HABITAT REQUIREMENTS OF YOUNG COLORADO RIVER CUTTHROAT TROUT IN RELATION TO ALTERATIONS IN STREAMFLOW

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1989

Technical Report WWRC-89-06

Technical Completion Report

to the

Wyoming Water Research Center

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Acknowledgments

We thank Peter Cavalli, Alan Gripentrog, Mark Bozek, Nancy Bozek, Michael Swanson and Joseph Bobbit for their assistance in the field and in the lab. Don Miller, Mel Oberholtzer and Ron Remmick of the Wyoming Game and Fish Department provided guidance in selecting study sites. Steve Wolff and Bill Bradshaw provided data and aided our analysis of how changes in streamflow would affect fish habitat. Critical review of this research was provided by Wayne Hubert, Tom Wesche, Mike Stone, and Bob Wiley. Funding was provided by the Wyoming Water Research Center, the Wyoming Game and Fish Department, the University of Wyoming Office of the Vice President for Research, and the University of Wyoming College of Arts and Sciences.

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INTRODUCTION

Relations between physical habitat and fish abundance are the foundation for fisheries management in lotic systems. Stream habitat quality and quantity are known to influence the population size, species composition, and size structure of fish in streams (Chapman 1966; Binns and Eisermann 1979; Scarnecchia and Bergersen 1986, 1987; Wesche et al. 1987a,b). Identifying fish habitat requirements is therefore a prerequisite to mitigating damage to fish populations from water development activities.

Water diversion can have a major impact on stream habitat by reducing flows which in turn reduce depths, modify velocities and decrease overall stream volume (Bovee 1982; Deacon 1988). These changes can then alter the microhabitats available to various life-stages of fish species. Long term impacts of reduced flows are less well understood. Stream channel morphology may change (Wesche et al. 1985) leading to an accumulation of fine sediments in spawning gravels and interstitial crevices used by young fish. Thermal regimes may become altered, and species abundance or composition may ultimately change.

The North Fork Little Snake River in south central Wyoming is presently being affected by water diversion as a result of the Cheyenne Stage II water diversion project. The project diverts 23,00 acre-feet of water from the headwater streams in the drainage at an elevation of 2621 meters, transports it to the east slope of the Continental Divide and discharges it to Hog Park Reservoir (U.S.D.A. Forest Service, 1981).

Minimum stream flows were established in 1979 by the U.S. Forest Service (Jespersen 1979, 1980) to protect the native Colorado River cutthroat trout (Oncorhynchus clarki pleuriticus). The species is considered sensitive by the Wyoming Game and Fish Department because its original distribution throughout most of the Colorado River headwater streams has been reduced to several isolated populations in Wyoming. Protecting the cutthroat trout in the North Fork Little Snake River drainage is particularly important because kthese populations are among the genetically purest Colorado River cutthroat trout remaining and are the source of broodstock for recovery efforts (Wyoming Game and Fish Department 1987).

To assess the immediate effects of reduced flows from water diversion projects on fish populations, the United States Fish and Wildlife Service has developed the Instream Flow Incremental Methodology (IFIM) (Stalnaker 1979; Bovee 1982; Reiser et al. 1989). This assessment methodology uses habitat curves that relate the suitability of a measured habitat variable to the observed optimal conditions for that species (Pajak and Neves 1987). The habitat suitability index (HSI) is a number between 0 and 1 used to rate overall habitat quality and when multiplied by the area of stream under consideration, it yields the total habitat units for the species being considered. Changes in these habitat units are then compared under different flow regimes to determine potential impacts to the fish population using the Physical Habitat Simulation model (PHABSIM). Use of the model assumes that standing stock is proportional to the weighted usable area (WUA) in the stream and that reduced WUA results in a proportionately reduced fish population. PHABSIM is considered to be the best tool available to assess flow-related impacts to fish populations particularly in cold water streams (Orth 1987; Gore and Nestler 1988).

While minimum flows have been set to protect populations of Colorado River cutthroat trout, little is known about the habitat requirements of the Colorado River cutthroat trout and in particular, newly-hatched stages (Hickman and Raleigh 1982). The objectives of this study were to:

1) identify habitat requirements of young Colorado River cutthroat trout in the North Fork Little Snake River and Green River drainages and examine spatial and temporal variability in habitat use;

2) estimate how changes in streamflow related to water development activities might affect young Colorado River cutthroat trout;

3) evaluate the usefulness of a laboratory stream for determining habitat requirements of young fish.

METHODS

Objective I: Identify habitat requirements of young Colorado River cutthroat trout in the North Fork Little Snake River and Green River drainages and examine spatial and temporal variability in habitat use.

Habitat use of Colorado River cutthroat trout fry was evaluated during the late summer and fall of 1987 and 1988 in the North Fork Little Snake River and Green River drainages (Figs. 1 and 2, and Appendix Table 1). Habitat use was quantified at the macrohabitat and microhabitat levels during the study. Macrohabitat represents the general stream features associated with cutthroat trout fry abundance whereas microhabitat represents the local habitat features measured at fish positions in the stream.

Macrohabitat

Seventeen sites were selected in the North Fork Little Snake River drainage in Carbon County, Wyoming, 1987 to identify the general habitat features associated with cutthroat trout fry abundance and density (Fig. 1). Each site was 100 m in thalweg length and was permanently marked in the field by an orange stake located at the bottom of each site on the right bank (facing upstream). Sites were selected to represent the range of habitat conditions found throughout the drainage. The primary selection criteria were stream order, gradient, and channel type (Table 1). Sites were chosen on first- through third-order streams with a range of stream gradients selected within each stream order. Stream

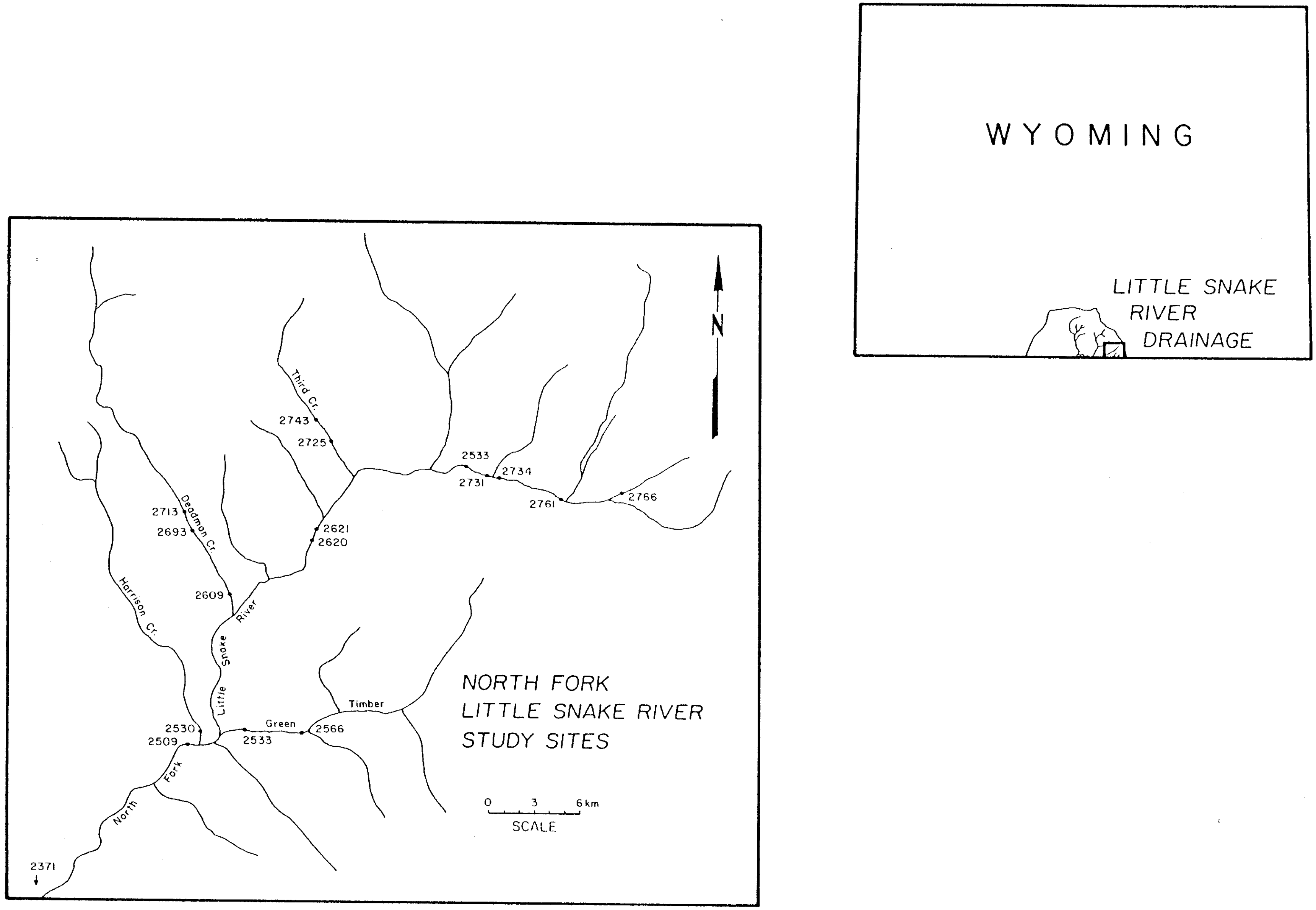


Figure 1. Study sites in the North Fork Little Snake River drainage, Carbon County, Wyoming. Site numbers refer to stream elevation (m) at each location.

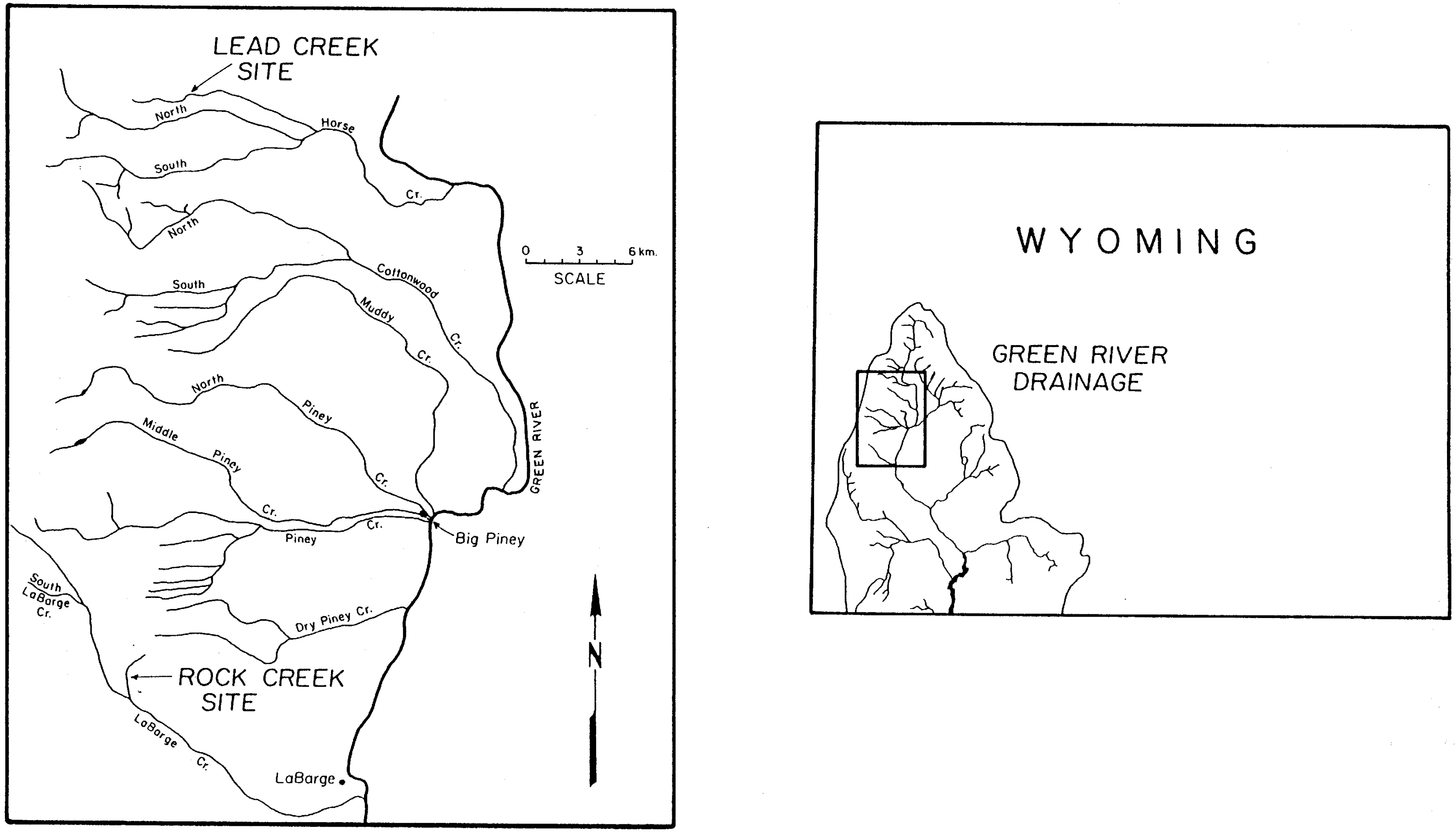


Figure 2. Study sites in the upper Green River drainage, Sublette County, Wyoming.

Table 1. Study sites in the North Fork Little Snake River (NFLSR) drainage used for macrohabitat analysis. Channel type follows Rosgen (1985).

Stream Order	Stream Name	Elev. (m)	Gradient (% Slope)	Channel Type*
1	Third Cr.	2743	14.0	A
	Third Cr.	2725	5.3	B
	NFLSR	2766	2.5	C
2	Deadman Cr.	2713	15.7	A
	Deadman Cr.	2693	14.7	A
	Deadman Cr.	2609	11.8	A
	Harrison Cr.	2530	10.8	B
	NFLSR	2734	7.5	B
	NFLSR	2731	7.0	B
	NFLSR	2533	7.0	B
	Green Timber	2533	3.2	B
	Green Timber	2566	1.4	B
	NFLSR	2761	2.0	C
3	NFLSR	2371	8.3	B
	NFLSR	2621	5.7	B
	NFLSR	2620	5.7	B
	NFLSR	2509	3.8	B

*A channels are steep, well-confined, and have large boulder or bedrock substrates. B channels have moderate to steep gradients, are moderately confined and have a variety of substrates. C channels have low gradients, poorly defined channels and mostly fine substrates.

widths ranged from 1-6 meters (Table 2). When possible, sites that are monitored for cutthroat trout fry abundance by the Wyoming Game and Fish Department were chosen (Bruscino and Miller 1985; 1987). Eleven sites were located on the North Fork Little Snake River proper to insure that a continuum of habitat types on the mainstream river were included for this analysis. The remaining sites were located on tributary streams.

General stream habitat characteristics were quantified at each site using both point-transect and non-transect measurements (Table 3). Each site was divided into pool, riffle, and run stream reaches based upon criteria outlined by Bisson et al. 1981) (Table 4). To quantify habitat features using the point transect-method, three equidistant transects were placed within each stream reach and habitat measurements were made at three equally spaced points on each transect. Stream gradient, spawning gravel abundance and bank stability were measured using other methods (Table 3).

Cutthroat trout fry were visually counted from stream banks at each site. Counts were conducted after emergence of fry from redds was complete. Complete emergence was verified by inspecting redds within the survey reach. Counts were conducted by two individuals crawling along the stream on opposite banks. Each individual stopped at each stream reach and remained stationary for 5 minutes while counting fry. After five minutes, the individuals compared and recorded counts, then crawled upstream to the next stream reach and repeated the observation until the entire reach was surveyed. This approach allowed the entire stream to be sampled without overlapping or missing stream reaches. Surface observations were used because the shallow depth typical of these streams precluded the use of underwater observations. When glare

Table 2. Habitat characteristics of 17 sites in the North Fork Little Snake River (NFLSR) drainage during 1987.

Stream	Elevation (m)	Gradient (% slope)	Discharge (ft^3/sec)	Mean width (cm)	Mean depth (cm)	Mean max depth	Mean velocity (m/s)	Bank stability (%)	Spawning gravel (m^2)
NFLSR	2766	2.5	0.15	114	8.9	14.9	0.15	100.0	20.25
NFLSR	2761	2.0	0.15	201	22.7	42.0	0.06	41.5	7.64
NFLSR*	2734	7.0	0.75	274	12.7	25.5	0.18	67.4	8.92
NFLSR*	2731	7.5	0.70	261	17.6	33.0	0.12	80.0	7.71
NFLSR	2533	7.0	1.9	490	29.8	59.0	0.08	79.8	20.44
NFLSR*	2621	5.7	1.3	479	23.3	40.6	0.22	100.0	5.23
NFLSR*	2620	5.7	1.3	457	21.1	39.0	0.16	100.0	5.60
NFLSR	2509	3.8	2.97	610	19.7	36.4	0.27	80.0	2.28
NFLSR*	2371	8.3	4.25	619	22.3	38.5	0.36	100.0	3.58
Third Cr.	2743	14.0	0.01	146	12.6	19.2	0.06	100.0	2.42
Third Cr*	2725	5.3	0.05	171	6.9	16.9	0.06	81.6	1.02
Deadman*	2713	15.7	0.30	298	12.8	25.6	0.16	99.8	1.72
Deadman*	2693	14.7	0.30	229	12.8	24.7	0.29	99.8	7.13
Deadman	2609	11.8	0.52	329	16.2	26.8	0.16	100.0	0.74
Gr.Timber*	2566	1.4	0.19	163	10.0	19.1	0.12	92.3	3.25
Gr.Timber*	2533	3.2	0.22	241	13.0	24.6	0.10	81.0	3.93
Harrison	2530	10.7	0.12	236	6.8	14.3	0.12	74.4	3.02

*Sites used by the Wyoming Game and Fish Department for counts of larval trout abundance.

Table 3. Methods used to collect macrohabitat data.

Variables	Measurement Method
Discharge (cfs)	Point transect
Depth (mean)	Point transect
Depth (mean maximum)	Point transect
Width	Point transect
Velocity (mean)	Point transect - Marsh McBirney Inc. current meter, Model 201D
Gradient (% slope)	Clinometer
Spawning Gravel (area)	Total area in square meters
Bank Stability	Percentage of bank length not visibly eroding.

Table 4. Habitat types used to evaluate the influence of macrohabitat and microhabitat features on the abundance of Colorado River cutthroat trout fry. Habitat types are modified from Bisson et al. (1981).

Code	Habitat Type
1	Riffle
2	Rapids
3	Cascade
4	Run
5	Secondary channel pool
6	Backwater pool associated with boulders
7	Backwater pool associated with rootwad
8	Backwater pool associated with large debris
9	Plunge pool associated with large debris
10	Plunge pool associated with boulders
11	Lateral scour pool associated with large debris
12	Lateral scour pool associated with rootwad
13	Lateral scour pool associated with bedrock
14	Upstream dam pool

or turbulence prevented observations, a clear plastic sled was pulled across the stream surface allowing a clear view of the bottom (Fig. 3).

The data were analyzed using simple linear and multiple all-subsets regressions. Fry counts and fry density were used as dependent variables and habitat variables were used as independent variables. Relationships were considered statistically significant based on $P \leq 0.05$.

Microhabitat

Microhabitat use by Colorado River cutthroat trout fry was measured on four sites in the North Fork Little Snake River drainage and two sites in the Green River drainage (Table 5). This sampling scheme allowed both temporal and spatial variability in microhabitat use to be assessed. Because brook trout (*Salvelinus fontinalis*) were absent in the North Fork Little Snake River drainage, sites in the Green River drainage were selected only if brook trout were absent.

Sites were selected to represent the three different channel types, A, B, and C (Rosgen 1985) found in the drainages (Table 5). A channels are steep, deeply entrenched, well-confined streams generally having large boulder/bedrock substrate types. Deadman Creek has an A channel type. Streams classified as B channels have moderate to steep gradients, are moderately entrenched and confined, with a wide variety of substrate types. Harrison Creek and Green Timber are both B channel types but were selected due to differences in their gradient. Harrison Creek would not be considered a typical B channel due to its steep gradient, but the channel morphometry more typically resembles B channels. Streams classified as C channels have low gradients, fine

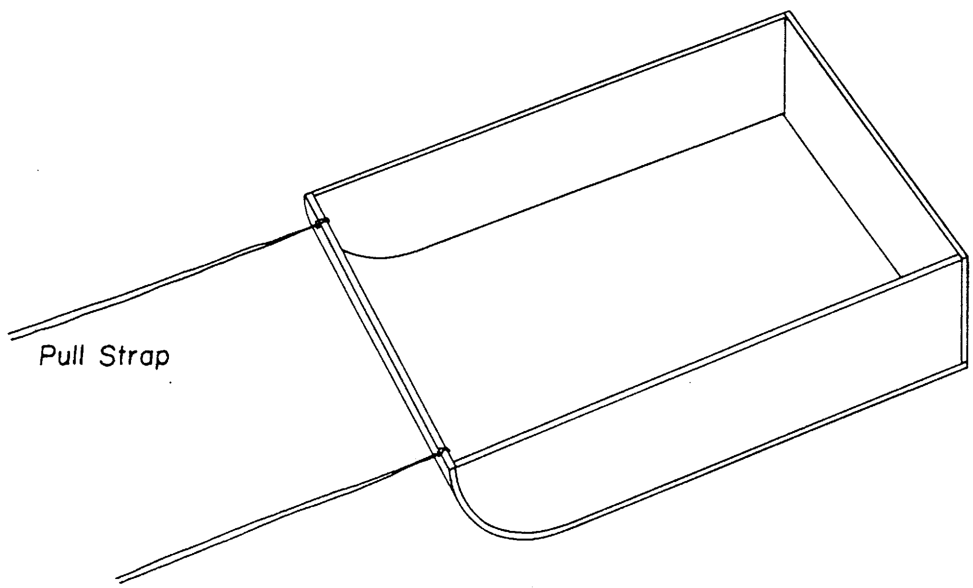


Figure 3. Diagram of clear plastic sled used to observe trout in stream reaches having surface turbulence.

Table 5. Sites used for microhabitat analysis. Shown are the number of transects and data points used to collect habitat availability data. All streams are in the North Fork Little Snake River drainage except for Lead Creek and Rock Creek which are in the Green River drainage.

Year	Stream	Channel Type	Date	Number of Transects	Number of Data Points
1987	Harrison Cr. (Elev. 2530 m)	B	9/03/87	40	297
			10/08/87	40	310
	Deadman Cr. (Elev. 2609 m)	A	8/30/87	35	382
			9/22/87	40	483
	Green Timber (Elev. 2533 m)	B	9/08/87	40	346
	North Fork (Elev. 2766 m)	C	9/13/87	40	356
1988	Harrison Cr. (Elev. 2530 m)	B	8/17/88	35	265
	Deadman Cr. (Elev. 2609 m)	A	8/19/88	40	266
	Lead Cr. (Elev. 2475 m)	C	8/11/88	30	293
	Rock Cr. (Elev. 2300 m)	C	8/09/88	30	268

substrate sizes and poorly-defined channels. The site on the North Fork Little Snake River and both Lead and Rock Creek in the Green River drainage are C channel types.

Microhabitat use by post-emergent fry was quantified after complete emergence of larvae at each site. The observation technique consisted of two individuals crawling on opposite banks and noting fish locations. The locations of undisturbed fish were marked with dowel rods after observations ceased and depth was recorded prior to observers proceeding upstream. Other microhabitat measurements were made later at the locations marked by the dowel rods (Table 6).

The microhabitat available to fry at each site was quantified using a point-transect method (Bovee 1986). Each site was divided into 10 m segments and three to four transects were randomly placed along each 10 m length of stream. At ten points along each transect, microhabitat features were recorded. For each 100 m section of stream, 300 to 400 points were measured for microhabitat features. The microhabitat features measured were the same ones previously described in Table 6.

Habitat preference was assessed by comparing the microhabitat used to the microhabitat available at each stream site. An index of preference for each microhabitat variable was calculated as follows (Bovee 1986):

$$P_i = U_i/A_i$$

where P_i = an unnormalized index of preference for the i^{th} interval of the microhabitat variable under consideration

U_i = the proportion of fish observations that occur in interval i

Table 6. Habitat features measured at each fish location to document microhabitat use or measured at each transect point to document microhabitat availability.

Variable name	Description		
1. Depth	Total water column depth		
2. Velocity	Current velocity measured at nose depth for fish locations or 0.6 of maximum depth for habitat availability measurements. Measured with a Marsh-McBirney Inc. current meter, model 201D.		
3. Substrate type	Coded as follows:		
	Code	Substrate type	Particle size (mm)
	1.	Detritus	Small organic debris
	2.	Silt	< 0.2
	3.	Sand	0.2 - 5.0
	4.	Small gravel	5.1 - 25.0
	5.	Large gravel	25.1 - 75.0
	6.	Rubble	75.1 - 305.0
	7.	Small boulder	305.1 - 610.0
	8.	Large boulder	< 610.0
	9.	Woody debris	Large organic debris
4. Habitat type	Habitat types described in Table 4.		

A_i = the proportion of available habitat that occurs in interval i. These preference curves were then standardized to a 0 to 1 scale by using the interval having the greatest P_i as 1.0 which indicates optimal conditions (Bovee 1986). The Kolmogorov-Smirnov two-sample test was then used to determine if the velocities and depths used by cutthroat trout fry were significantly different from those which were available.

Most studies of microhabitat use by fish are done at only one stream site, thus limiting our ability to generalize about habitat requirements throughout a species' range. To avoid this limitation, we examined microhabitat use at six sites chosen to represent the range of stream types inhabited by young Colorado River cutthroat trout. In addition to this spatial variability in habitat use, we examined temporal variability by comparing habitat use between successive years in two streams.

Objective II: Estimate how changes in streamflow related to water development activities might affect young Colorado River cutthroat trout.

To assess the effects of reduced flows on cutthroat trout fry, we employed the Physical Habitat Simulation (PHABSIM) model of the Instream Flow Incremental Methodology (IFIM)) to streams in the North Fork Little Snake River and Green River drainages. The United States Fish and Wildlife Service has developed the Instream Flow Incremental Methodology to assess impacts to fish populations from water diversion projects (Stalnaker 1979; Bovee 1982).

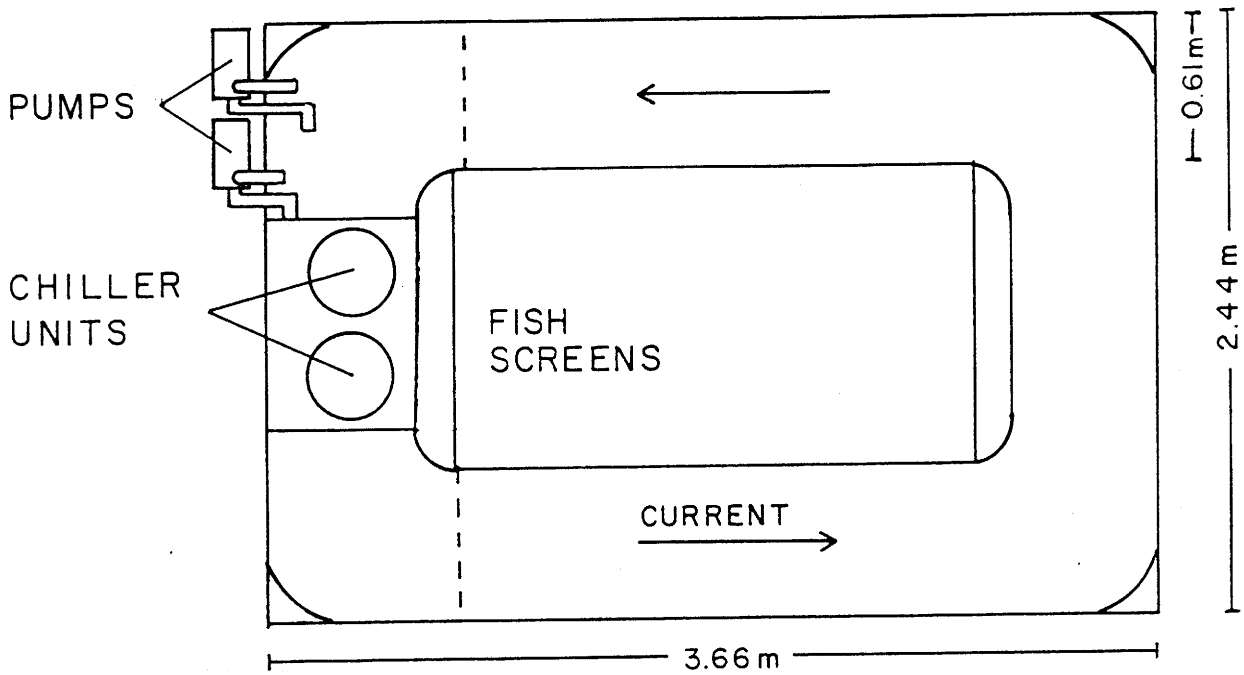
The PHABSIM model requires measures of habitat availability at several levels of stream discharge. Such data were not collected as part of our study, instead we utilized data from several other studies done within the North Fork Little Snake River drainage and the upper Green River drainage. We used four IFIM stream sites used by Wolff (1987) and located in the North Fork Little Snake River drainage to simulate how reduced flows from water diversion would change habitat availability in these streams. The sites and their elevations were Harrison Creek (2673 m), Green Timber Creek (2557 m) and two on the North Fork Little Snake River (Site 1 at 2699 m and Site 2 at 2615 m). Depth, current velocity and substrate preference curves developed for fry in Harrison Creek and Deadman Creek were used in the simulations to determine the effects of reduced flows on the availability of suitable habitat. Simulated flows ranged from 1 to 5 cfs. There were not enough observations of fry microhabitat use in Green Timber or the North Fork Little Snake River sites to develop reliable preference curves for these sites.

We also used an IFIM site on Fish Creek (elevation 2530 m) in the Green River drainage to simulate how changes in streamflow might affect Cutthroat trout habitat availability in the upper Green River drainage. Fish Creek was chosen because of the availability of physical habitat data and because of its similarity and proximity to our study sites on Lead and Rock Creeks. The data base for Fish Creek was supplied by Bill Bradshaw of the Wyoming Game and Fish Department (Bradshaw 1989). Depth, current velocity and substrate preference curves developed for fry in Lead Creek were used in the simulations to determine how reductions in streamflow would affect the availability of suitable fry habitat. Lead Creek and Fish Creek were both C channels with similar stream habitat.

Objective III: Evaluate the usefulness of a laboratory stream for identifying habitat requirements of young fish.

This portion of the research is still in progress and will be summarized in a doctoral thesis by Michael A. Bozek to be completed in 1990. We are examining microhabitat use by Colorado River cutthroat trout under controlled environmental conditions in a laboratory stream and comparing this with the habitat use observed in our field studies. This approach will allow us to evaluate the usefulness of laboratory streams for assessing habitat requirements of young fish and also determine how predators or competitors influence habitat use. In particular, we will examine how adult Colorado River cutthroat trout influence habitat use by young cutthroat trout.

The stream is located at the Red Buttes Environmental Laboratory of the University of Wyoming. The artificial stream is rectangular in shape and constructed of clear Plexiglas (Fig. 4). The corners have been rounded by molded plastic inserted within the stream channel. Stream dimensions are 3.66 x 2.44 m, with the channel having a cross section of 0.61 x 0.61 m. Current is generated by two, 1.5 hp Teel close-coupled bronze centrifugal pumps. Water temperature is controlled by two, 1 hp Frigid Cooling Units (Model D1-1100). The stream bottom is built with interchangable plastic plates that allow construction of various channel configurations. Maximum depth is 0.61 cm at full tank capacity. Water velocities vary with the bottom configuration and pump



LABORATORY STREAM

Figure 4. Schematic of laboratory stream constructed at the Red Buttes Environmental Laboratory of the University of Wyoming.

speed, with maximum attainable velocities in excess of 1 m/s. Water hardness can be controlled by mixing well water and distilled water.

Lighting is provided by fluorescent bulbs suspended over the stream channel. Timers allow simulation of natural photoperiods. The stream sides are covered with black plastic with viewing ports that allow observation without disturbing fish.

RESULTS

Objective I: Habitat requirements of young Colorado River cutthroat trout in the North Fork Little Snake River and Green River drainages and spatial and temporal variability in habitat use.

Macrohabitat

The study streams varied considerably in their habitat features. Of the seventeen streams, three were first-order, ten were second-order and four were third-order (Table 1). This approximates the ratio of stream order types found in the drainage based upon their representative stream lengths. For the first- and second-order streams, three different channel types were represented in our sampling: A, B, and C. For the third-order streams, only B channels were present in the drainage. Nine stream sites were located on the mainstem of the North Fork Little Snake River from the headwaters to the fish barrier location near the Colorado border, thus insuring a continuum of habitat types in the drainage. The remaining eight streams were tributaries to the North Fork Little Snake River. Elevations of streams sites ranged from 2371 to 2766 meters.

Stream gradients ranged from 1.4% for a site on Green Timber (B channel) to 15.7% for a site on Deadman Creek (A channel) (Table 2). Habitat in Green Timber Creek was typified by fallen logs that created log check dams while Deadman Creek was a steep boulder-strewn stream. Stream widths ranged from 1.14 meters at the headwater North Fork Little

Snake River Site, to 6.19 meters for the site located just above the barrier on the North Fork Little Snake River (Table 2). Average stream depths ranged from 6.8 cm on Harrison Creek to 29.8 cm for a site on the North Fork Little Snake River that had beaver ponds.

Cutthroat trout fry abundance varied considerably among sites (Table 7). No fish were observed at two sites located below water diversions structures on the North Fork Little Snake River (elevation 2693 m) and Deadman Creek (elevation 2693 m). Fry density ranged from 0 fry/m^2 at these sites below the diversion structures, to 95.6 fry/m^2 at the North Fork Little Snake River headwater site (elevation 2766 m) (Appendix Table 2).

Relationships between fry abundance (number per 100 m of stream length) or density (number per m^2 of stream area) and habitat features were examined using simple linear regressions. Using data from all seventeen sites, no significant relationships existed between habitat variables and fry numbers or fry density. After the two sites which lacked fry were removed from the analysis, fry density was found to be negatively related to mean depth ($r^2 = 0.33$) and mean maximum depth ($r^2 = 0.33$) (Table 8). Even after removing the two sites that lacked fish, fry abundance remained uncorrelated with habitat features ($p > 0.5$) although there was a trend for higher fry abundance in shallow streams. Results of these analyses suggest that cutthroat trout fry densities are highest in shallow streams in the North Fork Little Snake River drainage.

When all subsets regression was done, density of fry was best predicted by the model:

Table 7. Abundance of Colorado River cutthroat trout fry as determined by visual censusing for seventeen sites in the North Fork Little Snake River (NFLSR) drainage. Abundance expressed as number of fry per 100 m of stream, sample date is given in parenthesis.

Stream site	Elevation (m)	Fry abundance as Number/100 m 1987	(Month/date) 1988
NFLSR	2766	109 (8/18) 67 (9/19	15 (9/1)
NFLSR	2761	31 (8/18) 44 (9/12)	6 (9/1)
NFLSR	2734	66 (8/20) 17 (9/13)	39 (9/2)
NFLSR	2731	0 (8/20) 0 (8/29	8 (9/2)
NFLSR	2533	36 (8/20) 3(9/13)	*
NFLSR	2621	7 (9/2) 1 (9/24)	*
NFLSR	2620	13 (8/30) 4 (10/2)	*
NFLSR	2509	24 (9/4) 1 (10/2)	*
NFLSR	2371	0 (9/2) 1 (9/19)	*
Third Cr.	2743	7 (8/30) 16 (9/18) 18 (9/25)	3 (9/3) 6(9/5) 5 (9/8)
Third Cr.	2725	21 (9/5) 24 (9/25)	16 (9/3) 10(9/5) 13 (9/8)
Deadman Cr.	2713	21 (8/17) 11 (8/30)	9 (8/26)
Deadman Cr.	2693	0 (8/17) 0 (8/29)	7 (8/26)
Deadman Cr.	2609	80 (8/13) 31 (9/22)	85 (8/18)
Green Timber	2566	18 (8/4) 26 (8/6) 34 (8/12) 39 (8/19) 31 (10/3)	28 (8/24)
Green Timber	2533	34 (8/4) 35 (8/6) 45 (8/12) 40 (8/19) 30 (9/7) 12 (10/13)	19 (8/24)
Harrison Cr.	2530	191 (8/14) 175 (9/6) 134 (10/7)	174 (8/25)

*No fry counts were made.

Table 8. Univariate regressions with number of fry or fry density as dependent variables and habitat parameters as independent variables for streams in the North Fork Little Snake River drainage during 1987. Discharge was measured during low flows in late summer.

Density of fry (number per 100 m^2)					
Independent Variable	df	F value	r^2	p	Equation
Discharge	14	3.18	0.20	.098	-0.1006X + 0.3192
Gradient	14	0.16	0.01	.694	-0.0071X + 0.2731
Width	14	4.27	0.25	.059	-0.0007X + 0.4457
Mean depth	14	6.41	0.33	.025	-0.0235X + 0.5982
Mean max depth	14	6.41	0.33	.025	-0.0128X + 0.6005
Spawn gravel	14	2.24	0.15	.158	0.0173X + 0.1205
Mean velocity	14	0.69	0.05	.421	-0.7549X + 0.3379
Bank stability	14	0.11	0.01	.744	-0.0015X + 0.3574

Number of fry (number per 100 m)					
Independent Variable	df	F value	r^2	p	Equation
Discharge	14	2.53	0.16	.136	-15.9643X + 62.6916
Gradient	14	0.07	0.01	.800	0.7920X + 42.0933
Width	14	2.02	0.13	.179	-0.0833X + 76.0731
Mean depth	14	4.32	0.25	.058	-3.5621X + 104.3090
Mean max depth	14	3.78	0.23	.074	-1.8397X + 101.8597
Spawn gravel	14	0.44	0.03	.517	1.4255X + 39.0433
Mean velocity	14	0.71	0.05	.416	-133.1997X + 67.6688
Bank stability	14	0.79	0.06	.392	-0.6951X + 107.7401

$$\text{Fry density (Number/m}^2) = 0.571 + 0.030X_1 - 0.018X_2$$

where X_1 = area of spawning gravel in m^2

X_2 = mean maximum depth of the stream in cm

The equation has an adjusted R^2 of 0.67 ($F = 14.92$ $P < .001$). This suggests that fry density increases with increasing abundance of spawning gravel and with decreasing maximum stream depths. Smaller tributary streams with abundant spawning gravel therefore are likely to have higher densities of fry. Number of fry per 100 m of stream was not found to be related to habitat features based on all subsets regression.

Microhabitat

Colorado River cutthroat trout fry showed selectivity in the microhabitat they used at nearly all sites during both years of the study. Fry were found at depths ranging from 1 to 41 cm but generally used depths from 3 to 20 cm (Fig. 5). Depths used by fry were significantly different from those available on 12 of the 13 sample dates based upon Kolmogorov-Smirnov two-sample distribution tests (Table 9). Cutthroat trout fry generally used deep water in a higher proportion than it was available in those streams. Preference curves generated from use and availability data confirmed that fry chose deep water over shallow water (Fig. 5). Only on one sampling date (North Fork Little Snake River on 8/18/87) were depths used not significantly different from depths available.

Cutthroat trout fry were also selective in the velocities chosen at nearly all sites during both years of the study (Fig. 6). Fry generally selected stream locations where velocities were less than 0.06 m/s,

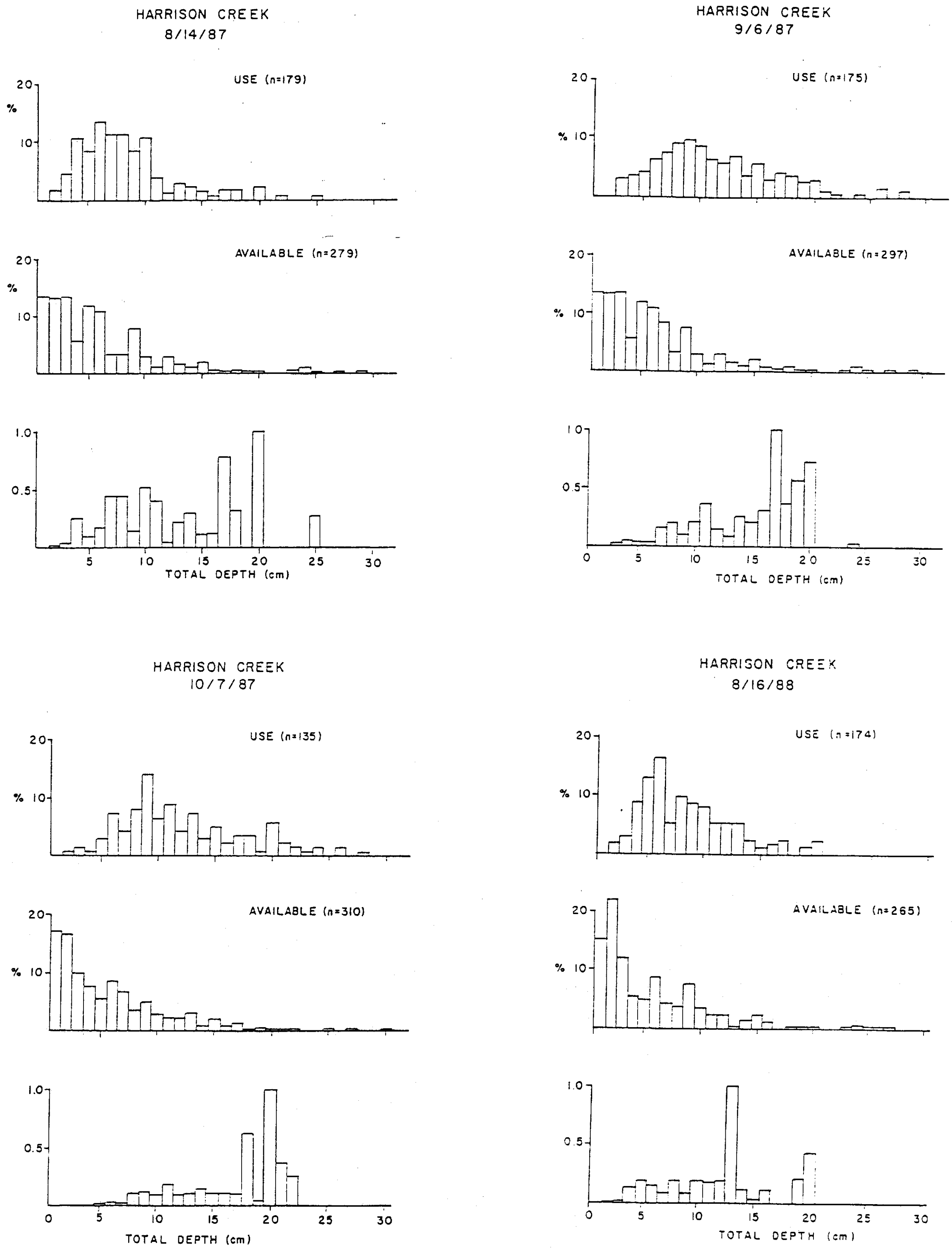


Figure 5. Water depths selected by fry versus water depths available in the study streams. For each data, the top histogram shows the depths used by fry, the middle histogram shows the depths available in the stream, and the bottom histogram is a preference curve.

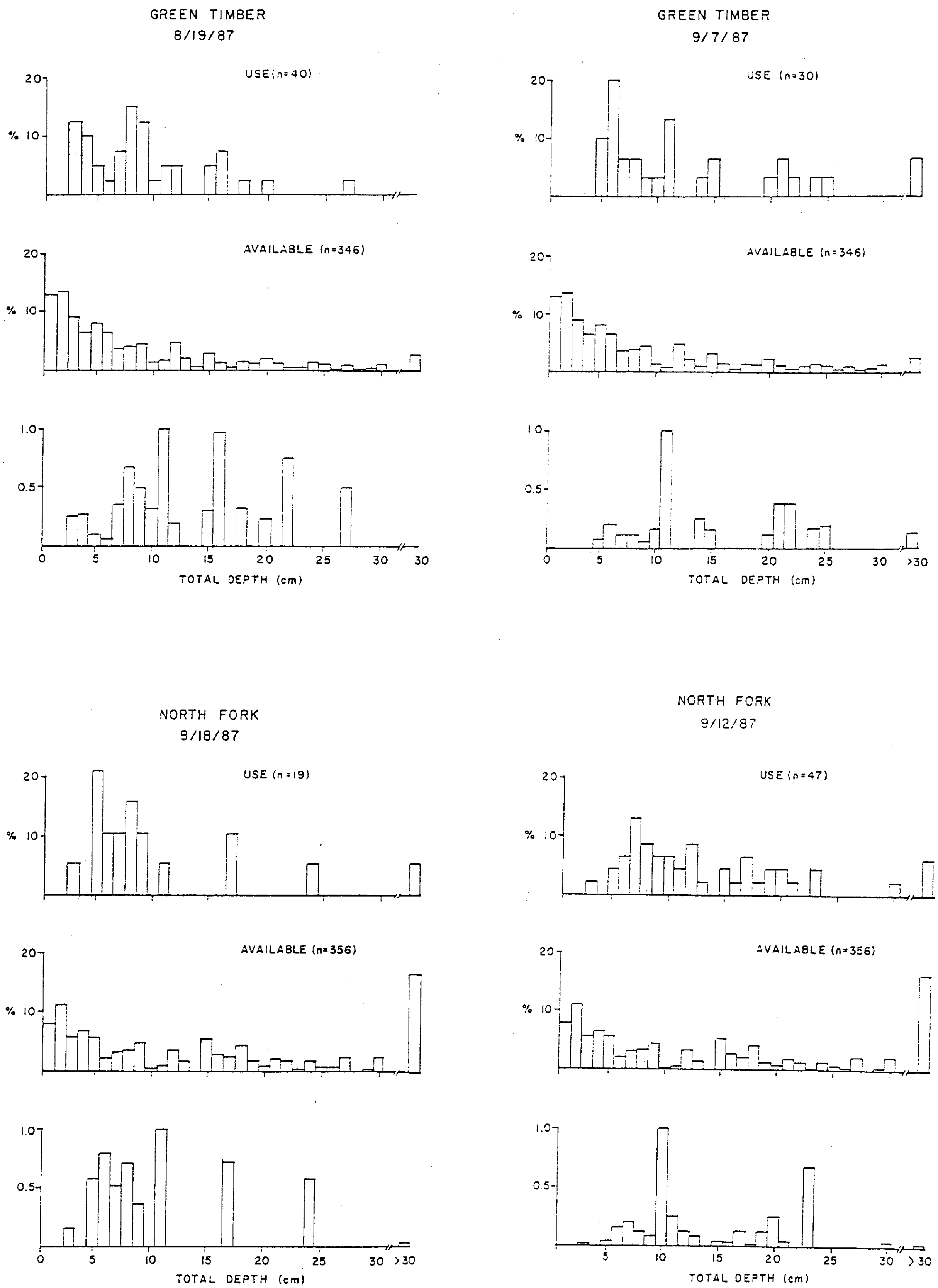
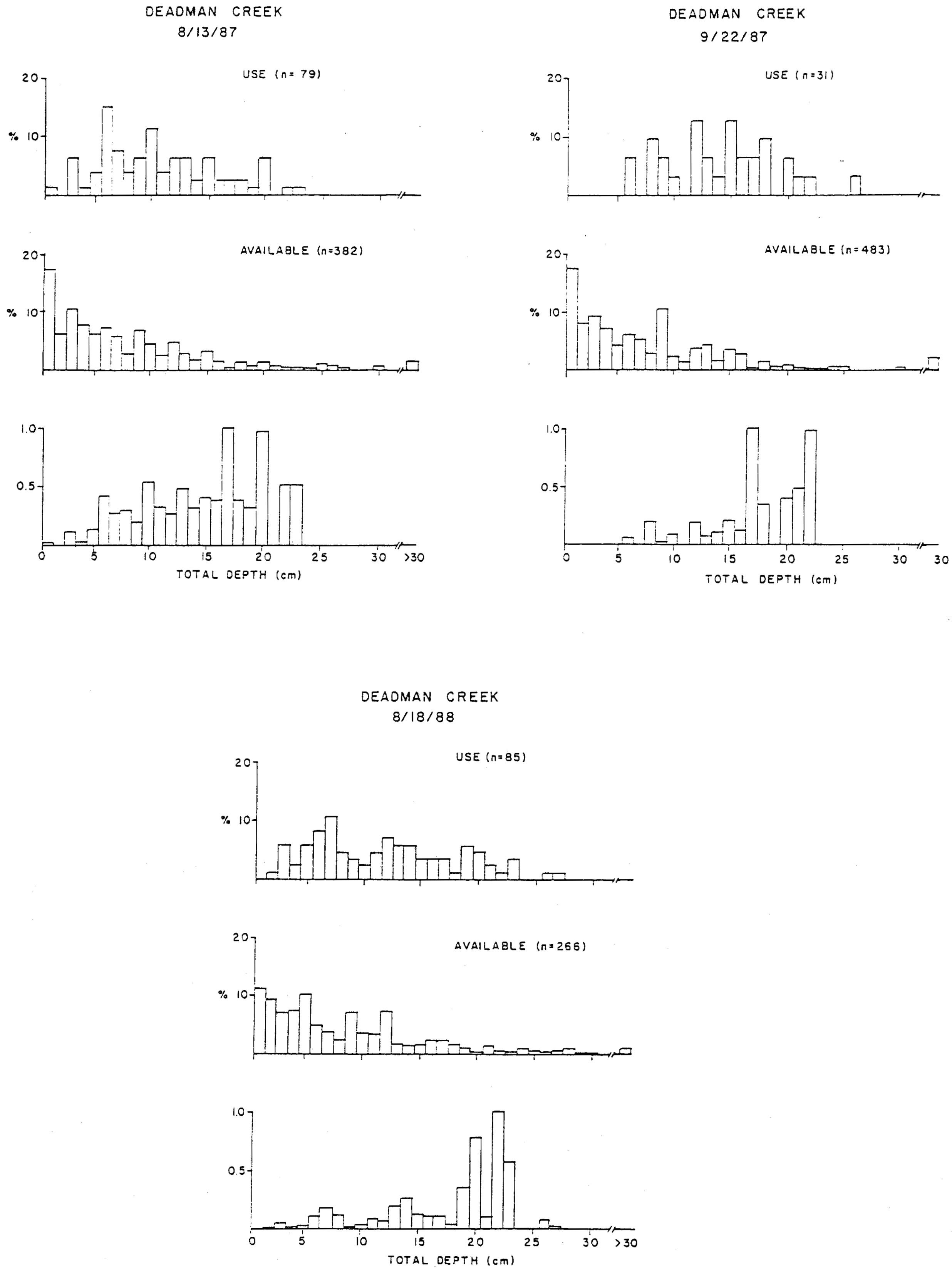


Figure 5. (continued).



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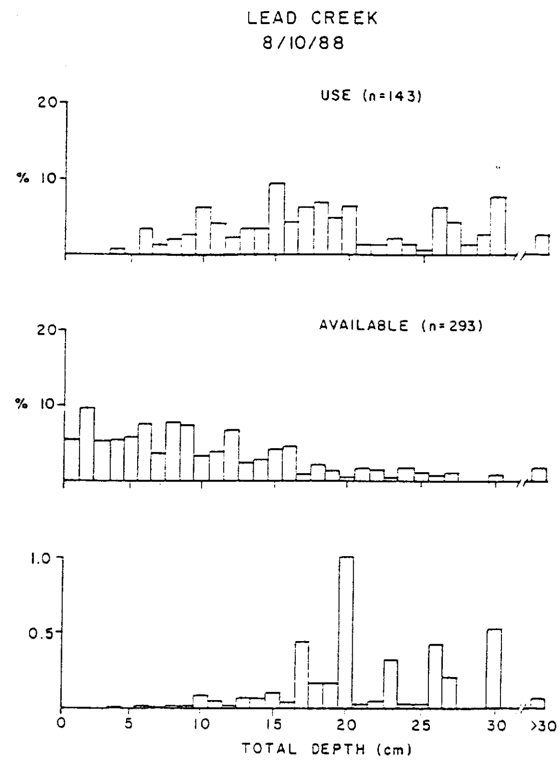


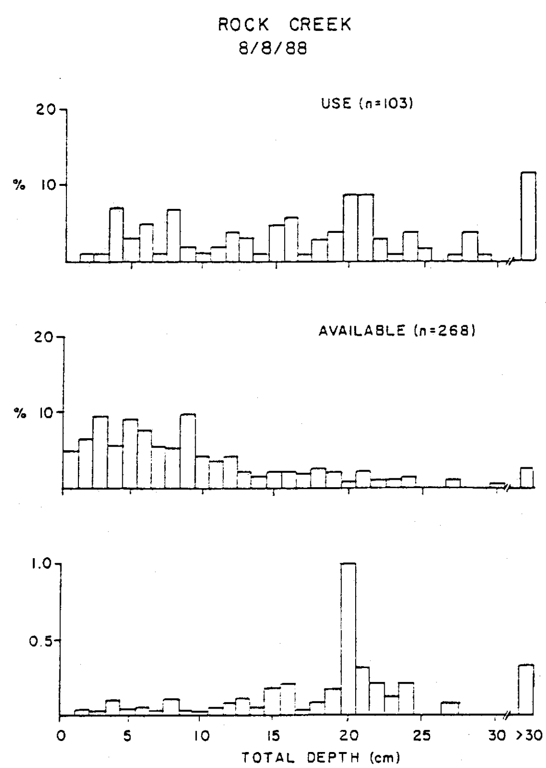


Figure 5. (continued)

Table 9. Results of the Kolmogorov-Smirnov two-sample test comparing the distribution of total depths used by Colorado River cutthroat trout fry with the distribution of depths available in each stream. Data were collected from streams in the North Fork Little Snake River and Green River drainages during 1987 and 1988.

Year	Stream	Date	n[a] (used)	n[b] (available)	D statistic	P value
1987						
	Harrison Cr.	8/14/87	179	297	.262	<.001
		9/6/87	175	297	.189	<.001
		10/7/87	135	310	.224	<.001
	Deadman Cr.	8/30/87	79	382	.449	<.001
		9/22/87	31	483	.494	<.001
	Green Timber	8/19/87	40	346	.257	.017
		9/07/87	30	346	.123	<.001
	North Fork	8/18/87	19	356	.259	.178
		9/12/87	47	356	.304	<.001
1988	Harrison Cr.	8/16/88	174	265	.345	<.001
	Deadman Cr.	8/18/88	85	266	.497	<.001
	Lead Cr.	8/10/88	143	293	.555	<.001
	Rock Cr.	8/08/88	103	268	.416	<.001

[a]Number of fish locations at which microhabitat data were collected.

[b]Number of transect points at which microhabitat measurements were made to assess habitat availability.

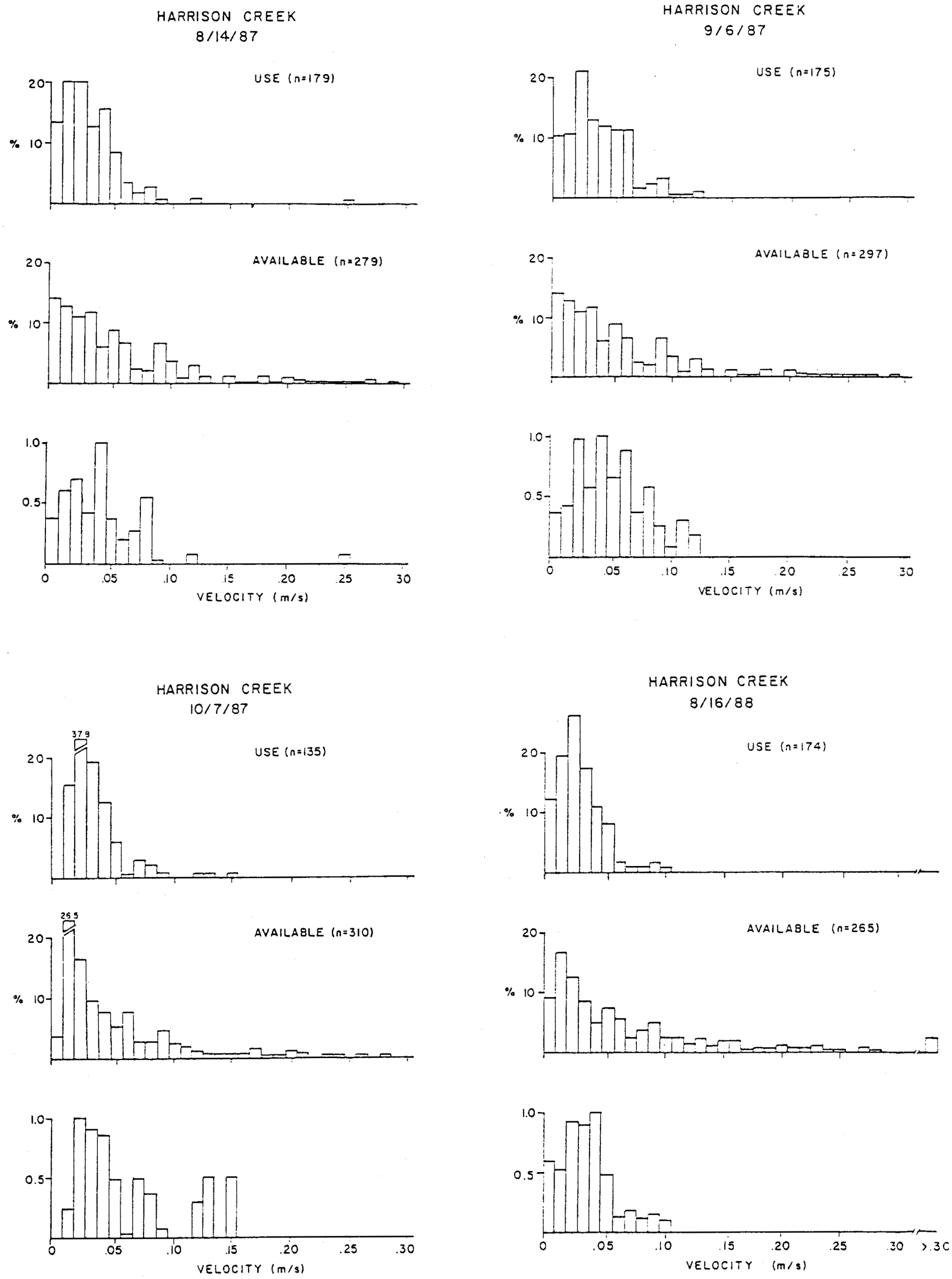


Figure 6. Current velocities selected by fry versus current velocities available in the study streams. For each sampling date, the top histogram shows the current velocities used by fry, the middle histogram shows the current velocities available in the stream, and the bottom histogram is a preference curve.

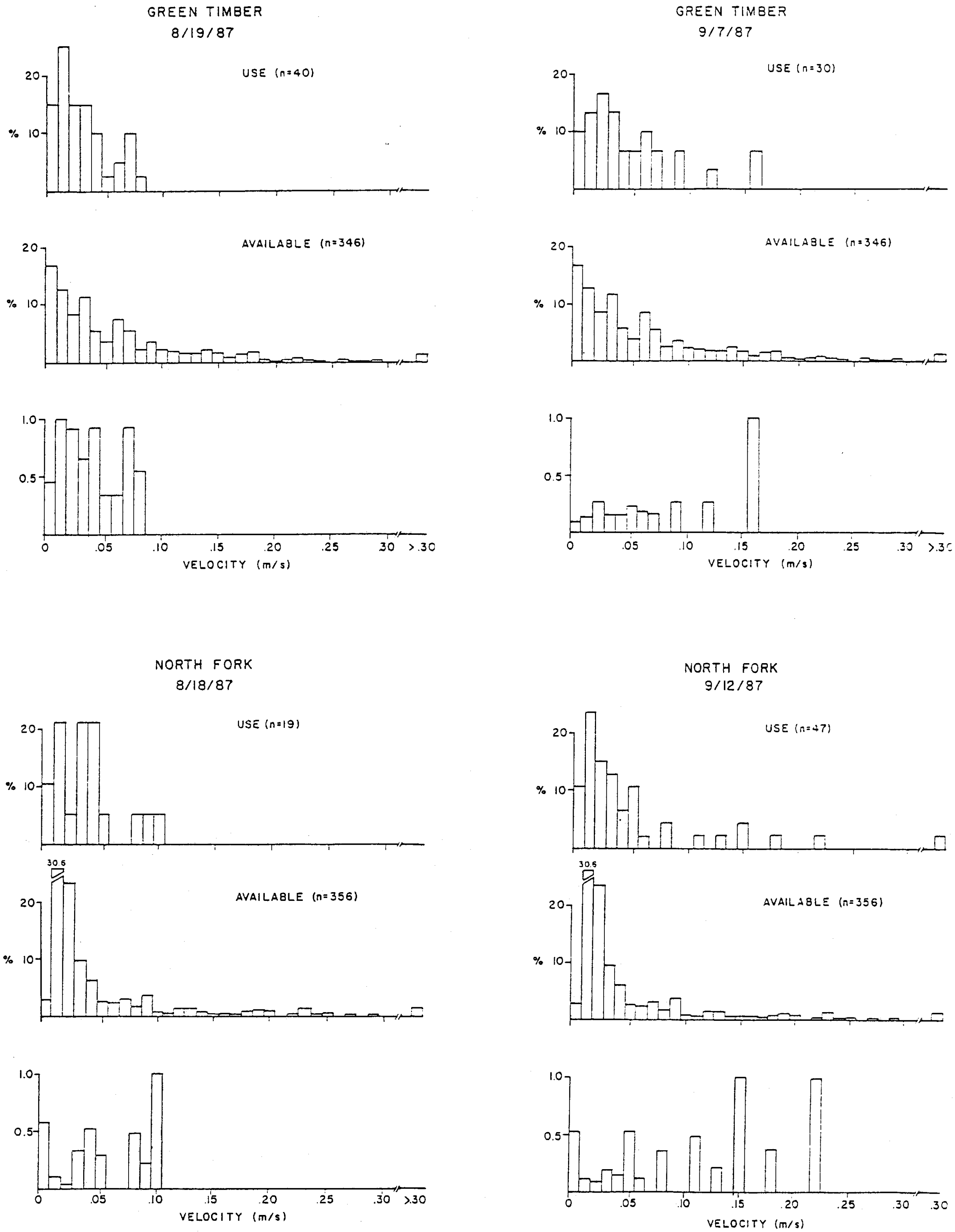


Figure 6. (continued)

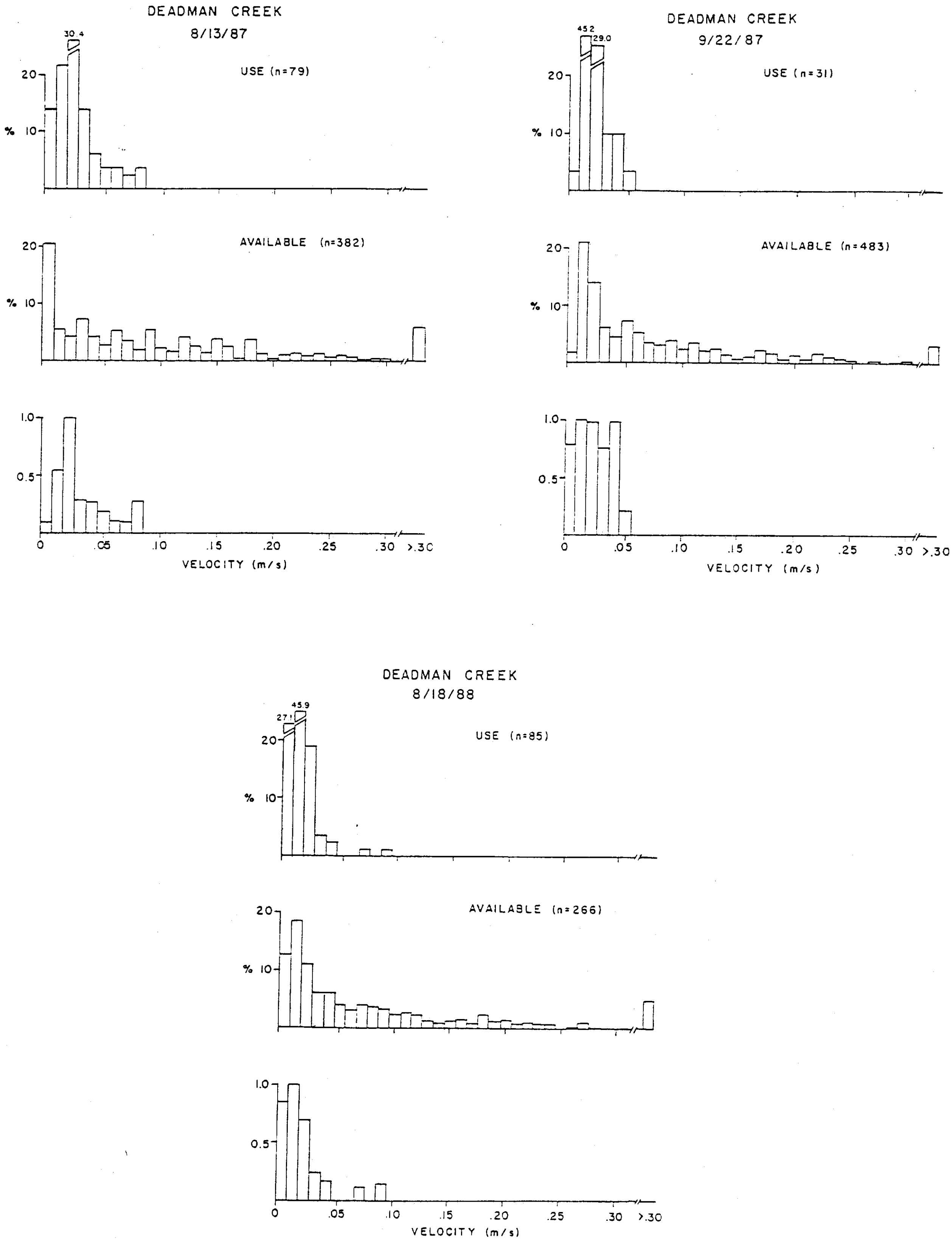


Figure 6. (continued)

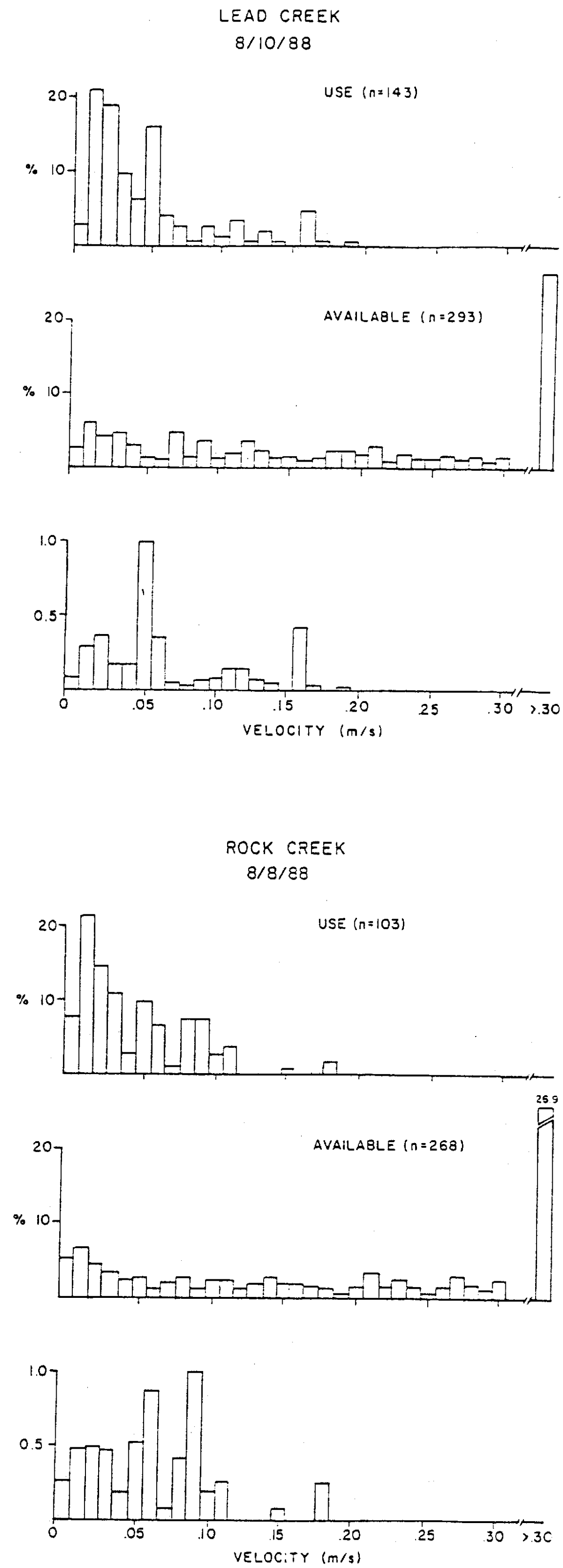


Figure 6. (continued)

although fry were found in faster water, particularly in the Rock Creek site. Maximum velocities used at all sites generally ranged from 0.10-0.20 m/s. Fish in Deadman Creek used the narrowest range of velocities being found only in water less than 0.09 m/sec. Preference curves generally indicate that fry were selecting water velocities less than 0.10 m/s (Fig. 6). Kolmogorov-Smirnov two-samples test showed that fry used significantly different velocities relative to what was available on eleven of the thirteen sample dates (Table 10). Both occasions when velocities used were not significantly different from those available involved sites on the North Fork Little Snake River.

Substrate associated with cutthroat trout fry positions varied among sites (Fig. 7). Typically however, substrates such as sand and particularly silt, were the most common substrate at fish positions. These fine substrates were also usually among the most common found in the stream. Exceptions to this are on the North Fork Little Snake River (8/18/87) where small gravel to rubble substrates were used and Deadman Creek (8/18/88) where rubble substrate was used most often. The use of rubble substrate in Deadman Creek in 1988 is interesting because fish in this stream showed a preference for silt substrate in 1987.

Despite some variation in the range of depths, current velocities and substrate types selected by fry among sites, the habitat types selected were similar among the study streams. Fry were usually found in backwater pools or upstream dam pools and were seldom observed in riffles, runs, or secondary channel pools (Table 11). Lead Creek had few upstream dam pools but fry were often present in lateral scour pools which were abundant at this stream site.

Table 10. Results of the Kolmogorov-Smirnov two-sample test comparing the distribution of depths used by Colorado River cutthroat trout fry with the distribution of depths available in each stream. Data were collected from streams in the North Fork Little Snake River and Green River drainages during 1987 and 1988.

Year	Stream	Date	n^a (used)	n^b (available)	D statistic	P value
1987						
	Harrison Cr.	8/14/87	179	297	.340	<.001
		9/6/87	175	297	.568	<.001
		10/7/87	135	310	.545	<.001
	Deadman Cr.	8/30/87	79	382	.347	<.001
		9/22/87	31	483	.511	<.001
	Green Timber	8/19/87	40	346	.355	<.001
		9/07/87	30	346	.422	<.001
	North Fork	8/18/87	19	356	.199	.479
		9/12/87	47	356	.078	.999
1988	Harrison Cr.	8/16/88	174	265	.445	<.001
	Deadman Cr.	8/18/88	85	266	.302	<.001
	Lead Cr.	8/10/88	143	293	.486	<.001
	Rock Cr.	8/08/88	103	268	.635	<.001

[a]Number of fish locations at which microhabitat data were collected.

[b]Number of transect points at which microhabitat measurements were made to assess habitat availability.

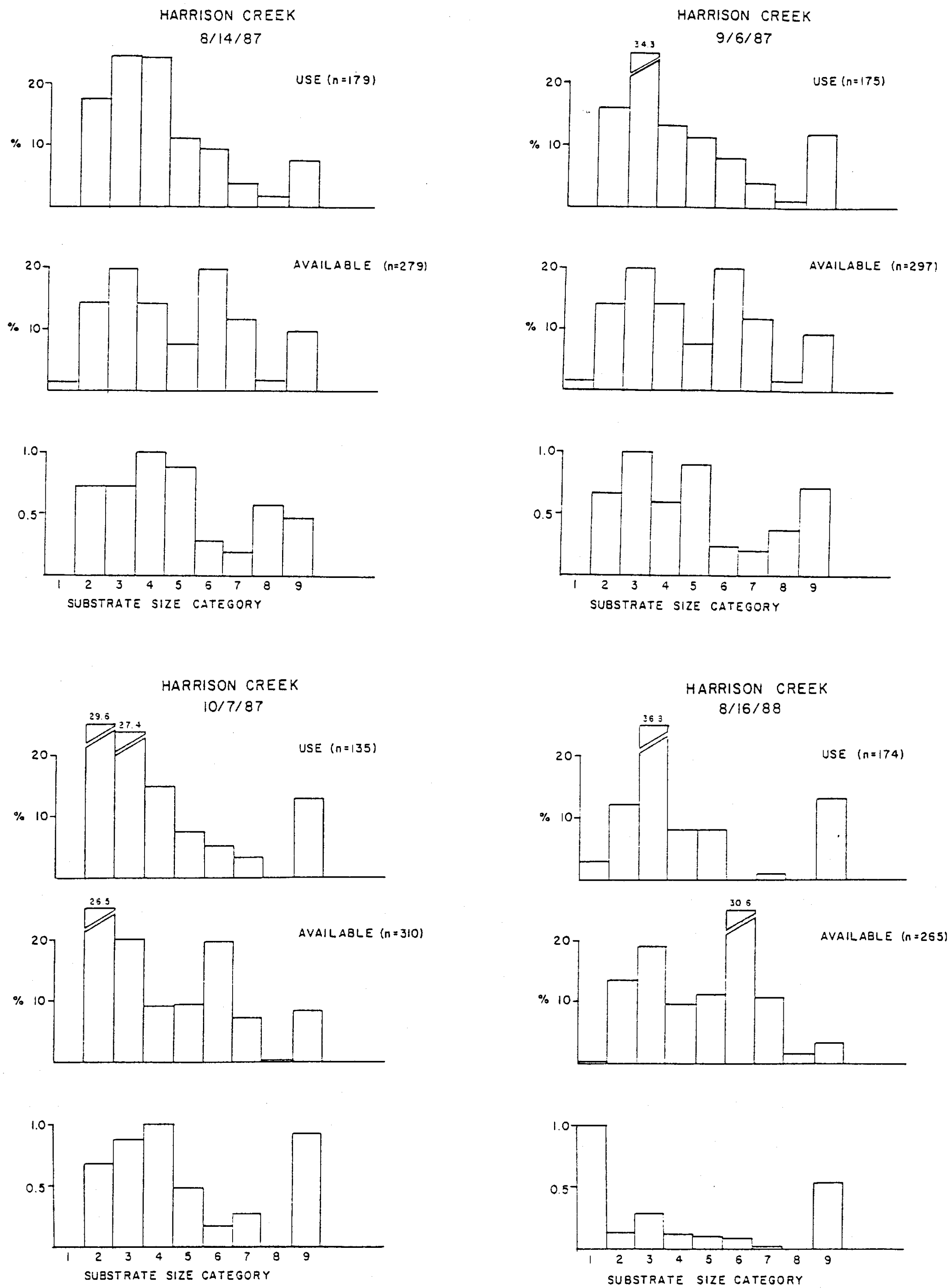


Figure 7. Substrates selected by fry versus substrates available in the study streams. For each sampling date, the top histogram shows the substrates used by fry, the middle histogram shows the substrates available in the stream, and the bottom histogram is a preference curve.

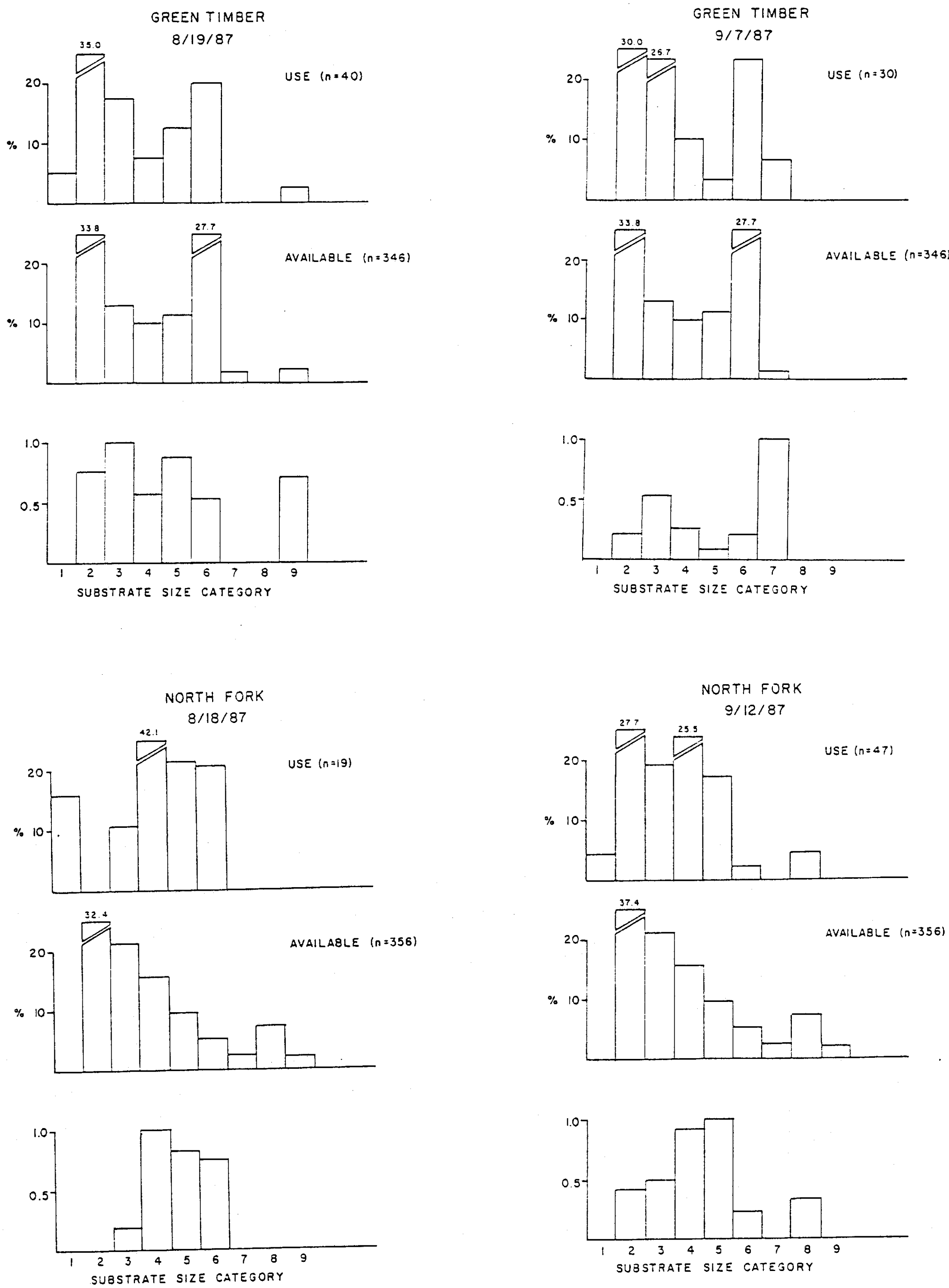


Figure 7. (continued)

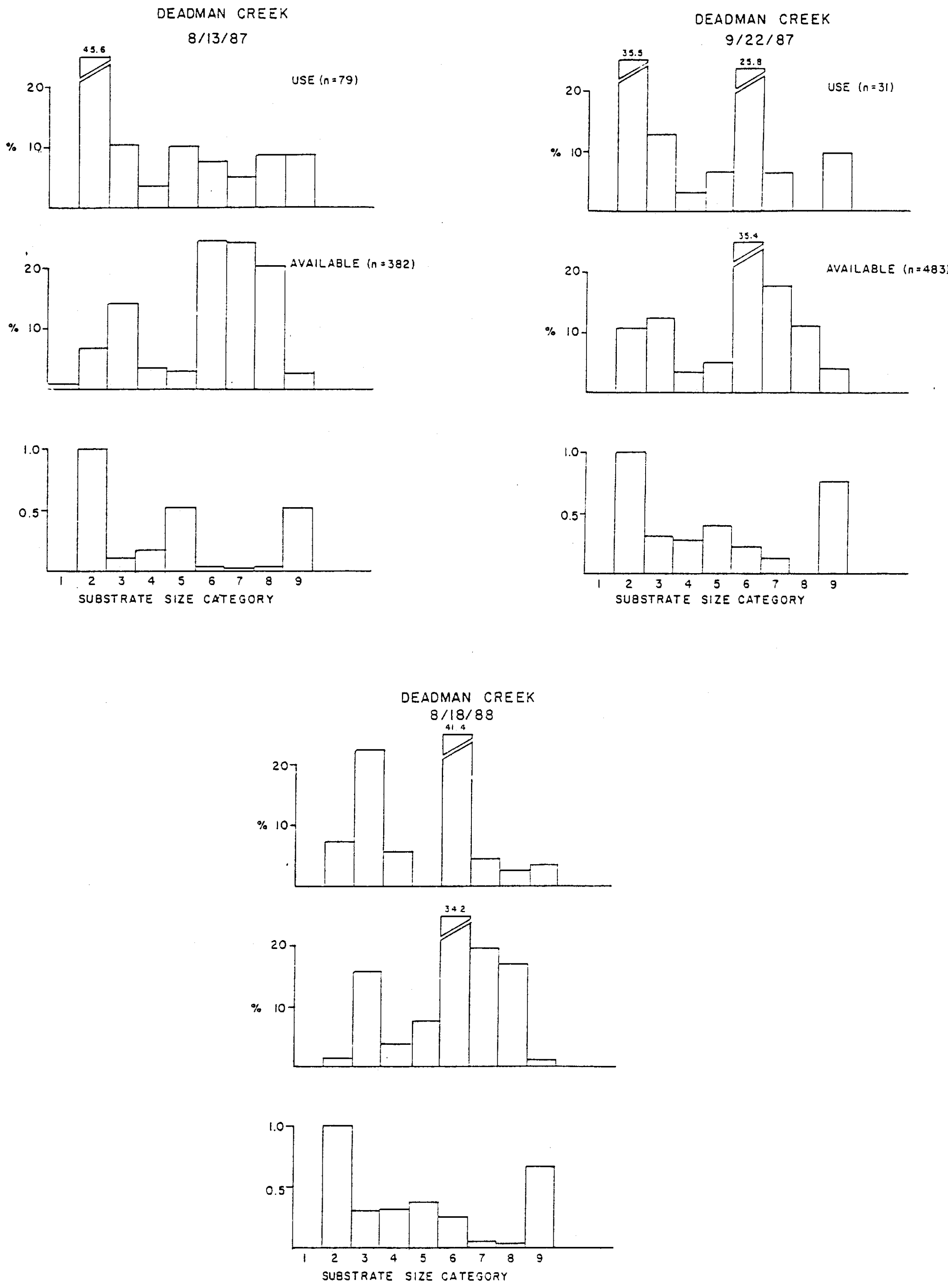
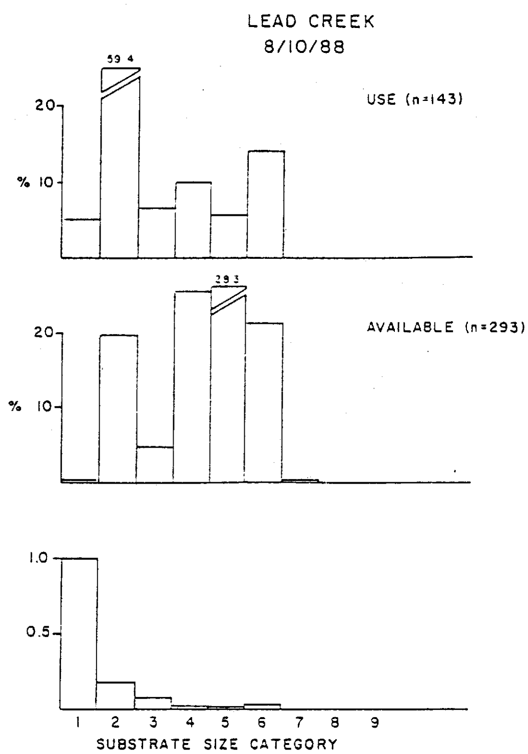


Figure 7. (continued)



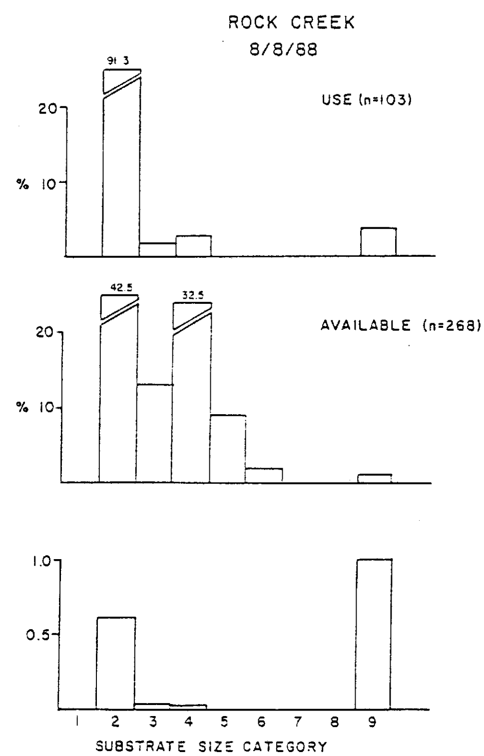


Figure 7. (continued)

Table 11. Percentage of observations of Colorado River cutthroat trout fry within each habitat type for the four sites examined in 1988. The total number of fry observations at each site is given in parentheses. Habitat categories have been modified from Table 4 by summing across similar habitat types.

		Percentage of observations occurring within each habitat type			
Habitat Code(s)	Habitat type	Deadman Cr. (n = 85)	Harrison Cr. (n = 174)	Lead Cr. (n = 143)	Rock Cr. (n = 103)
1-3	Riffle, Rapids, Cascade	0	0.6	2.8	1.0
4	Run	1.2	0.6	0	9.7
5	Secondary channel pool	0	1.1	0	0
6-8	Backwater pool	27.1	65.0	49.7	77.6
9-10	Plunge pool	13.0	2.8	0	0
11-13	Lateral scour pool	10.6	4.0	41.3	0
14	Upstream dam pool	48.2	25.9	6.3	11.7

Based on sequential habitat use data collected in Harrison Creek, Green Timber Creek and the North Fork Little Snake River site in 1987, changes in microhabitat use with ontogenetic development appear to be minimal during the first several months following emergence. Depths selected by fry in Harrison Creek and Green Timber Creek increased slightly during this time but no such shift to deeper water was apparent at the North Fork Little Snake River site (Fig. 5). Velocity use appeared to remain similar during this time period, with most of the locations occupied by fish at all three sites having current velocities below 0.06 m/s (Fig. 6). Substrate types used by fry also remained similar during this time period with fry generally found over silt or sand bottoms (Fig. 7).

Objective II: Effects of changes on streamflow on larval cutthroat trout habitat.

The results of the physical habitat simulations (PHABSIM) on the four sites in the North Fork Little Snake River indicated that fry habitat appears to be a small fraction of the available stream surface area under the range of flows simulated (Table 12). Three variables, total depth, velocity and substrate type were used in these simulations. Flows simulated were between 1 and 5 cfs on Harrison and Green Timber Creeks, and between 4 and 12 cfs on both North Fork Little Snake River sites. Weighted Usable Area (WUA) generally increased with decreasing flows on Harrison Creek and both North Fork Sites, while the reverse was true for Green Timber Creek. The lowest simulated flows however, are

Table 12. Changes in suitable habitat with changes in streamflow for Colorado River cutthroat trout fry at four sites in the North Fork Little Snake River (NFLSR) drainage. Suitable habitat is expressed as Weighted Usable Area (WUA) based on the PHABSIM model of the Instream Flow Incremental Methodology (IFIM). Physical habitat data used in the PHABSIM analysis were from Wolff (1987).

Simulation site[1]	Microhabitat-use site[2]	Streamflow (cfs)	Available habitat (ft^2)	WUA (ft^2)	WUA (% of available)
Harrison Creek	Deadman Creek	1	5494.2	36.5	0.7
		2	5945.4	6.9	0.1
		3	6402.4	3.0	<0.1
		4	6702.3	0.2	<0.1
		5	6821.7	0.2	<0.1
Harrison Creek	Harrison Creek	1	5494.2	136.1	2.5
		2	5945.4	38.6	0.7
		3	6402.4	21.1	0.3
		4	6702.3	5.4	<0.1
		5	6821.7	6.1	<0.1
Green Timber	Deadman Creek	1	6383.8	1.4	<0.1
		2	8967.9	17.3	0.2
		3	10429.3	165.6	1.6
		4	12094.2	270.3	2.2
		5	13015.4	256.0	2.0
Green Timber	Harrison Creek	1	6383.8	<0.1	<0.1
		2	8967.9	3.0	<0.1
		3	10429.3	35.0	0.3
		4	12094.2	80.2	0.7
		5	13015.4	182.9	1.4
NFLSR #1	Deadman Creek	4	12133.9	2.8	<0.1
		6	12644.1	5.7	<0.1
		8	13052.4	0.7	<0.1
		10	13429.4	0.3	<0.1
		12	13636.1	0.1	<0.1
NFLSR #1	Harrison Creek	4	12133.9	32.4	0.3
		6	12644.1	15.4	0.1
		8	13052.4	10.7	0.1
		10	13429.4	2.3	<0.1
		12	13636.1	2.7	<0.1

Table 12 (Continued)

Simulation site[1]	Microhabitat-use site[2]	Streamflow (cfs)	Available habitat (ft^2)	WUA (ft^2)	WUA (% of available)
NFLSR #2	Deadman Creek	4	16529.6	53.3	0.3
		6	17427.7	46.3	0.3
		8	17858.6	9.5	0.1
		10	18524.1	3.7	<0.1
		12	18839.6	5.8	<0.1
NFLSR #2	Harrison Creek	4	16529.6	252.2	1.5
		6	17427.7	155.3	0.9
		8	17858.6	64.9	0.4
		10	18524.1	37.5	0.2
		12	18839.6	38.1	0.2

[1]Site at which amount of suitable fry habitat was simulated by PHABSIM model.

[2]Site at which microhabitat-use data used in PHABSIM model were collected.

higher than the natural low flows concurrent with fry emergence during late summer in these streams.

The results of PHABSIM on Fish Creek in the Green River drainage likewise indicated that fry habitat comprises only a small fraction of the total stream surface area of this stream (Table 13). Again, three variables, total depth, velocity, and substrate were used. Simulated flows ranged from 0.5 to 20 cfs. WUA appeared to be optimized at an intermediate streamflow (3 cfs), but never made up more than 1% of the stream surface area. We tested the sensitivity of the PHABSIM model to inclusion of the substrate parameter. When substrate was eliminated from the analysis, WUA increased to 8.2% of the stream surface area. Because we do not know if fry actually select substrates (rather than correlates such as water depth and current velocity) it is difficult to determine if substrate ought to be included in the PHABSIM model.

Our PHABSIM analyses relied on stream habitat data collected by Wolfe (1987) and the Wyoming Game and Fish Department (Bradshaw 1989). Unfortunately, the habitat data needed for the PHABSIM model were not collected at the low streamflows (< 1 cfs) typical of our study streams in late summer. For example, stream habitat data were collected at discharges of 3.2 to 9.4 cfs for the North Fork Little Snake River sites, 1.3 to 3.7 cfs for the Green Timber Creek site and 0.5 to 1.7 cfs for the Harrison Creek site (Wolff 1987). Similarly, stream habitat data were collected at discharges of 8 to 71 cfs for the Fish Creek site (Bradshaw 1989). Thus we could not accurately employ the PHABSIM model with our habitat use data to simulate changes in suitable habitat at the low flows (below 1 cfs) typical of sites wher Colorado River cutthroat trout fry were abundant.

Table 13. Changes in suitable habitat with changes in streamflow for Colorado River cutthroat trout fry in Fish Creek of the Green River drainage. Suitable habitat is expressed as Weighted Usable Area (WUA) based on the PHABSIM model of the Instream Flow Incremental Methodology. Physical habitat data used in the PHABSIM analysis were provided by the Wyoming Game and Fish Department (Bradshaw 1989). Simulations were done both with and without a substrate component in the PHABSIM model.

Simulation site[1]	Microhabitat-use site[2]	Streamflow (cfs)	Available habitat (ft^2)	WUA (ft^2)	WUA (% of available)
with substrate					
Fish Creek	Lead Creek	1.0	11333.4	44.1	0.4
		3.0	13617.8	102.9	0.8
		5.0	14240.6	33.7	0.2
		8.0	14886.9	41.2	0.3
		10.0	15485.8	45.7	0.3
		15.0	17379.9	71.4	0.4
		20.0	18834.4	57.2	0.3
without substrate					
Fish Creek	Lead Creek	1.0	11333.4	769.1	6.8
		3.0	13617.8	1098.9	8.0
		5.0	14240.6	966.6	6.8
		8.0	14896.9	468.9	3.2
		10.0	15485.8	412.1	2.7
		15.0	17379.9	285.4	1.6
		20.0	18834.4	297.9	1.6

[1]Site at which amount of suitable fry habitat was simulated.

[2]Site at which microhabitat-use data used in PHABSIM model were collected.

The observed increase in suitable habitat with declining streamflow reflects the preference of larvae for slow moving water in side channel or backwater areas. It would not be safe to assume that decreases in flow below 1 cfs would continue to result in increases in suitable habitat for cutthroat trout fry. Continued declines in streamflow below 1 cfs would ultimately cause a loss of fry habitat, but we currently lack a methodology for determining at what streamflow this would occur. Conversations with various users of the PHABSIM model indicate that its ability to predict changes in suitable habitat at flows below 1 cfs is questionable. Clearly there remains a need for development of a method for predicting changes in suitable fish habitat in small streams. Despite these problems, the PHABSIM indicates that little suitable habitat for Colorado River cutthroat trout fry shoud exist at streamflows above several cfs. This agrees with our observation of few or no fry in the lower sections of the North Fork Little Snake River (elevations of 2509 and 2371 m) during 1987 when late summer streamflows were on the range of 3-4 cfs (Tables 2 and 7).

Objective III: The usefulness of laboratory streams for determining habitat requirements of young fish.

Microhabitat use information for Colorado River cutthroat trout fry is presently being collected at the Red Buttes Environmental Laboratory. Stream construction was completed in the summer of 1988 and laboratory experiments were begun following the emergence of fry in the autumn of that year. Preliminary results indicate that the depths used by cutthroat fry during the experiments completed to date are similar to those used in the field (Fig. 8). Nearly all available depths ranging from 5 to 23 cm were used in the experimental tank but fry seemed to select pools (10 to 25 cm deep) over riffles (1 to 10 cm deep). Final results are pending the completion of the experiments.

We are also conducting experiments to determine how the presence of adult cutthroat trout influences habitat selection by fry. It is clear that adults are aggressive toward fry and preliminary results suggest that fry shift into shallower areas when adults are present. Such habitat shifts have been observed for the young of other stream fishes and appear to result in younger age-classes being restricted to less than optimal habitat (Anderson 1985, Power 1987). The results of our laboratory experiments on adult-fry interactions will be summarized in a doctoral thesis by Michael A. Bozek that will be completed during 1990.

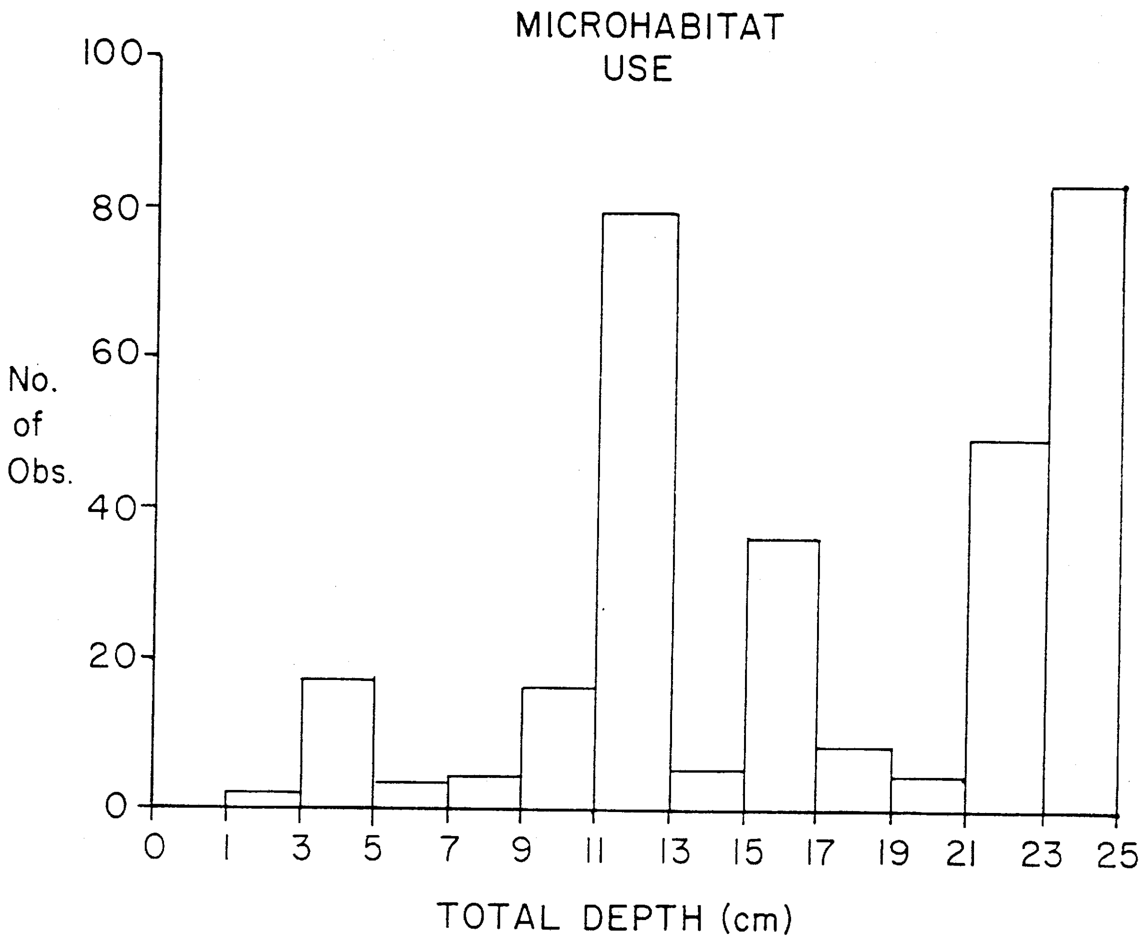


Figure 8. Water depths selected by Colorado River cutthroat trout fry in a laboratory stream.

DISCUSSION

Colorado River cutthroat trout fry were selective in the microhabitats used in both the North Fork Little Snake River and Green River drainages. They mainly used slow water (velocities < 0.06 m/s) and various water depths but avoided extremely shallow water (< 3 cm). The most common substrate types associated with fry were silt and sand. Habitat types used by cutthroat trout fry generally were similar among sites and time periods. Fry were typically found in backwater pools or upstream dam pools and were seldom observed in riffle or run habitats. It appears that fry avoid areas with no current, possibly because such areas provide no drifting food particles.

Areas of slow-moving water with structural protection from high discharge typically occur along stream margins, and have been termed lateral habitats by Moore and Gregory (1988a,b). Lateral habitats are used by the fry of many salmonid species (Everest and Chapman 1972; Bustard and Narver 1975; Symons and Heland 1979; Bisson et al. 1988; Moore and Gregory 1988a,b), and the abundance of this habitat type may determine fry density (Moore and Gregory 1988a,b).

The microhabitat used by cutthroat trout fry in our streams fit the definition of lateral habitats proposed by Moore and Gregory (1988a) (i.e., slow water with structural protection), but differed in that slow velocities occurred across the stream channel at some sites, not just at the stream edge. In fact, there often was no stream margin with a definite break between a main channel and the lateral habitats. Instead, pockets of slow water often occurred across the stream channel. For example, nearly all of the Harrison Creek study site fit this description. In other streams lateral subpockets often were present, but there usually was no velocity break from the main pocket when this occurred. Fry moving into these subpockets, may abandon larger pockets in an attempt to reduce competition for food or avoid adult interaction. Besides having slow water, these habitats also tend to have laminar flow that may facilitate increased feeding efficiency. Deadman Creek on the other hand, is a steep cascading stream channel where "true" lateral habitats exist and most of the cutthroat trout fry were found in such areas. Lateral habitats can also be found throughout the mainstem of the North Fork Little Snake River and this is where we found most of the larvae in this moderately large stream.

Our results confirm the importance of lateral habitats as nursery areas for young trout but indicate that such habitats may occur throughout the channel in small streams. The majority of Colorado River cutthroat trout fry were observed in small tributary streams, few fry were observed in the lower reaches of the North Fork Little Snake River. These small streams have naturally low flows (< 1 cfs) during the later summer period when Colorado River cutthroat trout are emerging from their redds. Further removal of water during this period would llikely have negative impacts on fry habitat.

As noted earlier, attempts to estimate changes in suitable fry habitat with PHABSIM were compromised by the lack of habitat data collected at low streamflows and by concerns about PHABSIM's ability to simulate habitat changes at the low streamflows (below 1 cfs) typical of stream inhabited by Colorado River cutthroat trout. Nevertheless, the PHABSIM analysis predicted that suitable fry habitat would be limited in most streams at discharges in the 1-10 cfs range. This agrees with our macrohabitat analysis where larval density was negatively related to stream size. The PHABSIM analysis predicted that suitable fry habitat would increase as flow decreased but given the inability of PHABSIM to simulate habitat changes below 1 cfs, it would be dangerous to assume this relationship holds below streamflows of 1 cfs.

Another concern with PHABSIM is the influence a single habitat variable can have on the determination of suitable habitat. This can be seen by comparing WUA in Fish Creek with and without substrate preference incorporated into the simulation (Table 13). Substrate preference curves varied from site to site and although smaller substrate sizes were used most often, it appeared that substrate preferences may be secondary to selection for appropriate current velocities and water depth. Thus substrates identified with fry positions may merely reflect collinearity with velocities. The model relies on complete independence of the habitat variables and this assumption probably was being violated. On the Fish Creek site, fry habitat increased by an order of magnitude when substrate was not considered (Table 13).

Insight into the effects of reduced flows on fry habitat can be deduced from the analysis of microhabitat and macrohabitat factors associated with fry density. Cutthroat trout fry emergence can start in late July and continue through September with fry densities highest in shallower streams in the North Fork Little Snake River drainage. Within these streams, fry prefer deeper water. These streams are tributaries to the mainstem and are at their natural flow levels at this time of year. These naturally low flows presently fall below the allowable diversion cutoff level set by the present instream flow conditions that protect the adult cutthroat trout populations in these streams (Wesche et al. 1977). Considering the preference that cutthroat trout fry have for deeper water and the already reduced stream size resulting from natural low flows, further diversion of water following emergence would dewater large areas of the stream channels and preclude its use as fry habitat.

Deep water is also a critical component of winter habitat for stream salmonids (Cunjak and Power 1986, Chisholm et al. 1987). Yet deep water is frequently limited during winter in Rocky Mountain streams because streamflows are at their annual low point and ice formation further reduces stream volume (Chisholm et al. 1987). Although we did not examine how water diversion would affect winter fry habitat, the documented importance of deep water as overwinter habitat and the naturally low flows in these streams during winter suggest that flow reductions in winter due to water diversion would be harmful to young Colorado River cutthroat trout.

The multiple regression analysis indicated that fry densities increase as abundance of spawning gravel increases. This suggests that fry dispersal after emergence is minimal and that spawning and rearing habitat need to be located in close proximity. Management practices that affect the abundance or quality of spawning gravel would affect the densities of cutthroat trout fry in these streams. Reduced flows might reduce the amount of spawning gravel in streams directly if the wetted stream perimeter is also reduced. This would primarily be a function of the channel morphometry. Shallow pan-shaped stream channels would be affected to a greater degree than would v-shaped channels.

Reduced flows however, may have a more subtle impact on spawning gravels. Accumulation of fine sediment at lower velocities would block interstitial waterflow thus causing embryos and fry to suffocate (Tappel and Bjornn 1983; Chapman 1988). The effects of sediment deposition onn survival of Colorado River cutthroat trout eggs is currently being investigated (Young et al. 1989). Sediment deposition would also eliminate larger substrate interstices used by fry as winter habitat (Gibson 1978; Taylor 1988). Deposition could also reduce the complexity and abundance of lateral habitats that are crucial habitat to fry (Moore and Gregory 1988a,b; Bisson et al. 1988).

Shirvell and Dungley (1983) suggest that microhabitat studies are best undertaken in locations where competitors are absent because this best represents the habitat preferences of a species. On the other hand, Moyle and Baltz (1985) believe that microhabitat use information should be collected for entire communities and although such information is site-specific, it provides a realistic view of habitat use under natural conditions. We understand the benefits of both types of data collection. But we specifically chose to exclude sites where other salmonids were absent primarily because this study focuses on the North Fork Little Snake River where other salmonids are not present. We feel for other reasons that this approach was appropriate as well. Specifically, microhabitat use curves that are uninfluenced by competitors provide baseline data on habitat requirements for a particular lifestage of a particular species (Hickman and Raleigh 1982). There is a strong need to know the microhabitat requirements of Colorado River cutthroat trout because it has been replaced by brook trout in much of its original range drainage (Wyoming Game and Fish Department

1987). Information on habitat requirements is needed before we can address reasons for this displacement.

Because our habitat use curves were generated from disjunct remnant populations of a species that was once widespread throughout the Colorado River drainage, they may not represent preferred habitat in streams where the species has been extirpated or in other drainages where the habitat is different. Microhabitat use curves are generally recommended for site specific use only (Condor and Annear 1987) and we urge caution oon applying our preference curves to other regions where Colorado River cutthroat trout are present such as the Blacks Fork drainage of extreme southwestern Wyoming (Binns 1977).

Our findings confirm the importance of small tributary streams and lateral habitat as nursery areas for Colorado River cutthroat trout fry. Because these small streams have naturally low flows when larvae emerge in late summer, removal of water during this period will likely decrease suitable fry habitat and thus decrease fry survival. Protection of present late summer flows is thus an important management consideration for preserving Colorado River cutthroat trout in the North Fork Little Snake River drainage. Enhancement of habitat to increase fry survival is another management option wiorth consideration. Experimental increases in lateral habitat have increased the abundance of cutthroat fry in small streams in the northwest U.S. (Moore and Gregory 1988a). Lateral habitat was increased by simply rearranging rocks within the stream bed, an inexpensive technique appropriate for remote streams such as those in the North Fork Little Snake River or upper Greeen River drainages.

Finally, given the limitations of the PHABSIM methodology for small streams, we need a better method of predicting how changes in streamflow will change habitat available to fish. Until more sophisticated approaches can be developed, empirical relations between stream discharge and amount of lateral habitat may be our best assessment tool. Such relations might be site-specific, but would allow us to begin to address the question of how suitable habitat changes with discharge in small streams critical for survival of Colorado River cutthroat trout.

SUMMARY AND CONCLUSIONS

In this two-year study, we 1) documented habitat use by Colorado River cutthroat trout fry, 2) evaluated how suitable habitat might change with changes in streamflow, and 3) began to evaluate the usefulness of a laboratory stream for understanding patterns of habitat selection. Major conclusions are as follows:

- Colorado River cutthroat fry were most abundant in the upper reaches of the North Fork Little Snake River or in tributary streams. Late-summer discharges in these streams were generally less than 1 cfs. Few larvae were present in the lower North Fork Little Snake River where late-summer discharges were on the order of 3 to 5 cfs.

- At the macrohabitat level, the best multiple-regression equation relating fry density to macrohabitat features was:

  $$\text{Fry density} = 0.571 + 0.030X_1 - 0.018X_2$$
  (Number/m^2)

  where X_1 = area of spawning gravel in the stream in m^2

  X_2 = mean maximum depth of the stream in cm

  the adjusted R^2 of the equation was 0.67 ($F = 14.92$, $P < .001$). Thus fry density increased with increasing abundance of spawning gravel and with decreasing maximum stream depth.

- At the microhabitat level, fry showed selectivity in habitat use. Fry were typically found in water from 3 to 20 cm with a preference for the deeper end of this range. Fry generally selected stream locations where velocities were less than 0.06 m/s and were most commonly found over silt or sand substrates.

- In terms of habitat categories, Colorado River cutthroat fry were most often found in backwater pools or upstream dam pools. Fry were seldom observed in fiffle or run habitats. Fry avoided areas with no water current, possibly because such area provided no drifting food particles.

- Results of PHABSIM analyses indicated that little of the habitat favored by Colorado River cutthroat trout fry would be present above discharges of 1 cfs for streams in the North Fork Little Snake River drainage or upper Green River drainage. Unfortunately, the PHABSIM methodology is not designed to simulate changes in stream habitat below 1 cfs.

- Alternate approaches to quantifying physical habitat changes in small streams (< 1 cfs) need to be developed.

- Because streams with abundant Colorado River cutthroat trout fry already have naturally low late-summer streamflows (< 1 cfs), further reductions in streamflow during this period would almost certainly be harmful to cutthroat populations.

- A laboratory stream shows promise for studying habitat selection under controlled conditions and for revealing which factors (e.g, interactions with adults or other species) influence habitat selection in the field.

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Appendix Table 1. Locations and site descriptions of the study streams.

Site	Elevation (m)	Location
NFLSR	2766	T13N R85W Sec 25 SW NW
NFLSR	2761	T13N R85W Sec 26 NW SE
NFSLR	2734	T13N R85W Sec 26 SE NW Above diversion
NFLSR	2731	T13N R85W Sec 26 SW NW Below diversion
NFLSR	2533	T13N R85W Sec 27 SE NE
NFLSR	2621	T13N R85W Sec 27 SW NE Above road
NFLSR	2620	T13N R85W Sec 27 SW NE Below road
NFLSR	2509	T12N R85W Sec 4 NE NW
NFLSR	2371	T12N R86W Sec 13 NW NW Above fish barrier
Third Cr.	2743	T13N R85W Sec 22 SE NE
Third Cr.	2725	T13N R85W Sec 22 NE NE
Deadman Cr.	2713	T13N R85W Sec 28 NW SW Above diversion
Deadman Cr.	2693	T13N R85W Sec 28 NW SW Below diversion
Deadman Cr.	2609	T12N R85W Sec 4 NW NE
Green Timber Cr.	2566	T12N R85W Sec 3 NW NW
Green Timber Cr.	2533	T12N R85W Sec 4 NW NE
Harrison Cr.	2530	T12N R85W Sec 4 NE NW
Lead Cr.	2475	T34N R114W Sec 26 SE SW
Rock Cr.	2300	T26N R114W Sec 20 SW NW

Appendix Table 2. Density of Colorado River cutthroat trout fry expressed as number per square meter for the seventeen study sites in the North Fork of the Little Snake River drainage. For sites with multiple censuses, the date with the highest fry count was used to calculate density.

Stream Site	Elevation (m)	Density (Number/m^2
NFLSR	2766	0.96
NFLSR	2761	0.22
NFLSR	2734	0.24
NFLSR	2731	0.00
NFLSR	2533	0.07
NFLSR	2621	0.02
NFLSR	2620	0.03
NFLSR	2509	0.04
NFLSR	2371	< 0.01*
Third Cr.	2743	0.12
Third Cr.	2725	0.14
Deadman Cr.	2713	0.07
Deadman Cr.	2693	0.00
Deadman Cr.	2609	0.24
Green Timber Cr.	2566	0.22
Green Timber Cr.	2533	0.19
Harrison Cr.	2530	0.81

*Only one larvae observed.

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89-06

THE UNIVERSITY OF WYOMING
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June 7, 1989

Dr. Steven P. Gloss, Director
Wyoming Water Research Center
University of Wyoming
Vocational Annex
Campus

Dear Steve:

Enclosed are two copies of the completion report for our project entitled "Habitat requirements of young Colorado River cutthroat trout in relation to alterations in streamflow." The project budget number was 538711 and the duration was from July 1, 1986 through December 31, 1989. Funding was from the state appropriation to the Wyoming Water Research Center. This project is continuing through June 30, 1990 with support from the Wyoming Game and Fish Department and will consititue the doctoral research of Michael A. Bozek in the Department of Zoology and Physiology. Because the work is ongoing, we will not have journal articles ready for submission until 1990. However support of the Water Center will be acknowledged in those articles and copies of accepted manuscripts will be sent to the Water Center.

We feel the research was successful in providing critical data on habitat requirements of young Colorado River cutthroat trout and in providing insight into how water development would affect this important gamefish. The objective of graduate training was also met as Michael Bozek is progressing nicely in his graduate program. I thank the Wyoming Water Research Center for its support.

Sincerely,

Frank J. Rahel

Frank J. Rahel, Ph.D.
Assistant Professor

FJR:mld

Enclosure: