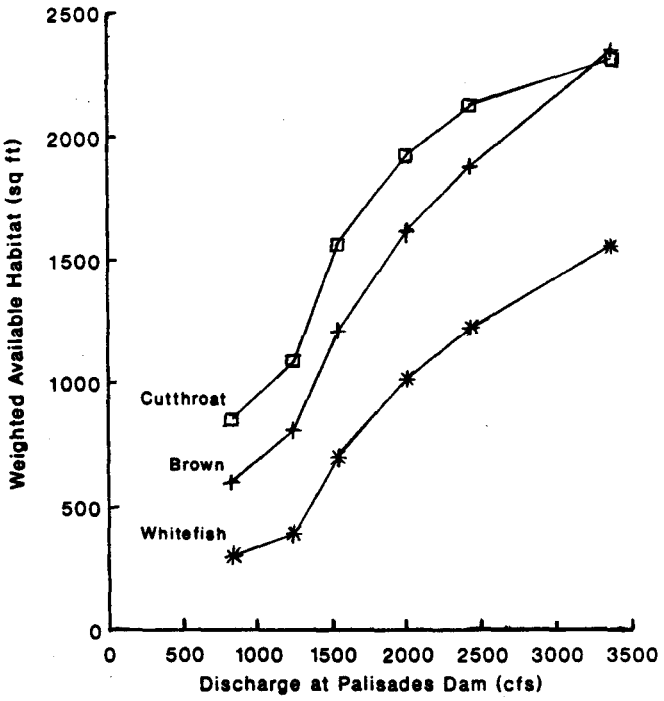
Volume 098
Article 01

FISHERY RESEARCH

WINTER HABITAT AVAILABILITY AND UTILIZATION BY JUVENILE CUTTHROAT TROUT, BROWN TROUT, AND MOUNTAIN WHITEFISH IN THE SOUTH FORK SNAKE RIVER, IDAHO



By:

William C. Schrader, Senior Fishery Research Biologist
Robert G. Griswold, Fishery Research Biologist

IDFG 94-23a
August 1994

TABLE OF CONTENTS

Page

FORWARD ix

ABSTRACT 1

INTRODUCTION 3

OBJECTIVES 6

STUDY AREA 6

METHODS 8

Winter Habitat Use 8
Flow versus Habitat Relationships 13
Data Management and Statistical Analysis 21

RESULTS 21

Winter Habitat Use 21
Flow versus Habitat Relationships 28

DISCUSSION 30

Winter Habitat Use 30
Flow versus Habitat Relationships 36

RECOMMENDATIONS 40

ACKNOWLEDGEMENTS 41

LITERATURE CITED 42

APPENDICES ..... Under separate cover

LIST OF TABLES

Table 1. Cover classification system developed for cover types found on the South Fork Snake River 10

Table 2. Substrate classification system based on particle size as modified from Platts et al. (1983) 12

LIST OF TABLES (Cont.)

Page

Table 3. Number of habitat sites counted on the upper (above the Dry Bed Canal) South Fork Snake River by channel and predominant cover type. Counts were conducted between October 15-23, 1990, when discharge was 3,500 cfs at the Irwin gauging station just below Palisades Dam 14

Table 4. Final sample size of habitat sites evaluated on the upper (above the Dry Bed Canal) South Fork Snake River. Percent of the original upriver count is in parentheses . 19

Table 5. Nighttime densities of subyearling cutthroat trout, brown trout, and mountain whitefish by channel type in the South Fork Snake River. Sample size is the number of areas dived during winter, 1990-91 22

Table 6. Nighttime densities of subyearling cutthroat trout, brown trout, and mountain whitefish by cover type in the South Fork Snake River. Sample size is the number of areas dived during winter, 1990-91 25

Table 7. Percent loss of weighted available habitat (WAH) with reduced discharge in the upper (above the Dry Ben Canal) South Fork Snake River. WAH is the sum of the 30 sites sampled; percent loss is the difference in WAH relative to 3,370 cfs 31

Table 8. Percent loss of unweighted available habitat (UAH) with reduced discharge in the upper (above the Dry Bed Canal) South Fork Snake River. UAH is the sum of the 30 sites sampled; percent loss is the difference in UAH relative to 3,370 cfs 33

LIST OF FIGURES

Figure 1. Lowest mean monthly discharge during winter storage (November 1 to March 31) for water years 1919-42 and 1950-92 at the Irwin gauging station just below Palisades Dam, South Fork Snake River (USGS, unpublished data) 4

Figure 2. Study area on the South Fork Snake River from Palisades Dam downstream to the Henrys Fork Snake River 7

CONTENTS

LIST OF FIGURES (Cont.)

Page

Figure 3. Map of a typical habitat site in the South Fork Snake River 15

Figure 4. Peak discharge for water years 1972-92 at the Irwin gauging station just below Palisades Dam, South Fork Snake River (USGS, unpublished data) 17

Figure 5. Hydrographs at the Irwin and Lorenzo gauges during autumn 1991 requested flow regime, South Fork Snake River (USGS, unpublished data) 20

Figure 6. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various channel types found in the South Fork Snake River during winter 1990-91 (n=66) 23

Figure 7. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various cover types found in the South Fork Snake River during winter 1990-91 (n=66). Cover types are: nc=no cover, av=aquatic vegetation, cb=cobble, sb=small boulder, lb=large boulder, swd=small woody debris, and lwd=large woody debris 26

Figure 8. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various water depths in the South Fork Snake River during winter 1990-91 (n=66) 27

Figure 9. Relationships of weighted available habitat with discharge in the upper (above the Dry Bed Canal) South Fork Snake River. Weighted available habitat is the sum of the 30 sites sampled during autumn 1991 29

Figure 10. Relationships of unweighted available habitat with discharge in the upper (above the Dry Bed Canal) South Fork Snake River. Unweighted available habitat is the sum of the 30 sites sampled during autumn 1991 32

Figure 11. Relationships of relative wetted area with discharge in the upper (above Riley Ditch) South Fork Snake River. Data are from aerial photos taken during autumn 1988 (USFWS, unpublished report, Boise, Idaho) 38

CONTENTS

THE FOLLOWING APPENDICES ARE PRINTED UNDER A SEPARATE COVER FROM THE TEXT.

LIST OF APPENDICES

Page

Appendix A. Frequency distributions of subyearling cutthroat trout, brown trout, and mountain whitefish nighttime use of water column depths, mean water column velocities, focal point velocities, and substrate types in the South Fork Snake River, winter 1990-91 47

Appendix A-i. Number of subyearling cutthroat trout observed at different water column depths during night dives on the South Fork Snake River, winter 1990-91 48

Appendix A-2. Number of subyearling brown trout observed at different water column depths during night dives on the South Fork Snake River, winter 1990-91 49

Appendix A-3. Number of subyearling mountain whitefish observed at different water column depths during night dives on the South Fork Snake River, winter 1990-91 50

Appendix A-4. Number of subyearling cutthroat trout observed at different mean water column velocities during night dives on the South Fork Snake River, winter 1990-91 51

Appendix A-5. Number of subyearling brown trout observed at different mean water column velocities during night dives on the South Fork Snake River, winter 1990-91 52

Appendix A-6. Number of subyearling mountain whitefish observed at different mean water column velocities during night dives on the South Fork Snake River, winter 1990-91 53

Appendix A-7. Number of subyearling cutthroat trout observed at different focal point water velocities during night dives on the South Fork Snake River, winter 1990-91 54

Appendix A-8. Number of subyearling brown trout observed at different focal point water velocities during night dives on the South Fork Snake River, winter 1990-91 55

CONTENTS

LIST OF APPENDICES (Cont.)

Page

Appendix A-9. Number of subyearling mountain *whitefish* observed at different focal point water velocities during night dives on the South Fork Snake River, winter 1990-91 56

Appendix A-10. Number of subyearling cutthroat trout, brown trout, and mountain whitefish observed using different substrate types during night dives on the South Fork Snake River, winter 1990-91 57

Appendix B. Densities of subyearling and yearling cutthroat trout, brown trout, and mountain *whitefish* observed during night and day in channel and cover types in the South Fork Snake River, winter 1990-91 58

Appendix B-1. Number observed and densities of subyearling and yearling cutthroat trout for each channel type during night dives on the South Fork Snake River, winter 1990-91 59

Appendix B-2. Number observed and densities of subyearling and yearling cutthroat trout for each channel type during day dives on the South Fork Snake River, winter 1990-91 59

Appendix B-3. Number observed and densities of subyearling and yearling brown trout for each channel type during night dives on the South Fork Snake River, winter 1990-91 59

Appendix B-4. Number observed and densities of subyearling and yearling brown trout for each channel type during day dives on the South Fork Snake River, winter 1990-91 60

Appendix B-5. Number observed and densities of subyearling and yearling mountain *whitefish* for each channel type during night dives on the South Fork Snake River, winter 1990-91 60

Appendix B-6. Number observed and densities of subyearling and yearling mountain whitefish for each channel type during day dives on the South Fork Snake River, winter 19 9 0-91 60

CONTENTS

LIST OF APPENDICES (Cont.)

Page

Appendix B-7. Number observed and densities of subyearling and yearling cutthroat trout for each cover type during night dives on the South Fork Snake River, winter 1990-91 61

Appendix B-8. Number observed and densities of subyearling and yearling cutthroat trout for each cover type during day dives on the South Fork Snake River, winter 1990-91 61

Appendix B-9. Number observed and densities of subyearling and yearling brown trout for each cover type during night dives on the South Fork Snake River, winter 1990-91 61

Appendix B-10. Number observed and densities of subyearling and yearling brown trout for each cover type during day dives on the South Fork Snake River, winter 1990-91 62

Appendix B-11. Number observed and densities of subyearling and yearling mountain whitefish for each cover type during night dives on the South Fork Snake River, winter 1990-91 62

Appendix B-12. Number observed and densities of subyearling and yearling mountain whitefish for each cover type during day dives on the South Fork Snake River, winter 1990-91 62

Appendix C. Frequency distributions of subyearling cutthroat trout, brown trout, and mountain whitefish daytime use and yearling nighttime use of water column depths. Mean water column velocities, focal point velocities, and substrate types in the South Fork Snake River, winter 1990-91 63

Appendix C-1. Number of subyearling cutthroat trout observed at different water column depths during day dives on the South Fork Snake River, winter 1990-91 64

Appendix C-2. Number of yearling cutthroat trout observed at different water column depths during night dives on the South Fork Snake River, winter 1990-91 65

CONTENTS

LIST OF APPENDICES (Cont.)

Page

Appendix C-3. Number of yearling mountain whitefish observed at different water column depths during night dives on the South Fork Snake River, winter 1990-91 . . . 66

Appendix C-4. Number of subyearling cutthroat trout observed at different mean water column velocities during day dives on the South Fork Snake River, winter 1990-91 67

Appendix C-5. Number of yearling cutthroat trout observed at different mean water column velocities during night dives on the South Fork Snake River, winter 1990-91 68

Appendix C-6. Number of subyearling cutthroat trout observed at different focal point water velocities during day dives on the South Fork Snake River, winter 1990-91 69

Appendix C-7. Number of yearling cutthroat trout observed at different focal point water velocities during night dives on the South Fork Snake River, winter 1990-91 69

Appendix C-8. Number of subyearling cutthroat trout, brown trout, and mountain whitefish observed using different substrate types during day dives on the South Fork Snake River, winter 1990-91 70

Appendix C-9. Number of yearling cutthroat trout, brown trout, and mountain whitefish observed using different substrate types during night dives on the South Fork Snake River, winter 1990-91 70

Appendix D. Measured surface area and calculated weighted available habitat for subyearling cutthroat trout, brown trout, and mountain whitefish in the South Fork Snake River, winter 1991-92 71

Appendix D-1. Measured surface area and calculated weighted available habitat for subyearling cutthroat trout in the South Fork Snake River, winter 1991-92. Weighting factors are for nighttime use during winter 72

CONTENTS

LIST OF APPENDICES (Cont.)

Page

Appendix D-2. Measured surface area and calculated weighted available habitat for subyearling brown trout in the South Fork Snake River, winter 1991-92. Weighting factors are for nighttime use during winter 102

Appendix D-3. Measured surface area and calculated weighted available habitat for subyearling mountain whitefish in the South Fork Snake River, winter 1991-92. Weighting factors are for nighttime use during winter 132

FORWARD

I feel it is necessary to provide background and history leading to the initiation of this research and to explain why some of the peer reviewers' comments were not addressed.

Initial planning for work on the South Fork Snake River winter instream flow needs began in 1989 after two winters of low flows (750 to 800 cfs) corresponded to lower population estimates of juveniles the next year.

Local sports groups took the U.S. Bureau of Reclamation (BOR) to court challenging the operation of Palisades Dam below 750 cfs (the lowest operation flow of record) when a 550 cfs winter flow was suggested by BOR. This court challenge upheld the BOR's authority to reduce flows for storage of irrigation water without a full Environmental Impact Statement. During the court proceedings, it became evident the scientific information regarding flows and habitat use for cutthroat and brown trout during winter periods were limited. The need for information for management of the South Fork and Palisades Reservoir prompted the USFWS, BOR, and IDFG to take the lead in developing a research study plan under the auspices of the South Fork Snake River Memorandum of Understanding (MOU) group.

A study scoping group was formed to determine the nature of the project activities to fit budget, time, and objective constraints. This group prioritized the study to winter periods of juvenile cutthroat trout, brown trout, and mountain whitefish. They also limited the flow range to a maximum of 3,500 cfs. This was to be a multi-agency research activity with the Idaho Department of Fish and Game (IDFG) providing the habitat use and preference information, the U.S. Fish and Wildlife Service (USFWS) the Instream Flow Incremental Methodology measurements and modeling, and the U.S. Bureau of Reclamation (BOR) providing major funding and experimental flows. Field work on this project began October 1990. IDFG completed the habitat winter use (preference) and habitat type work by April 1991 (Griswold 1991).

The USFWS Instream Flow group withdrew from the study stating time and funding constraints and the difficulty of using braided channel system data in their model. IDFG submitted a proposal for an empirical approach to measuring habitat at staged flow from 800 cfs to 3,500 cfs (versus the IFIM modeled approach). After review by the scoping group and South Fork Snake MOU group in February and March 1991, BOR approved May 1991.

Field work for this phase was conducted in the fall and early winter of 1991. Data analysis and draft report writing were completed by September 1992 and submitted to BOR.

The BOR requested IDFG do a full peer review of the report so the most defensible document possible could be produced for decisions on fish flow needs. I initiated peer review in November 1992, with all comments received by May 1993. Reassignment of Bill Schrader to a new position resulted in delays until 1994 to complete the edits.

As editor, I decided some peer review comments and suggestions should not be addressed. I limited these deletions to study design limitations set by the scoping team.

These include:

1. Discussion of whether 1,540 cfs minimum flow afforded protection and ice-free conditions for side channels.-There was no quantification of icing, flow-habitat relationships in the study design.

2. Some researchers suggest upwelling may be a key component of winter habitat. Do we know that fish were not selecting areas of upwelling?-The experimental design did not address upwelling and no measurements were made that would allow for quantifying or discussing this issue.

3. The report does not make a convincing argument that overwintering habitat for subyearlings is the major limiting factor to the trout population in the South Fork.-The objective of this work was to quantify flow versus habitat relationships. Population versus flow work was considered beyond the scope of this project. The scoping team worked under this assumption.

4. Discuss or recommend other options, habitat treatments, or measures which might be available to help compensate for low flow effects.-This was beyond the scope of the project's objectives, study design, and time limitations.

Virgil K. Moore
Fishery Research Manager

ABSTRACT

We used snorkel gear and SCUBA to identify and quantify winter habitat used by juvenile salmonids in the South Fork Snake River between Palisades Dam and the confluence of the North (Henrys) Fork Snake River. We measured habitat used at night by subyearlings, because few fish were observed during day dives and numbers of yearling fish were low during day and night.

For all species, nighttime densities of subyearlings were highest in side channels and in small woody debris cover. Yellowstone cutthroat trout Oncorhynchus clarki bouvieri densities were generally greater than brown trout Salmo trutta and mountain whitefish Prosopium williamsoni. Densities by channel type ranged from 14.8 cutthroat trout/100 yd^2 in side channels to 0.4 mountain whitefish/100 yd^2 in main channels. Densities by cover type ranged from 38.5 cutthroat trout/100 yd2 in small woody debris to zero mountain whitefish in boulders. Mountain whitefish differed from trout by having relatively high densities in backwater areas and in areas with no cover.

At night, subyearling cutthroat and brown trout were closely associated with cover (mean distance <1 ft), and all species used slow water (optimum mean column velocities <0.2 ft/s). Cutthroat trout used a more narrow range of water column depths (optimum 1.3 to 1.6 ft) compared to brown trout and mountain whitefish (optimum 1.3 to 3.3 ft). Subyearling mountain whitefish were farther from cover (mean distance = 5.7 ft) and they used relatively fewer areas with small or large boulder substrate than cutthroat and brown trout. Use of substrate by cutthroat and brown trout, in descending order of frequency, was generally cobble, large boulder, fines, small boulder, and gravel.

The winter flow versus habitat relationship developed for each species was curvilinear. Weighted available habitat at 30 sites sampled in the upper river

(above the Dry Bed Canal) decreased with discharge during winter, but not at a constant rate. The greatest rate of winter habitat loss for cutthroat trout, brown trout, and mountain whitefish occurred between 1,540 and 1,240 cfs.

Of the weighted habitat available to subyearling cutthroat trout at 3,370 cfs, one-third was lost as flows were reduced to 1,540 cfs and over half (53%) was lost at 1,240 cfs. For brown trout, about half (49%) was lost at 1,540 cfs and two-thirds at 1,240 cfs. For mountain whitefish, over half (55%) was lost at 1,540 cfs and three-fourths at 1,240 cfs. Although not directly comparable, these results concur with aerial photograph analysis done in 1988 (U.S. Fish and Wildlife Service, unpublished data); photographs showed that more than half (56%) of upriver side channel area was dewatered when flows were reduced from 2,200 to 750 cfs.

We recommend a winter minimum flow of 1,540 cfs from Palisades Dam to provide 45% to 67% of the juvenile salmonid habitat available at 3,370 cfs.

Authors:

William C. Schrader
Senior Fishery Research Biologist

Robert G. Griswold
Fishery Research Biologist

Idaho Department of Fish and Game
600 South Walnut
Boise, Idaho 83707

INTRODUCTION

The South Fork Snake River below Palisades Dam provides a blue-ribbon trout fishery and is becoming an increasingly popular recreation area. It provides quality wild trout fishery for large (>16 in) Yellowstone cutthroat trout Oncorhynchus clarki bouvieri and brown trout Salmo trutta. The current state record brown trout, weighing 26.4 lbs, was caught in the South Fork Snake River in 1981 (Idaho Department of Fish and Game [IDFG] files). However, mountain whitefish Prosopium williamsoni are the most abundant game fish in the river but are rarely sought by anglers (Jeppson 1970; Moore et al. 1981). Many are caught incidentally by anglers seeking cutthroat and brown trout. Mountain whitefish and cutthroat trout are important prey species for endangered bald eagles Haliaeetus leucocephalus (Whitfield et al. 1988).

South Fork Snake River stream flow is regulated at Palisades Dam primarily for irrigation and flood control. The dam was completed in 1956, and operated by the U.S. Bureau of Reclamation (BOR), with flow manipulations occurring during the spring run off (April-June), irrigation season (April 1 to October 31), and winter (November-April) for filling of Palisades Reservoir.

Drought occurred in the South Fork Snake River drainage from the winters of 1986-87 to 1991-92. During and since the drought, winter flows were unusually low, and recruitment to the cutthroat trout fishery declined. Lowest mean monthly winter discharge at the dam since 1956 were about 2,300 cfs. But since the beginning of the drought in winter 1986-87, these flows ranged from 700 to 1,200 cfs (Figure 1). Abundance estimates of age 2 cutthroat trout from 1988 to 1991 declined 70-90% compared to pre-drought abundance in 1986 (Elle and Gamblin 1992). Reductions in recruitment were significant and consistent, and they appear to be winter flow-related. Low abundance of age 2 fish correspond to low

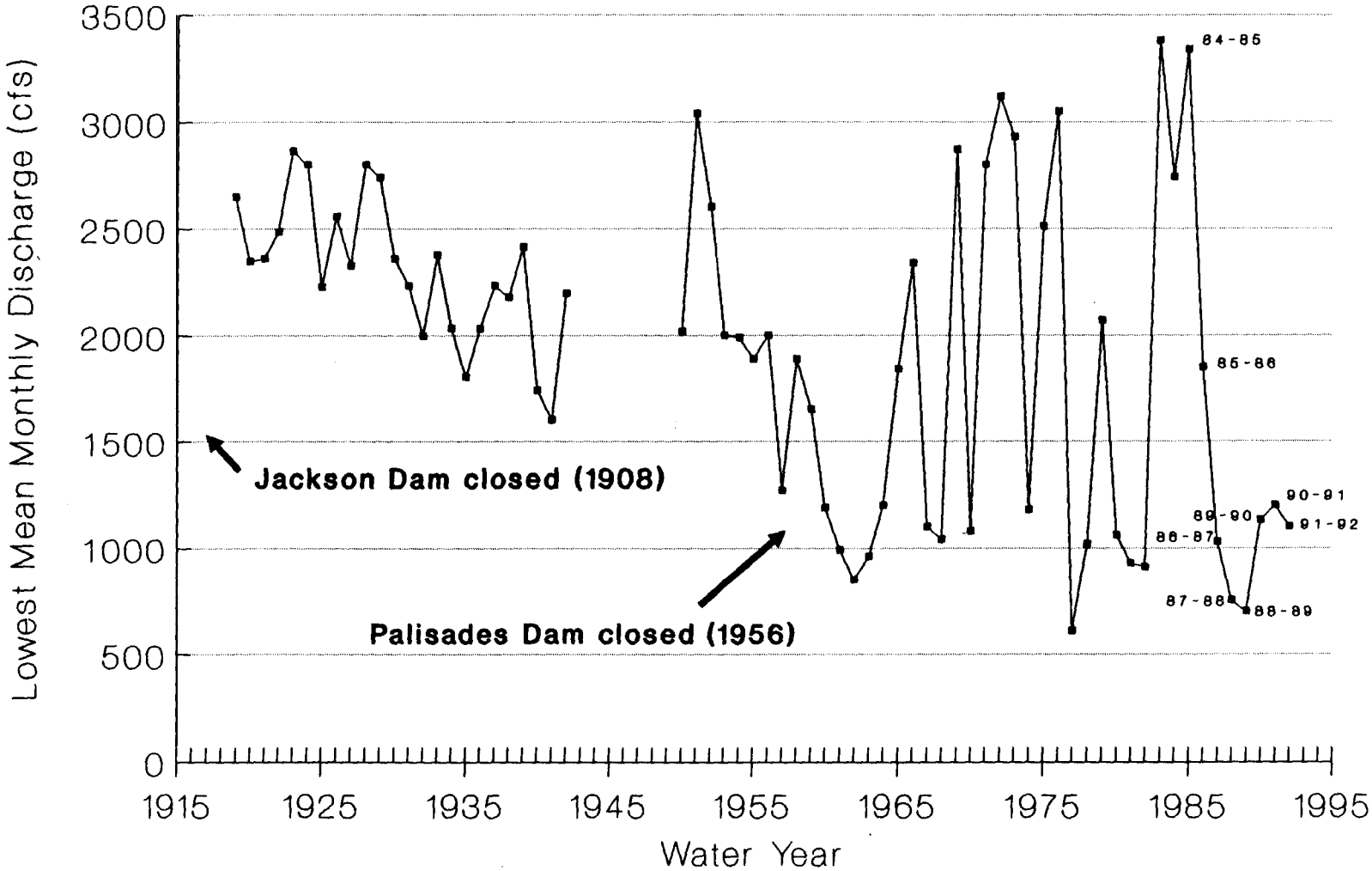


Figure 1. Lowest mean monthly discharge during winter storage (November 1 to March 31) for water years 1919-42 and 1950-92 at the Irwin gauging station just below Palisades Dam, South Fork Snake River (USGS, unpublished data).

flow conditions the previous two winters. Strong year classes produced prior to the drought have continued to support the fishery.

Habitat requirements of juvenile salmonids change during winter and are generally more narrow than during other seasons. During winter, juveniles are closely associated with concealment cover (Bustard and Narver 1975a; Rimmer et al. 1983; Johnson and Kucera 1985; Hillman et al. 1987), in shallow water (Cunjak and Power 1986; Johnson and Kucera 1985; Sheppard and Johnson 1985), and in relatively slow water (Cunjak and Power 1981; Johnson and Kucera 1985; Sheppard and Johnson 1985). The major factor limiting salmonid abundance in some streams may be the quantity and quality of winter habitat available (Mason 1976; Hall and Knight 1981; Tschaplinski and Hartman 1983).

A winter instream flow agreement for maintenance of aquatic resources has not been reached for the South Fork Snake River. Cochnauer and Buettner (1978) recommended a minimum flow of 1,084 cfs based on a wetted perimeter model. This model is used to predict the wetted stream bottom at various flows but does not incorporate habitat criteria. Their flow recommendation was based on a single channel (non-braided) section of the river, near Irwin, Idaho. No agreement was reached between BOR and IDFG concerning this flow recommendation. At present, BOR and the water users have agreed to maintain a minimum flow release of 550 cfs at Palisades Dam.

To better understand the winter flow limitations maintaining fish populations in the South Fork Snake River, the IDFG began a two-year research project in 1990 (Griswold 1991). The goal of this project is to: Determine the maintenance stream flow in the South Fork Snake River necessary to sustain the wild trout fishery (IDFG Fisheries Management Plan 1991-1995).

OBJECTIVES

1. To identify and quantify winter habitat used by juvenile salmonids in the South Fork Snake River, Idaho.

2. To quantify the relationships between flows and the relative amount of winter habitat available to juvenile salmonids in the South Fork Snake River.

3. To recommend a winter instream maintenance flow for the South Fork Snake River. The study was being conducted in cooperation with the BOR, U.S. Fish and Wildlife Service (FWS), U.S. Forest Service (USFS), and U.S. Bureau of Land Management (BLM).

STUDY AREA

The South Fork Snake River flows into southeastern Idaho from western Wyoming. The stream originates in Yellowstone and Grand Teton National Parks and flows northwest from the Idaho-Wyoming state line 83 miles to its confluence with the Henrys Fork Snake River (Figure 2). Completion of Palisades Dam in 1956 inundated the upper 20 miles of the Idaho portion of the river, and flows in the remaining 63 miles are regulated by the dam. The dam was authorized in 1950 (Public Law 81-864) and is operated by the BOR. The primary purpose of the Palisades Project is to provide water for irrigation, power production, flood control, and recreation.

Our study area is the regulated river between Palisades Dam and the Henrys Fork Snake River. The river first passes through a mountain valley between the

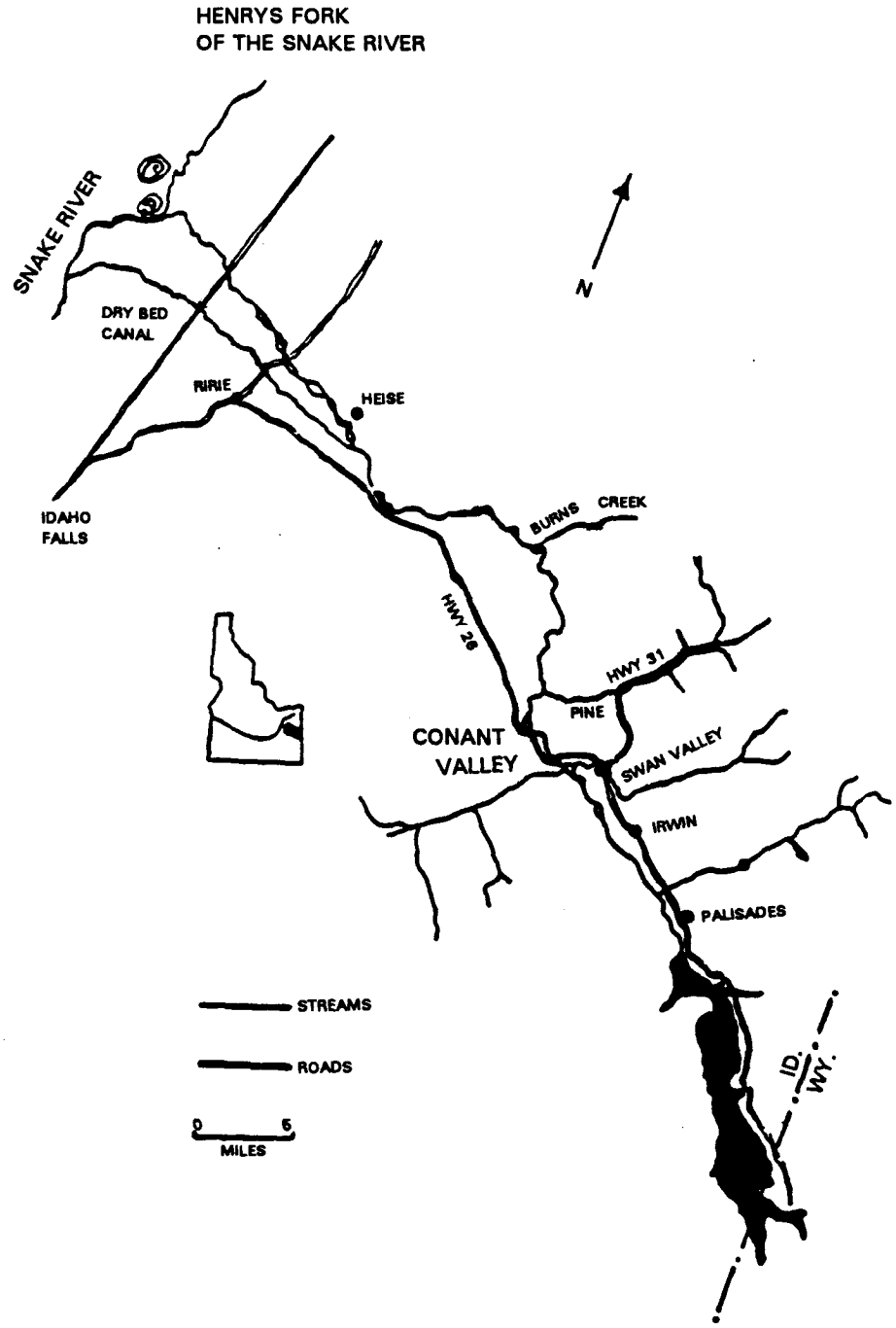


Figure 2. Study area on the South Fork Snake River from Palisades Dam downstream to the Henrys Fork Snake River.

dam and Conant Valley. This section is characterized by long runs and riffles with few pools and side channels. Between Conant Valley and Heise, the river is contained by a relatively steep-sided canyon. The river is moderately braided with good pool/riffle/run structure (FWS, unpublished data). Below Heise, the river flows through a wide flood plain and is characterized by extensive side channels and a large cottonwood riparian area (Moore et al. 1981).

METHODS

For the purpose of this study, we define "juvenile" fish as those age 0 (subyearlings) or age 1 (yearlings). "Salmonids" include cutthroat trout, brown trout, and mountain whitefish. "Winter" is defined as that period between November 1 and March 31 and corresponds to the time when irrigation withdrawals are generally not occurring, and water is being stored in Palisades Reservoir. "Discharge" or "flows," unless otherwise noted, are in reference to water released at Palisades Dam and measured at the Irwin gage near Irwin, Idaho. "Cover" is defined as those elements of habitat that are structural or physical, i.e. substrate, vegetation, wood debris, undercut banks, and aquatic vegetation.

Winter Habitat Use

We used snorkeling and SCUBA techniques to identify and quantify habitats used by juvenile salmonids in the South Fork Snake River during winter, 1990-91. Underwater observations were made by a diver equipped with drysuit, mask, snorkel, and flashlight. The diver approached each area from the downstream end and moved upstream. In areas with deep and fast water, divers ascended a rope which was anchored above the sampled area. When a fish or aggregate of fish was

observed, the diver counted them and visually determined species and size (or age class). We also observed fish to determine if they had been disturbed. All juvenile salmonids were counted; however, fish which were displaced or appeared alarmed were excluded from habitat use measurements.

Divers counted game fish in various channel types (main, side, or backwater) and cover types (Table 1). We randomly selected 105 dive locations by predominant cover type, and each location was classified by channel type. Fish were counted in the entire area containing cover; however, large areas of cobble and boulders were subsampled. Individual dives were confined to an area with uniform cover and in the same channel; this allowed comparing fish densities by cover and channel type. Areas lacking cover were sampled less frequently than they occurred in the river because fish were rarely observed there.

The diver also marked the focal point of individual fish (the point at the fish's snout) with weighted buoys and collected the following habitat data: distance to nearest cover, water column depth, focal point depth, mean water column velocity, focal point velocity, and substrate type. Water temperatures were measured to the nearest 1°F at each sampling location as well.

Distance to the nearest escape cover was measured to the nearest 0.1 ft. Water column depth and focal point depth (distance between the focal point and substrate) were measured to the nearest 0.1 ft with a 4 ft graduated aluminum rod.

Velocity measurements were taken immediately after fish counts were completed, except that measurements were made the following day if air temperatures were below 20°F during nighttime sampling. A temporary staff gage was set within the sample area to monitor changes in water elevation between the observation and measurement periods (Bovee 1986). If water levels changed more than 0.05 ft, velocities were not measured. Velocities were measured to the

Table 1. Cover classification system developed for cover types found on the South Fork Snake River.

Classification	Diameter (mm)	Diameter (in)
Small woody debris (SWD)`	<152	<6.0
Large woody debris (LWD)	>152	>6.0
Cobble (CB)[b]	76-303	3.0-11.9
Small boulder (SB)	304-608	12.0-23.9
Large boulder (LB)	>609	>24.0
Undercut bank (UB)	-	-
Bedrock (BR)	-	-
No cover (NC)[c]	-	-
Aquatic vegetation (AV)	-	-

[a]Includes root wads and willow clumps.
[b] Includes only large, clean cobbles with interstitial spaces available for concealment cover.
[c]Includes all other classifications which lack interstitial spaces due to presence of fines.

nearest 0.1 ft/s with a Swoffer Model 2100-14 current meter. Mean water column velocities were estimated by measuring at 0.6 of the depth for depths <2.5 ft and by averaging measurements taken at 0.2 and 0.8 of the depth for depths >2.5 ft (Bovee 1986). Focal point velocities were measured at each marked focal point. A weighted buoy was placed to identify each focal point location.

Substrate was classified using a modified particle-size scale (Table 2) (Platte et al. 1983). Substrate was considered a component of cover, but was tabulated separately for future comparisons. Substrate proportions were visually estimated to the nearest 10% within a 1 x 1 ft area centered on the focal point. Visual estimations of embeddedness were the area of dominant sized particle surrounded by fires in the following increments: 0-5%, 6-25%, 26-50%, 51-75%, 76-100%.

Utilization functions were developed for channel and cover types using subyearling cutthroat trout, brown trout, and mountain whitefish nighttime density data. Sampling during the day was less efficient than at night; most young fish hid within the substrate during the day and could not be seen (Griffith and Smith 1993). This precluded development of daytime utilization curves. Likewise, few yearling salmonids were observed during day or night, and curves were not developed for them. Functions were developed by normalizing data to a scale of 0 to 1. We normalized data to allow comparisons between species and to provide weighing factors for winter habitat availability calculations.

Utilization functions were also developed for water column depth using subyearling trout and mountain whitefish nighttime use data. Discrete, or step, functions were developed by normalizing frequencies of use by one foot depth intervals. These functions were also used in the winter habitat availability calculations.

Table 2. Substrate classification system based on particle size as modified from Platts et al. (1983).

Classification	Diameter (mm)	Diameter (in)
Fines	<4.7	<0.18
Gravel	4.8-75	0.19-2.9
Cobble	76-303	3.0-11.9
Small boulder	304-608	12.0-23.9
Large boulder	>609	>24.0
Bedrock	-	-

Flow versus Habitat Relationships

We used channel type, cover type (includes substrates as cover), and depth as weighting factors for final analysis. During the planning stages of this project, a scoping group (IDFG, BOR, FWS) recognized that it would not be practical to use all the habitat variables to develop the flow versus habitat relationships. They decided we should collect as much data on these variables as possible while diving in case it was needed for this project or for future work on the South Fork Snake River. The data might also be used in other habitat models or on other streams.

To quantify the flow versus habitat relationship, we first selected a random sample of habitat sites to evaluate. A "habitat site" is an area of river characterized by some channel type (side, main, or backwater) and some cover type (Table 1) except that bedrock, no cover, and aquatic vegetation were not included. Because sites often contained more than one type of cover, we classified the site by the predominant type. We classified and enumerated 1,400 habitat sites from Palisades Dam downstream to the confluence with the Henrys Fork Snake River during October, 1990, when discharge was 3,500 cfs. After stratifying by cover type, we randomly selected 122 sites for evaluation using a table of random numbers (Table 3) from 1,400 habitat sites (Griswold 1991).

All 122 sites were photographed and partially mapped from November 1990 to April 1991. A permanent baseline was constructed at each site above the mean high water mark and parallel to the stream flow (Figure 3). Two steel reinforcing rods marked the beginning and end of the baseline (headpin and tailpin). Baselines varied in length from less than 50 to over 200 ft. Transects perpendicular to the baseline were then established at 0.1, 0.3, 0.5, 0.7, and 0.9 of the baseline length. Next, the elevation of the headpin and of the stream bottom at points along the transects was measured with a level and

Table 3. Number of habitat sites counted on the upper (above the Dry Bed Canal) South Fork Snake River by channel and predominant cover type. Counts were conducted between October 15-23, 1990, when discharge was 3,500 cfs at the Irwin gauging station just below Palisades Dam.

Predominant cover type[a]	Channel type			Total	Percent of total
	Side	Main	Back		
SWD	176	292	4	472	77
LWD	0	0	0	0	0
CB	1	1	1	3	<1
SB	24	76	1	101	17
LB	11	15	1	27	4
UB	7	1	0	8	1
Total	219	385	7	611	
Percent	36	63	1		100

[a] SWD = Small Woody Debris, LWD = Large Woody Debris, CB = Cobble, SB = Small Boulder, LB = Large Boulder, UB = Undercut Bank.

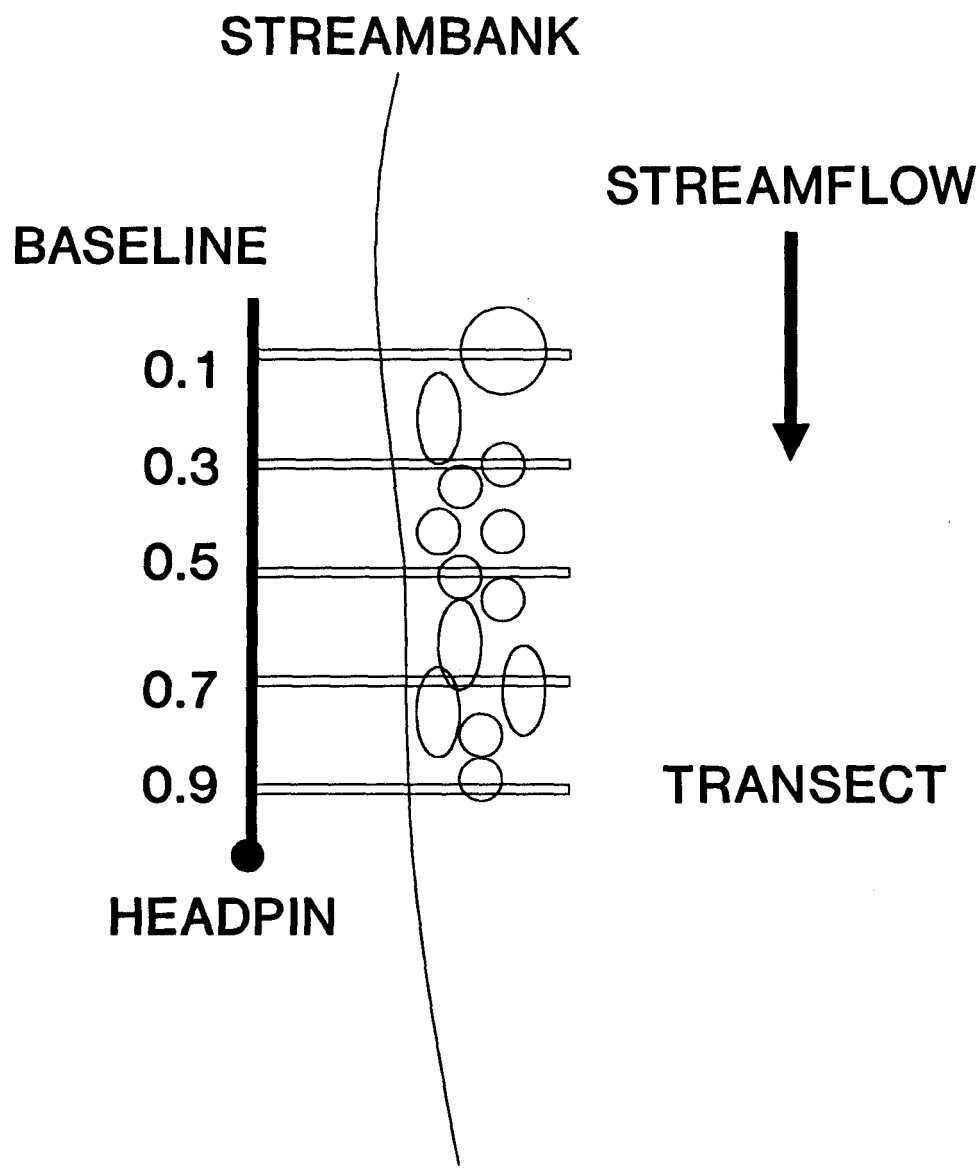


Figure 3. Map of a typical habitat site in the South Fork Snake River.

survey rod. Stream bottom elevations were subtracted from the headpin elevation to give a relative elevation for each point. Cover and substrate were also classified at each point. Finally, the relative elevations of the baseline and the stream bottom were mapped to scale on graph paper. Substrate and cover were mapped to scale on transparencies that could be overlain. Cover polygons were constructed by interpolating between points.

Peak discharge of >22,200 cfs during a late spring 1991 runoff event (Figure 4) eliminated over half (66) of the original 122 sites. Habitat sites were considered unusable for mapping and measurement if headpins had moved or were missing. We also used photographs and maps to identify and eliminate sites which had experienced major channel changes caused by erosion or deposition. Sites where the channel had not visibly changed were used even if the cover, especially small woody debris, had been altered. These sites were still considered usable because cover had been previously mapped. We attempted to resurvey some of the sites, but time did not permit resurveying and remapping all of them. We assumed channel changes would average out, i.e. some sites would increase in elevation, some would decrease, but channel controls would remain about the same.

From October to December 1991, BOR provided six different flows at Palisades Dam in order to complete our habitat mapping measurements. Flows were 3,370, 2,430, 2,000, 1,540, 1,240, and 830 cfs. During each of these flows we returned to the remaining 56 sites to measure headpin and water surface elevations. Water surface elevations were measured at the 0.1, 0.5, and 0.9 transects, except at larger sites where we measured all five transects (0.1, 0.3, 0.5, 0.7, 0.9). Water surface elevations were subtracted from the headpin elevation to give a water surface relative elevation for each transect. For each point along a transect, subtracting the stream bottom relative elevation from the water surface relative elevation gave the depth of the water column.

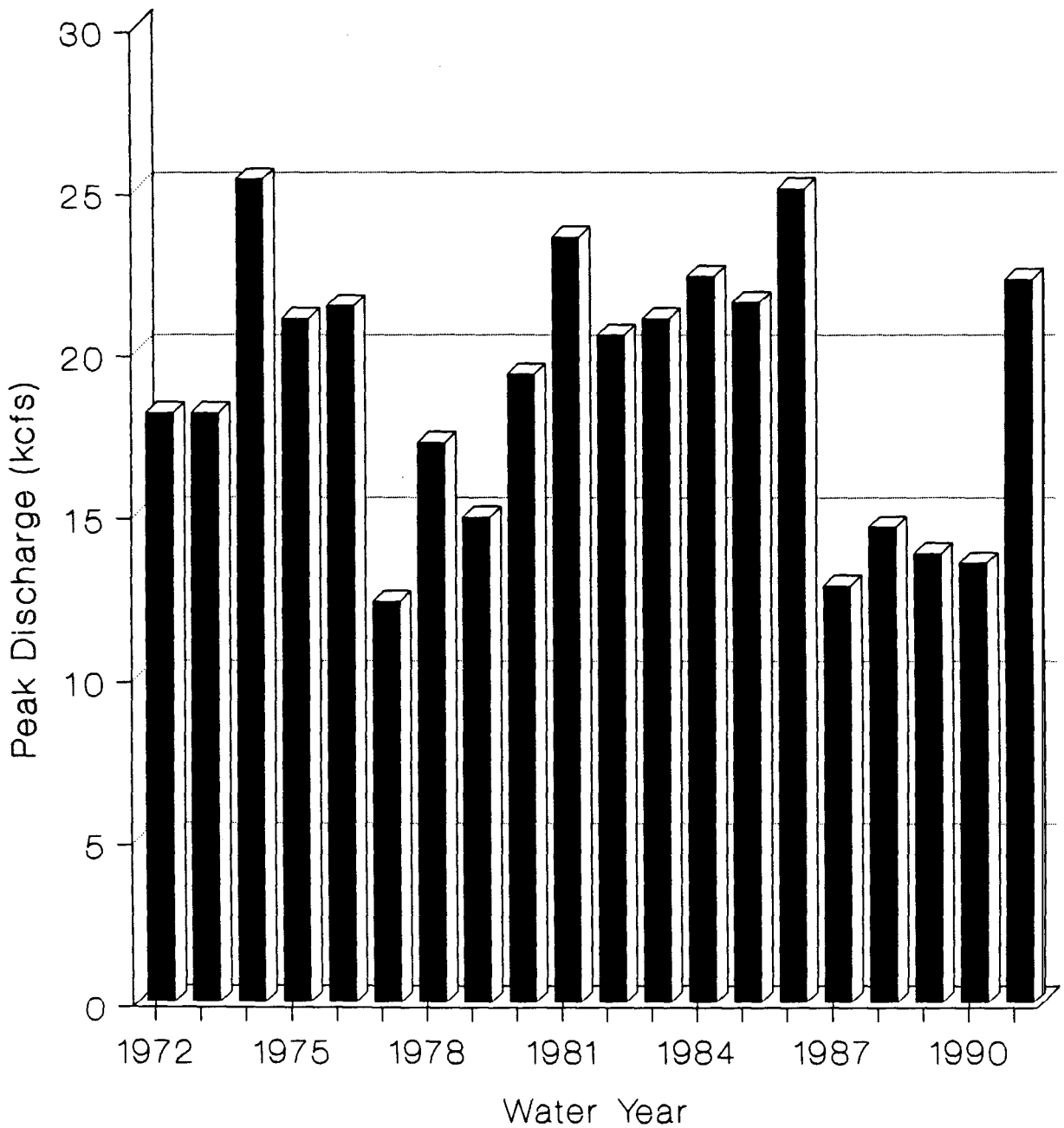


Figure 4. Peak discharge for water years 1972-92 at the Irwin gauging station just below Palisades Dam, South Fork Snake River (USGS, unpublished data).

Thirty sites above the Dry Bed Canal were used to complete the mapping and to develop the flow versus habitat relationships (Table 4). Twenty-six sites in the lower one-third of the river (below the Dry Bed Canal) were not used because large irrigation withdrawals kept flows in this section low and they (Figure 5) did not correlate to discharge at Palisades Dam until the end of the irrigation season (October 31).

Using the calculated water column depths, wetted edges and one foot depth contours were mapped to scale on transparencies that could be overlain. The contours were interpolated between measured points. Six different depth contour maps, one for each flow, were made for each of the 30 sites.

Once the maps were made, we measured surface areas of available habitat. We laid the depth contour map over the cover map and measured surface areas of cover by depth interval for each flow. A Lasico Model 42-P digital planimeter, calibrated for different map scales, was used for measuring. Measurements were made twice and averaged; if the measurements were >5% of the averaged value, we remeasured them until average values were <5%.

Surface areas were then weighted using utilization functions, summed over the depth intervals, and summed over the sites to estimate the weighted available habitat at each flow for each species. "Weighing factors" were species specific and were the probability of fish using a particular type of habitat. Our weighing factors were derived for subyearling fish at night from the winter habitat use portion of this study. Griffith and Smith (1991) found 61-66% of estimated juvenile trout emerged each night in the South Fork Snake River during the winter. We used channel type, cover type, and depth at night as the most important habitat variables to juvenile salmonids in the South Fork Snake River (Griswold 1991). Other habitat components such as substrate, velocity, and temperature were not used as weighing factors. Hence, each measured surface area was weighted by multiplying by a channel, cover, and depth weighing factor.

Table 4. Final sample size of habitat sites evaluated on the upper (above the Dry Bed Canal) South Fork Snake River. Percent of the original upriver count is in parentheses.

Predominant cover type[a]	Channel type: Side	Main	Back	Total	Percent of sample
SWD	15	4	1	20 4)	67
LWD	0	0	0	0 (0)	0
CB	1	0	0	1 (33)	3
SB	0	8	0	8 (8)	27
LB	0	1	0	1(4)	3
UB	0	0	0	0(0)	0
Total	16 (7)	13 (3)	1 (14)	30 (5)	
Percent of sample	53	43	3		100

[a] SWD = Small Woody Debris, LWD = Large Woody Debris, CB = Cobble, SB = Small Boulder, LB = Large Boulder, UB = Undercut Bank.

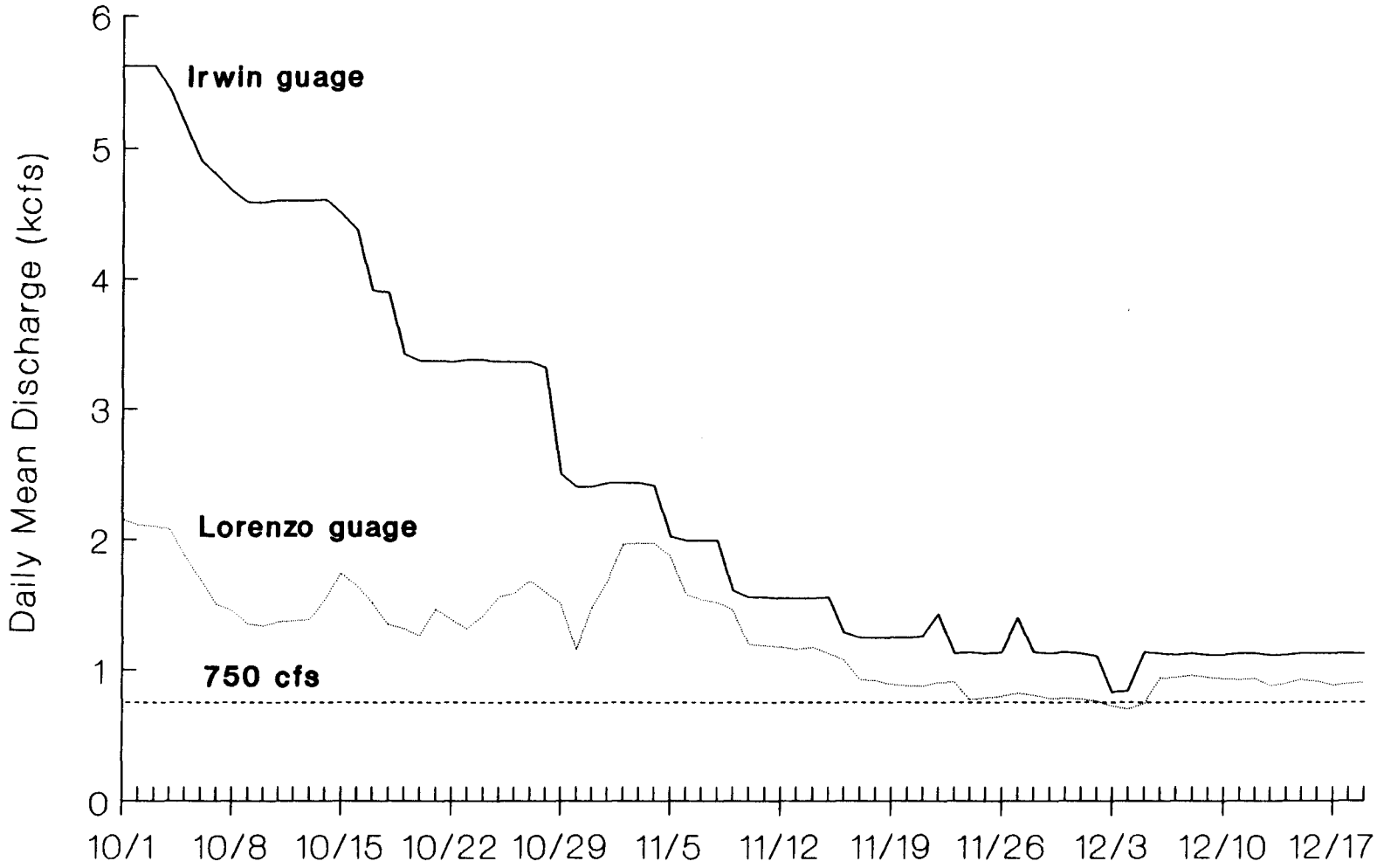


Figure 5. Hydrographs at the Irwin and Lorenzo gauges during autumn 1991 requested flow regime, South Fork Snake River (USGS, unpublished data).

Summing the weighted surface areas gave the weighted area for each site, and summing the site areas gave the weighted available habitat for the sample at each flow.

Data Management and Statistical Analysis

We used a computer spreadsheet (Lotus 1-2-3) for data management and analysis. No statistical comparisons were performed.

RESULTS

Winter Habitat Use

Over 56 hours were spent in the water during 149 dives. Snorkel gear was used for 139 of the dives, and 10 dives were made using SCUBA. Project personnel randomly sampled 105 areas for fish; 44 were sampled both day and night, 35 during the day only, and 26 at night only. Water temperatures ranged from 33 to 43°F during diving.

Nighttime densities of subyearling cutthroat trout, brown trout, and mountain whitefish were highest in side channels (Table 5; Figure 6). Cutthroat trout density was higher than the other species in side and main channels, but mountain whitefish density was higher in backwaters. Densities in side channels ranged from 14.8 cutthroat trout/100 yd^2 to 1.6 brown trout/100 yd^2. Cutthroat trout density was higher in the main channel than in backwater areas, but

Table S. Mean nighttime densities (fish/100 yd^2) of subyearling cutthroat trout, brown trout, and mountain whitefish by channel type in the South Fork Snake River. Sample size is the number of areas dived during winter, 1990-91.

Channel type	Sample size	Mean Density (fish/100 yd^2)		
		Cutthroat trout	Brown trout	Mountain whitefish
Side	31	14.8	1.6	10.9
Main	26	5.8	0.7	0.4
Backwater	9	1.9	0.6	4.5
Combined	66	7.6	1.0	5.3

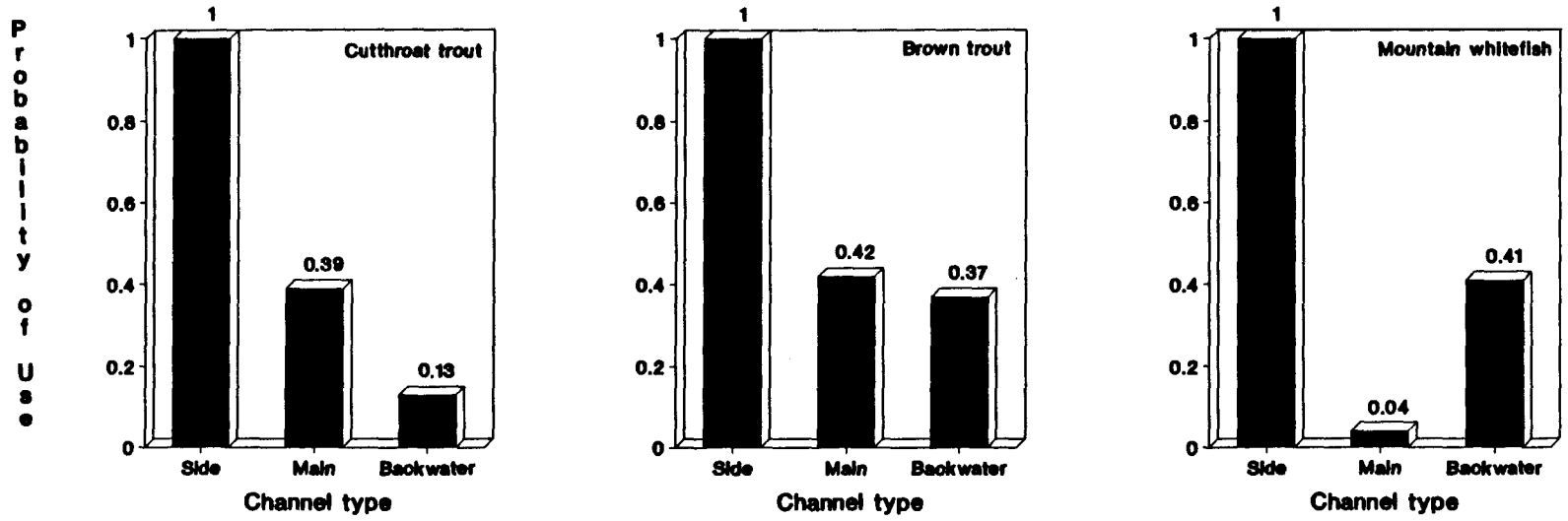


Figure 6. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various channel types found in the South Fork Snake River during winter 1990-91 (n=66).

densities were nearly equal for brown trout. Mountain whitefish density was higher in backwater areas than main channels.

Nighttime densities of subyearling cutthroat trout, brown trout, and mountain whitefish were highest in small woody debris (Table 6; Figure 7). Except for areas that lacked cover, cutthroat trout densities were always larger than other species. Cutthroat trout density was next largest in aquatic vegetation, but only one area was sampled. Cutthroat trout densities were intermediate in small and large boulder and large woody debris areas, and were low in areas with cobble and no cover. Brown trout densities were next highest in areas with large and small boulders and large woody debris. Their densities were low in areas with aquatic vegetation, cobble, and no cover. Unlike the other species, mountain whitefish densities were next highest in areas with no cover, and they were not observed using small or large boulders or large woody debris. Their densities were low in aquatic vegetation and cobble areas.

Mean distance to nearest cover was less than 1.0 ft for subyearling trout at night, but ranged from 0.0 to 15.7 ft for cutthroat (n = 222) and 0.0 to 4.0 ft for brown trout (n = 65). Mountain whitefish were found farther from cover with a mean distance of 5.6 ft and a range of 0.0 to 29.3 ft (n = 30).

Relative to the other species, subyearling cutthroat trout used a narrower range of water column depths at night (Figure 8; Appendix A-1 to A-3). Preferred depths for this species were 1.3 to 1.6 ft, and depths used ranged from 0.3 to 4.4 ft (n = 235). Brown trout and mountain whitefish used a wider range of depths with the preferred between 1.3 to 3.3 ft. They used depths ranging from 1.0 to 10.0 ft for brown trout (n = 78) and 0.6 to 15.0 ft for mountain whitefish (n = 116). Mean focal point depths were 0.20 ft for subyearling cutthroat trout at night, 0.14 ft for brown trout, and 0.10 ft for mountain whitefish.

Table 6. Mean nighttime densities of subyearling cutthroat trout, brown trout, and mountain whitefish by cover type in the South Fork Snake River. Sample size is the number of areas counted during winter, 1990-91.

Channel Type[a]	**Sample** size	Density (fish/100 yd^2) Cutthroat trout	Brown trout	Mountain whitefish
NC	13	1.5	0.5	9.6
AV	1	18.5	0.0	2.3
CB	12	3.6	0.2	0.2
SB	10	11.3	1.3	0.0
LB	7	9.0	2.0	0.0
SWD	22	38.5	4.0	14.9
LWD	1	7.0	1.4	0.0
Combined	66	7.6	1.0	5.3

[a] NC = No Cover, AV = Aquatic Vegetation, CB = Cobble, SB = Small Boulder, LB = Large Boulder, SWD = Small Woody Debris, LWD = Large Woody Debris.

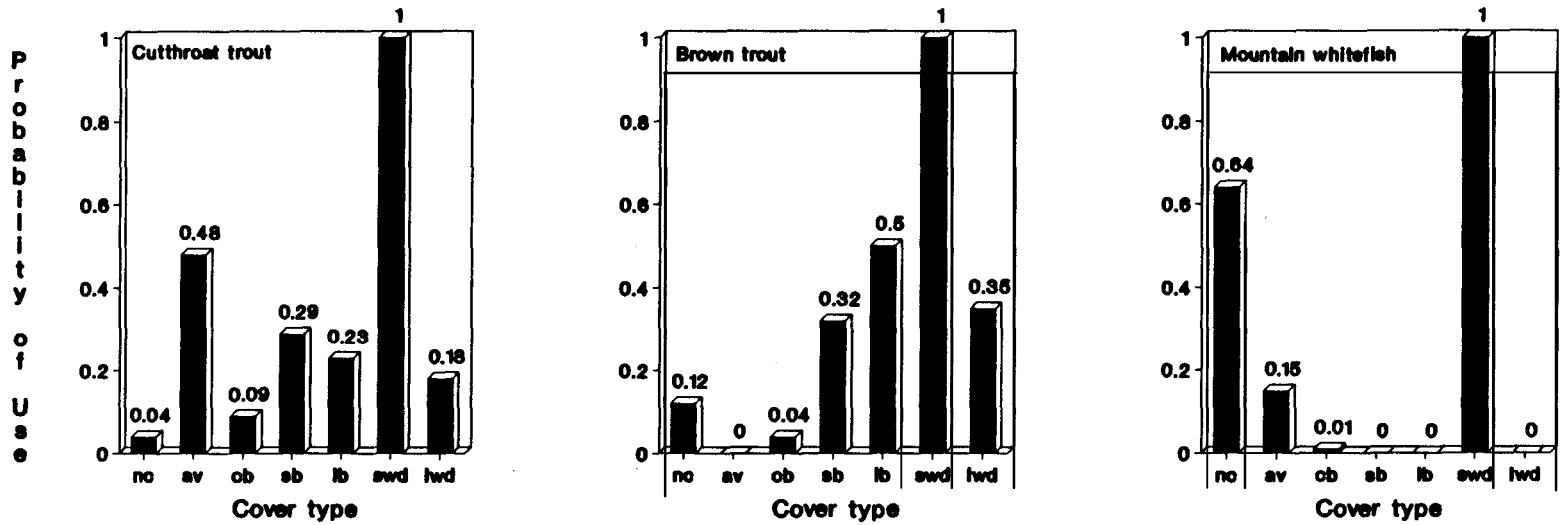


Figure 7. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various cover types found in the South Fork Snake River during winter 1990-91 (n=66). Cover types are: nc=no cover, av=aquatic vegetation, cb=cobble, sb=small boulder, lb=large boulder, swd=small woody debris, and lwd=large woody debris.

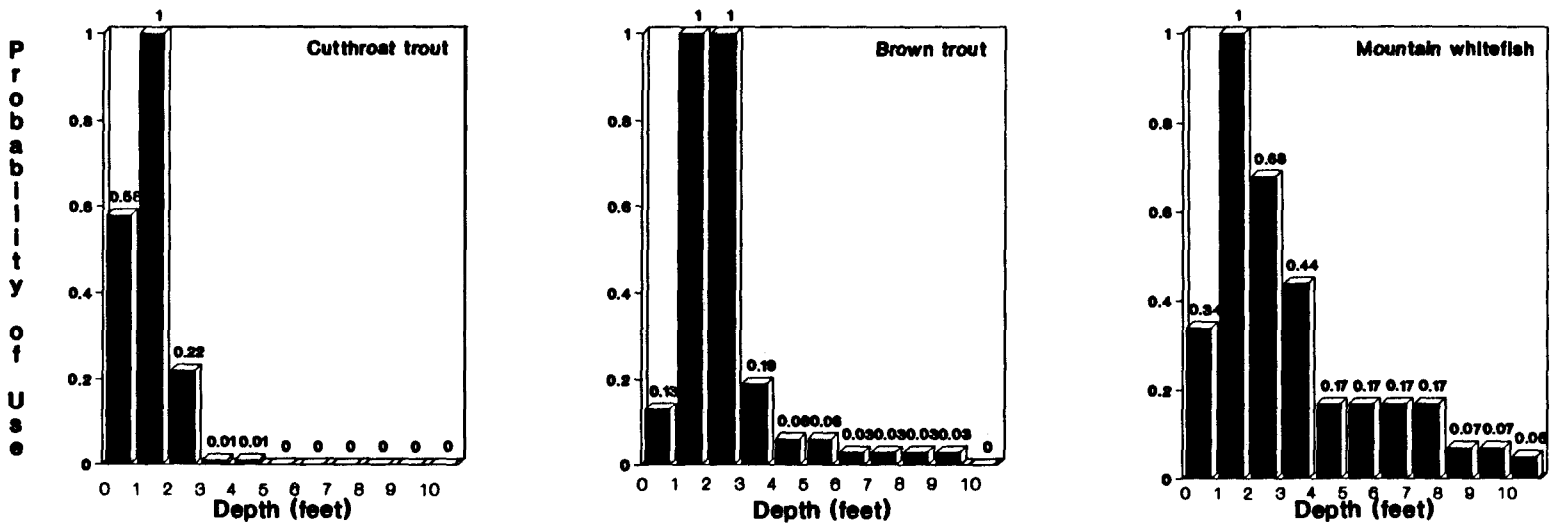


Figure 8. Probability of use for subyearling cutthroat trout, brown trout, and mountain whitefish at night for various water depths in the South Fork Snake River during winter 1990-91 (n=66).

Preferred nighttime mean water column velocities for all species was less than 0.2 ft/s. The maximum water column velocities observed were 1.80 ft/s for subyearling cutthroat trout, 0.83 ft/s for brown trout, and 1.43 ft/s for mountain whitefish (Appendix A-4 to A-6). Focal point velocities reflected this use of near zero water column velocities, with the preferred for all species less than 0.1 ft/s. No fish were observed with focal point velocities greater than 0.8 ft/s (Appendix A-7 to A-9).

Nighttime use of substrate by subyearling trout, in descending order of frequency, was generally cobble, large boulder, fines, small boulder and gravel (Appendix A-10). Mountain whitefish differed from cutthroat and brown trout in that they used relatively fewer areas with small and large boulders and more areas with fines and gravel. Densities at night verses day were 2.5,2.2, and 3.2 times higher for cutthroat trout, brown trout, and mountain whitefish, respectively (Appendix B and C).

Winter habitat use data was insufficient for analysis of subyearling salmonids during day and for yearlings during day and night. However, we report their densities by channel and cover types (Appendix B) and any habitat use data with more than 20 observations (Appendix C) for possible application in other habitat models.

Flow versus Habitat Relationships

Weighted available habitat of the 30 sites sampled in the upper South Fork Snake River decreased with discharge, but not at a constant rate (Figure 9). The flow versus habitat relationship for each species is curvilinear with the greatest rate of loss occurring between 1,540 and 1,240 cfs. The rate of habitat loss declined between 1,240 and 830 cfs.

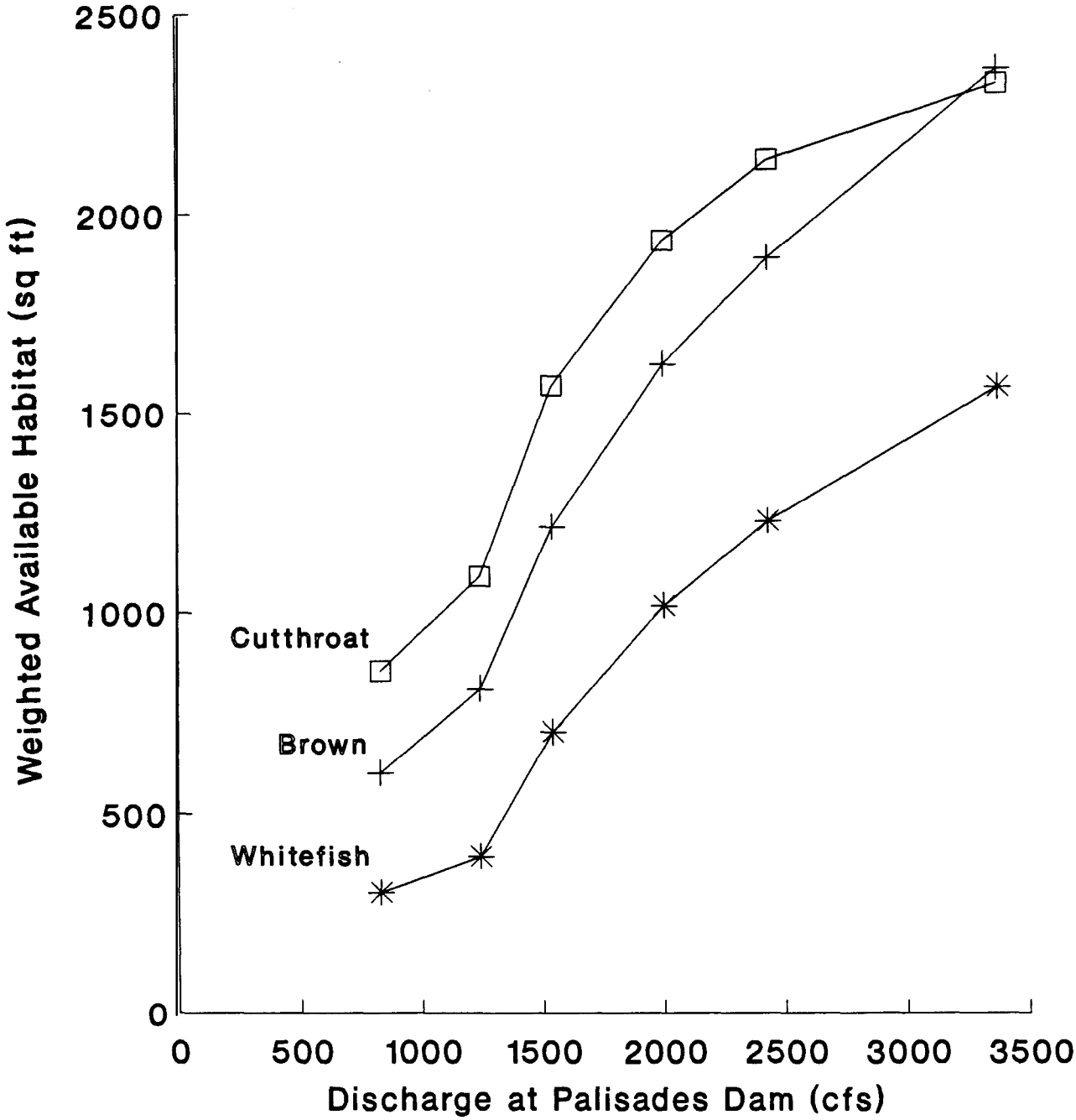


Figure 9. Relationships of weighted available habitat with discharge in the upper (above the Dry Bed Canal) South Fork Snake River. Weighted available habitat is the sum of the 30 sited sampled during autumn 1991.

Of the weighted habitat available to subyearling cutthroat trout at 3,370 cfs, one-third (33%) was lost as flows were reduced to 1,540 cfs, and over half (53%) was lost at 1,240 cfs (Table 7, Appendix D-1). For brown trout, about half (49%) was lost at 1,540 cfs and two-thirds (66%) at 1,240 cfs (Table 7, Appendix D-2). And for mountain whitefish, over half (55%) was lost at 1,540 cfs and three-fourths (75%) at 1,240 cfs (Table 7, Appendix D-3).

Unweighted available habitat of the 30 sites sampled also decreased with discharge, but the rate of loss increased below 1,540 cfs (Figure 10). Unlike the above weighted relationship, rates of loss were approximately constant but unequal above and below the 1,540 cfs inflection point. Like the above relationships, however, the greatest rate of loss occurred below 1,540 cfs. Of the unweighted habitat available to juvenile salmonids at 3,370 cfs, one-fourth (26%) was lost as flows were reduced to 1,540 cfs, over one-third (28%) was lost at 1,240 cfs, and over one-half (53%) was lost at 830 cfs (Table 8, Appendix D-1 to D-3).

DISCUSSION

Winter Habitat Use

We evaluated winter habitats used by juvenile salmonids during both day and night, but concentrated our efforts on nighttime use. Daytime observations were inadequate for analysis of juveniles habitat use in the South Fork Snake River. Wintering juveniles move into concealment cover during the day in the South Fork Snake River where they are less visible to divers (Griffith and Smith, 1991). Densities were 2 to 3 times higher at night than during the day for cutthroat trout, brown trout, and mountain whitefish. After consulting with cooperating

Table 7. Percent loss of weighted available habitat (WAH) with reduced discharge in the upper (above the Dry Bed Canal) South Fork Snake River. WAH is the sum of the 30 sites sampled; percent loss is the difference in WAH relative to 3,370 cfs.

Discharge at Palisades Dam (cfs)	Cutthroat trout WAH (sq ft)	Cutthroat trout % Loss	Brown trout WAH (sq ft)	Brown trout % Loss	Mountain whitefish WAH (sq ft)	Mountain whitefish % Loss
3,370	2,325	0	2,363	0	1,566	0
2,430	2,136	8	1,890	20	1,230	21
2,000	1,933	17	1,624	31	1,017	35
1,540	1,569	33	1,215	49	705	55
1,240	1,091	53	811	66	395	75
830	856	63	603	74	305	81

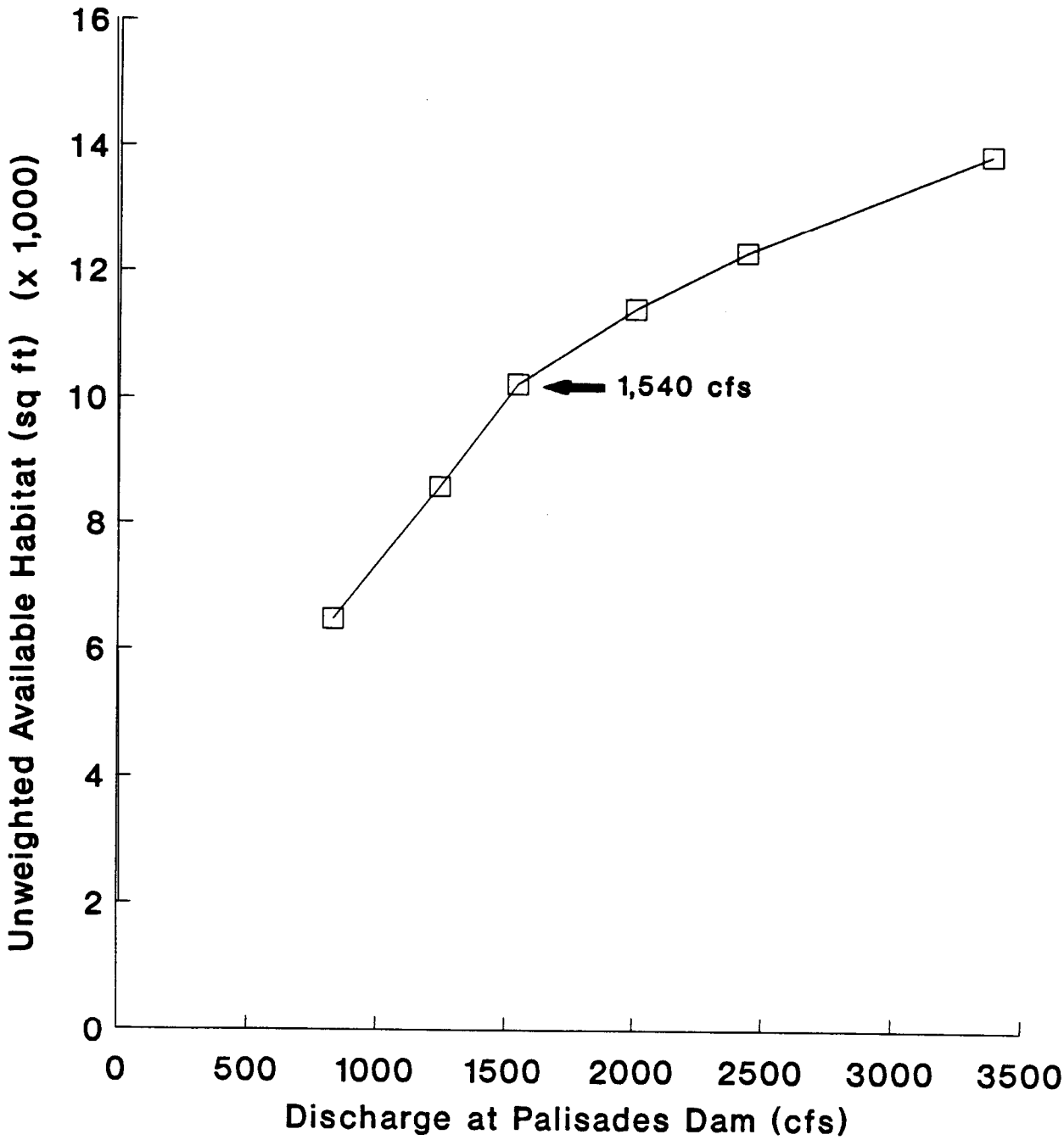


Figure 10. Relationships of unweighted available habitat with discharge in the upper (above the Dry Bed Canal) South Fork Snake River. Unweighted available habitat is the sum of the 30 sites sampled during autumn 1991.

Table 8. Percent loss of unweighted available habitat (UAH) with reduced discharge in the upper (above the Dry Bed Canal) South Fork Snake River. UAH is the sum of the 30 sites sampled; percent loss is the difference in UAH relative to 3,370 cfs.

Discharge at Palisades Dam (cfs)	UAH	Percent loss
3,370	13,901	0
2,430	12,319	11
2,000	11,417	18
1,540	10,228	26
1,240	8,602	38
830	6,488	53

agencies during late winter 1991 we decided to concentrate our efforts on nighttime work, which allowed us to collect sufficient data. Fish generally stayed within one foot of concealment cover when they emerged at dusk, and we never observed them leaving an area of habitat that we measured. Although habitat use changes between day and night, Griffith and Smith (1991) believe that the differences are not large since all fish are concentrated in near shore areas.

We evaluated winter habitats used by subyearling and yearling salmonids, but we observed few yearlings and concentrated our efforts on subyearlings. Our observed low densities of yearlings (0.0 to 0.8 fish/100 yd^2) may be a result of poor recruitment but was compounded by difficulties we encountered during sampling. Yearlings in the South Fork Snake River used a wider range of habitats than subyearlings and were more difficult to observe. Yearlings were found in habitats ranging from the shallow water areas with dense concealment cover used by subyearlings to deep pools with little physical cover used by adult fish. The yearlings we observed in open water were more mobile and were disturbed more easily than subyearling fish. This, combined with relatively poor visibility (approximately 8 ft), made their identification difficult. When we were able to identify yearlings they were frequently displaced, which precluded measurement of habitat parameters.

We decided to use only channel type, cover type, and depth as weighing factors. We did not use velocity or all substrate sizes for the following reasons. First, juvenile salmonids were observed using areas with water velocities <0.1 ft/s when water temperatures were <43°F. Areas with dense cover generally provided these low velocities regardless of velocities in adjacent areas. Therefore, we believe as adequate cover is provided with discharge, young fish will be provided with near zero water velocities. Second, substrate was not included as a weighting factor because it was accounted for in our cover designations, i.e. no cover, cobble, small boulder, and large boulder. Areas

designated "no cover" lacked interstitial spaces where fish could be concealed. These included areas with fines, gravel, or larger substrate which were embedded with fines. We did not observe differences in substrate used except when used as cover (Appendices A, B, C).

Nighttime densities of subyearling salmonids varied by channel and cover type, with side channels and small woody debris being most important during winter for all species. Observations during our SCUBA sampling support the concept that subyearling salmonids generally use shallow, near-shore habitats associated with concealment cover. Side channels have been previously recognized as important wintering areas for juvenile salmonids (Bustard and Narver 1975b; Tschaplinski and Hartman 1983; Swales et al. 1986). Our results show they are important during night for mountain whitefish as well as cutthroat and brown trout.

Cutthroat and brown trout densities at night were two to four times higher in small woody debris than in small and large boulders, and 9 to 25 times higher than in cobble or areas with no cover. Close association of young trout with cover during winter has been well documented (Bustard and Narver 1975a; Rimmer et al. 1983; Johnson and Kucera 1985; Hillman et al. 1987). Our results show cover is perhaps important during night, and that woody debris cover is particularly important.

Aquatic vegetation had the second highest subyearling cutthroat trout densities at night, however, we sampled only one area. Two areas with aquatic vegetation were sampled during the day, and subyearling densities were higher in this cover type than in any other type. We observed that aquatic vegetation dies and decomposes by midwinter, forcing fish to seek other cover. Since aquatic vegetation does not persist throughout the winter, it was not included as a weighing factor to develop the flow versus habitat relationships.

Mountain whitefish do not appear to be as dependent on cover as cutthroat and brown trout. Although highest densities were observed in small woody debris, large numbers were also observed in areas devoid of physical cover as we define it (Table 1). In addition, distance to cover was greater for mountain whitefish than cutthroat and brown trout. Because we were unable to determine if mountain whitefish moved into cover during the day, we do not know if its presence is an important factor in determining juvenile habitat use. We suspect that mountain whitefish may use depth as a cover component (Figure 8).

Subyearling mountain whitefish were rarely observed, but when they were seen, they were often in schools which numbered up to 280 individuals. They were observed at night in low-velocity pools and pool tailouts in areas with little or no physical concealment cover. They were seldom seen during the day. When observed at daytime, they were using deep (>4 ft), low velocity pools near tailouts where they had been observed at night. We were unable to locate subyearling mountain whitefish during the day in many areas where they had been previously observed at night.

Flow versus Habitat Relationships

Our qualitative observations on the South Fork Snake River support the flow versus habitat relationships presented. We began to see habitat sites drying up or freezing with 1,540 cfs flow. The greatest number of sites became unusable between 1,540 and 1,240 cfs. Of our 30 study sites, one became dry or frozen at 1,540 cfs, an additional five at 1,240 cfs, and another four at 830 cfs. Most of these sites were in side channels. We also noted dramatic changes in the river between 1,540 and 1,240 cfs, but not as much change between 1,240 and 830 cfs. For example, a large number of side channels went dry between 1,540 and

1,240 cfs and floating the river became very difficult. Such a dramatic change was not observed between 1,240 and 830 cfs.

Our criteria was to call a site dry if there was no surface outflow. Standing pools, or pools with inflow but no outflow, were often observed in side channels but would probably freeze and not provide overwintering habitat to juvenile salmonids.

Our results (Figure 9) generally agree with aerial photo analysis done on the South Fork Snake River in 1988 (Figure 11; FWS unpublished data, Boise, Idaho). In both studies, winter habitat availability decreased with discharge at Palisades Dam. Decreases were at similar rates as well. Our results showed that of the weighted habitat available at 2,430 cfs, from 60 to 75% was lost as flows were reduced to 830 cfs; the aerial photo work showed more than half (56%) of the upriver side channel area was lost when flows were reduced from 2,200 to 750 cfs.

Winter flow reductions have the most potential to affect mountain whitefish habitat availability, followed by brown trout and cutthroat trout. At any given flow, the percent loss of weighted habitat (relative to that available at 3,370 cfs) was greatest for mountain whitefish followed by brown trout and cutthroat trout. Differences between the species are due to different weighing factors used. We emphasize these relationships were developed for subyearling fish at night; the relationships might be different if other age class or daytime criteria were used.

We consider our relative habitat losses with reduced discharge to be conservative for two reasons. First, optimum or peak amounts of weighted habitat were not measured, i.e. they were at flows above our requested flow regime (Figure 9). Our curves indicate that these peaks probably occurred at flows

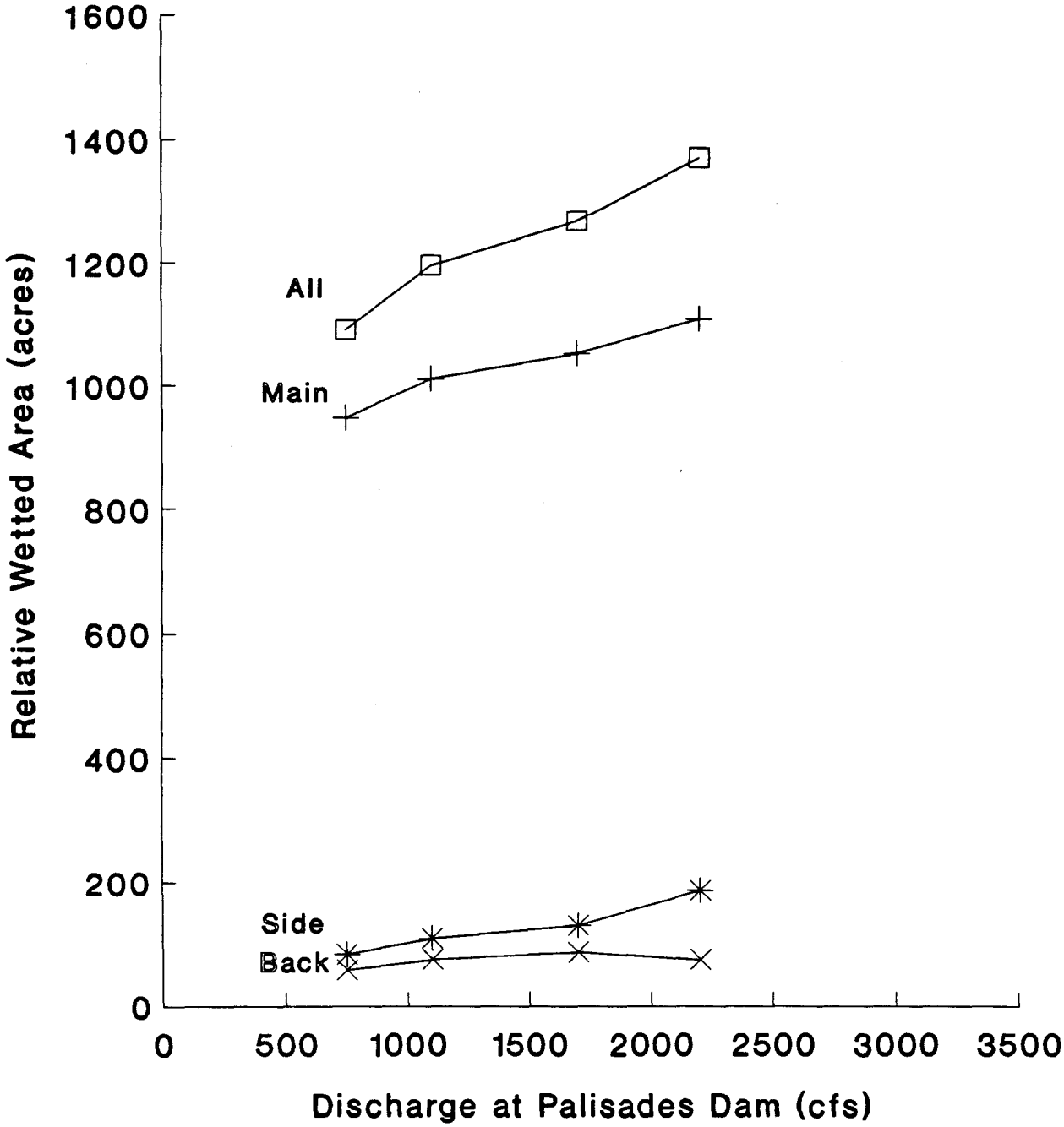


Figure 11. Relationships of relative wetted area with discharge in the upper (above Riley Ditch) South Fork Snake River. Data are from aerial photos taken during autumn 1988 (USFWS, unpublished report, Boise, Idaho).

greater than 3370 cfs. Had we measured habitat at larger flows, relative losses would have been greater as well.

Second, our random sample of habitat sites may have become biased against our most preferred cover type (small woody debris). The sample may have become biased due to the disproportionate reduction of sites by spring runoff in 1991 and our elimination of lower river sites. Small woody debris sites made up 77% of our original sample (Table 3), whereas our final sample contained only 67% (Table 4). In contrast, small boulder sites increased from 11 to 27% of the sample. Weighted habitat losses with reduced discharge may have been greater had the number of small woody debris sites not been disproportionately reduced. Alternatively, the increase in the preferred side channels from 39 to 53% may have balanced this bias.

We suspect the flow versus habitat curves developed for the river above the Dry Bed may be applied to the lower river as well. Although habitat use did not differ between the two river sections, such application would probably be conservative because of differences in channel morphology. The lower river is more braided, contains more side channels and woody debris, and is shallower on average than the upper river. As flows decrease, these important winter habitat types are probably lost at a greater rate than in the upper river. Water withdrawals further compound the effect of flow reductions at Palisades Dam in the lower river. Large amounts of water (sometimes more than half during low water years) are diverted into the Dry Bed Canal, and diversion generally continues through the winter period. As a result, flows in the lower river at Lorenzo are often less than 500 cfs (USGS, unpublished data). The lower river is also affected by erratic and extreme flow fluctuations during the autumn as a result of irrigation withdrawals at other canals. We observed little relationship between flows at Palisades Dam and flows in the lower river during our mapping efforts (Figure 5). Fish were often observed stranded in side

channels, and flow fluctuations may contribute to stranding losses by repeatedly dewatering many of these channels.

A major assumption of this study is that salmonid populations in the South Fork are limited primarily by the quantity and quality of winter habitat available to juveniles. Other investigators have shown habitat availability to be associated with higher densities of salmonids (Murphy et al. 1986; Smith 1992). This winter habitat, as we have shown, is related to flows released at Palisades Dam. Our study has provided the flow versus habitat relationships; we have not tried to provide the flow versus juvenile abundance relationships. However, population estimates show reduced numbers of juveniles from years of very low (<1,000 cfs) winter flows as compared with years of higher flows (>1,500 cfs) (Gamblin et al 1993; Elle and Gamblin 1993). This suggests that winter flows, and hence winter habitat, are limiting recruitment to the fishery. Further monitoring is needed to fully test this assumption.

RECOMMENDATIONS

Maintain a minimum flow of at least 1,500 cfs at Palisades Dam during winter. This would provide one-half to two-thirds of the juvenile salmonid habitat available at 3,370 cfs and would prevent important habitat from drying up or freezing. Additional flows above 1,500 cfs would provide additional habitat. Historic winter flows prior to Palisades Dam averaged 2,200 cfs, well above this minimum level (Figure 1).

ACKNOWLEDGEMENTS

Scott Clemons, Jeff Hursh, Larry Wade, Tom Dakai, and Kent Morrison assisted with field work in the cold and snow. Personnel from the U.S. Fish and Wildlife Service (Boise Field Office), U.S. Forest Service (Palisades District), U.S. Bureau of Land Management (Idaho Falls Office), U.S. Bureau of Reclamation, and Idaho Department of Fish and Game (Region 6) also provided field assistance. Mark Fuller, Mike McGee, Wade Sinnen, and Robyn Armstrong conducted field work and assisted with data analysis. The U.S. Forest Service (Palisades District) provided office space and housing for the project. Ray White (Trout Habitat Specialist, Edmonds, Washington), Jack Griffith (Idaho State University), Tim Cochnauer (IDFG), Richard Prange (BOR), Fred Craze (BOR), Walter Lurrick (BOR), Russ Thurow (USFS), and Steve Duke (USFWS) reviewed the manuscript. Barbara Dunn and Sherri Moedl provided word processing and graphics support. Signe Sather Blair (FWS) provided the initial energy to get this study started and coordinated the scoping group and funding. Virgil Moore provided the study design and final technical edits. Primary funding for this project was provided by the U.S. Bureau of Reclamation, Project No. O-AG-10-10920; IDFG with Federal Aid in Fish Restoration (F-73-R-14); and USFWS, Boise Field Office.

LITERATURE CITED

Bovee, R.D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper 21. United States Fish and Wildlife Service Biological Report 86(7).

Bovee, K.D., and T.C. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: fisheries. Cooperative Instream Flow Service Group, Instream Flow Information Paper No. 3. FWS/OBS-77/63.

Bustard, D.R., and D.W. Narver. 1975a. Aspects of the winter ecology of juvenile coho salmon (Oncorhvnchus kisutch) and steelhead trout (Salmo qairdneri). Journal of the Fisheries Research Board of Canada 32:667-680.

Bustard, D.R., and D.W. Narver. 1975b. Preferences of juvenile coho salmon (Oncorhvnchus kisutch) and cutthroat trout (Salmo clarki) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Cochnauer, T.C. and E. Buettner. 1978. Stream resource maintenance flow determinations on Idaho streams. Idaho Department of Fish and Game. Job Performance Report, Project F-69-R-3, Job II, Boise.

Cunjak, R.A., and G. Power. 1986. Winter habitat utilization by stream resident brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta). Canadian Journal of Aquatic Sciences 43: 1970-1981.

Elle, S., and M. Gamblin. 1993. Regional Fisheries Management Investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-15, Boise.

Gamblin, M., S. Elle, and J. Tharp. 1993. Regional Fisheries Management Investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-16, Boise.

Griffith, J.S., and R.W. Smith. 1993. Us of winter concealment cover by juvenile cutthroat and brown trout in the South Fork of the Snake River, Idaho. North American Journal of Fisheries Management, 13:823-830.

Griswold, R. 1991. Winter Habitat availability and utilization by juvenile cutthroat, brown trout, and mountain whitefish in the South Fork of the Snake River, Idaho. Annual Progress Report. Project 0-AG-10-10920. Idaho Department of Fish and Game. Boise.

Hall, J.D., and N.J. Knight. 1981. Natural variation in abundance of salmonid populations in streams and its implications for design of impact studies. U.S. Environmental Protection Agency EPA-600/53-81-021. Corvallis, Oregon.

Hillman, T.W., J.S. Griffith, and W.S. Platts. 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho Stream. Transactions of the American Fisheries Society 116:185-195.

Jeppson, P. 1970. South Fork of Snake River investigations. Test for increasing the returns of hatchery trout. Job Completion Report, F-32-R-12, Job No. 2. Idaho Department of Fish and Game. Boise.

Johnson, J.H., and P.A. Kucera. 1985. Summer-autumn habitat utilization of subyearling steelhead trout in tributaries of the Clearwater River, Idaho. Canadian Journal of Zoology 63:2283-2290.

Mason, J.C. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. Journal of Wildlife Management 40:775-778.

Moore, V.K., K. Aslett, and C. Corsi. 1981. Palisades Reservoir creel census and tributary evaluation. Job Performance Report. River and Streams Investigations. Idaho Department of Fish and Game, Boise.

Murphy, M., J. Heifetz, S.W. Johnson, K.V. Koski, and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fish and Aquatic Sciences, 43:1521-1533.

Platte, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. United States Department of Agriculture, United States Forest Service, Intermountain Experiment Station, General Technical Report INT-138. Ogden, Utah.

Rimmer, D.M., U. Paim, and R.L. Saunders. 1983. Autumnal habitat shift of juvenile Atlantic salmon (Salmo salar) in a small river. Canadian Journal of Fish and Aquatic Sciences 40:671-680.

Sheppard, J.D., and J.H. Johnson. 1985. Probability-of-use for depth, velocity, and substrate by subyearling coho salmon and steelhead in Lake Ontario tributary streams. North American Journal of Fisheries Management 5:277-282.

Smith, R.W. 1992. Effects of concealment cover availability and water temperature on overwinter survival of juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. Masters Thesis. Idaho State University, Pocatello.

Swales, S., R.B. Lauzier, and C.D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology 64:1506-1514.

Tschaplinski, P.J., and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhvnchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwintering survival. Canadian Journal of Fish and Aquatic Sciences 40:452-461.

Whitfield, M.B., S.M. Patla, and P.F. Brussard. 1988. Greater Yellowstone Ecosystem. Annual Report. United States Department of the Interior. Bureau of Land Management. Idaho Falls, Idaho.

A P P E N D I C E S

Published as a separate document
Available upon request

Idaho Department of Fish and Game
Boise, Idaho

Submitted by:

William C. Schrader
Senior Fishery Research Biologist

Robert G. Griswold
Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
Bureau of Fisheries

Virgil K. Moore
Fishery Research Manager