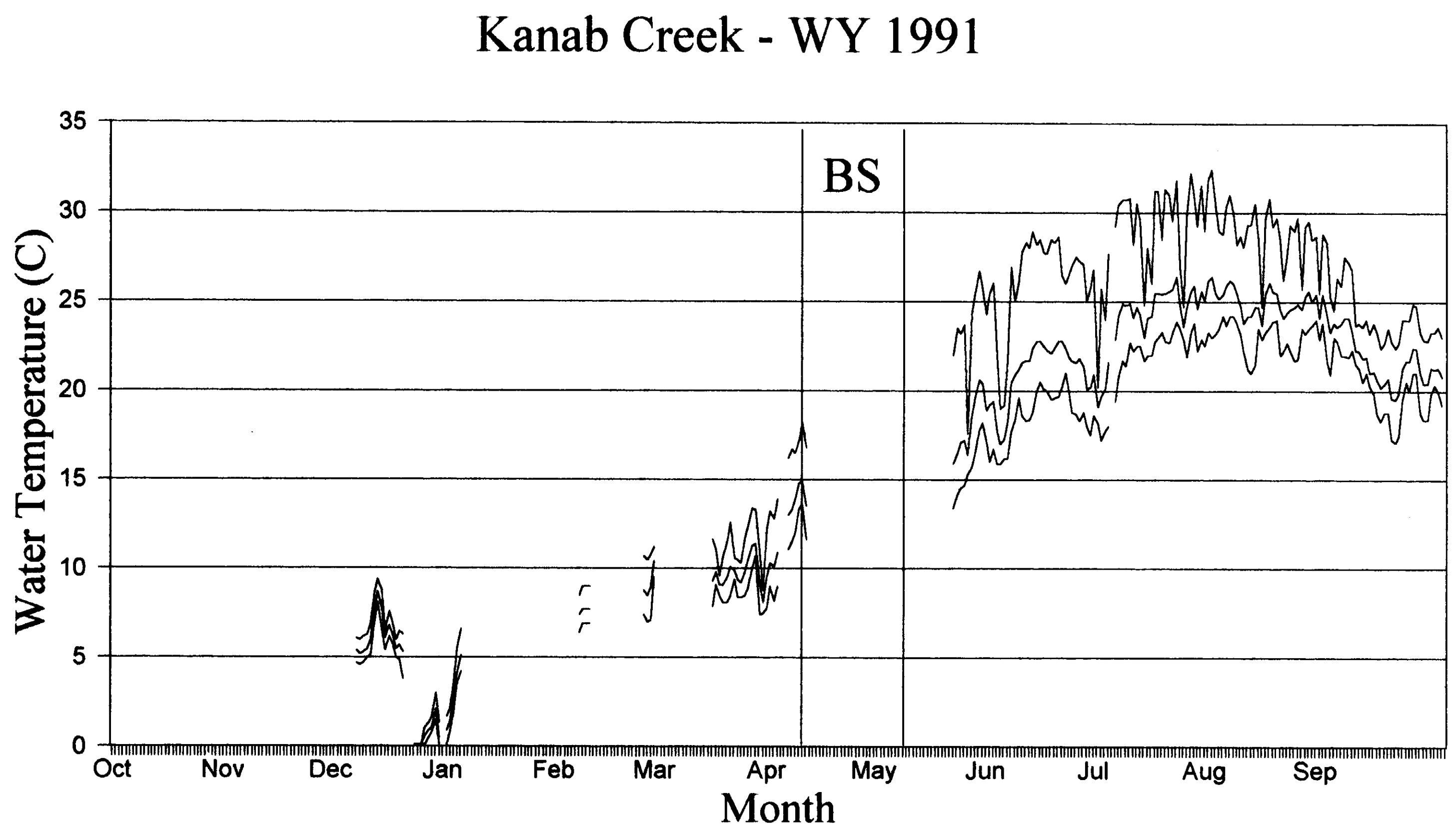


Figure 19. Period of bluehead sucker spawning (BS) in Kanab Creek relative to the 1991 (the most complete recent data set) thermograph for that stream; values are maximum, minimum, and mean daily water temperatures (adapted from USGS raw provisional data).

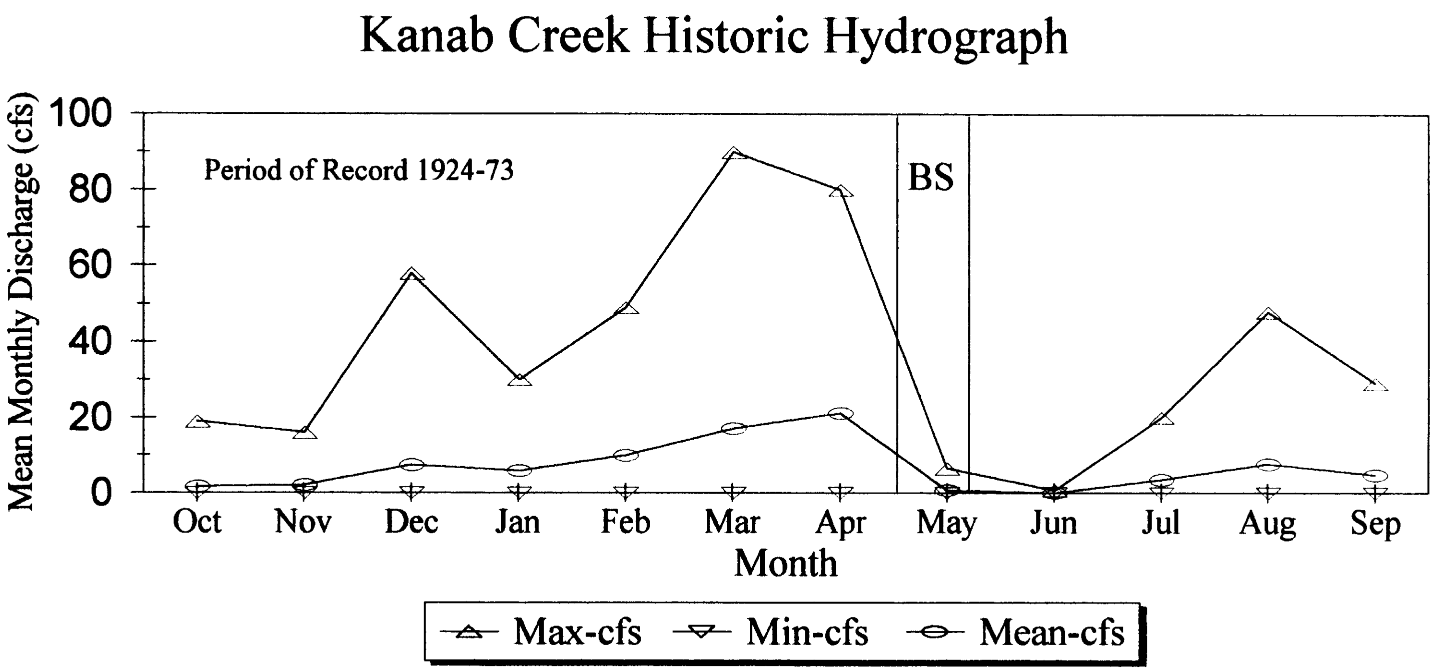


Figure 20. Historic hydrograph of Kanab Creek showing period in which I observed bluehead suckers spawning (BS).

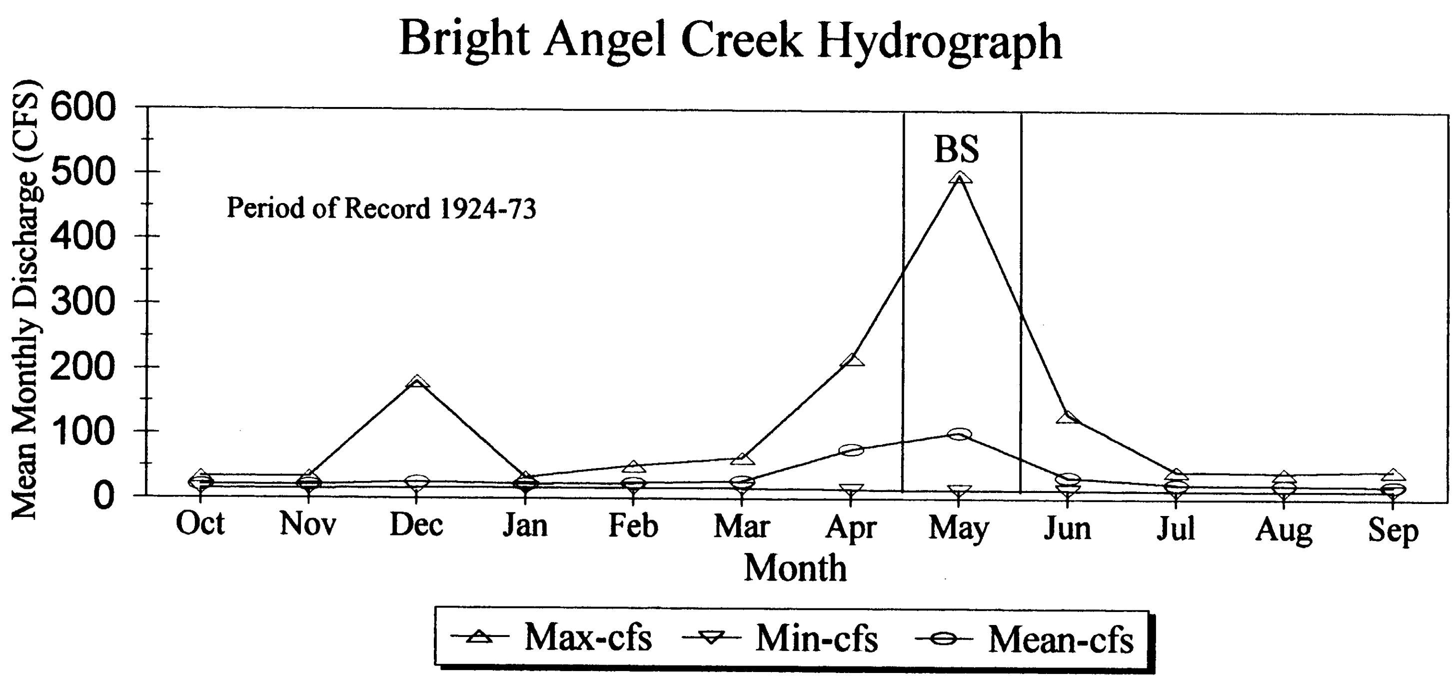


Figure 21. Historic hydrograph of Bright Angel Creek showing the approximate period in which Minckley (1981) observed bluehead suckers spawning (BS).

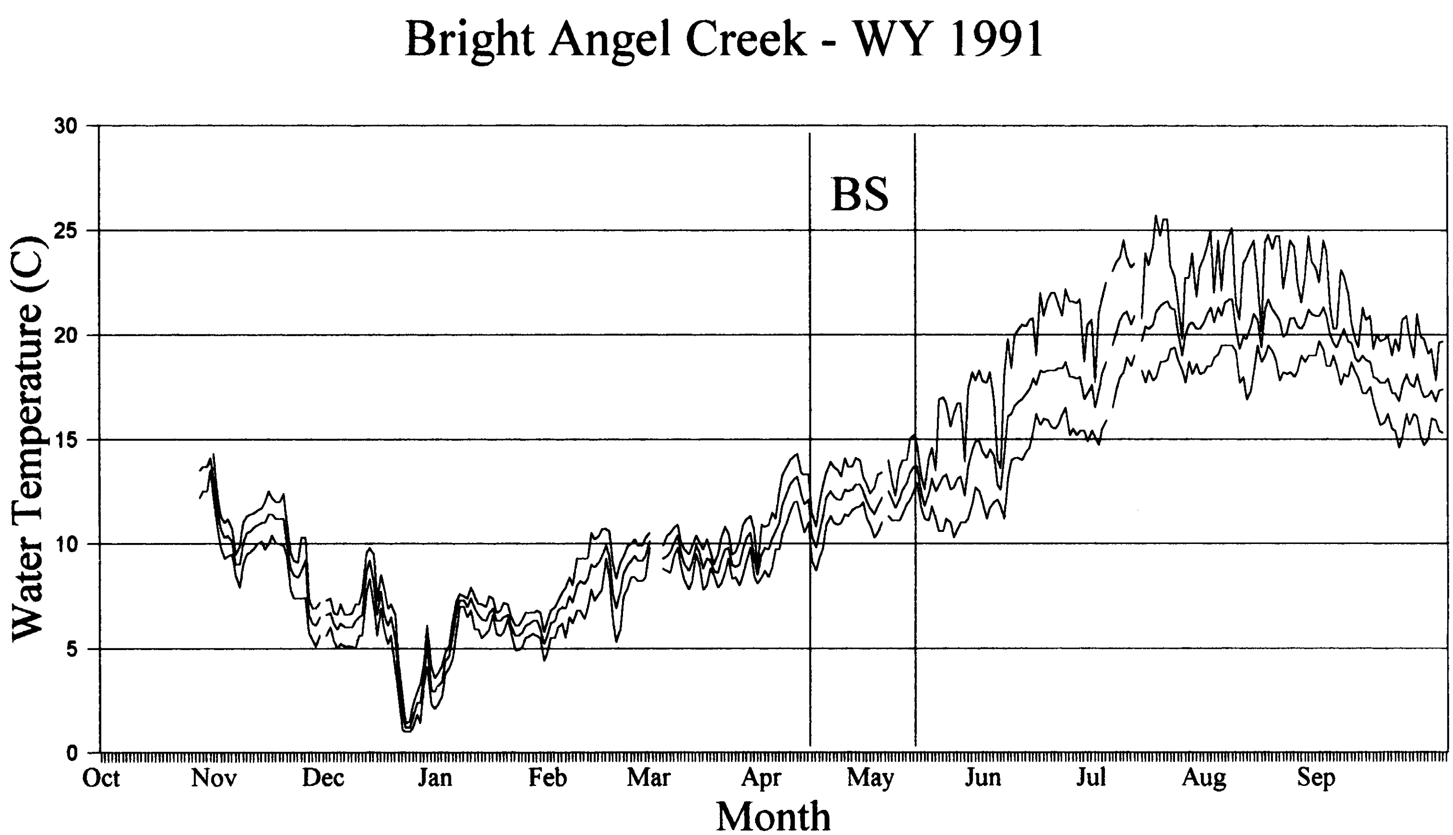


Figure 22. Period of bluehead sucker spawning (BS) in Bright Angel Creek relative to the 1991 (the most complete recent data set) thermograph for that stream; values are maximum, minimum, and mean daily water temperatures (adapted from USGS raw provisional data).

Water clarity increased dramatically throughout April-May in Kanab Creek. Maddux and Kepner (1988) and I saw activities decrease when direct sunlight was on the spawning area. I also observed spawning activities decline stream-wide as water clarity increased, regardless of the amount of sunlight. Furthermore, larger adult bluehead suckers (> 200 mm TL) that had been spawning in the lower 3.2 km, did not remain in the creek after the water cleared. The end of stream-wide spawning may have coincided by chance with increasing water clarity, but there may be a negative relationship between water clarity (i.e., light penetration) and spawning intensity and duration. Photophobic responses have been suggested for many desert fishes, particularly *Gila spp.* (Deacon and Minckley 1974) and *C. latipinnis* (Chart and Bergersen 1992). However, Chart and Bergersen (1992) found numbers of bluehead suckers increased in the clear tailwater of a recently closed dam. While this increase is probably due to higher forage availability in this newly productive zone (Voelz and Ward 1991), it infers that this species has a tolerance for low turbidity.

Spawning Behavior and Habitat Selection

My observations of timing, temperatures, sex ratios, diel activity, and general behavior of spawning of bluehead suckers in Kanab Creek parallel those made by Maddux and Kepner (1988). However, there were some subtle differences in our descriptions of the spawning habitats used by bluehead suckers.

I found that fish selected a slower mean current velocity than reported by Maddux and Kepner (1988) (0.20 m/sec vs. 0.34 m/sec respectively). I also found that fish used a larger mean substrate size than that reported by Maddux and Kepner (1988) (27.6 mm vs. 6.6 mm, respectively). However, mean substrate size by itself is misleading because outliers can inflate the mean. More importantly, Maddux and Kepner (1988) and I found that fish spawned over a mixture of loosely compacted substrates, with a high degree of interstitial spaces. I generally found a high percentage of smaller particles mixed with larger ones at spawning locations, reflected by the modal substrate size of 17 mm.

Most of the disparity between my observations, and those made by Maddux and Kepner (1988), can be explained by differences in our procedures and sample sizes. All of the observations by Maddux and Kepner were made in 1 area, whereas my observations were from 24 spawning micro-sites from 5 locations stream-wide. My data reflect a range of spawning habitats selected by bluehead suckers and offer additional resolution to the data reported by Maddux and Kepner. All 3 habitat variables (depth, current, substrate) are linked and several physical conditions probably must be met before fish recognize an area as appropriate for spawning. My observations indicate that the shallow tail ends of slow runs and pools in Kanab Creek often provided these specific habitat features and that these conditions are available throughout the accessible lower portion of Kanab Creek.

Species Interactions

Occasionally in Kanab Creek, groups of 5-10 speckled dace swam wildly around and behind groups of spawning bluehead suckers. Immediately following the spawning act by suckers, dace would dig aggressively in the substrate where spawning had occurred; their bodies were vertically positioned as they thrust their heads into interstitial spaces. These behaviors match those reported for prespawning and spawning speckled dace (John 1963), but they also gave the appearance that dace were preying upon bluehead suckers eggs. No ova were recovered from the stomachs of 20 speckled dace subsequently seined from the spawning area, nor did I recover speckled dace eggs from the area. It's possible that the dace were attracted by the organic debris displaced by the rapid fanning of fins during spawning by bluehead suckers. It is also possible that the dace were attempting to feed upon recently deposited sucker eggs (as they do their own; John 1963), but were either unsuccessful, or I simply didn't sample those that were successful.

Size at Spawning

My study, and those of others (Smith 1966, Carothers and Minckley 1981), indicate that bluehead suckers may spawn as age 1+ fish. Growth studies on bluehead suckers in the Grand Canyon indicate that they can reach lengths of 70-100 mm TL during their first year (Carothers and Minckley 1981, Maddux et al. 1987, Gorman 1994). My data (length-frequency histograms) suggest that bluehead suckers in Kanab Creek may reach 120-140 mm at age 1, probably as a result of higher stream temperatures (relative to the Colorado River). Male bluehead suckers < 100 mm TL in Kanab Creek often expressed milt; and virtually all those > 110 mm TL expressed milt. I also found gravid females as small as 102 mm TL. While many individuals in Kanab Creek were sexually mature at small sizes, spawners I observed were rarely under 140 mm TL, and most were considerably larger (mean TL of spawners at the 1.35 km site = 198 mm).

Smith (1966) reported mature male bluehead suckers as small as 79 mm (SL) in the San Juan and Little Colorado rivers, but reported that Grand Canyon (Colorado River) populations did not reach maturity until they were 152 mm (SL). Many riverine populations of a species grow larger than conspecific populations inhabiting small streams (Smith 1981). Smith (1981) found this fish size/habitat size relationship to be true with bluehead suckers. It is unclear whether fish are smaller in small streams due to stunted growth or decreased longevity; however, it appears that small stream populations also reach sexual maturity at smaller sizes.

Larval Habitats

Slow backwaters and pools, and small pockets along the bank contained large numbers of larval bluehead suckers in May 1993. While larvae used a variety of depths and substrates, there was an obvious trend for larvae to select areas with low current velocities (< 0.1 m/sec, Figure 18). Banks (1964, as cited in Sublette 1990) and Snyder and Muth (1990) also reported larval bluehead suckers used quiet shoreline areas.

Harvey (1987) suggested that larval fishes select slow velocity habitats because maintenance of position requires minimal energy expenditure.

Comparison of Upper and Lower Drainage Populations

Several differences are apparent between populations of bluehead suckers in the upper and lower Colorado River drainages. Both Andreason and Barnes (1975) and McAda and Wydoski (1983) indicated that upper drainage populations contain considerably larger individuals than those in the Grand Canyon. Maximum size in the upper drainage is about 450 mm TL (Andreasen and Barnes 1975, McAda and Wydoski 1983). Carothers and Minckley (1981) reported a maximum size of 397 mm TL for a female bluehead sucker caught in the Grand Canyon.

Andreason and Barnes (1975) and McAda and Wydoski (1983) reported the minimum size at sexual maturity for females as about 380 mm TL and 313mm TL, respectively. McAda and Wydoski (1983) reported, however, that some of their size at maturity data may have been biased towards larger fish because of collection methods. I found 1 ripe gravid female 102 mm TL in Kanab Creek and several others < 160 mm TL. Even disregarding the significantly smaller fish from above the 3.2 km barrier, Kanab Creek spawners averaged under 200 mm TL. These fish are made up, in part, by mainstem Colorado River suckers that enter Kanab Creek to spawn. McAda and Wydoski (1983) did not report mature female bluehead suckers < 313 mm TL in the Colorado, Gunnison, Green, or Yampa rivers. Apparently, some Grand Canyon populations of bluehead suckers (including tributary populations) reach sexual maturity at smaller sizes, and attain smaller maximum lengths, than conspecific populations in the upper drainage.

Usher et al. (1979) reported that bluehead suckers in the Grand Canyon grow at a slower rate than those in the Upper Basin (Gunnison River). They attributed this difference to the cold waters prevailing in Grand Canyon, thus inferring that the difference in sizes did not occur prior to impoundment of Lake Powell.

The diameters for bluehead sucker eggs (unpreserved) in the upper drainage were larger (3.3 - 3.5 mm, Snyder and Muth 1990) than those observed in Kanab Creek (2.4 - 3.1 mm, Maddux and Kepner 1988, and my data). McAda and Wydoski (1983) reported an ova diameter range for preserved eggs of 1.22 - 2.26 mm for populations from 4 upper drainage rivers, and Andreasen and Barnes (1975) reported mature preserved ova diameters ranging from 1.55-2.25 mm for Weber River populations. However it is difficult to use the data from the last 2 studies for comparison to my data since preservation shrinks ova considerably.

There also appear to be differences in fecundity between populations in the Upper Basin and the Grand Canyon. McAda and Wydoski (1983) reported fecundities ranging from roughly 5,000 to about 20,000 eggs (fish ranging about 325-425 mm TL) for populations in the Upper Basin. Minckley (1978) reported fecundities ranging from 1,269-2,304 (mean = 1,777, n = 3; fish 144-166 mm TL) for bluehead suckers taken from Phantom Creek. He also reported a mean fecundity of 3,181 for bluehead suckers from

Bright Angel Creek (fish 227-312 mm TL) and fecundities ranging from 4,836-17,902 (mean = 9,341; fish 172-281 mm TL) for suckers from Pipe Creek (Phantom Creek is a tributary to Bright Angel Creek, and Pipe Creek is a small tributary to the Colorado River in the Grand Canyon).

There appears to be considerable variation in fecundities reported for Upper and Lower Basin populations, and even among populations within Grand Canyon. It seems unlikely that such disparity in fecundities could be attributed soley to differences in body length. The apparent differences in body size, size at sexual maturity, and fecundities among populations of bluehead suckers suggest that each population may have developed life history strategies based upon unique sets of environmental conditions. However since virtually all of the data on Grand Canyon populations is "post-dam", we cannot disregard the hypothesis that some differences have resulted from depressed mainstem temperatures (Usher et al. 1979). It is difficult to evaluate how the dam-altered Colorado River has affected the general reproductive success of bluehead sucker populations in Grand Canyon; future studies may illuminate these effects by comparing Grand Canyon populations with those from more pristine areas in the Upper Basin.

CHAPTER 4. SPAWNING OF FLANNELMOUTH SUCKERS

INTRODUCTION

The flannelmouth sucker, *Catostomus latipinnis* (Baird and Girard), is found only in the Colorado River and it's tributaries. It is 1 of 8 species native to the Grand Canyon and is the only endemic member of that fauna that is still relatively abundant. There is some concern about the status of the flannelmouth sucker, and it is under consideration for listing as an endangered species by the U.S. Fish and Wildlife Service (Category 2 species, USFWS 1993).

Smith and Koehn (1971) have investigated the phenetic and cladistic relationships between flannelmouth suckers and other western catostomids. Minckley (1973) and Sublette et al. (1990) have provided general species descriptions. McAda and Wydoski (1985) have described growth, maturity, and fecundity for upper basin populations from the Green, Yampa, Gunnison, and Colorado Rivers. Descriptions of diet have been reported by Carothers and Minckley (1981) and Carlson et al. (1979). Snyder and Muth (1990) have described the characteristics and ecology of early life stages and provided identification keys. Recently, Weiss (1993) has investigated spawning requirements and movements of flannelmouth suckers associated with the Paria River in the Grand Canyon.

Previous aquatic surveys in the Grand Canyon found flannelmouth suckers to be abundant (Suttkus and Clemmer 1976, Minckley and Blinn 1976, and Maddux et al.

1987). Recent and ongoing fisheries investigations (GCES Phase II) in the Grand Canyon still indicate relatively high numbers of adults, but there may be reason for concern regarding successful recruitment of juveniles (Weiss 1993).

Objectives

There are no published accounts on spawning behavior and spawning habitat selection by this species. Also lacking is baseline information regarding use of small tributaries in the Grand Canyon (with the notable exception of Weiss 1993). My study will address the:

1. spawning behavior of flannelmouth suckers;
2. timing and duration of spawning by flannelmouth suckers in Bright Angel Creek;
3. spawning locations used by flannelmouth suckers in Bright Angel Creek; and
4. habitat used by spawning flannelmouth suckers in Bright Angel Creek.

This "big river fish" primarily occurs in large, sediment laden waters. The preference for those environments has made it difficult to observe certain aspects of its life history. However, in the Grand Canyon, spawning runs ascend several tributaries (e.g., Paria and Little Colorado rivers, Bright Angel Creek); one of these (Bright Angel Creek) is generally clear.

National Park Service (NPS) personnel stationed at Phantom Ranch at the mouth of Bright Angel Creek have for years observed a spawning run of flannelmouth suckers in that system (J. Hutton and D. Deurn, NPS, pers. comm.). However, previous fishery investigations in the Grand Canyon have either not included or only briefly noted this fact (Carothers and Minckley 1981, Usher et al. 1984). Bright Angel Creek is generally clear during the early spring when fish enter the stream to spawn. For that reason, it appeared to be an ideal study site to document aspects of the spawning ecology of this species.

METHODS

Timing, Duration, and Observations of Spawning

I was able to determine when flannelmouth suckers first entered the stream to spawn via phone contact with Dave Deurn (NPS employee stationed at Bright Angel Creek). Upon my arrival at the creek (16 March 1993), I visually surveyed the distribution and spawning locations of flannelmouth suckers. I then returned to those locations and made observations of spawning fish.

Observations of spawning fish were made between 1100-1600 hr on 18 March 1993 from positions along the stream bank (fish were undisturbed by still observers). For each spawning act I recorded sex ratio (males:female), exact stream location (to facilitate subsequent habitat measurements), duration of the act, and general behavior of the fish. I also took hourly readings of water temperature, pH, and conductivity throughout the observation period.

Spawning Habitat Measurements

Depth, current velocity, and substrate characteristics were measured at 13 spawning sites. Sites were too heterogeneous for a single measurement to be representative, so 5 measurements of depth and current velocity were made at each site: 1 location was at the center, and 1 each at the upper, lower, left, and right edges of the spawning site. Depths and current velocities were measured using a Marsh-McBirney current meter, in the same manner as described previously on Kanab Creek. Substrate measurements followed the same procedures as used on Kanab Creek, except that 20 particles from each site were measured. I also characterized substrate as either compact, moderately compact, loose, or very loose. Lateral position to the nearest stream-bank (meters) and the amount of overhanging cover within 2 m of the water's surface was described for each site. I also attempted to collect eggs from some sites using a fine meshed aquarium net. Egg diameter measurements were made in the field using unpreserved ova.

Three transects (4 m apart) were established perpendicular to flow within each of 2 heavily used spawning areas on Bright Angel Creek. Point measurements of water depth, current velocity, and substrate were made at 1-m intervals across these transects; these data represent conditions available in the general spawning areas. I compared conditions available in the spawning areas to conditions selected at the 13 spawning sites.

I made point estimates of depth, current velocity, and substrate along transects spaced every 500 m from the mouth of the creek (0.0 km) to a point 10 km upstream to represent habitat availability stream-wide. I used the habitat pole to collect these "macro-habitat" data in the same manner as described in chapter 3 (Gorman and Karr 1978, Gorman 1988). Current velocities and substrate diameters measured within spawning areas and at spawning sites were converted to categories (Table 15) to facilitate comparisons with conditions available stream-wide (500 m transects).

Data Analysis

I used the Kolmogorov-Smirnov (K-S) two-sample test to compare the distributions of depths, current velocities, and substrates used, vs. those available stream-wide ($p < 0.05$ significance level). The power of this test is greatest for continuous variables such as depth and water velocities measured with a Marsh-McBirney current meter. The K-S test is conservative for categorical data such as current (pole technique) and substrate; but it is sensitive to differences both in location and scale (Gibbons 1985).

Fish Handling

I seined flannelmouth suckers on 2 occasions to determine sex ratios and sexual condition. I blocked the lower end of each site (3.2-mm mesh seine, 9.14 m x 1.22 m) and made 2 seine hauls downstream into the block seine with a seine of similar proportion. Fish were held in a "live box" (1.27-cm PVC pipe frame, 12.7-mm mesh cotton netting material) until total length (nearest 5 mm), sex, sexual condition and external parasite loads were recorded for each individual. Native fish > 150 mm TL were implanted with a Passive Integrated Transponder (PIT) tag in the same manner as described in chapter 2. Handling of fish required < 1 min; fish were then released back into the section of stream from which they were captured.

RESULTS

Timing, Location, and Duration of Spawning

Flannelmouth suckers were already spawning when I arrived on Bright Angel Creek on 16 March 1993. Dave Deurn (NPS, Phantom Ranch) indicated that he first saw fish on 11 March, but this was the first inspection of the creek in a week, so fish may have already been in the stream for up to 7 days. Spawning suckers were concentrated at 3 locations: rk 0.45, rk 0.70, and rk 1.25. No flannelmouth suckers were observed above rk 1.25 in March.

The spawning area at rk 0.45 (area 1) occurred directly in front of the backcountry camping sites at the Phantom Campground and just below the upper bathrooms. This area contained the largest number of spawning fish (about 30-50 individuals), and I made most of the spawning observations at this location. The spawning area at rk 0.70 (area 2) was located directly in front of the pumphouse on river right that feeds the small canal providing water to the riparian vegetation maintained around the Phantom Campground. This site was the second most heavily used (about 20-30 fish). The spawning area at rk 1.25 (area 3) occurred at "the revetment" just upstream of Phantom Ranch and about 50 m above the wind sock near the Phantom Ranch laundry building. I never observed spawning at this location, but I captured 1 ripe male flannelmouth sucker (370 mm TL) and observed several other suckers there (10-15 individuals).

I observed between 75-150 flannelmouth suckers in the lower 1.25 km of Bright Angel Creek between 16-24 March 1993 and a single pair 3.84 km upstream on 13 June 1993. Increasing water levels and turbidity in between these 2 periods made it impossible to determine the duration of spawning activities. Conversations with various Phantom Campground personnel indicated that flannelmouth suckers are generally present in Bright Angel Creek for 3-6 weeks (J. Hutton, D. Deurn, Shores, NPS, pers. comm.).

Spawning Behavior

Spawning activities were observed between 0600-1600 hr; however, decreased visibility made it difficult to discern spawning during crepuscular periods. Spawning occurred at water temperatures ranging from 12-15 C. Thirty three separate spawning acts were observed on 18 March 1993. Generally, male suckers held positions individually or in small loose groups throughout the spawning area. Sometimes a single female would enter the area and approach a group of males, and spawning would commence immediately. After spawning, the female generally would swim off upstream while the males maintained their positions. Alternatively, a female would approach one or more males but not immediately initiate spawning. Under these conditions, males would occasionally nudge the sides of the female until spawning was initiated. These individuals would often stay together through several subsequent spawning acts. On still other occasions, a female would enter the general spawning area and several males would leave their positions and accost the female until she either left the area or spawning was initiated. Individual females were observed spawning with different groups of males throughout the general spawning area. Thus, there was an open exchange of individuals between spawning groups, and there often were multiple deposits of eggs from several females in a single location.

The spawning act was usually accomplished by 2 males positioning themselves posterio-laterally to the female, with their pectoral and pelvic fins slightly behind hers. The female would then begin rapid fanning movements of the caudal region while sometimes moving slightly upstream (< 1 m). Males would follow suit, pressing their bodies tightly to the female, their anal fins visibly cupped and directed toward the uro-genital vent of the female. Spawning lasted 2-8 seconds. Other males in the area often tried to participate once the act began; these males swam aggressively from side to side over the top of the spawning trio, trying to gain position. Rarely would they displace a spawning male. The mean sex ratio of spawning males to a single female was 2.3:1

(mode = 2). Sometimes debris was visibly displaced during spawning, but generally there were no excavations at egg deposition sites. Flannelmouth suckers did not visibly feed at any time between spawning activities.

No territorial or defensive behavior was observed, even when trout moved in close to spawning groups and preyed upon eggs. One adult rainbow trout (about 350 mm TL) appeared to nudge the side of a female sucker, presumably attempting to induce her to release eggs. The stomach of a 238-mm TL brown trout from the 0.70 km spawning area contained over 50 flannelmouth sucker eggs. This was the only trout stomach sampled during this period.

Spawning Habitat Selection

Spawning was documented at 13 sites located within areas 1 and 2. Areas 1 and 2 could be characterized as shallow glides with moderate currents. Both areas occurred in stream sections that were wider than the average for the stream; thus, depths and current velocities appeared slightly lower than those stream-wide. There were some riffle characteristics (exposed rocks, surface turbulence) in area 1, and also a "hole" behind a large rock; however, most of area 1 was shallow (<50 cm) with moderate current velocities (< 1.0 m/sec). Though lower Bright Angel Creek has moderate riparian vegetation, no overhanging cover occurred within 2 m of the waters surface at spawning sites. Lateral position of spawning sites to the closest stream bank was highly variable (1.4-3.6 m) but was always less than half the stream width.

Flannelmouth suckers spawned at depths ranging from 19-41 cm (mean = 28.2 ± 5.3; n = 65), mean column velocities ranging from 0.23-0.89 m/sec (mean = 0.57 ± 0.24; n = 65), and over substrate diameters ranging from 30-64 mm (mean = 49 ± 39.1, median = 34.0; n = 257) (Figure 23). Spawning substrates were very loosely compacted, and generally consisted of coarse gravel (20-50 mm) mixed with a small percentage of fine gravel (10-20 mm). Cobble-sized substrates occasionally occurred at spawning sites; thus, mean substrate sizes may have been slightly inflated. Eggs recovered from spawning sites ranged from 2.5-3.8 mm in diameter (mean = 3.3 ± 0.28; n = 25). During spawning observations, pH ranged from 8.74-8.82 (mean = 8.80 ± 0.03), conductivity ranged from 259-266 micro-siemens (mean = 264 ± 3), and water temperatures were stable (13.5 - 14.5 C). Spawning activity occurred throughout the period of observation on 18 March (Figure 24).

Spawning flannelmouth suckers selected shallow depths and small to moderate-sized substrates significantly out of proportion to their stream-wide availabilities ($p < 0.02$ and $p < 0.03$, respectively, Figure 23). There were no significant differences between conditions available in the general spawning areas (areas 1 and 2) and those available stream wide. However the depth variable was borderline ($p = 0.059$); depths in the spawning area were generally shallower than those available stream-wide (Figure 23). Likewise, conditions available at spawning sites were not significantly different than those available in the general spawning areas (Table 17).

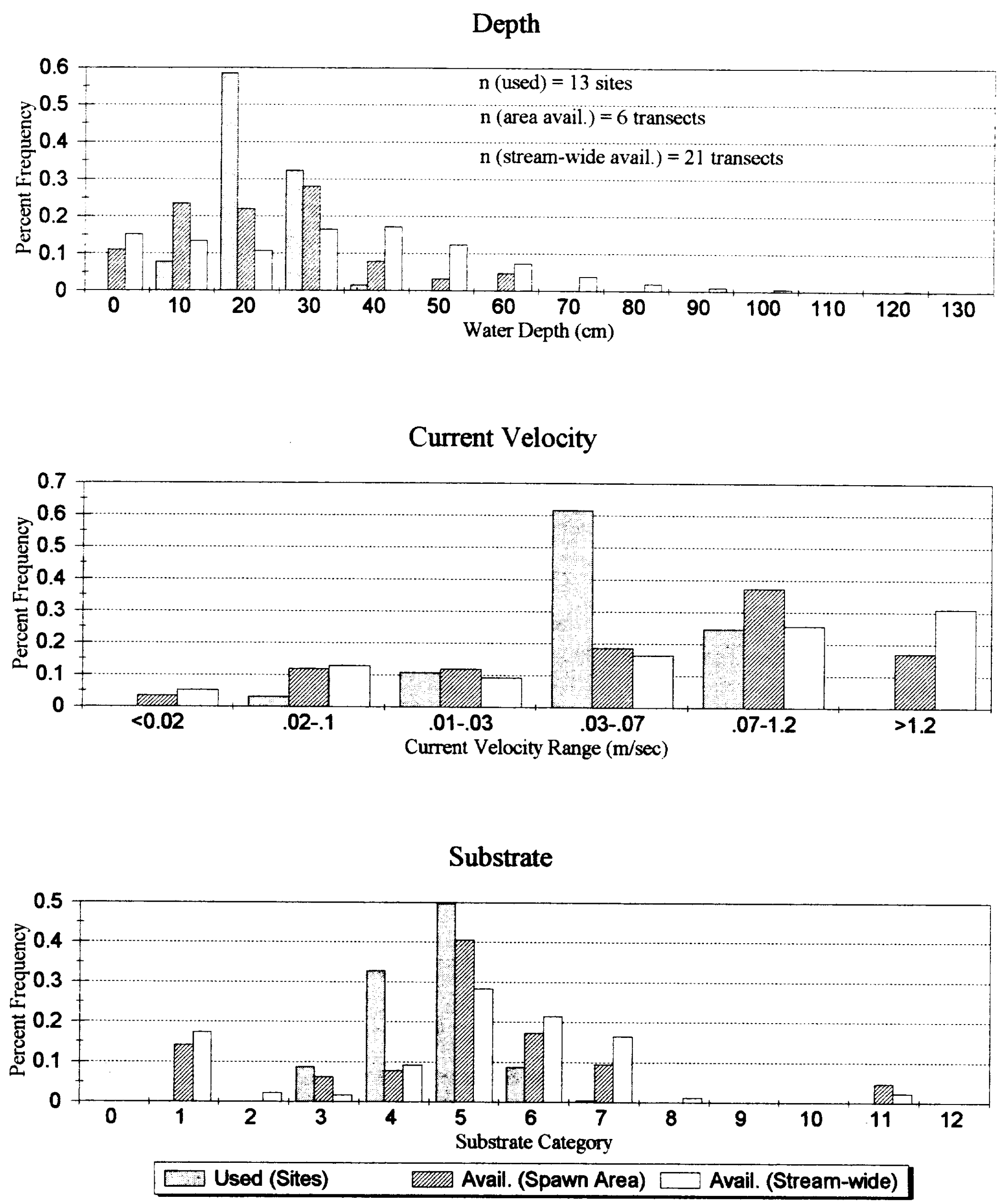


Figure 23. Relative frequency histograms of depths, current velocities, and substrates used by, and available to, spawning flannelmouth suckers in Bright Angel Creek, March 1993.

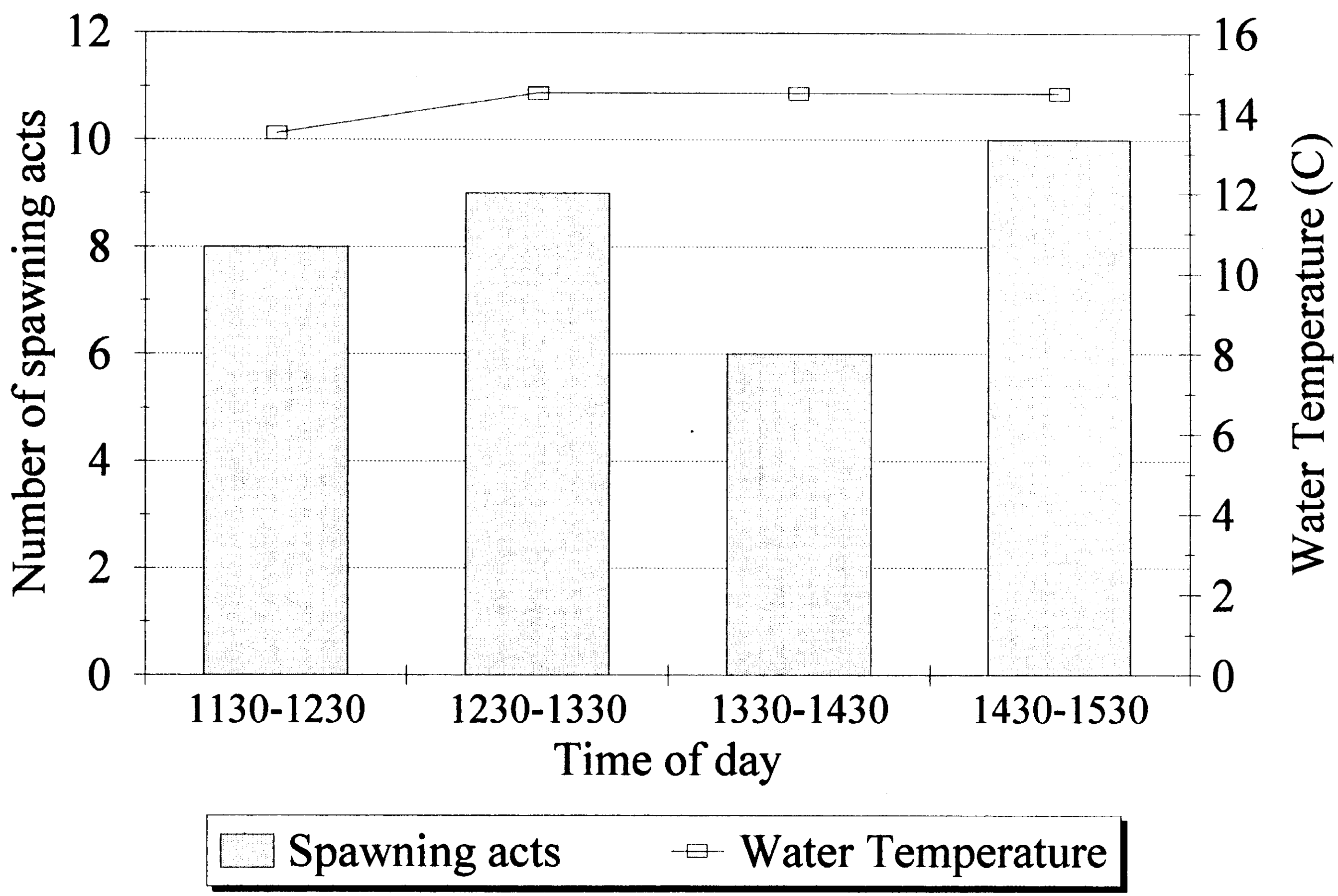


Figure 24. Flannelmouth sucker spawning activity relative to water temperature and time of day, 18 March 1993, Bright Angel Creek (n = 23 acts).

Table 17. Comparisons (Kolmogorov-Smirnov two-sample test) of the distributions of depth, current, and substrate used by flannelmouth suckers at 13 documented spawning areas, vs. habitat available stream-wide, and in two general spawning areas; Bright Angel Creek, 18 March 1993. *Denotes significance ($p < 0.05$).

Variable	Test	n1	n2	Max. Abs. Difference	Z-value	p-value
Depth	Stream-wide avail. vs. Spawning sites	153	13	0.44444	1.538	0.018*
	Stream-wide avail. vs. Spawning areas	153	48	0.21977	1.328	0.059
	Spawning areas vs. Spawning sites	48	13	0.39583	1.266	0.081
Current	Stream-wide avail. vs. Spawning sites	153	13	0.35265	1.221	0.101
	Stream-wide avail. vs. Spawning areas	153	48	0.09578	0.579	0.890
	Spawning areas vs. Spawning sites	48	13	0.27083	0.866	0.441
Substrate	Stream-wide avail. vs. Spawning sites	153	13	0.42581	1.475	0.026*
	Stream-wide avail. vs. Spawning areas	153	48	0.15497	0.938	0.342
	Spawning areas vs. Spawning sites	48	13	0.27083	0.866	0.441

Fish Captures

To limit stress on spawning fish, I made only 3 seine attempts. Twelve flannelmouth suckers were captured (10 males, 2 females), all of which were either ripe or running ripe. Their sizes ranged from 370 mm TL (male) to 569 mm TL (female). None of these fish exhibited traits (such as a dorsal keel or large lateral line scales) characteristic of a putative razorback x flannelmouth hybrid. No external parasites were noted. All fish were implanted with PIT tags (Appendix IV).

DISCUSSION

Spawning Behavior

The spawning behavior of flannelmouth suckers is very similar to that of bluehead suckers (chapter 3) and other catostomids (Bozek et al. 1991). Sex ratios and initiation behaviors were comparable to those I observed for bluehead suckers in Kanab Creek. Body alignment and the cupping and placement of anal fins during spawning was also analogous between species. Flannelmouth suckers did not create "spawning depressions" through rapid fanning during spawning, as did bluehead suckers. Instead, flannelmouth suckers deposited eggs into the interstitial spaces of loosely compacted and medium sized substrates. Both species were non-guarding; however, flannelmouth suckers, particularly males, tended to maintain general positions within the spawning area. These locations were frequently used for egg deposition by more than 1 female. This behavior was not as prevalent in bluehead suckers, which acted more like the "open-substrate lithophils" described by Snyder and Muth (1990).

The skewed male to female sex ratio observed during spawning (2.3:1) could be explained in 1 of 3 ways (Quinn and Ross 1985): 1) differential mortality of the sexes, 2) deferred maturity of 1 sex, or 3) a greater tendency for members of 1 sex to spawn on a non-annual basis. While little information is available to evaluate the first 2 possibilities, several studies report non-annual spawning in white sucker, *Catostomus commersoni* (Olson and Scidmore 1963, Geen et al. 1966, Quinn and Ross 1985, Trippel and Harvey 1989), a similarly long-lived *Catostomus spp.* Trippel and Harvey (1989) postulated non-annual spawning was due, in part, to hypoxia and poor forage availabilities in the lakes they investigated. However, Quinn and Ross (1985) demonstrated non-annual spawning in a white sucker population free of these environmental constraints. Further study of the reproductive ecology of flannelmouth suckers is necessary to clarify whether non-annual spawning occurs in this species.

Y-O-Y Suckers

No Y-O-Y flannelmouth suckers were observed in Bright Angel Creek. I was unable to determine if they emigrated as emergent fry, or were eaten by trout, or if eggs did not hatch. Bedload movement that accompanied high flows during the spawning season (pers. obs.) may have damaged eggs. During 1993, Bright Angel Creek had high spring flows from mid-March through early June. Alternatively, Y-O-Y flannelmouth suckers may have emigrated or been flushed from the stream immediately after emerging from the gravel. Harvey (1987) suggested that Y-O-Y fishes may be particularly vulnerable to floods due to their small size and reduced swimming capabilities.

Timing, Duration, and Locations of Spawning

Bright Angel Creek appears to be used annually by spawning flannelmouth suckers (my data and casual observations made by NPS personnel). Suckers enter the creek in late February or early March and spawn in specific areas in the lower 1.2 km of the creek. I was unable to define the duration of their spawning activities in March 1993 because of rising water and low visibility, but NPS personnel indicated that spawning flannelmouth suckers generally reside in Bright Angel Creek for about 3-6 weeks. Weiss (1993) found that flannelmouth suckers spawning in the Paria River had a similarly short period of stream residency. Analogous spawning migrations have also been shown in other catostomids (Raney and Webster 1942).

Studies have shown the timing of spawning to be related to water temperatures for many fishes (De Vlaming 1972, Burger et al. 1985), including catostomids (Geen 1966, Tyus and Karp 1989). Flannelmouth sucker populations from the upper basin have been reported to spawn in May and June at water temperatures from 6-17 C (McAda 1977, Tyus and Karp 1990). Few published data are available regarding when flannelmouth suckers spawn in the Grand Canyon. Weiss (1993) reported spawning in the Paria River during March and April when water temperatures ranged from 7-19 C.

Flannelmouth suckers appear to spawn during this same time period and temperature range in the Little Colorado River (O. Gorman, USFWS, pers. comm.). Spawning in Bright Angel Creek occurs during March when water temperatures range from 7-15 C (Figure 25). Thus, it would appear that flannelmouth suckers spawn at similar temperatures throughout the Colorado River Drainage and that spawning is synchronous among Grand Canyon fish.

Temperature and photoperiod are not the only environmental cues that can affect timing of spawning in fishes. Weiss (1993) showed that the timing of flannelmouth sucker spawning coincided with a receding hydrograph on the Paria River. My data support this hypothesis for bluehead suckers spawning in Kanab Creek (Figure 20) but not for flannelmouth suckers spawning in Bright Angel Creek. Flow rates on Bright Angel Creek for the period of my study were not available; however, historic discharge data indicate a rising hydrograph during the period when I observed flannelmouth suckers spawning (Figure 26; USGS 1989). In fact, my observations of spawning were cut short by rising flows and associated turbidity in 1993.

Flannelmouth suckers are known to spawn in only 3 tributaries in Grand Canyon: the Paria and Little Colorado rivers and Bright Angel Creek. Limited spawning may also occur at the mouths of Kanab and Havasu creeks. The hydrograph of Bright Angel Creek is unique among these systems. Bright Angel Creek has a relatively short basin and drains high elevations of the north rim. High spring flows associated with snow melt begin later and last about 1 month longer on Bright Angel Creek than in any of the

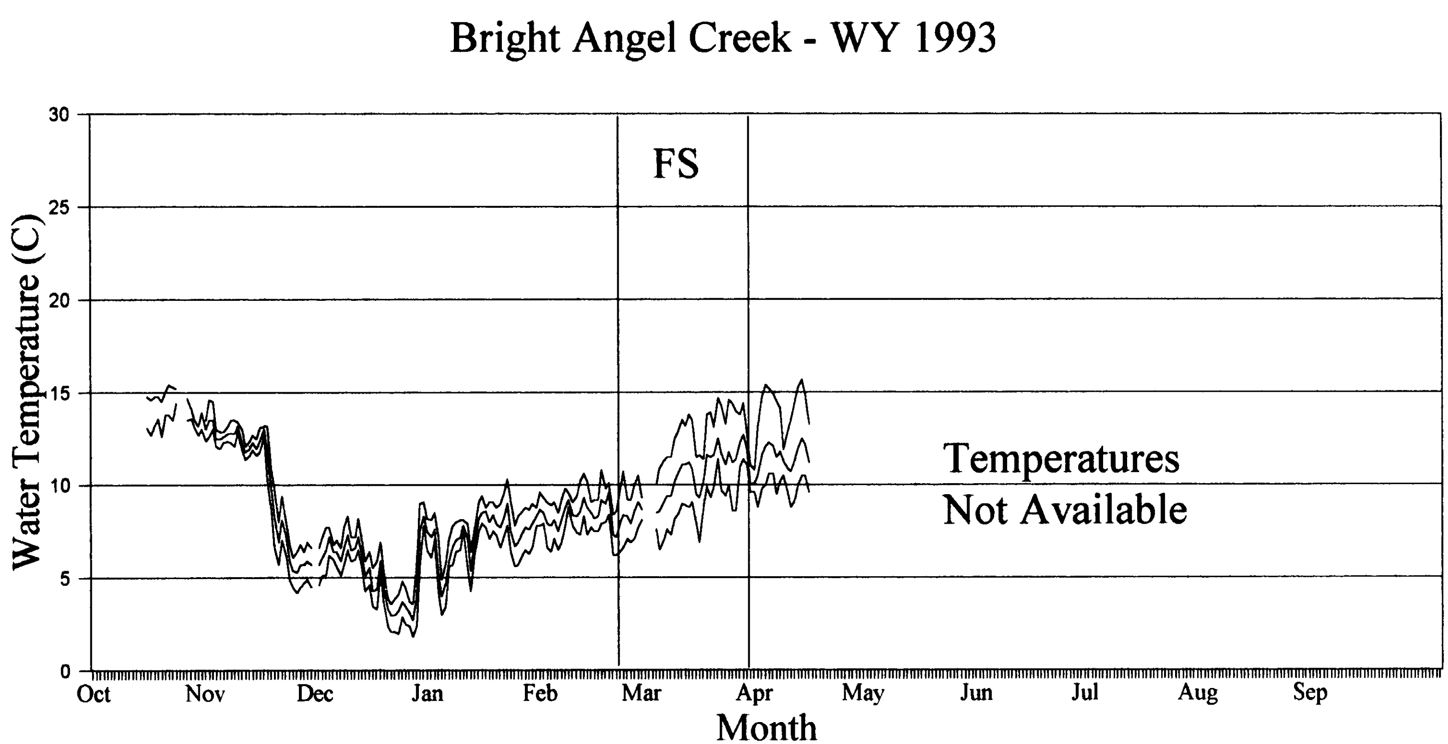


Figure 25. Period of flannelmouth sucker spawning (FS) in Bright Angel Creek relative to the 1993 thermograph for that stream; values represent maximum, minimum, and mean daily water temperatures (adapted from USGS raw provisional data).

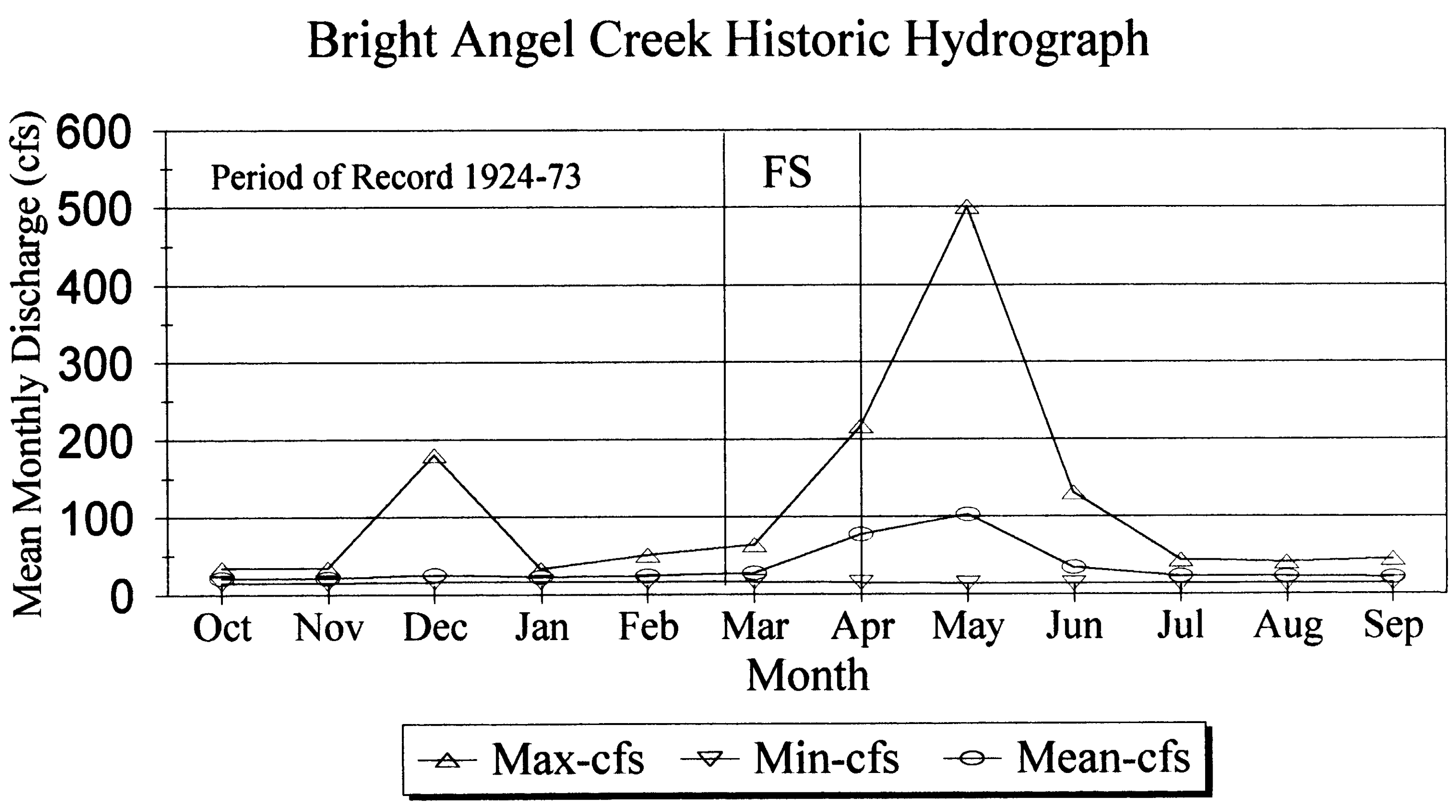


Figure 26. Period of flannelmouth sucker spawning (FS) in Bright Angel Creek relative to the historic hydrograph for that stream (adapted from USGS 1989).

aforementioned tributaries. Thus, flannelmouth suckers spawning in March and April in most tributaries in the Grand Canyon do so on or just before a receding hydrograph, except in Bright Angel Creek.

I offer 3 hypotheses to explain the differences in spawning in relation to the hydrographs for streams in which spawning occurs. First, given the mobility shown by flannelmouth suckers in Grand Canyon (Weiss 1993) and elsewhere in the Colorado River Drainage (Chart and Bergersen 1992), one could reasonably assume that the fish spawning in all tributaries come from a single population. If this assumption is true, the population as a whole may have evolved a strategy for the timing of spawning that assures the greatest overall success. By spawning on or just before a receding hydrograph, stable flows are more likely during incubation and early rearing stages. It is possible that fish spawning in Bright Angel Creek are simply reflecting the genetic adaptations of the population, even though that strategy is not well fit to conditions in Bright Angel Creek. This hypothesis assumes one population (i.e., homing to natal streams is not obligatory); for example, individuals spawning in Bright Angel Creek last year may spawn in the Paria River next year. Further tag recovery data from tributary spawners should clarify the extent of movements and mixing of flannelmouth suckers in the Grand Canyon.

Alternatively, tributary spawners may represent separate populations. Tyus and Karp (1990) found high spawning site fidelity in some radio tagged razorback suckers in the Upper Colorado River Basin. If fish spawning in Bright Angel Creek show similar fidelity, then successful recruitment to that population must be occurring. However, as noted by Weiss (1993), spawning need not be successful every year for the population to persist given the longevity of the species. Scoppetone (1988) reported a maximum age of 28 years for flannelmouth suckers from an upper basin population. Therefore, even if spawning is only successful in Bright Angel Creek during years with low winter precipitation and low associated spring flows, it's possible that sporadic successful recruitment may allow the run to persist. Weiss (1993) hypothesized that spawning by flannelmouth suckers on a receding hydrograph on the Paria River allowed incubating eggs to avoid bedload movement associated with high flows. The run of flannelmouth suckers into the Paria River appears considerably larger than the run of fish in Bright Angel Creek. The larger run of fish in the Paria River could be a reflection of more frequent spawning success on that stream due to the low flow conditions prevailing during incubation.

Finally, it's possible that spawning in relation to the hydrograph is not important for flannelmouth suckers. Support for the hypothesis that timing of spawning and emergence are related to stream discharge is perhaps strongest for native species that rear in small tributaries (e.g., bluehead suckers). Neither Weiss (1993) nor I found significant numbers of larval flannelmouth suckers in the Paria River or Bright Angel Creek following spawning events in 1992 or 1993 (Weiss caught 8 Y-O-Y in 1992). Either spawning was unsuccessful, or fry immediately emigrated or were flushed from the streams following emergence. Conversely, flannelmouth sucker larvae and Y-O-Y were abundant in the LCR throughout the spring and summer of 1993 (O. Gorman, FWS, pers. comm). The size the LCR, along with the diversity of physical habitats it offers, make it unique among Grand Canyon tributaries in which flannelmouth suckers are known to spawn. While a few Y-O-Y fish may remain in the Paria River during low flow years (Weiss 1993), it seems apparent that most emigrate to the Colorado River soon after emergence, assuming successful incubation. The regular collection of many larval and Y-O-Y flannelmouth suckers in backwaters downstream of tributary mouths (G. Doster, AGF, pers. comm.) supports this hypothesis. Thus, it would appear that emergent flannelmouth sucker fry do not generally rear in the smaller tributaries. If fry leave the smaller tributaries following emergence, then stream hydrographs may be unimportant for this species, except in regards to high flows creating bedload movement during incubation periods. Because bluehead sucker larvae generally remain in their natal streams for early rearing, the timing of their emergence and its relation to the stream hydrograph may be more closely linked.

Information reported by Tyus and Karp (1990) further complicates the question of spawning by flannelmouth suckers in relation to the hydrograph. These authors found spawning of razorback suckers in the Upper Basin during ascending and peak flows in spring. They also found considerable spatial and temporal overlap in spawning by razorback and flannelmouth suckers (further evidenced by the consistent capture of putative razorback x flannelmouth hybrids). While this overlap would infer that these species spawn in response to the same cues, Tyus and Karp (1990) reported that spawning overlap between the species was less apparent during high flow years. This might suggest that flannelmouth suckers adjust their spawning activities according to flow conditions. Weiss (1993) reported that flannelmouth suckers terminated spawning at the onset of a low pressure system and left the Paria River immediately prior to a flash flood in 1992. He reported that flannelmouth sucker spawning was more prolonged in the Paria River in 1993 when flows were relatively stable. Further study is necessary to interpret the relationship between flannelmouth sucker spawning and the hydrograph.

Spawning Habitat Selection

Flannelmouth suckers spawn in a number of riverine environments. In the upper basin, they reproduce in the mainstem Colorado River and some of its larger tributaries (e.g., Green, Yampa, Gunnison rivers), apparently spawning over gravel bars (McAda 1977). In the Grand Canyon, flannelmouth suckers have been documented spawning in 3 very different tributaries (Paria and Little Colorado rivers, Bright Angel Creek). The Paria River is a low gradient, low volume (3.5-35.3 cfs base flow, Graf et al. 1991), sediment laden, desert stream prone to high summer temperatures and flooding (Weiss 1993). Weiss (1993) documented spawning flannelmouth suckers penetrating at least 10 km upstream from the mouth of this river. The Little Colorado River is perennial (base flow of over 200 cfs) below Blue Springs, located about 21 km upstream from the mouth. Calcium carbonate ($CaCO_3$) deposition conglomerates substrates and creates travertine dams in the lower 14 km of the LCR. Flannelmouth suckers are believed to spawn throughout the lower 10 km of this river (Gorman 1994). Bright Angel Creek is swift, high gradient, cool, and clear and has been likened to a mountain trout stream. Flannelmouth suckers spawn in the lower 1.2 km of this system.

These data suggest that flannelmouth suckers have fairly general spawning habitat requirements. However, my data and those of Weiss (1993) show similarities in spawning habitat selected, despite the gross physical differences between Bright Angel Creek and the Paria River. In each stream, flannelmouth suckers selected similar sized substrates (gravel, pebble, and rock), and did so significantly out of proportion to availability. Mean column velocities used for spawning were also similar between streams (Paria River mean = 0.48 m/sec; Bright Angel Creek mean = 0.57 m/sec). Mean depths used for spawning in the Paria River were shallower than those used in Bright Angel Creek (15.4 cm vs. 28.2 cm, respectively). However, Weiss (1993) noted that depths > 25 cm rarely occurred in the Paria River, and that such deep pockets generally contained silt and fine sand substrates making them unlikely spawning habitats.

Comparison of Upper and Lower Basin Populations

Some differences are apparent between upper and lower basin populations of flannelmouth suckers. McAda (1977) found no evidence of spawning migrations in upper basin populations. Conversely, flannelmouth suckers in the Grand Canyon are apparently highly mobile, particularly in relation to spawning migrations. Weiss (1993) caught a spawning flannelmouth sucker in the Paria River that had been tagged near

Kanab Creek, 228 km downstream. In addition, many of his recaptures had originally been tagged at or near the Little Colorado River, 107 km downstream.

Spawning migrations into sidestreams appear to be commonplace in the Grand Canyon. However, stream residency appears to be short for adults, with individuals quickly returning to the mainstem Colorado River following spawning. In the Upper Basin, flannelmouth suckers were collected year round at locations where they were observed spawning (McAda 1977); spawning was not reported in small tributaries.

The timing of spawning appears to be 6-8 weeks later in the Upper Basin populations, than in lower basin populations. Such a delay might be explained by slower warming of water temperatures in the upper basin in the spring due to the difference in latitude.

Usher et al. (1979) provide a discussion of growth differences between upper and lower Basin populations of flannelmouth suckers. While the work of Scoppetone (1988) largely supplants the maximum ages suggested by Usher et al. (1979), Usher et al.'s discussion of growth in pre-adult fishes probably remains relevant because age and growth are still highly correlated prior to sexual maturity (Weiss 1993).

CHAPTER 5. RECOMMENDATIONS

The lowermost kilometer of Bright Angel Creek is used annually by flannelmouth suckers for spawning. Hikers staying at Phantom Campground often build rock dams to create swimming pools throughout this reach during the summer and fall. Some of these dams persist through the winter. I have no evidence to indicate that rock dams inhibit the spawning migrations of flannelmouth suckers into Bright Angel Creek (no dams were in place during the 1993 spawning run), but there is that potential. Therefore, GCNP should assure that dams are breached prior to February, the likely onset of flannelmouth sucker spawning migrations.

There is need for research that will evaluate the success of flannelmouth sucker spawning in small tributaries like Bright Angel Creek. Specifically, it is important to determine if emergent fry immediately emigrate to the Colorado River, and to evaluate the effect of predation and bedload movement on recruitment. It is also important to evaluate the extent of movements and the degree of mixing by flannelmouth sucker "stocks" in Grand Canyon. An understanding of these life history aspects is necessary to facilitate management strategies directed towards the preservation of this species in Grand Canyon.

Standardized quantitative surveys of fish populations in the tributaries should also be continued. Many tributaries are used by native species each spring for spawning. By monitoring fish densities in tributaries during spawning events, it may be possible to evaluate trends in the status of several native and introduced species in Grand Canyon.

There is some indication that the abundances of speckled dace, and possibly bluehead suckers, have been reduced in Bright Angel Creek since the late 1970's. This decline may be due, in part, to brown trout becoming the dominant predator in Bright Angel Creek in recent years. The effect of predation on native fishes in Grand Canyon needs further evaluation, particularly in Bright Angel Creek where native species and piscivorous trout coincide in time and space during spring.

Finally, I recommend that studies be undertaken to better understand how *Lernaea cyprinacea* affects Y-O-Y and juvenile native fishes, and what biotic and abiotic conditions contribute to the mortality of native fishes infected by this introduced parasite. An understanding of these relationships is particularly relevant given the current proposal to retrofit Glen Canyon Dam with a multi-level intake structure.

APPENDIX I

POPULATION ESTIMATES (Program CAPTURE -Rexstad and Burnham 1991) FOR BLUEHEAD SUCKERS, SPECKLED DACE, AND FLANNELMOUTH SUCKERS SEINED FROM BLOCKED STREAM REACHES ON KANAB CREEK, AUGUST 1992 - JUNE 1993.

Table 18. Population estimates (Program CAPTURE- Removal Estimator) for various species seined from blocked stream reaches in Kanab Creek, August 1992 - May 1993.

Stream	Sample Period	Sample Site (rk)	Sample Area (sq. m)	Stream Condition	# seines	Species	Population Estimate	Standard Error	Approx. 95% C.I.
Kanab	Aug '92	3.00	128	V. Turbid	4	*C. discobolus*	29	11.7127	21 - 83
Kanab	Aug '92	4.00	164	V. Turbid	5	*C. discobolus*	25	1.3845	25 - 25
Kanab	Aug '92	5.23	120	V. Turbid	4	*C. discobolus*	11	0.3722	11 - 11
Kanab	Aug '92	6.00	146	V. Turbid	4	*C. discobolus*	43	2.0157	42 - 51
Kanab	Nov' 92	1.80	250	V. Turbid	4	*C. discobolus*	30	11.5092	22 - 82
Kanab	Nov' 92	3.00	77	V. Turbid	4	*C. discobolus*	12	2.5236	11 - 26
Kanab	Nov' 92	4.00	100	V. Turbid	3	*C. discobolus*	53	4.068	49 - 69
Kanab	Nov' 92	5.23	120	V. Turbid	3	*C. discobolus*	10	0.6272	10 - 10
Kanab	May '93	1.80	519	Turbid	3	*C. discobolus*	33	1.8849	32 - 43
Kanab	May '93	3.00	61	Turbid	5	*C. discobolus*	46	2.6338	44 - 58
Kanab	May '93	4.00	69	Turbid	3	*C. discobolus*	43	2.2081	41 - 52
Kanab	May '93	5.23	91	Turbid	3	*C. discobolus*	16	1.1593	16 - 16
Kanab	May '93	6.00	165	Turbid	7	*C. discobolus*	103	4.2653	99 - 119
Kanab	Aug '92	3.00	128	V. Turbid	4	*R. osculus*	15	0.9337	15 - 15
Kanab	Aug '92	5.23	109	V. Turbid	4	*R. osculus*	46	5.4389	41 - 67
Kanab	Nov' 92	1.80	250	V. Turbid	4	*R. osculus*	11	0.7891	11 - 11
Kanab	Nov' 92	3.00	77	V. Turbid	4	*R. osculus*	11	1.1838	11 - 11
Kanab	Nov' 92	4.00	100	V. Turbid	3	*R. osculus*	14	0.6328	14 - 14
Kanab	May 93	1.80	519	Turbid	3	*R. osculus*	6	0.3761	6 - 6
Kanab	May 93	3.00	61	Turbid	5	*R. osculus*	4	1.199	4 - 4
Kanab	May 93	4.00	69	Turbid	3	*R. osculus*	8	2.8532	7 - 25
Kanab	May 93	5.23	91	Turbid	3	*R. osculus*	5	0.4435	5 - 5
Kanab	May 93	6.00	165	Turbid	7	*R. osculus*	7	2.5004	6 - 21
Kanab	May 93	0.00	282	Turbid	4	*C. latipinnis*	95	4.8909	91 - 117

APPENDIX II

STANDARD DENSITY ESTIMATES FOR ADULT, JUVENILE, AND YOUNG-OF-YEAR BROWN AND RAINBOW TROUT SAMPLED IN BRIGHT ANGEL CREEK DURING THE PERIOD JANUARY 1992 - JUNE 1993.

Table 19. Standard Density Estimates (SDE) for juvenile and adult brown trout in the lower 14.3 km of Bright Angel Creek during January and June 1992. January's estimates were derived from electrofishing (riffles and pools) and those in June were derived from snorkel surveys (pools only).

Sampling Period	Stream Reach	ADULT BROWN TROUT (>250mm TL) Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	JUVENILE BROWN TROUT (100-250mm TL) Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)
	0-3 km	0.542	0.000	1.803	0.766	2	6	0.638	0.555	0.722	0.118	2	7
	3-6 km	0.828	0.828	0.828		1	4	1.656	1.656	1.656		1	8
Jan 1992	6-9 km	1.708	0.368	3.048	1.895	2	18	3.111	1.842	4.381	1.796	2	33
	9-12 km	NOT SAMPLED						NOT SAMPLED					
	12-14.3 km	NOT SAMPLED						NOT SAMPLED					
PERIOD	TOTALS	1.026	0.000	3.048		5	28	1.351	0.555	4.381		5	48
	0-3 km	2.048	0.000	4.167	1.515	5	10	0.941	0.000	4.706	2.105	5	4
	3-6 km	4.717	2.703	6.731	2.848	2	9	0.481	0.000	0.962	0.680	2	1
Jun 1992	6-9 km	8.091	5.556	11.667	2.913	4	18	5.054	1.852	11.111	4.131	4	11
	9-12 km	9.824	4.762	15.789	4.671	5	31	2.879	0.000	6.122	2.668	5	9
	12-14.3 km	6.210	2.817	10.638	2.820	7	34	2.347	0.000	5.556	2.138	7	12
PERIOD	TOTALS	6.178	0.000	15.789		23	102	2.341	0.000	11.111		23	37

Table 20. Standard Density Estimates (SDE) for adult and juvenile rainbow trout in the lower 14.3 km of Bright Angel Creek during January and June 1992. January's estimates were derived from electrofishing (riffles and pools), and those in June were derived from snorkel surveys (pools only).

		ADULT RAINBOW TROUT (>250mm TL)						JUVENILE RAINBOW TROUT (100-250mm TL)					
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)
	0-3 km	0.090	0.000	0.181	0.128	2	1	0.636	0.370	0.903	0.377	2	7
	3-6 km	0.207	0.207	0.207		1	1	0.828	0.828	0.828		1	4
Jan 1992	6-9 km	0.000	0.000	0.000		2	0	0.648	0.190	1.105	0.647	2	7
	9-12 km	NOT SAMPLED						NOT SAMPLED					
	12-14.3 km	NOT SAMPLED						NOT SAMPLED					
PERIOD	TOTALS	0.099	0.000	0.207		5	2	0.704	0.190	1.105		5	18
	0-3 km	3.212	1.176	4.348	1.283	5	18	0.984	0.000	3.529	1.545	5	4
	3-6 km	1.637	1.351	1.923	0.404	2	3	0.481	0.000	0.962	0.680	2	1
Jun 1992	6-9 km	0.463	0.000	1.852	0.926	4	1	0.000	0.000	0.000	0.000	4	0
	9-12 km	0.483	0.000	1.818	0.790	5	2	0.000	0.000	0.000	0.000	5	0
	12-14.3 km	0.000	0.000	0.000	0.000	7	0	0.000	0.000	0.000	0.000	7	
PERIOD	TOTALS	1.159	0.000	4.348		23	24	0.293	0.000	3.529		23	5

Table 21. Standard Density Estimates (SDE) for Y-O-Y trout (rainbows and browns combined) in the lower 14.3 km of Bright Angel Creek during January and June 1992. January's etimates were derived from electrofishing (riffles and pools), and those in June were derived from snorkel surveys (pools only).

		Y-O-Y TROUT (<100mm TL)					
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)
	0-3 km	1.008	0.722	1.294	0.404	2	11
	3-6 km	0.828	0.828	0.828		1	4
Jan 1992	6-9 km	0.657	0.552	0.762	0.148	2	7
	9-12 km	NOT SAMPLED					
	12-14.3 km	NOT SAMPLED					
PERIOD	TOTALS	0.831	0.552	1.294		5	22
	0-3 km	15.158	0.000	28.986	10.789	5	80
	3-6 km	16.892	0.000	33.784	23.889	2	25
Jun 1992	6-9 km	0.980	0.000	3.922	1.961	4	2
	9-12 km	4.642	0.000	8.696	3.572	5	12
	12-14.3 km	0.411	0.000	1.389	0.644	7	2
PERIOD	TOTALS	7.616	0.000	1.389		23	121

Table 22. Standard Density Estimates (SDE) for rainbow and brown trout (all sizes) in the lower 14.3 km of Bright Angel Creek during January and June 1992. Estimates were derived from electrofishing (Jan) and snorkel surveys (Jun).

		BROWN TROUT (>100mm TL)			RAINBOW TROUT (>100mm TL)			YOY TROUT (<100mm TL)			
Sampling Period	Stream Reach	Mean SDE	n (sites)	n (fish)	Mean SDE	n (sites)	n (fish)	Mean SDE	n (sites)	n (fish)	REACH TOTALS
	0-3 km	1.180	2	13	0.726	2	8	1.008	2	11	2.914
	3-6 km	2.484	1	12	1.035	1	5	0.828	1	4	4.347
Jan 1992	6-9 km	3.364	2	51	0.648	2	7	0.657	2	7	4.669
	9-12 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
	12-14.3 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
PERIOD	TOTALS	2.343	5	76	0.803	5	20	0.831	5	22	3.977
	0-3 km	3.349	5	14	4.196	5	22	15.158	5	80	22.703
	3-6 km	4.765	2	10	2.118	2	4	16.892	2	25	23.775
Jun 1992	6-9 km	13.145	4	29	0.463	4	1	0.980	4	2	14.588
	9-12 km	12.703	5	40	0.483	5	2	4.642	5	12	17.828
	12-14.3 km	8.557	7	46	0.000	7	0	0.411	7	2	8.968
PERIOD	TOTALS	8.504	23	139	1.452	23	29	7.616	23	121	17.572

Table 23. Standard Density Estimates (SDE) for adult brown trout (>250mm TL) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

		POOL SITES						RIFFLE SITES						
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	REACH MEANS
	0-3 km	0.934	0.000	2.857	1.347	4	2	0.589	0.000	1.325	0.690	4	3	0.672
	3-6 km	3.960	0.000	10.811	4.443	5	11	1.111	0.000	3.333	1.925	3	2	1.795
Dec 1992	6-9 km	10.000	10.000	10.000		1	4	1.789	0.000	3.509	1.381	7	8	3.760
	9-12 km	10.711	5.882	20.000	8.047	3	11	0.377	0.000	1.887	0.844	5	1	2.857
	12-14.3 km	9.956	1.149	18.000	8.359	4	18	2.638	0.000	5.714	2.350	4	6	4.394
PERIOD	TOTALS	7.112	0.000	20.000		17	46	1.301	0.000	5.714		23	20	2.696
	0-3 km	0.000	0.000	0.000	0.000	1	0	1.319	0.000	3.947	1.366	7	8	1.002
	3-6 km	0.658	0.000	1.316	0.930	2	1	0.982	0.000	1.802	0.662	6	7	0.904
Jun 1993 A	6-9 km	2.413	0.000	4.545	1.865	4	4	0.368	0.000	1.235	0.576	6	2	0.858
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	1.024	0.000	4.545		7	5	0.889	0.000	3.947		19	17	0.921
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.842	0.000	2.703	1.001	7	5	0.640
	3-6 km	0.658	0.000	1.316	0.930	2	1	0.422	0.000	1.042	0.477	6	3	0.479
Jun 1993 B	6-9 km	1.276	0.000	2.667	1.477	4	3	1.018	0.000	2.913	1.236	6	5	1.080
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.645	0.000	2.667		7	4	0.761	0.000	2.913		19	13	0.733

Table 24 . Standard Density Estimates (SDE) for juvenile brown trout (100-250mm TL) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

		POOL SITES						RIFFLE SITES						
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	REACH MEANS
	0-3 km	1.664	0.000	3.797	1.959	4	4	0.497	0.000	1.987	0.993	4	3	0.777
	3-6 km	2.291	0.000	3.529	1.374	5	7	0.267	0.000	0.800	0.462	3	1	0.753
Dec 1992	6-9 km	5.000	0.000	0.000	0.000	1	2	0.588	0.000	2.667	1.064	7	3	1.647
	9-12 km	0.980	0.000	2.941	1.698	3	1	0.000	0.000	0.000	0.000	5	0	0.235
	12-14.3 km	0.644	0.000	2.000	0.944	4	2	0.000	0.000	0.000	0.000	4	0	0.154
PERIOD	TOTALS	2.116	0.000	3.797		17	16	0.270	0.000	2.667		23	7	0.713
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.931	0.000	2.941	1.079	7	6	0.707
	3-6 km	0.658	0.000	1.316	0.930	2	1	0.510	0.000	1.342	0.587	6	4	0.546
Jun 1993 A	6-9 km	1.926	0.000	4.878	2.079	4	4	0.805	0.000	1.961	0.958	6	4	1.074
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.861	0.000	4.878		7	5	0.749	0.000	2.941		19	14	0.776
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.664	0.000	2.222	0.896	7	5	0.505
	3-6 km	1.794	1.316	2.273	0.677	2	2	0.430	0.000	1.639	0.702	6	3	0.758
Jun 1993 B	6-9 km	2.536	0.000	7.317	3.257	4	5	0.481	0.000	1.961	0.814	6	2	0.974
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	1.443	0.000	7.317		7	7	0.525	0.000	2.222		19	10	0.746

Table 25. Standard Density Estimates (SDE) for adult rainbow trout (>250mm TL) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

		POOL SITES						RIFFLE SITES						
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	REACH MEANS
	0-3 km	1.153	0.000	2.857	1.405	4	3	0.331	0.000	1.325	0.662	4	2	0.528
	3-6 km	1.414	0.000	2.941	1.414	5	3	0.000	0.000	0.000	0.000	3	0	0.339
Dec 1992	6-9 km	0.000	0.000	0.000	0.000	1	0	0.190	0.000	1.333	0.504	7	1	0.145
	9-12 km	1.042	0.000	3.125	1.804	3	1	0.000	0.000	0.000	0.000	5	0	0.250
	12-14.3 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	4	0	0.000
PERIOD	TOTALS	0.722	0.000	3.125		17	7	0.104	0.000	1.333		23	3	0.253
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.563	0.000	1.481	0.711	7	4	0.428
	3-6 km	0.000	0.000	0.000	0.000	2	0	0.137	0.000	0.820	0.335	6	1	0.104
Jun 1993 A	6-9 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	6	0	0.000
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.000	0.000		0.000	7	0	0.233	0.000	1.481		19	5	0.177
	0-3 km	0.000	0.000	0.000	0.000	1	1	0.423	0.000	2.222	0.840	7	3	0.322
	3-6 km	1.316	0.000	2.632	1.861	2	2	0.273	0.000	1.639	0.669	6	2	0.523
Jun 1993 B	6-9 km	0.000	0.000	0.000	0.000	4	0	0.278	0.000	1.667	0.680	6	1	0.211
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.439	0.000	2.632		7	3	0.325	0.000	2.222		19	6	0.352

Table 26. Standard Density Estimates (SDE) for juvenile rainbow trout (100-250mm TL) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

		POOL SITES						RIFFLE SITES						
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	REACH MEANS
	0-3 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	4	0	0.000
	3-6 km	0.588	0.000	2.941	1.315	5	1	0.312	0.000	0.935	0.540	3	1	0.378
Dec 1992	6-9 km	0.000	0.000	0.000	0.000	1	0	0,000	0.000	0.000	0.000	7	0	0.000
	9-12 km	0.000	0.000	0.000	0.000	3	0	0.000	0.000	0.000	0.000	5	0	0.000
	12-14.3 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	4	0	0.000
PERIOD	TOTALS	0.118	0.000	2.941		17	1	0.062	0.000	0.935		23	1	0.076
	0-3 km	0.000	0.000	0.000	0.000	1	0	1.073	0.000	3.947	1.407	7	6	0.815
	3-6 km	1.794	1.316	2.273	0.677	2	2	0.467	0.000	1.042	0.517	6	3	0.786
Jun 1993 A	6-9 km	0.333	0.000	1.333	0.667	4	1	0.000	0.000	0.000	0.000	6	0	0.080
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.709	0.000	2.273		7	3	0.513	0.000	3.947		19	9	0.560
	0-3 km	0.000	0.000	0.000	0.000	1	0	1.011	0.000	4.444	1.804	7	6	0.768
	3-6 km	1.136	0.000	2.273	1.607	2	1	0.000	0.000	0.000	0.000	6	0	0.273
Jun 1993 B	6-9 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	6	0	0.000
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.379	0.000	2.273		7	1	0.337	0.000	4.444		19	6	0.347

Table 27. Standard Density Estimates (SDE) for Y-O-Y trout (<100 mm TL) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

		POOL SITES						RIFFLE SITES						
Sampling Period	Stream Reach	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	Mean SDE	Range Min.	Range Max.	Std. Dev.	n (sites)	n (fish)	REACH MEANS
	0-3 km	0.000	0.000	0.000	0.000	4	0	0.712	0.000	1.818	0.883	4	2	0.541
	3-6 km	1.963	0.000	4.255	1.891	5	5	0.556	0.000	1.667	0.962	3	1	0.893
Dec 1992	6-9 km	2.500	2.500	2.500		1	1	0.571	0.000	4.000	1.512	7	3	1.034
	9-12 km	0.279	0.000	0.000	0.000	3	0	0.230	0.000	1.149	0.514	5	1	0.242
	12-14.3 km	0.000	0.000	0.000		4	0	0.000	0.000	0.000	0.000	4	0	0.000
PERIOD	TOTALS	0.948	0.000	4.255		17	6	0.414	0.000	4.000		23	7	0.542
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.420	0.000	2.941	1.112	7	2	0.319
	3-6 km	0.658	0.000	1.316	0.930	2	1	0.000	0.000	0.000	0.000	6	0	0.158
Jun 1993 A	6-9 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	6	0	0.000
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.219	0.000	1.316		7	1	0.140	0.000	2.941		19	2	0.159
	0-3 km	0.000	0.000	0.000	0.000	1	0	0.246	0.000	0.980	0.426	7	2	0.187
	3-6 km	0.658	0.000	1.316	0.930	2	1	0.112	0.000	0.671	0.274	6	1	0.243
Jun 1993 B	6-9 km	0.000	0.000	0.000	0.000	4	0	0.000	0.000	0.000	0.000	6	0	0.000
	9-12 km	NOT SAMPLED						NOT SAMPLED						
	12-14.3 km	NOT SAMPLED						NOT SAMPLED						
PERIOD	TOTALS	0.219	0.000	1.316		7	1	0.119	0.000	0.980		19	3	0.143

Table 28. Standard Density Estimates (SDE) for rainbow and brown trout (all sizes) in the lower 14.3 km of Bright Angel Creek during December 1992 and June 1993. Estimates were derived from snorkel surveys of established sites.

Sampling Period	Stream Reach	BROWN TROUT (>100mm TL) Mean SDE	n (sites)	n (fish)	RAINBOW TROUT (>100mm TL) Mean SDE	n (sites)	n (fish)	YOY TROUT (<100mm TL) Mean SDE	n (sites)	n (fish)	REACH TOTALS
	0-3 km	1.449	8	12	0.528	8	5	0.541	8	2	1.597
	3-6 km	2.548	8	21	0.717	8	5	0.893	8	6	2.327
Dec 1992	6-9 km	5.407	8	17	0.145	8	1	1.034	8	4	1.324
	9-12 km	3.092	8	13	0.250	8	1	0.242	8	4	0.742
	12-14.3 km	4.548	8	26	0.000	8	0	0.000	8	0	0.000
PERIOD	TOTALS	3.409	40	89	0.328	40	12	0.542	40	16	1.198
	0-3 km	1.709	8	14	1.243	8	10	0.319	8	2	2.805
	3-6 km	1.450	8	13	0.890	8	6	0.158	8	1	1.938
Jun 1993 A	6-9 km	1.932	10	14	0.080	10	1	0.000	10	0	0.160
	9-12 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
	12-14.3 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
PERIOD	TOTALS	1.697	26	41	0.738	26	17	0.159	26	3	1.634
	0-3 km	1.190	1	10	1.090	8	10	0.187	8	2	2.367
	3-6 km	1.237	2	9	0.796	8	5	0.243	8	2	1.835
Jun 1993 B	6-9 km	2.054	4	15	0.211	10	1	0.000	10	0	0.422
	9-12 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
	12-14.3 km	NOT SAMPLED			NOT SAMPLED			NOT SAMPLED			
PERIOD	TOTALS	1.494	7	34	0.699	26	16	0.143	26	4	1.541

APPENDIX III

STANDARD DENSITY ESTIMATES FOR ADULT, JUVENILE, AND YOUNG-OF-YEAR BLUEHEAD SUCKERS AND SPECKLED DACE CAUGHT BY SEINING ESTABLISHED SITES IN KANAB CREEK DURING THE PERIOD AUGUST 1992 - JUNE 1993.

Table 29. Standard Density Estimates (SDE) for adult (BHSA), juvenile (BHSJ), and Y-O-Y (BHSY) bluehead suckers depletion seined from individual sites on Kanab Creek during August 1992 and November 1992.

					BHSA (>160 mm)				BHSJ (30-160 mm)				BHSY (<30 mm TL)				Adults and Juveniles Combined		
Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	Catch Top 2	Catch Total	Top 2 SDE	Total SDE	Catch Top 2	Catch Total	Top 2 SDE	Total SDE	Catch Top 2	Catch Total	Top 2 SDE	Total SDE	SDE(2)	SDE(T)	SDE(C)
		0.00 km	752	3	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	1	1.20 km	103	3	0	0	0.000	0.000	1	1	0.971	0.971	0	0	0.000	0.000	0.971	0.971	
		1.80 km	230	3	0	0	0.000	0.000	2	2	0.870	0.870	0	0	0.000	0.000	0.870	0.870	
		3.00 km	128	4	0	0	0.000	0.000	13	20	10.156	15.625	0	0	0.000	0.000	10.156	15.625	22.656
	Reach	Totals	1213	13	0	0	0.000	0.000	16	23	2.999	4.366	0	0	0.000	0.000	2.999	4.366	
		4.00 km	164	5	0	0	0.000	0.000	18	25	10.976	15.244	0	0	0.000	0.000	10.976	15.244	15.244
Aug 1992	2	5.23 km	109	4	0	0	0.000	0.000	10	11	9.174	10.092	0	0	0.000	0.000	9.174	10.092	10.092
		6.00 km	125	4	1	1	0.800	0.800	33	41	26.400	32.800	0	0	0.000	0.000	27.200	33.600	34.400
	Reach	Totals	398	13	1	1	0.267	0.267	61	77	15.517	19.379	0	0	0.000	0.000	15.783	19.645	19.912
		7.20 km	146	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	3	7.80 km	164	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	253	3	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		10.00 km	136	4	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach	Totals	699	9	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	PERIOD	TOTALS	2310	35	1	1	0.114	0.114	77	100	8.364	10.800	0	0	0.000	0.000	8.478	10.914	20.598
		0.00 km	276	3	1	1	0.362	0.362	0	0	0.000	0.000	3	3	1.087	1.087	0.362	0.362	
	1	1.20 km	71	3	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		1.80 km	250	4	3	4	1.200	1.600	12	17	4.800	6.800	0	0	0.000	0.000	6.000	8.400	12.000
		3.00 km	77	4	0	0	0.000	0.000	8	11	10.390	14.286	0	0	0.000	0.000	10.390	14.286	15.584
	Reach	Totals	674	14	4	5	0.391	0.491	20	28	3.797	5.271	3	3	0.272	0.272	4.188	5.762	
		4.00 km	100	3	0	0	0.000	0.000	44	49	44.000	49.000	0	0	0.000	0.000	44.000	49.000	53.000
Nov 1992	2	5.23 km	120	3	1	1	0.833	0.833	8	9	6.667	7.500	0	0	0.000	0.000	7.500	8.333	8.333
		6.00 km	146	3	0	0	0.000	0.000	1	1	0.685	0.685	0	0	0.000	0.000	0.685	0.685	
	Reach	Totals	366	9	1	1	0.278	0.278	53	59	17.117	19.062	0	0	0.000	0.000	17.395	19.339	
		7.20 km	114	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	3	7.80 km	203	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	291	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		10.00 km	70	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach	Totals	678	8	0	0			0	0			0	0					
	PERIOD	TOTALS	1718	31	5	6	0.342	0.399	73	87	9.506	11.182	3	3	0.155	0.155	9.848	11.581	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.

Catch (Total)- Total sum of fish from all seine hauls at that site.

SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.

SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.

SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

Table 30. Standard Density Estimates (SDE) for adult (BHSA), juveniles (BHSJ), and Y-O-Y (BHSY) bluehead suckers depletion seined from individual sites on Kanab Creek during January and May 1993.

Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	BHSA (>160mm) Catch Top 2	BHSA Catch Total	BHSA Top 2 SDE	BHSA Total SDE	BHSJ (30-160mm) Catch Top 2	BHSJ Catch Total	BHSJ Top 2 SDE	BHSJ Total SDE	BHSY (<30mm TL) Catch Top 2	BHSY Catch Total	BHSY Top 2 SDE	BHSY Total SDE	Adults and Juveniles Combined SDE(2)	SDE(T)	SDE(C)
		0.00 km			NOT SAMPLED				NOT SAMPLED				NOT SAMPLED				0.000	0.000	
	1	1.25 km	100	1	0	0	0.000	0.000	2	2	2.000	2.000	0	0	0.000	0.000	2.000	2.000	
		1.80 km	329	2	6	6	1.824	1.824	0	0	0.000	0.000	0	0	0.000	0.000	1.824	1.824	
		3.00 km	105	3	0	0	0.000	0.000	5	6	4.762	5.714	0	0	0.000	0.000	4.762	5.714	
	Reach Totals		534	6	6	6	0.608	0.608	7	8	2.254	2.571	0	0	0.000	0.000	2.146	2.384	
		4.00 km	120	3	0	0	0.000	0.000	3	3	2.500	2.500	0	0	0.000	0.000	2.500	2.500	
Jan 1993	2	5.23 km	250	2	1	1	0.400	0.400	30	30	12.000	12.000	0	0	0.000	0.000	12.400	12.400	
		6.00 km	172	2	0	0	0.000	0.000	6	6	3.488	3.488	0	0	0.000	0.000	3.488	3.488	
	Reach Totals		542	7	1	1	0.133	0.133	39	39	5.996	5.996	0	0	0.000	0.000	6.129	6.129	
		7.20 km	243	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	3	7.80 km	228	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	241	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		10.00 km	161	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach Totals		873	4	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	PERIOD TOTALS		1949	19	7	7	0.371	0.371	46	47	4.125	4.284	0	0	0.000	0.000	3.853	3.989	
		0.00 km	282	4	1	1	0.355	0.355	0	0	0.000	0.000	0	0	0.000	0.000	0.355	0.355	
	1	1.25 km	67	5	13	21	19.403	31.343	5	5	7.463	7.463	0	0	0.000	0.000	26.866	38.806	
		1.80 km	519	3	8	9	1.541	1.734	23	23	4.432	4.432	0	0	0.000	0.000	5.973	6.166	6.358
		3.00 km	61	5	1	1	1.639	1.639	25	43	40.984	70.492	0	0	0.000	0.000	42.623	72.131	75.410
	Reach Totals		929	17	23	32	5.735	8.768	53	71	13.219	20.597	0	0	0.000	0.000	18.954	29.364	
		4.00 km	69	3	0	0	0.000	0.000	39	41	56.522	59.420	0	0	0.000	0.000	56.522	59.420	62.319
May 1993	2	5.23 km	91	3	0	0	0.000	0.000	14	16	15.385	17.582	0	0	0.000	0.000	15.385	17.582	17.582
		6.00 km	165	7	0	0	0.000	0.000	49	102	29.697	61.818	0	0	0.000	0.000	29.697	61.818	62.424
	Reach Totals		325	13	0	0	0.000	0.000	102	159	33.868	46.274	0	0	0.000	0.000	33.868	46.274	47.442
		7.20 km	147	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	3	7.80 km	133	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	176	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		10.00 km	142	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach Totals		598	5	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	PERIOD TOTALS		1852	35	23	32	3.277	5.010	155	230	22.069	31.601	0	0	0.000	0.000	25.346	36.611	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.

Catch (Total)- Total sum of fish from all seine hauls at that site.

SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.

SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.

SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

Table 31. Standard Density Estimates (SDE) for adult (BHSA), juvenile (BHSJ), and Y-O-Y (BHSY) bluehead suckers depletion seined from individual sites on Kanab Creek during June 1993.

Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	BHSA (>160 mm) Catch Top 2	Catch Total	Top 2 SDE	Total SDE	BHSJ (30-160 mm) Catch Top 2	Catch Total	Top 2 SDE	Total SDE	BHSY (< 30 mm) Catch Top 2	Catch Total	Top 2 SDE	Total SDE	Adults and Juveniles Combined SDE(2)	SDE(T)	SDE(C)
		0.00 km			NOT SAMPLED				NOT SAMPLED				NOT SAMPLED						
	1	1.25 km	75	2	0	0	0.000	0.000	1	1	1.333	1.333	1	1	1.333	1.333	1.333	1.333	
		1.80 km	325	4	0	0	0.000	0.000	1	1	0.308	0.308	0	0	0.000	0.000	0.308	0.308	
		3.00 km	55	3	0	0	0.000	0.000	3	3	5.455	5.455	0	0	0.000	0.000	5.455	5.455	
	Reach	Totals	455	9	0	0	0.000	0.000	5	5	2.365	2.365	1	1	0.444	0.444	2.365	2.365	
		4.00 km	65	4	0	0	0.000	0.000	9	10	13.846	15.385	0	0	0.000	0.000	13.846	15.385	
Jun 1993	2	5.23 km	126	2	0	0	0.000	0.000	2	2	1.587	1.587	0	0	0.000	0.000	1.587	1.587	
		6.00 km	173	2	0	0	0.000	0.000	1	1	0.578	0.578	0	0	0.000	0.000	0.578	0.578	
	Reach	Totals			0	0	0.000	0.000	12	13	5.337	5.850	0	0	0.000	0.000	5.337	5.850	
		7.20 km	116	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	3	7.80 km	120	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	167	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		10.00 km	121	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach	Totals	524	4	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	PERIOD	TOTALS	1343	21	0	0	0.000	0.000	17	18	3.851	4.108	1	1	0.222	0.222	3.851	4.108	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.

Catch (Total)- Total sum of fish from all seine hauls at that site.

SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.

SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.

SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

Table 32. Standard Density Estimates (SDE) for adult (SPDA), juvenile (SPDJ), and Y-O-Y (SPDY) speckled dace depletion seined from individual sites on Kanab Creek during August 1992 and November 1992.

					SPDA (>65 mm)				SPDJ (25-65 mm)				SPDY (<25 mm TL)				Adults and Juveniles Combined		
Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	Catch Total	Catch Top 2	Top 2 SDE	Total SDE	Catch Total	Catch Top 2	Top 2 SDE	Total SDE	Catch Total	Catch Top 2	Top 2 SDE	Total SDE	SDE(2)	SDE(T)	SDE(C)
		0.00 km	752	3	0	0	0.000	0.000	4	4	0.532	0.532	0	0	0.000	0.000	0.532	0.532	
	1	1.20 km	103	3	0	0	0.000	0.000	2	2	1.942	1.942	0	0	0.000	0.000	1.942	1.942	
		1.80 km	230	3	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		3.00 km	128	4	1	1	0.781	0.781	14	11	8.594	10.938	0	0	0.000	0.000	9.375	11.719	11.719
	Reach Totals		1213	13	1	1	0.195	0.195	20	17	2.767	3.353	0	0	0.000	0.000	2.962	3.548	
		4.00 km	164	5	1	1	0.610	0.610	41	23	14.024	25.000	0	0	0.000	0.000	14.634	25.610	
Aug 1992	2	5.23 km	109	4	1	1	0.917	0.917	39	29	26.606	35.780	0	0	0.000	0.000	27.523	36.697	42.202
		6.00 km	125	4	2	2	1.600	1.600	8	5	4.000	6.400	0	0	0.000	0.000	5.600	8.000	
	Reach Totals		398	13	4	4	1.042	1.042	88	57	14.877	22.393	0	0	0.000	0.000	15.919	23.436	
		7.20 km	146	1	0	0	0.000	0.000	4	4	2.740	2.740	0	0	0.000	0.000	2.740	2.740	
	3	7.80 km	164	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	253	3	1	1	0.395	0.395	5	5	1.976	1.976	0	0	0.000	0.000	2.372	2.372	
		10.00 km	136	4	2	2	1.471	1.471	5	5	3.676	3.676	0	0	0.000	0.000	5.147	5.147	
	Reach Totals		699	9	3	3	0.466	0.466	14	14	2.098	2.098	0	0	0.000	0.000	2.565	2.565	
	PERIOD TOTALS		2310	35	8	8	0.525	0.525	122	88	5.826	8.089	0	0	0.000	0.000	6.351	8.614	
		0.00 km	276	3	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	1	1.20 km	71	3	2	2	2.817	2.817	0	0	0.000	0.000	0	0	0.000	0.000	2.817	2.817	
		1.80 km	250	4	6	5	2.000	2.400	5	4	1.600	2.000	0	0	0.000	0.000	3.600	4.400	4.400
		3.00 km	77	4	5	4	5.195	6.494	6	5	6.494	7.792	0	0	0.000	0.000	11.688	14.286	14.286
	Reach Totals		674	14	13	11	2.503	2.928	11	9	2.023	2.448	0	0	0.000	0.000	4.526	5.376	
		4.00 km	100	3	0	0	0.000	0.000	14	14	14.000	14.000	0	0	0.000	0.000	14.000	14.000	14.000
Nov 1992	2	5.23 km	120	3	1	1	0.833	0.833	6	5	4.167	5.000	8	7	5.833	6.667	5.000	5.833	
		6.00 km	146	3	0	0	0.000	0.000	4	3	2.055	2.740	7	7	4.795	4.795	2.055	2.740	
	Reach Totals		366	9		1	0.278	0.278		22	6.740	7.247	15	14	3.543	3.820	7.018	7.524	
		7.20 km	114	2	0	0	0.000	0.000	0	0	0.000	0.000	38	38	33.333	33.333	0.000	0.000	
	3	7.80 km	203	2	0	0	0.000	0.000	1	1	0.493	0.493	1	1	0.493	0.493	0.493	0.493	
		8.80 km	291	2	0	0	0.000	0.000	1	1	0.344	0.344	7	7	2.405	2.405	0.344	0.344	
		10.00 km	70	2	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	Reach Totals		678	8	0	0	0.000	0.000	2	2	0.209	0.209	46	46	9.058	9.058	0.209	0.209	
	PERIOD TOTALS		1718	31	14	12	0.986	1.140	37	33	2.650	2.943	61	60	4.260	4.336	3.636	4.083	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.
Catch (Total)- Total sum of fish from all seine hauls at that site.
SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.
SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.
SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

Table 33. Standard Density Estimates (SDE) for adult (SPDA), juvenile (SPDJ), and Y-O-Y (SPDY) speckled dace depletion seined from individual sites on Kanab Creek during January and May 1993.

Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	SPDA (>65 mm) Catch Total	SPDA Catch Top 2	SPDA Top 2 SDE	SPDA Total SDE	SPDJ (25-65 mm) Catch Total	SPDJ Catch Top 2	SPDJ Top 2 SDE	SPDJ Total SDE	SPDY (<25 mm TL) Catch Total	SPDY Catch Top 2	SPDY Top 2 SDE	SPDY Total SDE	Adults and Juveniles Combined SDE(2)	SDE(T)	SDE(C)
		0.00 km			NOT SAMPLED				NOT SAMPLED				NOT SAMPLED						
	1	1.25 km	100	1	2	2	2.000	2.000	0	0	0.000	0.000	0	0	0.000	0.000	2.000	2.000	
		1.80 km	329	2	0	0	0.000	0.000	25	25	7.599	7.599	1	1	0.304	0.304	7.599	7.599	
		3.00 km	105	3	1	1	0.952	0.952	0	0	0.000	0.000	0	0	0.000	0.000	0.952	0.952	
	Reach Totals		534	6	3	3	0.984	0.984	25	25	2.533	2.533	1	1	0.101	0.101	3.517	3.517	
		4.00 km	120	3	1	1	0.833	0.833	3	3	2.500	2.500	0	0	0.000	0.000	3.333	3.333	
Jan 1993	2	5.23 km	250	2	5	5	2.000	2.000	8	8	3.200	3.200	0	0	0.000	0.000	5.200	5.200	
		6.00 km	172	2	1	1	0.581	0.581	1	1	0.581	0.581	0	0	0.000	0.000	1.163	1.163	
	Reach Totals		542	7	7	7	1.138	1.138	12	12	2.094	2.094	0	0	0.000	0.000	3.232	3.232	
		7.20 km	243	2	2	2	0.823	0.823	15	15	6.173	6.173	0	0	0.000	0.000	6.996	6.996	
	3	7.80 km	228	2	5	5	2.193	2.193	5	5	2.193	2.193	0	0	0.000	0.000	4.386	4.386	
		8.80 km	241	1	0	0	0.000	0.000	5	5	2.075	2.075	0	0	0.000	0.000	2.075	2.075	
		10.00 km	161	1	2	2	1.242	1.242	0	0	0.000	0.000	0	0	0.000	0.000	1.242	1.242	
	Reach Totals		873	4	9	9	1.065	1.065	25	25	2.610	2.610	0	0	0.000	0.000	3.675	3.675	
	PERIOD TOTALS		1949	19	19	19	1.063	1.063	62	62	2.432	2.432	1	1	0.030	0.030	3.495	3.495	
		0.00 km	282	4	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
	1	1.25 km	67	5	26	20	29.851	38.806	3	3	4.478	4.478	0	0	0.000	0.000	34.328	43.284	
		1.80 km	519	3	5	5	0.963	0.963	1	1	0.193	0.193	0	0	0.000	0.000	1.156	1.156	1.156
		3.00 km	61	5	3	3	4.918	4.918	1	1	1.639	1.639	0	0	0.000	0.000	6.557	6.557	6.557
	Reach Totals		929	17	34	28	8.933	11.172	5	5	1.577	1.577	0	0	0.000	0.000	10.510	12.749	
		4.00 km	69	3	0	0	0.000	0.000	7	7	10.145	10.145	0	0	0.000	0.000	10.145	10.145	11.594
May 1993	2	5.23 km	91	3	2	2	2.198	2.198	3	3	3.297	3.297	0	0	0.000	0.000	5.495	5.495	5.495
		6.00 km	165	7	4	4	2.424	2.424	4	3	1.818	2.424	0	0	0.000	0.000	4.242	4.848	4.242
	Reach Totals		325	13	6	6	1.541	1.541	14	13	5.087	5.289	0	0	0.000	0.000	6.627	6.829	7.110
		7.20 km	147	2	0	0	0.000	0.000	7	7	4.762	4.762	0	0	0.000	0.000	4.762	4.762	
	3	7.80 km	133	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	176	1	1	1	0.568	0.568	3	3	1.705	1.705	0	0	0.000	0.000	2.273	2.273	
		10.00 km	142	1	1	1	0.704	0.704	1	1	0.704	0.704	0	0	0.000	0.000	1.408	1.408	
	Reach Totals		598	5	2	2	0.318	0.318	11	11	1.793	1.793	0	0	0.000	0.000	2.111	2.111	
	PERIOD TOTALS		1852	35	42	36	3.784	4.598	30	29	2.613	2.668	0	0	0.000	0.000	6.397	7.266	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.
Catch (Total)- Total sum of fish from all seine hauls at that site.
SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.
SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.
SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

Table 34. Standard Density Estimates (SDE) for adult (SPDA), juvenile (SPDJ), and Y-O-Y (SPDY) speckled dace depletion seined from individual sites on Kanab Creek during June 1993.

Sampling Period	Stream Reach	Sample Site	Site Area	# of Seines	SPDA (>65 mm) Catch Total	Catch Top 2	Top 2 SDE	Total SDE	SPDJ (25-65 mm) Catch Total	Catch Top 2	Top 2 SDE	Total SDE	SPDY (<25 mm TL) Catch Total	Catch Top 2	Top 2 SDE	Total SDE	Adults and Juveniles Combined SDE(2)	SDE(T)	SDE(C)
		0.00 km																	
	1	1.25 km	75	2	0	0	0.000	0.000	93	93	124.000	124.000	5	5	6.667	6.667	124.000	124.000	
		1.80 km	325	4	0	0	0.000	0.000	82	51	15.692	25.231	0	0	0.000	0.000	15.692	25.231	
		3.00 km	55	3	0	0	0.000	0.000	13	9	16.364	23.636	0	0	0.000	0.000	16.364	23.636	
	Reach	Totals	455	9	0	0	0.000	0.000	188	153	52.019	57.622	5	5	2.222	2.222	52.019	57.622	
		4.00 km	65	4	1	1	1.538	1.538	36	30	46.154	55.385	1	1	1.538	1.538	47.692	56.923	
Jun 1993	2	5.23 km	126	2	0	0	0.000	0.000	44	44	34.921	34.921	19	19	15.079	15.079	34.921	34.921	
		6.00 km	173	2	1	1	0.578	0.578	14	14	8.092	8.092	4	4	2.312	2.312	8.671	8.671	
	Reach	Totals			2	2	0.705	0.705	94	88	29.722	32.799	24	24	6.310	6.310	30.428	33.505	
		7.20 km	116	1	0	0	0.000	0.000	1	1	0.862	0.862	3	3	2.586	2.586	0.862	0.862	
	3	7.80 km	120	1	0	0	0.000	0.000	0	0	0.000	0.000	0	0	0.000	0.000	0.000	0.000	
		8.80 km	167	1	0	0	0.000	0.000	5	5	2.994	2.994	3	3	1.796	1.796	2.994	2.994	
		10.00 km	121	1	0	0	0.000	0.000	11	11	9.091	9.091	1	1	0.826	0.826	9.091	9.091	
	Reach	Totals	524	4	0	0	0.000	0.000	17	17	3.237	3.237	7	7	1.302	1.302	3.237	3.237	
	PERIOD	TOTALS	1343	21	2	2	0.212	0.212	299	258	25.817	28.421	36	36	3.081	3.081	26.029	28.633	

Catch (Top 2)- Sum of the catches from the two seine hauls that yielded the greatest number of fish.
Catch (Total)- Total sum of fish from all seine hauls at that site.
SDE (2)- Standard Density Estimate derived from the Top 2 seine hauls.
SDE (T)- Standard Density Estimate derived from the total catch from all seine hauls for a site.
SDE (C)- Standard Density Estimate derived from the population estimate generated by the program CAPTURE (for adults and juvenile size classes combined).

APPENDIX IV

INFORMATION ON 109 NATIVE FISH THAT WERE IMPLANTED WITH PASSIVE INTEGRATED TRANSPONDER (PIT) TAGS IN KANAB AND BRIGHT ANGEL CREEKS DURING THIS STUDY.

Table 35. Information on 109 native fish that were implanted with Passive Integrated Transponder (PIT) tags in Kanab and Bright Angel Creeks during this study.

Stream	Tag/Release Location (rk)	Date mmddyy	Species	Sex	Sexual Condition	Standard Length (mm)	Total Length (mm)	Weight (g)	Recap	PIT Tag Number
Kanab	0.000	42993	FMS	M	2	395	468	840	N	7F7D3F781A
Kanab	0.000	42993	FMS	F	4	385	460	988	N	7F7D440E5B
Kanab	0.000	42993	FMS	M	2	350	407	548	Y	7F7D08640E
Kanab	0.000	42993	FMS	F	0	290	350	386	N	7F7D3C5079
Kanab	0.000	42993	FMS	F	0	270	323	318	N	7F7B026D61
Kanab	0.000	42993	FMS	F	0	272	330	370	Y	7F7F28441A
Kanab	0.000	42993	FMS	F	0	303	360	454	Y	7F7D3F796D
Kanab	0.000	42993	FMS	F	0	285	335	374	N	7F7B033C73
Kanab	0.000	42993	FMS	M	0	312	372	452	N	7F7D7C1B4B
Kanab	0.000	42993	FMS	M	0	313	367		Y	7F7B0D4B37
Kanab	0.000	42993	FMS	M	0	270	325	358	N	7F7B034439
Kanab	0.000	42993	FMS	F	0	276	332	310	N	7F7D440B6C
Kanab	0.000	42993	FMS	M	0	274	330	326	N	7F7B016511
Kanab	0.000	42993	FMS	M	0	277	321	326	N	7F7D440B09
Kanab	0.000	42993	FMS	F	0	240	286	214	N	7F7B014C31
Kanab	0.000	42993	FMS	M	0	260	310	254	N	7F7B035441
Kanab	0.000	42993	FMS	F	0	264	310	278	N	7F7B020B6B
Kanab	0.000	42993	FMS	M	0	236	281	182	N	7F7B025D29
Kanab	0.000	42993	FMS	F	0	255	306	256	N	7F7B016D76
Kanab	0.000	42993	FMS	M	0	230	271	182	N	7F7B032939
Kanab	0.000	42993	FMS	F	0	250	295	224	N	7F7D441029
Kanab	0.000	42993	FMS	F	0	235	280	216	N	7F7B021C5B
Kanab	0.000	42993	FMS	M	0	265	315	262	N	7F7D3C475F
Kanab	0.000	42993	FMS	F	0	205	246	148	N	7F7D40104B
Kanab	0.000	42993	FMS	M	0	236	284	206	N	7F7B08276E
Kanab	0.000	42993	FMS	F	0	210	257	142	N	7F7B032073
Kanab	0.000	42993	FMS	M	0	247	292	222	N	7F7B026D55
Kanab	0.000	42993	FMS	F	0	210	249	142	N	7F7D44563C
Kanab	0.000	42993	FMS	F	0	220	260	172	N	7F7D401250

Sexual Condition Codes: 0 = No gametes, no tubercles, etc.; 1 = Tubercles, no gametes, 2 = Ripe, 3 = Running Ripe, 4 = Post-spawning.

Table 35 (Continued). Information on 109 native fish that were implanted with Passive Integrated Transponder (PIT) tags in Kanab and Bright Angel Creeks during this study.

Stream	Tag/Release Location (rk)	Date mmddyy	Species	Sex	Sexual Condition	Standard Length (mm)	Total Length (mm)	Weight (g)	Recap	PIT Tag Number
Kanab	0.000	42993	FMS	M	0	234	278	184	N	7F7B02072E
Kanab	0.000	42993	FMS	F	0	253	299	212	N	7F7B036D6E
Kanab	0.000	42993	FMS	M	0	250	300	242	N	7F7B022B6D
Kanab	0.000	42993	FMS	F	0	225	269	182	N	7F7B03561D
Kanab	0.000	42993	FMS	F	0	267	221	180	N	7F7D401110
Kanab	0.000	42993	FMS	M	0	235	283	184	Y	7F7D1B6A71
Kanab	0.000	42993	FMS	M	0	212	262	146	N	7F7B036912
Kanab	0.000	42993	FMS	F	0	227	266	178	N	7F7B033D41
Kanab	0.000	42993	FMS	F	0	235	288	184	N	7F7B024765
Kanab	0.000	42993	FMS	F	0	242	285	200	N	7F7B081D6C
Kanab	0.000	42993	FMS	F	0	240	280	186	N	7F7D7B152A
Kanab	1.260	42793	BHS	M	2	194	220	84	N	7F7B015F33
Kanab	1.260	42793	BHS	F	2	193	221	104	N	7F7D400C66
Kanab	1.260	42793	BHS	M	2	200	227	106	N	7F7D40166B
Kanab	1.260	42793	BHS	M	2	222	267	0	Y	7F7F290315
Kanab	1.260	42793	BHS	M	2	200	229	98	N	7F7D400165
Kanab	1.260	42793	BHS	M	1	154	182	46	N	7F7B026A55
Kanab	1.260	42793	BHS	M	2	198	234	108	N	7F7D3F0043
Kanab	1.260	42793	BHS	M	1	167	199	84	N	7F7D40181B
Kanab	1.260	42793	BHS	M	2	162	191	63	N	7F7B08174D
Kanab	1.260	42793	BHS	M	2	210	244	124	N	7F7D436D62
Kanab	1.260	42793	BHS	F	2	184	220	98	N	7F7B034820
Kanab	1.260	42793	BHS	M	1	190	226	94	N	7F7D3C5329
Kanab	1.260	42793	BHS	M	2	189	220	88	N	7F7D3E6621
Kanab	1.260	42793	BHS	M	1	165	190	51	N	7F7B034749
Kanab	1.260	42793	BHS	M	2	167	198	57	N	7F7B02237D
Kanab	1.260	42793	BHS	M	1	167	203	63	N	7F7B081A5E
Kanab	1.260	42793	BHS	F	4	226	247	138	N	7F7B016918
Kanab	1.800	42693	BHS	F	4	145	173	44	N	7F7B015F1E

Sexual Condition Codes: 0 = No gametes, no tubercles, etc.; 1 = Tubercles, no gametes, 2 = Ripe, 3 = Running Ripe, 4 = Post-spawning.

Table 35 (Continued). Information on 109 native fish that were implanted with Passive Integrated Transponder (PIT) tags in Kanab and Bright Angel Creeks during this study.

Stream	Tag/Release Location (rk)	Date mmddyy	Species	Sex	Sexual Condition	Standard Length (mm)	Total Length (mm)	Weight (g)	Recap	PIT Tag Number
Kanab	1.800	42693	BHS	M	2	126	151	29	N	7F7D400771
Kanab	1.800	42693	BHS	F	2	221	266	152	N	7F7B08184D
Kanab	1.800	42693	BHS	F	4	180	211	80	N	7F7B015B5A
Kanab	3.000	42693	BHS	F	3	185	231	102	N	7F7B08180F
Kanab	1.350	42893	BHS	M	2	224	245	108	N	7F7B015C61
Kanab	1.350	42893	BHS	F	2	255	302	250	N	7F7B020C08
Kanab	1.350	42893	BHS	F	4	186	218	92	N	7F7B034D0E
Kanab	1.350	42893	BHS	M	2	187	216	68	N	7F7B03436A
Kanab	1.350	42893	BHS	M	2	175	201	57	N	7F7B035619
Kanab	1.350	42893	BHS	M	1	195	225	86	N	7F7B080F09
Kanab	1.350	42893	BHS	M	2	178	210	78	N	7F7B081211
Kanab	1.350	42893	BHS	F	3	195	221	94	N	7F7D7D1D2E
Kanab	1.350	42893	BHS	F	3	183	213	78	N	7F7B024B22
Kanab	1.350	42893	BHS	M	3	178	203	64	N	7F7B082443
Kanab	1.350	42893	BHS	M	2	174	199	59	N	7F7D3C4A39
Kanab	1.350	42893	BHS	M	2	183	214	90	N	7F7D446800
Kanab	1.350	42893	BHS	M	2	157	185	38	N	7F7BO14147
Kanab	1.350	42893	BHS	M	4	172	198	62	N	7F7BO20205
Kanab	1.350	42893	BHS	M	2	142	165	37	N	7F7D3C4862
Kanab	1.350	42893	BHS	F	1	174	202	60	N	7F7D3C4F74
Kanab	1.350	42893	BHS	M	2	163	194	54	N	7F7D7D2B15
Kanab	1.350	42893	BHS	M	4	140	169	29	N	7F7D3F7E55
Kanab	1.350	42893	BHS	M	3	144	177	33	N	7F7B026612
Kanab	0.000	42993	FMS	M	0	257	305	228	Y	7F7B102F21
Kanab	0.000	42993	FMS	M	0	257	300	270	Y	7F7F1F7C4F
Kanab	0.005	42293	FMS	M	0	245	290	198	N	7F7D401327
Kanab	0.005	42293	FMS	F	4	365	427	686	N	7F7D7D2778
Kanab	0.005	42293	FMS	M	0	260	312	282	Y	7F7F334B68
Kanab	0.005	42293	FMS	M	0	260	320	312	N	7F7D3F7D30

Sexual Condition Codes: 0 = No gametes, no tubercles, etc.; 1 = Tubercles, no gametes, 2 = Ripe, 3 = Running Ripe, 4 = Post-spawning.

Table 35 (Concluded). Information on 109 native fish that were implanted with Passive Integrated Transponder (PIT) tags in Kanab and Bright Angel Creeks during this study.

Stream	Tag/Release Location (rk)	Date mmddyy	Species	Sex	Sexual Condition	Standard Length (mm)	Total Length (mm)	Weight (g)	Recap	PIT Tag Number
Kanab	0.005	42393	BHS	F	2	172	210	84	N	7F7D441114
Kanab	0.005	50593	FMS	F	0	270	315	334	Y	7F7F332722
Kanab	0.005	50693	FMS	M	0	270	310	360	Y	7F7B034439
Kanab	0.010	42393	BHS	M	1	150	182	52	N	7F7B037C7C
Kanab	0.040	42293	FMS	M	0	238	285	186	N	7F7D3C495E
Kanab	0.040	42293	FMS	M	0	255	310	306	N	7F7D441A40
Kanab	0.040	42293	FMS	M	0	255	309	284	N	7F7B023C59
Kanab	0.040	42293	FMS	M	0	295	350	466	N	7F7D3F7925
Kanab	0.040	42393	FMS	M	0	229	275	222	N	7F7B02332D
Kanab	0.040	42393	FMS	M	0	255	302	285	N	7F7B034A2B
Kanab	1.260	42793	BHS	M	2	170	201	60	N	7F7D3F0043
Kanab	0.000	42993	FMS	M	0	247	295	230	N	7F7B020947
Bright Angel	0.700	31793	FMS	F	2	485	569		N	7F7B032068
Bright Angel	0.700	31793	FMS	F	2	417	494		N	7F7D7D2369
Bright Angel	0.700	31793	FMS	M	3	435	509		N	7F7D40147D
Bright Angel	0.700	31793	FMS	M	3	435	514		N	7F7D3C4F68
Bright Angel	0.700	31793	FMS	M	2	425	500		N	7F7B081847
Bright Angel	0.700	31793	FMS	M	2	440	524		N	7F7D400C3D
Bright Angel	0.700	31793	FMS	M	3	422	501		N	7F7B036577
Bright Angel	0.700	31793	FMS	M	3	419	500		N	7F7D7C1846
Bright Angel	0.700	31993	FMS	M	3	435	520		N	7F7B081847
Bright Angel	0.700	31993	FMS	M	3	0	485		N	7F7D40041E
Bright Angel	1.250	31793	FMS	M	1	319	370	450	N	7F7B020216

Sexual Condition Codes: 0 = No gametes, no tubercles, etc.; 1 = Tubercles, no gametes, 2 = Ripe, 3 = Running Ripe, 4 = Post-spawning.

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