

# **Final Report Flaming Gorge Tailwater Fisheries Investigations**



## **Growth, Survival and Microhabitat Selection in the Green River of Utah 1978-1982**

**Funding Provided by the United States Department of Interior  
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FINAL REPORT  
FLAMING GORGE TAILWATER FISHERIES

INVESTIGATIONS:

Trout Growth, Harvest, Survival, and Microhabitat  
Selection in the Green River, Utah, 1978-82

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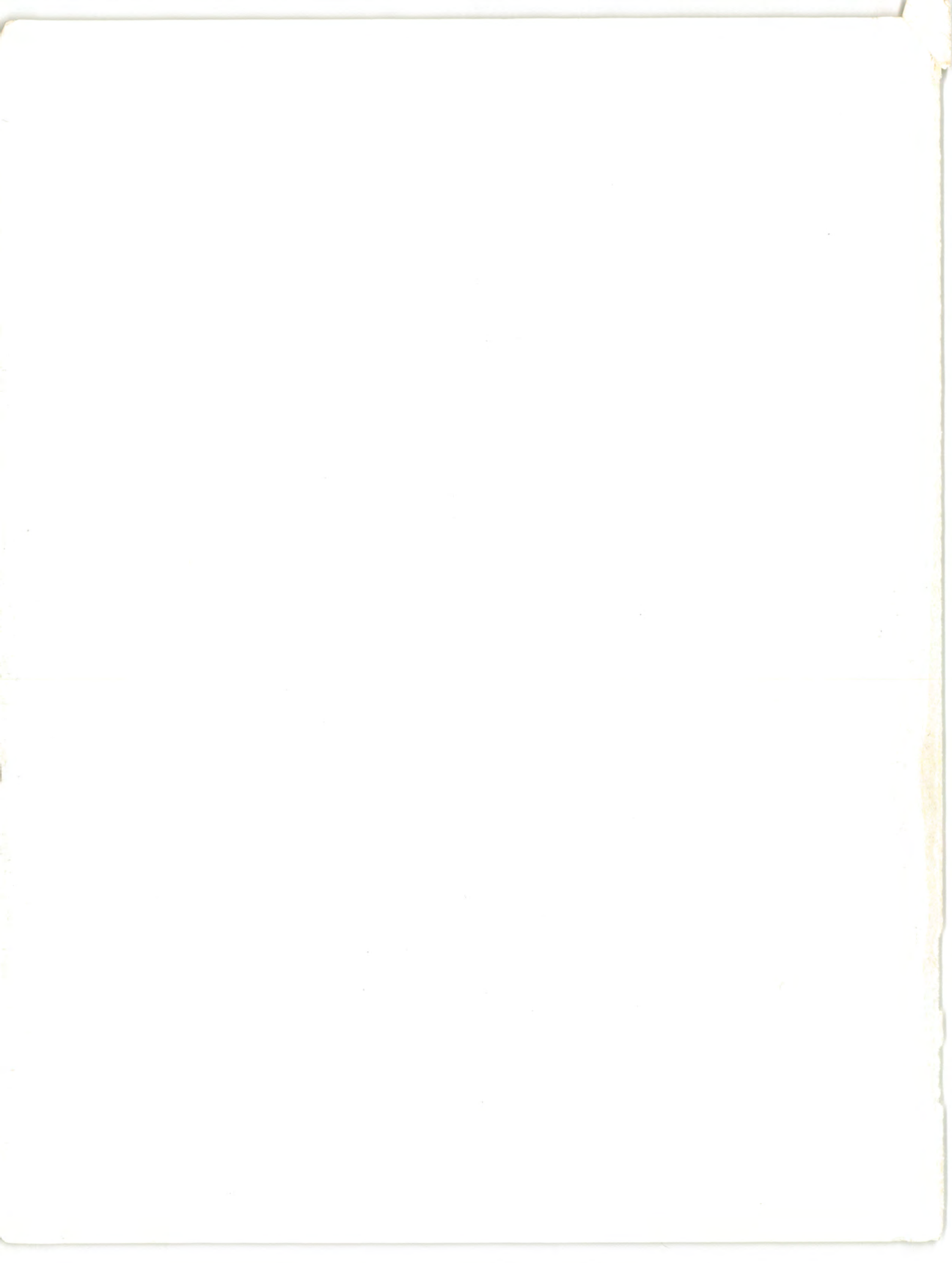
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Wildlife Resources





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## EXECUTIVE SUMMARY

### Introduction

The inlet works to Flaming Gorge Dam were modified in 1978 to permit withdrawal of epilimnetic waters from Flaming Gorge Reservoir. This modification was primarily to produce warmer temperatures and thereby increase growth of trout in the 47.2 km tailwater between Flaming Gorge Dam and the Colorado - Utah state line. In 1978, the United States Bureau of Reclamation (BOR) provided funding to the Utah Division of Wildlife Resources (UDWR) to document response of trout growth and angler utilization to the penstock modification. In 1980 the study was expanded to include an investigation of what appeared to be unacceptably low survival of fingerling trout stocked in the tailwater. Concurrently, BOR proposed that additional turbines be installed in Flaming Gorge Dam to increase power generation during periods of peak power demand, resulting in the need to evaluate the effects of discharge upon trout habitat. Consequently, the Flaming Gorge tailwater study was composed of three elements: 1) response of the tailwater fishery to the warmer temperatures produced by the penstock modification; 2) survival of trout planted in the tailwater; and 3) habitat conditions for trout at various levels of discharge. The purpose of this report is to draw together the findings of these three study elements, to use the study findings to synthesize management recommendations, and to identify further needs for research. Although investigations have continued and other study elements have since been funded, this report will be confined to studies from September 1978 through November 1982. Harvest data are presented for 1983-1985 but only to track survival of trout originating during the 1978-1982 study years.



### Trout Growth

In 1978, the penstock inlets of Flaming Gorge Reservoir were modified to permit selective withdrawal of warmer, epilimnetic water from the reservoir. As a result, growth of rainbow and cutthroat trout in the tailwater increased to levels above those recorded any time prior to 1978. Annual growth increased approximately 3-fold over that measured in 1976. Consequently, trout fingerlings stocked at 100-125 mm (4-5 inches) total length (TL) in May began contributing to the creel during their first summer at large. In contrast, the 1976 year class of fingerlings, stocked prior to the penstock modification, required two years in the tailwater to reach a catchable size. Prior to the modification, growth was fastest at Browns Park, the downstream extremity of the Utah tailwater, and slowest at the dam. Following penstock modification, growth had increased at all stations, but fastest growth was registered at the tailrace.

The modification has, therefore, met the objectives for enhanced trout growth set forth in the 1975 Environmental Assessment of the penstock modification project. Growth is now comparable to that in other productive western tailwaters, such as the Bighorn River below Yellowtail Dam and the Beaverhead River below Clark Canyon Dam, Montana.

The increase in growth undoubtedly resulted from the direct effect of the warmer water temperatures in summer on trout metabolic rate. Other indirect mechanisms may also have been involved. Benthic invertebrates, a major food for trout, increased in diversity and abundance. Warmer temperatures, and the more natural synchronization of temperature and photoperiod cycles, contributed to increases both in macroinvertebrate biomass and species diversity.

### Survival of Trout Planted in the Tailwater

Harvest, use, and yield reached record levels in 1981, 3 years after the penstock modification became operational. The record yield of 111 kg/ha (99 lb/ac) in 1981 was not sustainable, and angler use and success rates fell in subsequent years. The outstanding success experienced by anglers in 1981 was due to the combination of warmer water temperatures, which stimulated the tailwater's productivity, and exceptional survival of trout fingerlings planted in 1980, an estimated 30% of which were harvested during 1981. No other stocking of fingerling trout during the 1978-1982 study period produced second year creel returns of more than 8.2%, and even the 1980 stockings contributed significantly for only two years.

The successful fingerling stockings of 1980 were introduced earlier and at larger mean TL than any other cohorts; thus, by winter 1981 many of these fish may have recruited to the adult (larger than 250 mm) life stage. Trout that were larger than 300 mm when tagged prior to the winter of 1982 experienced much higher angler tag returns the next summer than those less than 300 mm TL. Sampling in Dinosaur National Monument, Colorado, downstream of the study area, demonstrated that some trout emigrated downstream from the tailwater during winter to habitats that were marginal for trout. The emigration appeared to be largely confined to juvenile trout. Creel statistics for stocked fingerlings suggested that winter natural mortality of juvenile trout ranged near 90% in most years. Natural mortality of adult trout, based upon angler catch curves, appeared to be much lower than that of juveniles.

Instability of the sportfishery and disappointing survival rates of stocked fingerlings were the result of the interactions of factors



involving physical habitat limitations, fishery management practices, reservoir operations, and behavioral and physiological responses of the trout to the tailwater environment.

#### Habitat Conditions as Functions of Lifestage and River Discharge

Physical habitat simulation (PHABSIM) models were employed to evaluate seasonal habitat conditions. Microhabitat electivity data for rainbow and cutthroat trout, juveniles and adults, were collected during summer and winter at different levels of discharge. These data were then integrated with physical models of three winter habitat types located at the Tailrace, Pipe Creek, and Indian Crossing. The resulting model projections strongly suggested habitat for trout less than 250 mm (10 inches) TL was relatively scarce in winter, at least at the three habitat simulation stations. Conditions were apparently not limiting for either adult or juvenile trout in summer or for the adult life stage in winter. Results and observations of other study elements appeared to verify the PHABSIM projections.

In general, there appeared to be more usable winter habitat for trout at lower levels of discharge. The habitat simulation stations at Pipe Creek and Indian Crossing were, together, probably the most representative of the tailwater's winter habitats. The output from these two stations produced an inverse relationship between total weighted usable area and discharge. Overall winter habitat was greater at Pipe Creek and Tailrace than at Indian Crossing. There was a positive relationship between weighted usable area and discharge at Tailrace. These model projections were corroborated by the substantially higher tag return rates (reflecting higher winter survival) for trout tagged prior to winter at and near the tailrace.



Juvenile trout appeared to select certain large pool areas offering consistently low water velocity. Such sites appeared to be conducive to energy-conserving "random swimming" activity. In higher velocity areas, the trout were oriented to the current, an activity we referred to as stationary swimming. Swimming speed of fish engaged in stationary swimming activity was a positive function of discharge rate. As discharge increased, it appeared that many trout abandoned the energy conserving random swimming mode, perhaps due to increased water velocities in certain pool areas and, simultaneously, the facing velocity for stationary swimming activity increased. The net effect of increasing discharge, therefore, appeared to be an increase in energy expenditure. This increased activity level would tend to be more taxing for smaller trout. Metabolic rate is considerably higher among smaller fish and swimming efficiency increases with body length.

It appeared, therefore, that for the majority of the tailwater, usable area and juvenile trout survival in winter were favored at lower discharge levels. The winter of 1982 was one of relatively high discharge. That winter only juvenile trout near the dam experienced satisfactory survival, based upon pre-winter tagging. Scuba observations suggested the emigration of juvenile trout in 1982 peaked during and immediately after a month-long period of high winter discharges. Fingerling trout stocked in 1980 were subjected to the lowest winter discharges of the study period, which may have contributed to their exceptional survival in the winter of 1981. Angler catch curves suggested that survival of adult trout may have suffered during a year of exceptionally high discharges from June 1983 - May 1984.

Those trout that survived winter were subject to high angler induced mortality during the ensuing fishing season. Total harvest during the study period ranged from 53-111 kg/ha (47-99 lb/ac), levels that approximate total fish biomass densities of many other Utah watercourses. Summer catch curves indicated mortality during the angling season exceeded 60% for trout that were fully recruited to the fishery. Almost all tag returns were received during the first angling season following each marking study. Estimates of hooking mortality (mortality of fish caught and released by anglers) ranged from 16,000 - 64,000 trout/yr.

Thus, it appeared that fishery management practices were at odds with the river's physical habitat limitations, habitat constraints attendant with operating criteria for the Flaming Gorge hydroelectric units, and with high rates of angler harvest.

#### Recommendations

The following fishery management recommendations have been implemented as a result of this study and are currently being evaluated:

1. Trout should be stocked at 150 mm (6 inches) TL in early May. Summer growth averaged near 30 mm (1.2 inches)/month during the study period. Therefore, trout stocked in early May at 150 mm TL should exceed 300 mm TL by their first winter. The majority of these trout should recruit to the adult life stage prior to experiencing winter conditions and, theoretically, experience considerably higher first winter survival.

2. To better utilize the available habitat for adult trout and enhance the quality element of the sportfishery, trout between 330 mm and 508 mm (13-20 inches) should be protected from harvest. Only two trout less than 330 mm and one trout greater than 508 mm TL should be permitted in the creel.
3. To reduce mortality attributable to hooking, terminal gear should be restricted to lures and flies.
4. Stocking rate should be reduced from 200,000 to no more than 100,000 150-mm fingerlings per year. Stocking of catchable sized trout should be eliminated.
5. Population estimates should be employed, both during fall and spring, to monitor response of the fish population to these management alterations.

In addition, changes in operations of the Flaming Gorge hydroelectric units should be closely followed. A proposal to rewind and uprate the generators could increase maximum discharge by about 15% and increase the range of fluctuation by as much as 19 percent. Results of the current study suggest that usable winter habitat for trout is negatively affected at higher discharge levels. The role of discharge rate on winter habitat should be more precisely defined, and means of mitigating any negative effects identified, before proposals that would elevate winter discharge are implemented.

Finally, the contribution of instream recruitment to the sportfishery was not evaluated during the study period. Brown trout were not stocked during the study but their annual contribution to the creel increased steadily. Rainbow and cutthroat trout recruitment was clearly



inadequate to support the level of harvest experienced during the study period. The proposed fishery management plan, however, will greatly reduce sportfishery harvest and thus, the level of recruitment required to support the fishery. The contribution of instream recruitment should, therefore, be assessed. Stocking rates should also be reassessed for the same reasons.

Emergent salmonid fry are particularly susceptible to stage fluctuation and hydroelectric ramp rates (rate of change of flow). Any change in hydroelectric operations should, therefore, be considered in light of how success of instream recruitment might be affected.

## INTRODUCTION

### Background

The Green River, in Daggett County, Utah, historically supported a fish community predominated by native cyprinids and catostomids. Flaming Gorge Dam, completed by the U.S. Bureau of Reclamation (BOR) in 1962, trapped the river's suspended sediment and bedload, producing dramatic increases in water transparency and resultant changes in channel morphology in the tailwater. Immediately following closure of the dam, water temperatures in the tailwater were nearly ideal for salmonid fish species. In 1962, the Utah Division of Wildlife Resources (DWR) established a tailwater sportfishery by stocking, primarily, rainbow trout fingerlings. This put-grow-and-take program was initially successful -- approximately 20% of stocked fingerlings eventually returned to angler's creels at sizes averaging more than 300 mm total length. As the reservoir filled, however, hydroelectric releases increased to operational levels. Filling of the reservoir also caused progressively colder water to be released through the fixed elevation penstock inlets, from deeper in the reservoir's hypolimnion. Higher discharges decreased ambient warming rates and protracted the effects of cold release temperatures downstream. Excessively cold water temperatures depressed trout growth and detracted from the tailwater's recreational appeal. Consequently, the BOR and DWR cooperatively conceived a plan to permit selective withdrawal of warmer surface water from the reservoir.

BOR implemented the plan and modifications to the penstock inlets were completed in June 1978. Steel intake extensions were fastened to

the face of the dam, extending downward to each of the three fixed-elevation inlets. Shutter gates along the face of each extension can now be opened to withdraw water from selected elevations in the reservoir's water column. Thus, during summer, water temperatures optimal for trout growth (12.2°C or 54°F) are released to the tailwater. In spring and fall, tailwater temperatures are maximized by raising penstock inlet elevations to as near the surface as possible. Warmest temperatures (4°C or 39°F) are available deep in the reservoir in winter, when water is drawn into the fixed penstock inlets, bypassing the inlet extensions.

BOR funded this study for the initial purpose of evaluating the response of the tailwater fishery to the penstock modifications. From September 1978 - November 1980 the study was focused primarily upon increase in growth rate of trout and its ramifications to the sportfishery. However, it became apparent during this period that the sportfishery response to the penstock modification was constrained by poor winter survival of stocked fingerlings. Concurrently, modifications to the dam that would increase hydroelectric capacity and peak discharge rates were under consideration. In 1980, therefore, BOR funded a second phase of research to identify factors influencing trout survival. This second phase of work, which ran from fall of 1980 - November 1982, required a wide range of study elements and methodologies, including angler creel surveys, fish tagging, surveys of physical habitat, measurement of trout microhabitat selection, and observations of fish behavior. The entire field study period was from September 1978 - November 1982. Angler harvest data for 1983-1985 are presented in this report to track survival of trout originating during the 1978-1982 study years.



## Objectives

This report, therefore, addresses three major objectives in the following sequence: 1) response of trout growth to warmer water temperatures (produced by the penstock modification); 2) trends in angler use and factors influencing survival of stocked fingerlings; and 3) trout microhabitat, particularly with reference to the influence of discharge upon habitat suitability of the Green River.

The ultimate goal of these studies was to provide a basis for the synthesis of fishery management and hydroelectric operational planning. Thus, the final portion of this report draws on the three study elements to generate conclusions and recommendations for use in planning. At this writing a number of the recommendations have been implemented.

## Units of measure

Most measurements are presented in metric units. However, this report is to be used by several agencies, some of which continue to use English units of measure for discharge measurements (volume). River distances and elevations are also, by convention, still predominantly referred to in English units - thus, English units are used to designate river locations, gradient, discharge, and elevations. Following are units of measure commonly employed in this study.

### Used in this Report

1 millimeter (mm)  
1 centimeter (cm)  
1 centimeter/second (cm/sec)  
1 meter (m)  
1 mile (mi)  
1 cubic foot/second (cfs)  
1 kilogram (kg)  
1 degree centigrade (°C)  
1 foot/mile (ft/mi)

### Equivalent Unit

0.039 inches (in)  
0.394 in.  
0.0328 feet/second (ft/sec)  
39.34 in.  
1.609 kilometers (km)  
0.02832 cubic meters/sec (cms)  
2.205 pounds (lb)  
 $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{Fahrenheit } (^\circ\text{F})$   
0.189 meters/kilometer (m/km)

### Study area

The Green River drains southward from the Wind River Range in west-central Wyoming, joining the Colorado River as its largest tributary in southeast Utah. Upon entering Utah from Wyoming, the river bends sharply eastward, exits into the northeast corner of Colorado (Figure 1) and, passing through Dinosaur National Monument, bends back westward, reentering northeast Utah near the City of Vernal.

Flaming Gorge Dam is located 33 river miles downstream of the Utah-Wyoming state line. The study area is composed of the 29 mi (47.2 km) tailwater extending from Flaming Gorge Dam to the Colorado state line (Figure 1). The upper 15.5 mi (24.9 km) is bounded by the steep walls of Red Canyon. Consequently, access to this upper reach is limited to raft and foot trails between three vehicle access points -- Tailrace, Little Hole, and Indian Crossing. Little Hole and Indian Crossing are raft ramps located 7.2 and 15.7 mi (11.6 and 25.3 km), respectively, below Flaming Gorge Dam. Approaching Indian Crossing from upstream, the steep walls of Red Canyon are gradually replaced by the wide valley bottom known as Browns Park. Vehicle access to the river is relatively unrestricted in Browns Park, except where the bottom is briefly interrupted by Swallow Canyon, near the Utah-Colorado state line.

The elevation of the tailwater ranges from 5,594 ft. (1,705 m) at Tailrace to 5,375 ft. (1,638 m) at the Utah-Colorado state line. Mean gradient of the study area is 7.6 ft/mi (1.4 m/km). Above Red Creek, the river's gradient is stairstepped at regular intervals by rapids and large pools. In contrast, below Red Creek Rapids (4.2 mi downstream of Little Hole) gradient is seemingly unbroken by distinct hydraulic controls.

# FLAMING GORGE TAILWATER

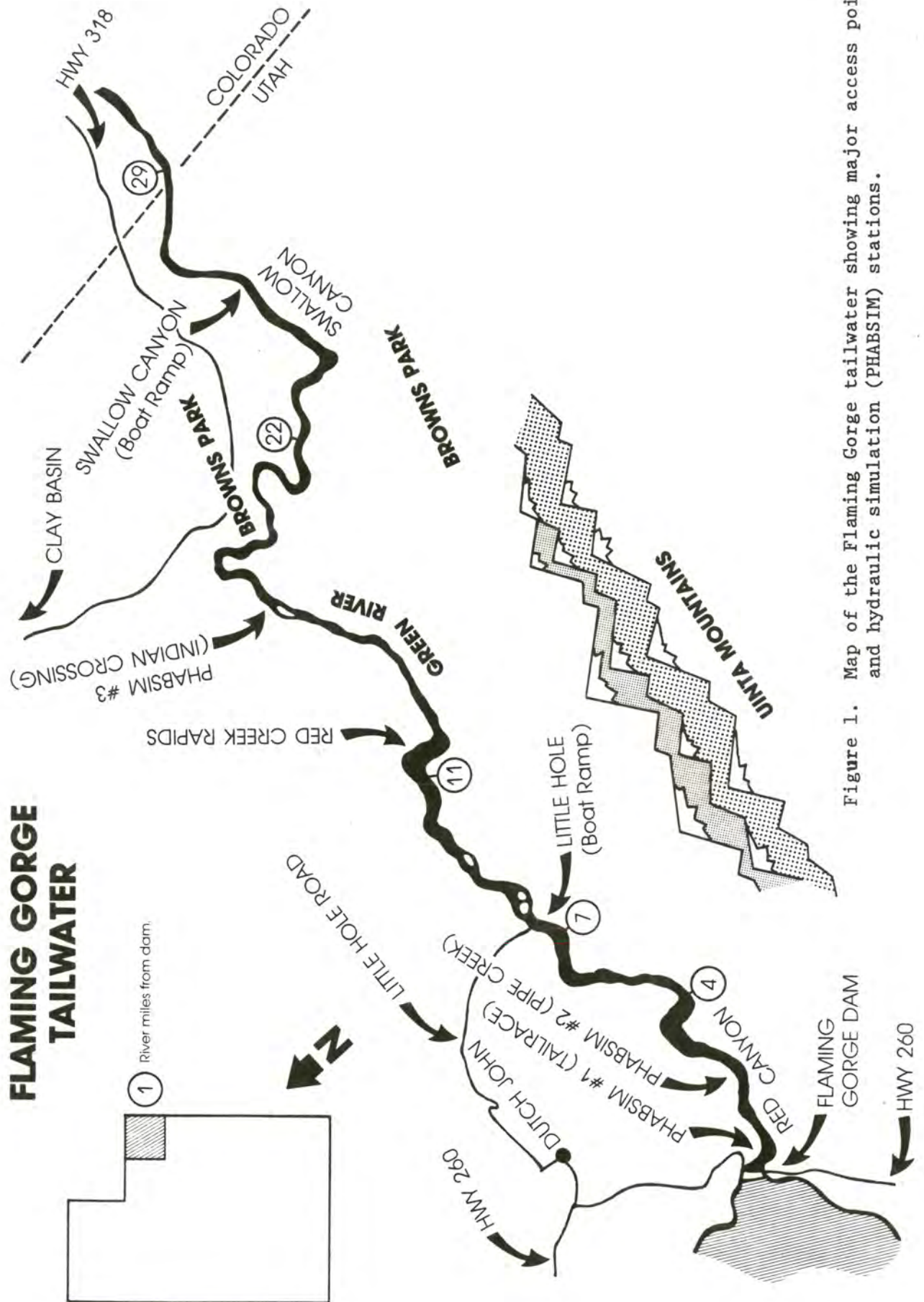


Figure 1. Map of the Flaming Gorge tailwater showing major access points and hydraulic simulation (PHABSIM) stations.



Gradient averages 8.7 ft/mi (1.64 m/km) from the dam to Red Creek, and 8.8 ft/mi (1.6 m/km) from Red Creek to Swallow Canyon. Gradient declines to 4.8 ft/mi in Swallow Canyon and 1.6 ft/mi in the lower portion of Browns Park. Increasing sediment load from tributaries, combined with declining gradient, cause the river channel to become shallow and braided downstream of the Utah-Colorado state line. Summer water temperatures and habitat conditions in Colorado are marginal for trout.

Maximization of revenue from hydroelectric power generation is a major criterion for operation of Flaming Gorge Dam. Consequently, discharges from Flaming Gorge Reservoir to the tailwater follow a pattern that parallels electric demand, with peak flows usually occurring in winter (Appendix Figure C1). Daily releases also tend to follow electrical demand, varying from 800 cfs to 4,200 cfs, with peak discharges often occurring in morning and evening.

The Flaming Gorge tailwater of the Green River offers a combination of scenery, history, and public ownership that have enhanced its recreational appeal. Originally navigated and mapped by Major John Wesley Powell in 1869 and 1872, many canyons and landmarks bear names ascribed by the two Powell expeditions. Superimposed on the eastern end of the Uinta Range, Red Canyon's walls rise more than 1,000 feet above the river's bed, where they meet the timbered flanks of the mountains. The study reach is almost entirely in public ownership. From Flaming Gorge Dam to near Red Creek Rapids, the tailwater is encompassed by the Flaming Gorge National Recreation Area, administered by the U.S. Forest Service. The remainder of the tailwater passes through U.S. Bureau of Land Management and DWR Browns Park Waterfowl Management Area holdings. A small number of private tracts are located near the river east of Indian Crossing.

## OBJECTIVE #1

### ASSESS TROUT GROWTH RESPONSE TO ELEVATED HYDROELECTRIC WATER RELEASE TEMPERATURES

#### METHODS - OBJECTIVE #1

Between 1979 and 1981, growth of fish was monitored by weighing and measuring marked, known-age fish recovered during electrofishing surveys at three river reaches -- Tailrace, Little Hole, and Browns Park (Figure 1). Because growth estimates taken from creeled fish may be biased by angler selectivity, especially among fish of smaller sizes, length-weight data taken during creel surveys were not used to assess growth, except during the 1963-1970 period, when electrofishing gear was not available.

Growth was estimated for known-age fish only. The rainbow and cutthroat trout fishery was sustained almost entirely by stocking. Fingerlings (approximately 100 mm total length) were marked prior to stocking with a colored (red, green or yellow) granular fluorescent pigment applied with a compressed air sprayer at the hatchery, as in Phinney et al. (1967). Rainbow trout of catchable size (approximately 250 mm) were also stocked in the tailwater; although these were marked by fin clipping, fish stocked as catchables were not used in estimating trout growth. Brown trout were present in the tailwater, but this species was sustained by instream recruitment and known-age fish were not available. No attempt was made during this study segment to back-calculate brown trout growth.

A total of 821 usable total length (TL) and weight measurements from known-age trout were taken between October 1979 and October 1981. The majority of samples were taken during October end-of-growing-season surveys in 1979, 1980, and 1981. Valuable growth data were also collected during July 1980, one year following stocking of the 1979 year class; during May 1981, about one year following stocking of the 1980 rainbow trout cohort; and during the winters of 1980 and 1981. Although TL, weight, and age were recorded from numerous samples collected for other purposes, these efforts were not all specifically designed for growth assessment and sample sizes were often insufficient to permit their use.

Response of aquatic invertebrates to the penstock modification was monitored by BIO/WEST, Inc., Logan, Utah, under contract with BOR. Further invertebrate studies were subcontracted by UDWR to Aqua-Tech Biological Consultants, Logan, Utah. Methods employed in invertebrate studies can be found in Holden and Crist (1981) and Gosse (1982).

Length-weight data for rainbow and cutthroat trout were analyzed by species, year, and capture site, with respect to time since stocking. Growth increments were calculated based upon mean TL at time of stocking, taken from hatchery records. Individual lengths were measured from fish representing some, but not all, hatchery lots; thus errors due to variation in TL at time of stocking were not systematically accounted for. Trout at large for less than 6 months, most of which were sampled in October, were used to estimate monthly first summer growth; those trout at large for approximately 12 months were used to estimate annual growth. Condition (KTL) was calculated using the formula:

$$K_{TL} = \frac{\text{Weight (gm)}}{\text{Total Length (mm)}^3} \times 100,000$$



The penstock modification was completed ahead of schedule and, consequently, the growth study was not funded until after the penstock modification became operational. Furthermore, adequate electrofishing gear was not available until 1981 and sampling schedules were frequently interrupted. Premodification growth data were, therefore, not systematically collected; however, data from electrofishing samples collected in 1977 included measurements of marked trout stocked as fingerlings in 1976. In addition, back calculated growth of creel fish had been estimated between 1964 and 1970. The data from the 1964-1970 period was available only in summarized form, but records of individual measurements from 1977 were obtained and differences between growth increments measured in 1977 and the present study were summarized and tested. Growth differences were tested primarily using the general linear models procedure for analysis of variance for unbalanced data, employing the Statistical Analysis System (SAS) of packaged computer programs.

Continuous temperature records were obtained during 1979, 1980, and 1981 at Tailrace, Little Hole, and Browns Park (at mile 22, see Figure 1) using Ryan thermographs. Temperature records for the period prior to penstock modification were obtained using thermographs and from continuous penstock water temperature records maintained by the Bureau of Reclamation.

#### RESULTS - OBJECTIVE #1

Mean annual growth for the 1976 year class of rainbow trout, as measured at Tailrace in 1977, was 64.2 mm. During 1979, the first full growing season the penstock modification was operational, mean annual growth at Tailrace increased to  $183.3 \pm 14.4$  mm, a highly significant improvement ( $p = 0.01$ ). Growth for all samples taken from Tailrace and

Little Hole for the 1979 and 1980 cohorts, in fact, exceeded that of the 1976 cohort ( $p = 0.01$ ; Table 1).

Mean annual growth for 40 rainbow trout collected in July 1980 from all stations (8 at Browns Park, 14 at Little Hole, and 18 at Tailrace), collected exactly 12 months following stocking, was  $179.5 \pm 8.9$  mm. No cutthroat trout were collected after exactly 12 months of growth; however, the 1980 cohort, represented by 20, 15, and 21 individuals, from Browns Park, Little Hole, and Tailrace, respectively, was sampled after 13.1 months at large. These cutthroat trout had grown at an annually adjusted increment of  $183.0 \pm 3.23$  mm. Growth of rainbow and cutthroat trout could not be compared statistically, due to differences in age at time of collection, but growth appeared to be very similar for the two species.

Growth differed significantly between stations and with time following release ( $p = 0.01$ ; Table 2). In general growth differed very little between years, but growth of rainbow trout of the 1980 cohort, after 11.42 months at large was significantly greater ( $p = 0.05$ ) than that based on the other post-modification annual growth samples (Table 1).

There was a general tendency, with individual exceptions, for growth to be most rapid at Tailrace (Table 3). Prior to penstock modification, growth was generally considered slowest at Tailrace and fastest in Browns Park.

The tendency for monthly growth to decline with increasing time at large (Table 2) was primarily because: 1) trout sampled 2.4 months after stocking had not experienced a winter season; 2) growth in length is in general greater for smaller, immature fish. It was not possible to determine trends in annual growth with increasing age. Very few fish

Table 1. Growth (mm) of rainbow trout before (1976 year class) and after (1979 and 1980 year classes) modification of penstocks, as measured at Tailrace (TR) and Little Hole (LH).

Year Class	Stations	Time at large (months)	TL at Capture	Monthly Growth Increment <sup>a,b</sup>	Annual Growth Increment <sup>b</sup>	Sample Size
1976	TR	14.13	202.6	$5.3 \pm 0.7_x$	$64.2 \pm 8.5$	19
1979	TR	12.00	282.3	$15.3 \pm 0.9_y$	$183.3 \pm 14.4$	18
1979	LH	12.00	267.0	$14.0 \pm 1.3_y$	$168.0 \pm 15.0$	14
1980	TR	11.42	330.1	$18.4 \pm 1.3_z$	$220.7 \pm 16.1$	21
1980	LH	11.42	288.0	$14.7 \pm 0.9_y$	$176.5 \pm 10.9$	20

<sup>a</sup> A shared subscript indicates difference (Tukey's Standardized Range Test) not significant at 95% confidence level. The 1976 year class was significantly different from post-modification year classes at 99% level.

<sup>b</sup> 95% Confidence intervals.

Table 2. Monthly growth increment (mm) according to time (months) since stocking, by sampling locations, rainbow trout.<sup>a,b</sup>

Sampling Location	Months at Large			
	2.4 (1980 cohort)	8.7 (1980 cohort)	12.0 (1979 cohort)	13.9 (1980 cohort)
Tailrace	40.2 (20)	22.7 (12)	15.3 (18)	17.3 (6)
Little Hole	32.9 (19)	19.7 (22)	14.0 (14)	15.1 (20)
Browns Park	37.7 (13)	15.5 (21)	15.9 (8)	15.7 (18)

<sup>a</sup> Monthly growth increment affected by location and time at large ( $p = 0.01$ ) based upon two-way multivariate analysis for unbalanced samples.

<sup>b</sup> Sample sizes in parentheses.



that had experienced more than two growing seasons (larger than 350 mm TL) were collected (Appendix Figures A1 and A2). Data presented in Table 4 represent growth of the limited number of trout collected that had experienced more than one growing season.

First summer growth rates for trout (both species) sampled in October at Tailrace varied from 27.2 to 35.1 mm/mo during 1979-1981. Rainbow trout first summer growth rate varied by only 3.1 mm per month during the three years. Differences between cohorts in length at capture in October were functions of stocking date (time at large) and size when stocked, rather than annual differences in first-summer growth rate (Table 5).

Fish weight varies according to the expression:  $W=aL^b$ , where W=weight and L=length (Ricker 1975). The length-weight regressions for Green River rainbow and cutthroat trout, from samples of fish ranging in age from 1.6 to 21.2 months after stocking, all locations combined, were:

$$\begin{aligned} W &= 0.0000193 \times L^{2.91} \\ &\quad (95\% \text{ CI for } b = 2.82 - 2.99) \text{ for rainbow trout;} \\ W &= 0.0000525 \times L^{2.70} \\ &\quad (95\% \text{ CI for } b = 2.57 - 2.83) \text{ for cutthroat trout.} \end{aligned}$$

For fish populations that do not change in body form or condition over the size ranges of their individual members, the exponential value of the length-weight regression is near 3.0 (Ricker 1975). The b-coefficient for both species was slightly below 3.0 suggesting that, over the relatively narrow range of sizes represented, condition declined slightly with increasing body size.

Like the b-coefficient, the condition factor ( $K_{TL}$ ) was generally higher for rainbow than for cutthroat trout. Condition was better at Tailrace than at the other stations and in some instances the differences were significant ( $p = 0.05$ ) (Table 6).

Table 3. Total growth increment (mm) from time of stocking and 95% C.I., comparison between sampling stations, rainbow and cutthroat trout.<sup>a</sup>

	1979 Year Class			1980 Year Class		
	Cutthroat 4.3 mo @ large	Rainbow 12.0 mo @ large	Cutthroat 6.6 mo @ large	Cutthroat 13.1 mo @ large	Rainbow 2.4 mo @ large	Rainbow 5.8 mo @ large
Tailrace	116.8 ± 15.1 <sub>x</sub> (21)	183.3 ± 10.4 <sub>x</sub> (18)	133.7 ± 7.5 <sub>x</sub> (23)	204.2 ± 6.2 <sub>x</sub> (21)	95.7 ± 8.4 <sub>x</sub> (20)	117.1 ± 8.9 <sub>x</sub> (46)
Little Hole	110.1 ± 8.5 <sub>x</sub> (21)	168.0 ± 15.0 <sub>x</sub> (14)	--	197.7 ± 7.0 <sub>x,y</sub> (15)	78.7 ± 9.5 <sub>y</sub> (19)	-- (22)
Browns Park	120.1 ± 3.8 <sub>x</sub> (20)	191.0 ± 33.4 <sub>x</sub> (8)	120.3 ± 10.2 <sub>y</sub> (23)	194.4 ± 5.5 <sub>y</sub> (20)	90.0 ± 8.5 <sub>x,y</sub> (13)	125.5 ± 9.2 <sub>x</sub> (28)
						136.4 ± 11.9 <sub>z</sub> (21)

<sup>a</sup> A shared subscript within column indicates no significant difference ( $p = .05$ ). Sample size in parentheses.

Table 4. Growth (mm) of rainbow (RBT) trout and cutthroat (CTT) trout at large more than one growth season.

Year class	Stations <sup>a</sup>	Species	Time at large (months)	Number complete growing seasons at large	Total length at capture	Monthly growth increment	Annual growth increment	Sample size
1979 <sup>b</sup>	A11	RBT	21.2	2	315.9	10.2 ± 0.9	122.8 ± 11.0	14
1979	A11	CTT	15.5	2	349.5	14.7 ± 0.8	176.8 ± 9.3	17
1979	A11	RBT	14.7	2	318.7	14.9 ± 0.9	178.9 ± 10.9	23
1980	TR	RBT	13.9	1.3	359.8	17.3 ± 2.3	207.5 ± 30.2	6
1980	LH	RBT	13.9	1.3	329.2	15.1 ± 0.9	181.0 ± 10.8	20
1980	BP	RBT	13.9	1.3	337.5	15.7 ± 0.9	188.2 ± 10.6	18

<sup>a</sup> A11 = Tailrace, Little Hole and Browns Park data combined.

TR = Tailrace

LH = Little Hole

BP = Browns Park.

<sup>b</sup> Includes two winters in tailwater; other groups had experienced only one winter season.



Table 5. First summer growth (mm) for trout stocked as advanced fingerling and sampled in October 1979, 1980, and 1981 at Tailrace.

	Cutthroat				Rainbow			
	Time at large (mo)	Length <sup>a</sup> at capture	Monthly <sup>a,b</sup> increment	Sample size	Time at large (mo)	Length <sup>a</sup> at capture	Monthly <sup>a,b</sup> increment	Sample size
1979	3.4	221.1 <sub>x</sub>	29.2 ± 4.4 <sub>x</sub>	19	2.7	183.0 <sub>x</sub>	31.6 ± 4.6 <sub>x</sub>	16
1980	4.3	238.8 <sub>y</sub>	27.2 ± 3.5 <sub>x</sub>	21	5.1	268.9 <sub>y</sub>	29.2 ± 2.3 <sub>x</sub>	16
1981	3.6	229.5 <sub>x,y</sub>	35.1 ± 2.4 <sub>y</sub>	20	4.7	253.6 <sub>y</sub>	32.3 ± 2.5 <sub>x</sub>	19

<sup>a</sup> A shared subscript within column indicates insignificant difference (F and multiple t tests;  $p = 0.05$ ).

<sup>b</sup> 95% confidence limits given.

Table 6. Condition factors at various times following stocking and 95% C.I., with comparison between sampling stations.<sup>a</sup>

	1979 Year Class			1980 Year Class			
	Cutthroat 4.3 mo @ large	Rainbow 2.4 mo @ large	Rainbow 12.0 mo @ large	Cutthroat 6.6 mo @ large	Cutthroat 13.1 mo @ large	Rainbow 5.8 mo @ large	Rainbow 8.7 mo @ large
Tailrace	1.39 ± 0.450 <sub>x</sub> (21)	1.40 ± 0.050 <sub>x</sub> (20)	1.29 ± 0.066 <sub>x</sub> (18)	0.979 (23)	1.04 ± 0.038 <sub>x</sub> (21)	1.19 (46)	1.17 ± 0.053 <sub>x</sub> (12)
Little Hole	0.949 ± 0.032 <sub>x</sub> (21)	1.19 ± 0.050 <sub>x</sub> (19)	1.20 ± 0.077 <sub>x</sub> (14)	--	0.983 ± 0.055 <sub>x</sub> (19)	--	1.04 ± 0.034 <sub>y</sub> (22)
Browns Park	0.904 ± 0.032 <sub>x</sub> (20)	1.22 ± 0.240 <sub>x</sub> (13)	1.11 ± 0.370 <sub>y</sub> (8)	0.889 (23)	1.03 ± 0.400 <sub>x</sub> (20)	1.10 (28)	0.932 ± 0.036 <sub>z</sub> (21)

<sup>a</sup> Shared subscript within column indicates insignificant difference ( $p = 0.05$ ). Sample size in parentheses.

## DISCUSSION - OBJECTIVE #1

Growth of fingerling stocked in the tailwater was substantially increased with warmer waters released from the modification of the Flaming Gorge Dam penstock intakes. The present study was not initiated until after the penstock modification became operational and information regarding growth prior to 1978 is somewhat scant. Although the increase in growth could not be systematically measured, it appears, based upon growth of the 1976 year class (Table 1), that annual growth has increased approximately three-fold. It took the 1976 year class approximately two years to reach a "catchable" size of 250 mm. Stockings subsequent to the modification grew during their first summer in the tailwater at rates of approximately 30 mm/mo and reached 250 mm in 3.6 - 4.6 months. The faster growing individuals now contribute to the creel during midsummer of their first season at large.

Growth during this study apparently represents the fastest rate of growth measured in the history of the tailwater, including the reservoir filling period. During 1964-1969, the fishery was considered generally good (Objective #2, Table 8), and return of stocked fingerling trout to the creel often approached 25%. By 1970, the fishery had declined as deeper and colder strata from the reservoir were drawn into the Flaming Gorge outlet works, and increasing discharge reduced the rate of ambient warming. Return to the creel dropped to as low as 1% (Varley et al. 1970), and beginning in 1970, the DWR resorted to stocking catchables and advanced (100-125 mm) fingerlings in place of the previous fingerling (75 mm) put-grow-and-take program.



Growth during the 1960's, back calculated from creeled fish, is shown in Table 7. Unfortunately, the original records from those early studies are missing and statistical comparisons cannot be made. In general, however, the annual growth increments for trout during the present study exceeded those measured prior to penstock modification — including the early years of the tailwater (Table 7) when temperatures were not considered limiting. During 1966-1969, total length of the fish during their second year at large increased from 228 mm to 315 mm, for a mean increment of 87 mm (Table 7). The annual growth increment for trout at large 14.1 months was only 64.2 mm in 1976-1977 (Table 1). The annual growth increment during the present study, for fish of roughly comparable size, ranged from 122.8 mm (Table 4) to 220.7 mm (Table 1). Because stockings during the premodification period consisted of both fingerling and advanced fingerling trout and were scheduled for late summer and fall, the premodification data are not strictly comparable to the present study. There can be no doubt, however, that growth increased after 1978 to levels much above those ever experienced prior to penstock modification.

Several factors probably contributed to the magnitude of the increase in growth, the most important being the direct effect of increased temperature. Prior to modification, the river at the tailrace exceeded 7 C for only approximately 3.5 months (September through mid-December) (Figure 2). In 1980, the Tailrace exceeded 7 C for at least 6 months and ranged from 10-14 C for approximately 4.5 months. The growth season in 1980 was similar in length at all stations, but summer maxima were higher downstream (Figures 3, 4, and 5; see also thermograph data, Appendix A, Tables A1-A3). The maximum recorded at Tailrace in 1980 was 14 C on 3 August and ranged between approximately 12 C and 14 C from 23

Table 7. Back-calculated growth of Flaming Gorge tailwater rainbow trout by year class, 1963-1969.

Year Class	Sample Size	Mean Calculated TL, end of each year (mm)				
		1	2	3	4	5
1969	118	225				
1968	320	238	320	396		
1967	333	233	320	396		
1966	408	217	311	376	454	
1965	215	--	309	331	483	512
1964	65	--	--	382	455	503
1963	2	--	--	--	472	--
7-Year Mean		228	315	383	468	508
Mean Annual Increment		87	68	85	40	

June - 17 October. The thermal maximum in 1980, at Little Hole was 16.5 C and reached 19.8 C at Browns Park. Daily maxima generally ranged above 16 C during June, July, and early August at Browns Park in 1980 (Appendix A, Tables A1-A3). It should be noted that the penstock gates were lowered during mid to late summer to prevent excessive temperatures at Browns Park. Temperatures above those measured in 1980 were, therefore, theoretically attainable. Low flows prevailed in 1980, increasing the warming rate of the tailwater. In years of higher flows, especially when hypolimnetic spills from the reservoir prevail, maxima can fall below optimal, and growth seasons become abbreviated.

# MEAN MONTHLY TEMPERATURE

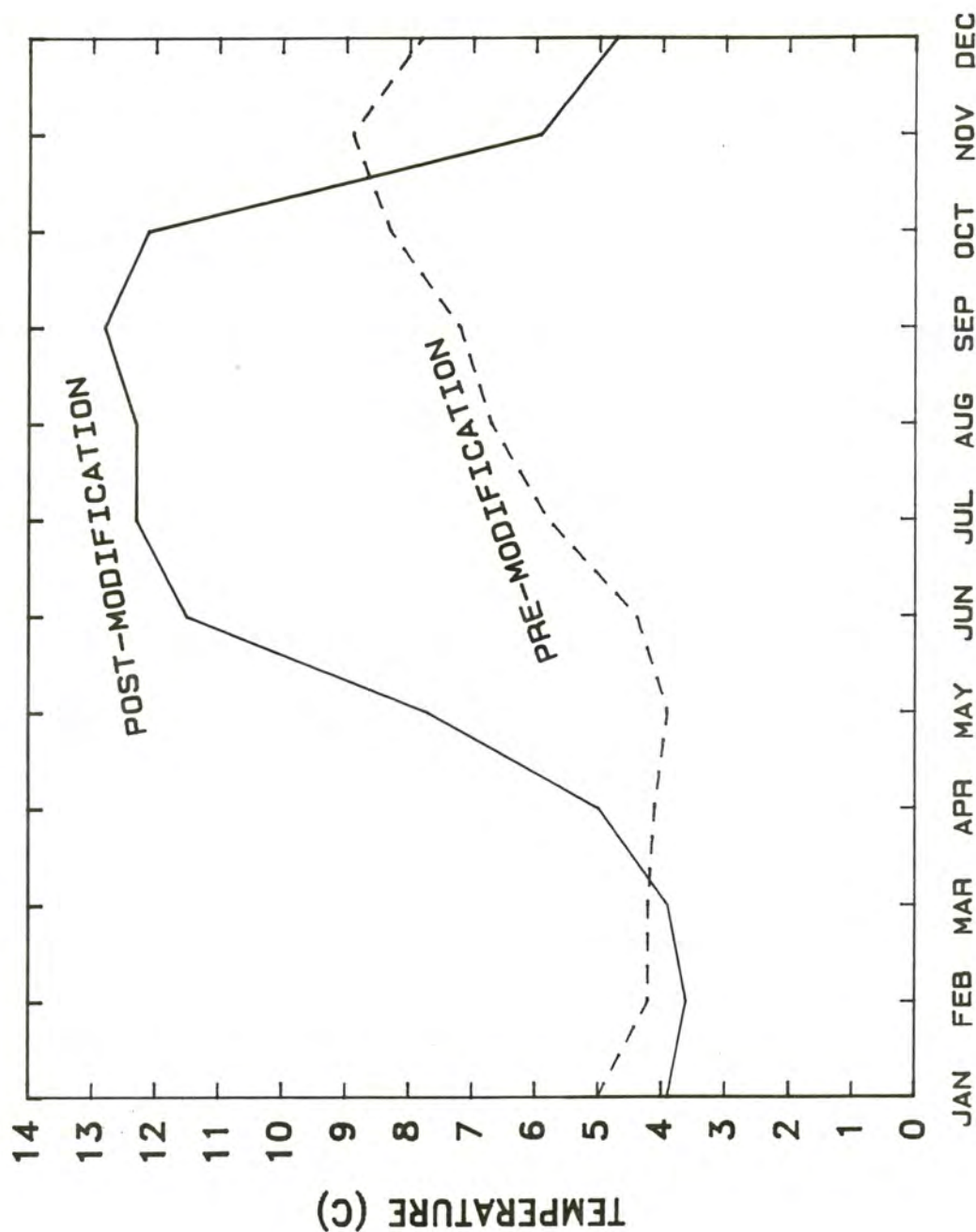


Figure 2. Water temperatures recorded by thermographs at Tailrace in 1973, prior to penstock modification, and mean temperatures from 1979 through 1981, following modification.



# TAILRACE TEMPERATURE, 1980

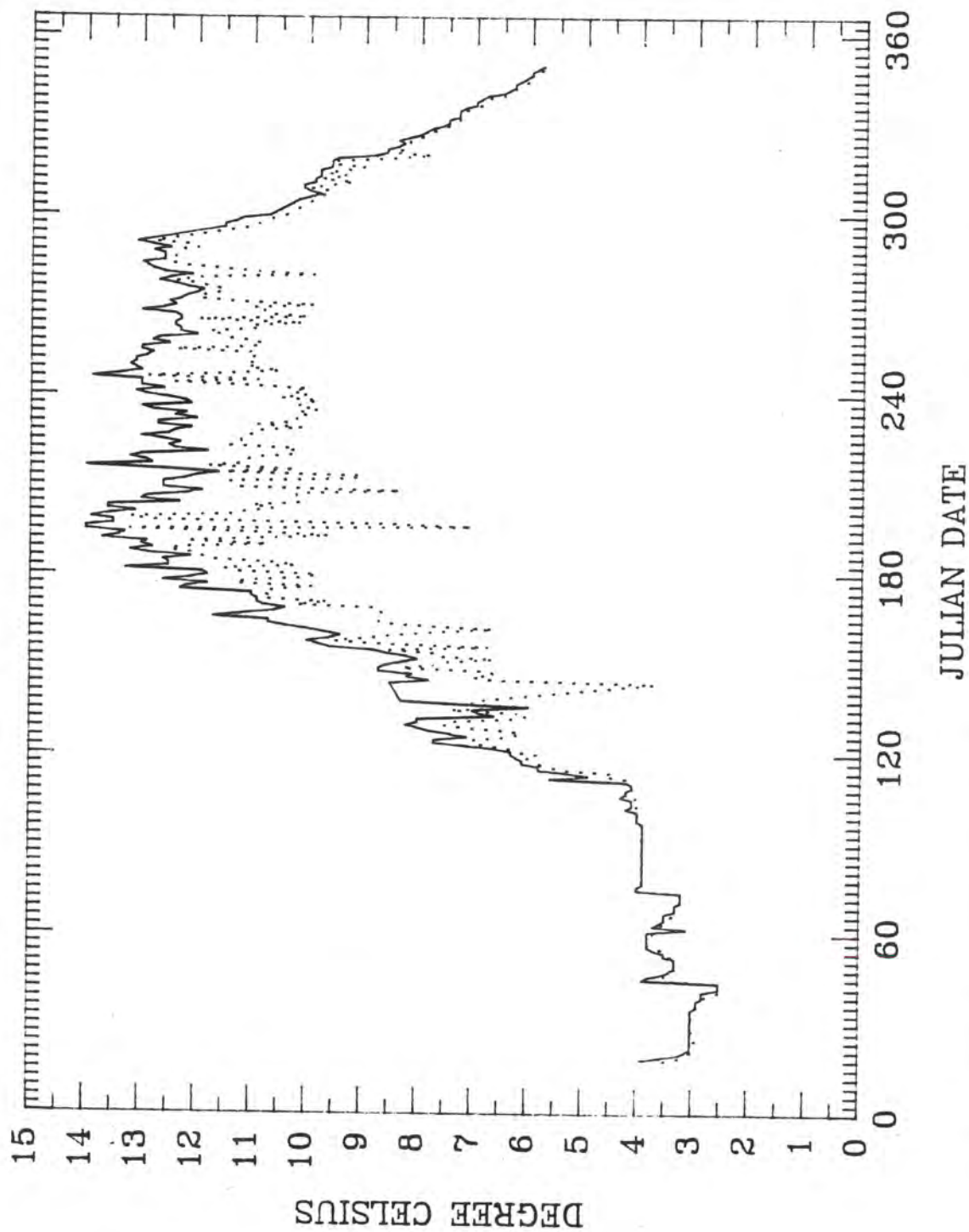


Figure 3. Water temperature trends recorded by Ryan thermographs placed at Tailrace, January-December, 1980.

# LITTLE HOLE TEMPERATURE, 1980

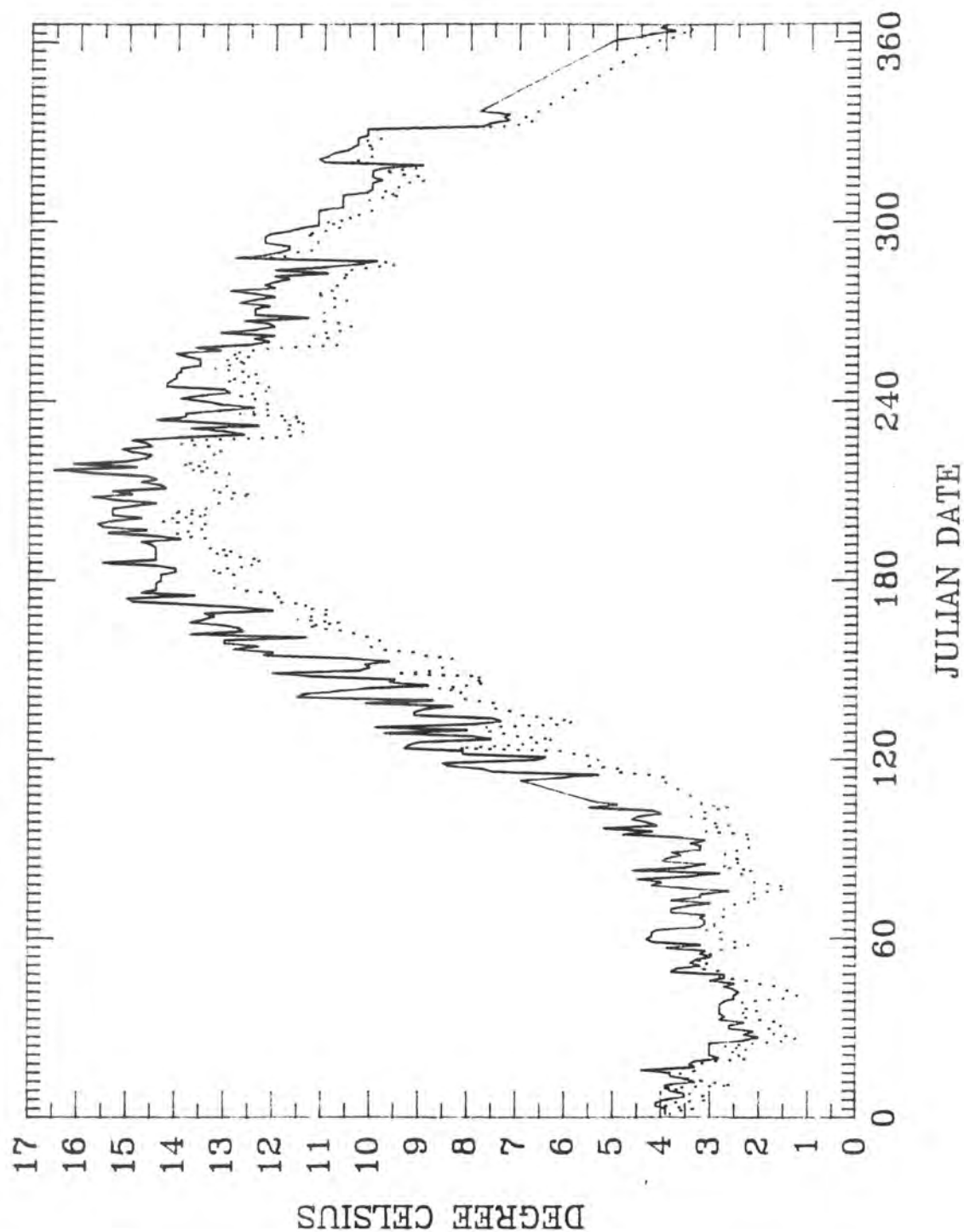


Figure 4. Water temperature trends recorded by Ryan thermographs placed at Little Hole, January-December, 1980.

# BROWNS PARK TEMPERATURE, 1980

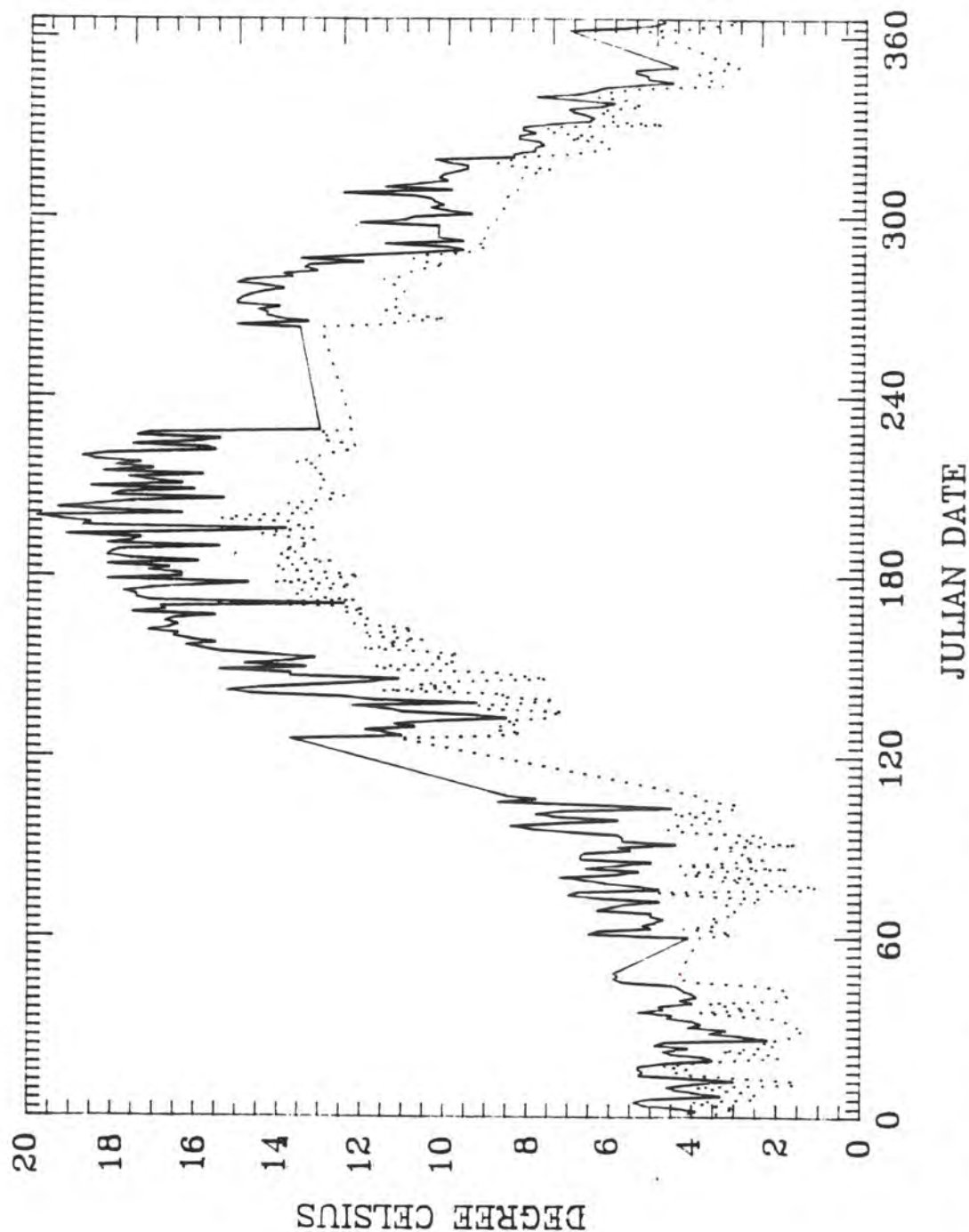


Figure 5. Water temperature trends recorded by Ryan thermographs placed in Browns Park, 22 miles from Flaming Gorge Dam, January-December 1980.



Annual temperature cycles now fairly closely mimic those of a natural river system, which also may have contributed to improved growth. The metabolic rate of pumpkinseed sunfish (Lepomis gibbosus) and growth of green sunfish (Lepomis cyanellus) have been shown to respond to photoperiod trends, increasing in spring and decreasing in fall, when temperature is held constant (Evans 1984; Gross et al. 1965). If the same pattern is exhibited by salmonids, growth would have been particularly enhanced by warmer temperatures in spring when photoperiod is increasing. Temperatures seldom exceeded 4°C during spring prior to modification. No evidence of a photoperiod/temperature interaction was observed after modification, however. In fact, the 1979 rainbow trout year class, stocked in July, exhibited greater first season monthly growth than did the 1980 cohort, which was stocked in May (Table 5).

The more natural synchronization of photoperiod and temperatures could have favored diversification of the river's invertebrate population and, in turn, the prey base for the sportfishery. Delayed growing season of the premodification years retarded emergence and nearly eliminated a species of Baetis from the first 9.5 km below the dam (Pearson et al. 1968). Emergence was suppressed until fall and winter, which can result in loss of adult forms due to lethal air temperatures (Ward and Stanford 1979).

Constant low water temperatures can suppress species diversity and production of invertebrates. Invertebrates such as Gammarus lacustris, are able to complete their life cycles under isothermal conditions and are thus favored by constant temperatures (Ward and Stanford 1979). Gammarus may not cope well in excessively cold constant temperatures,

however (Ward 1976). Species that require thermal cues to initiate various phases of their life cycles (i.e. hatching, emergence) may be suppressed or eliminated by thermal constancy (Ward and Stanford 1979).

The response of invertebrates to the warmed tailwater below Flaming Gorge Dam was initially monitored by Holden and Crist (1981). Standing crop and diversity increased at their two upper stations (Browns Park and Little Hole). Peak densities of the trichopteran Hydroptila sp., for instance, increased from 0/m<sup>2</sup> at Little Hole and Taylor Flat (Browns Park) in 1978 to 724/m<sup>2</sup> and 886/m<sup>2</sup>, respectively, in 1980. The amphipod Gammarus lacustris increased at Little Hole from peak densities of 452/m<sup>2</sup> in 1978 to 3,224/m<sup>2</sup> in 1979 and 3,992/m<sup>2</sup> in 1980. Gammarus peak numbers increased at Taylor Flat from 0/m<sup>2</sup> in 1978 to 617/m<sup>2</sup> in 1980. The mayfly Ephemerella inermis, the stonefly Malenka sp., the caddisfly Hydropsyche sp. and planeria also exhibited slight to moderate increases in the tailwater study sites. Annear (1980) recorded increases in chlorophyll-a concentrations in benthic samples taken near the dam between late summers of 1978 and 1979. Holden and Crist (1981) concluded the increase in chlorophyll-a probably reflected a positive response to warmer temperatures by periphyton, primarily Cladophora, and that increases in periphyton had been particularly favorable to the caddisfly Hydroptila and the amphipod Gammarus, because both species are associated with periphyton communities.

Gosse (1982), investigating invertebrate associations with aquatic vegetation, found Gammarus lacustris dominated the invertebrate biomass in his samples of December 1980, April 1981, and July 1981. This amphipod was especially important in the December 1980 sample (Appendix A,

Tables A4-A9). Gammarus were strongly associated with macrophyte beds and, to a lesser extent, with Cladophora (Gosse 1982). Salmonid food habits have not yet been studied, but based upon observations of stomach contents, Gammarus lacustris is now a very important component of the diets of rainbow, brown, and cutthroat trout in the tailwater.

The abundance of macrophytes in the tailwater also increased, which may have contributed to increased habitat diversity and substrate for invertebrate production. No quantitative observations were made prior to the inlet modifications. In 1981 and 1982, Chara sp., Zannichellia palustris and Ranunculus sp. were the primary macrophytes and Potamogeton crispus was reported to be increasing (Gosse 1982). Zannichellia palustris and Potamogeton crispus were not observed by DWR personnel prior to penstock modification and beds of Chara sp. appear to have become more abundant in the upper portion of the study area. Potamogeton pectinatus was reported by DWR personnel prior to the present study but not by Gosse (1982).

From 1979 - 1981, growth of trout was remarkably consistent between years (Table 5); however, changes in flow can affect the river's benthic invertebrate and macrophyte communities and alter growing seasons. For example, high flows in 1983 and 1984, ranging up to 13,600 cfs, visibly scoured the Green River and caused an apparent drastic decline in macrophytes, filamentous algae (Cladophora) and amphipods. No growth data were collected in those years, however. Pearson et al. (1968), cautioned that under the operating conditions of Flaming Gorge Dam, "new extremes in flow, temperature, and perhaps in some aspects of water chemistry can be expected. As a result the invertebrate community,



particularly that in the first 20 km below the dam, may never stabilize and will continually be in stages of succession as varying conditions favor some groups, then others."

The penstock modification has met the objectives for enhanced trout growth set forth in the 1975 environmental assessment (UDWR/BOR unpublished report) of the project. The assessment predicted that trout growth following modification would be similar to that of the Big Horn River below Yellowtail Dam and the Beaverhead River below Clark Canyon Dam. Rainbow trout growth in the Green River is now almost identical to the two Montana tailwaters. Stevenson (1975) reported the average summer growth for rainbow and brown trout below Yellowtail Dam, Montana, was 30/mm month and growth for cutthroat trout was 21 mm/month. Mullan et al. (1976) reported that during the 1960's rainbow trout stocked at an average of 191 mm TL grew 76 to 102 mm per year in the Glen Canyon tailwater, Arizona. Following the introduction of Gammarus lacustris to enhance the prey base, growth at Lee's Ferry, Glen Canyon tailwater, has increased (Persons et al. 1985) and now apparently resembles that of the Flaming Gorge tailwater. Growth of rainbow trout in the Green River below Fontenelle Dam, Wyoming, was highly variable, with annual increments between age I and age II averaging 87.8 mm during six years of study (Snigg 1979). In comparison, mean annual growth for the stocked 1979 rainbow trout cohort from the Flaming Gorge tailwater, all stations combined, was 179.5 mm.

Kiefling (1978) reported mean first year growth of 108 mm for Snake River cutthroat trout from the Snake River between Jackson Lake and Palisades Reservoir, Wyoming. First year growth in Kiefling's study area

largely reflected conditions in tributary nursery streams -- the second year increment, representing growth in the Snake River proper, averaged 84 mm. Yearling Snake River cutthroat trout from the South Fork Snake River, Idaho, below Palisades Reservoir, measured 86 mm. Annual increments of growth were 98, 93, 66, and 77 mm between ages 1-2, 2-3, 3-4, and 4-5, respectively (Moore and Schill 1984). The 1980 cohort of Snake River cutthroat trout sampled from the Flaming Gorge tailwater in 1981 had grown at an annual rate of 183.0 mm.

In a letter appended to the environmental assessment, the UDWR estimated the fishery yield would increase to 30,758 kg due to improved growth, and angler use would increase to 30,000 angler days, double the 1973 use level. Post modification yield peaked at 33,000 kg in 1981, a year of exceptionally high winter survival, and use exceeded the predicted 30,000 angler days per year in 1980, 1981, and 1982, reaching 43,316 days in 1981 (see Objective #2 below). From the standpoint of those original objectives, the penstock modification has clearly met expectations.

## OBJECTIVE #2

DESCRIBE ANGLER USE AND HARVEST TRENDS,  
SEASONAL MORTALITY, AND MIGRATION OF STOCKED FINGERLINGS

### METHODS - OBJECTIVE #2

#### Trout stocking and marking

Salmonid reproduction in the Flaming Gorge tailwater was most evident in the Browns Park area, where brown trout was the most successful species. Limited reproduction of rainbow trout and Snake River cutthroat trout was noted, but the contribution of natural recruitment to the fishery has not been ascertained. Due to high levels of angler harvest and apparent deficiencies in spawning success, stocking was necessary to provide a suitable fishery, even with warmer water temperatures produced by the penstock modification.

All trout stocked in the tailwater during the study period were marked to identify the year of stocking. Originally this was necessitated by poor formation of scale annuli due to uniformly cold water temperatures. Following penstock modification, marking was continued because of the ease of the techniques and the certain and rapid identification of year class and origin.

Trout stocked were marked using two methods. Catchable-size rainbow trout were marked by clipping the adipose or a pelvic fin. Fingerling rainbow and Snake River cutthroat trout were marked as in Phinney (1967)



with a granular fluorescent pigment, which was applied with a compressed air sandblasting sprayer while the fish were suspended in a screen-bottomed box. The box was large enough to hold 200-300 fingerlings at one time.

Trout were stocked using an 8.2 m long transport raft to distribute them between access areas. A few loads were planted at the heavily used access areas by truck. The transport raft was equipped with a 20 hp outboard motor. Two gasoline-powered pumps were used to circulate river water in and out of the raft.

#### Creel survey and sportfishery trends

An angler-interview creel survey, utilizing a stratified-random design, was conducted on the Flaming Gorge tailwater from the dam to the Colorado border throughout each fishing season (June - November). The survey was stratified by month, area, weekly use pattern (weekend-weekday), and fishing method (raft-shore). During the study period (1978-1982), four full-day surveys, including morning and afternoon shore angler counts, were randomly scheduled during June, July, August and September for each of the three access areas: Tailrace, Little Hole and Browns Park. During the low use months of October and November, surveys were scheduled at only half the intensity of the rest of the season, and these two months were combined and treated as a single period in the analysis of survey results. Somewhat lower survey intensities were employed prior to and following the 6-year study period.

Data collected during the angler interviews included party size, whether the party had completed its fishing trip, total angler-hours of fishing, and the number of fish caught and/or released. When possible

all fish were examined for marks and the catch was recorded by both species and mark. During each survey day, a subsample of fish was randomly selected for collection of length (TL) and weight data.

Estimates of shore fishing pressure were made using "instantaneous" counts of anglers over established sections of shoreline at each area. Length of shoreline counted was established so that counts could be completed within one hour on foot (Tailrace and Little Hole) or from a vehicle (Browns Park). The single counting zone at Tailrace extended approximately 1.5 mi (2.4 km) from the dam to below Pipe Creek. Two zones were used at Little Hole, one from the gabion at the raft ramp upstream approximately 1.0 mi (1.6 km) and the other from the gabion downstream to the large island (at "Devils Hole"), approximately 2 mi (3.2 km). All of the Utah portion of Browns Park was included in the count.

Mean counts for each area were expanded by the total number of available daylight hours within the particular time period to estimate shore fishing pressure. In addition, a correction factor was used to expand the estimate to include anglers that hiked into the area between the Tailrace and Little Hole count zones and for anglers that hiked between the Little Hole downstream count zone and Browns Park. These correction factors were obtained from trips down the river for routine purposes and from several additional trips randomly scheduled each month.

During the study period, three time-lapse 8-mm movie cameras were mounted at strategic locations along the river, one between the dam and Little Hole, one between Little Hole and Browns Park, and one overlooking the Swallow Canyon raft ramp in Browns Park. The two upstream cameras were positioned to photograph along a straight portion of river, with the

time interval between exposures adjusted to just less than the time required for a fast boat to pass through the stretch (about two minutes). Thus, all boats floating past the cameras were photographed at least once. The camera at Swallow Canyon was set to photograph boats taken out at the raft ramp, with the time lapse set at four minutes.

Frame by frame analysis of the films resulted in a nearly complete enumeration of boats using the river. Interview information from subsamples of boaters launching during the scheduled creel surveys provided the ratio of fishing to nonfishing parties. Creel interviews provided data on average fishing party size and average length of time fished for boat anglers, allowing the estimation of boat fishing pressure, expressed as angler-hours. A boat fishing party was defined as all people fishing from a single boat. The calculation of boat fishing pressure was made as follows:

$$P = B \times PCNT \times FPS \times HRS$$

where: P = fishing pressure as hours;

B = total count of boats during period;

PCNT = percentage of boats fishing;

FPS = mean size of fishing party;

HRS = mean length of completed boat fishing trip.

Harvest estimates were calculated independently for boat and shore fishing at each access point each month. Harvest was estimated by multiplying the estimated fishing pressure by the creel rate. Yield was calculated as the product of mean weight and harvest for each species caught. Harvest estimates were summed over all species, areas, types of



fishing, and survey periods to obtain total harvest. Total harvest divided by total fishing pressure provided the weighted estimate of overall creel rate for the year.

#### Electrofishing catch trends

In addition to annual electrofishing samples, taken at each access point in October, periodic samples were collected during the winters of 1981 and 1982. An inboard jet-powered 5.5 m welded aluminum river boat was equipped for electrofishing in February 1981. With this equipment, standardized electrofishing techniques were developed to improve comparability of catch rate data. The electrofishing unit was a Coffelt "VVP-15" powered with a 5,000 watt A.C. generator. Dual circularly arrayed sets of annodes were rigged from booms forward of the work deck. Cathodes consisted of weighted flexible aluminum conduit suspended from the side of the boat. D.C. current was pulsed at a rate of 80/sec, with a pulse width of 60 percent. The unit delivered in the range of 200 volts and 3-5 amps. Conductivity of the Green River ranged from 600-700 micromhos. Two dip netters and one boat operator constituted the crew. Only experienced crew members were employed and seldom were crew participants alternated. Electrofishing zones, discharge rate, boat operation and netting efficiency were standardized to the maximum degree possible. All trend electrofishing was conducted at night.

#### Site specific dye marks -- movement between stocking sites

To monitor movement from points of stocking, samples of 10,000 rainbow and Snake River cutthroat trout stocked in 1979 were each given site-specific dye marks and released at Tailrace, Little Hole and Browns

Park. Thus, 10,000 cutthroat and 10,000 rainbow trout were marked with yellow-green dye and released at Tailrace; 10,000 of each species were marked with red-green dye and released at Little Hole; and 10,000 of each species destined for Browns Park were marked with a red-yellow dye combination.

Monitoring of movement of these fish was confined to electrofishing of the stocking sites and observed harvest by shore fishermen during creel census. In addition, it was possible in a few instances to ascertain the creel location of fish harvested by raft anglers. Electrofishing of points between stocking sites was not possible because a jet-powered electrofishing boat was not yet available.

#### Movement and harvest of tagged trout

Floy FD 68B serially numbered and color coded anchor tags were used. All tagged trout were held in live cages until they recovered. Tags of any trout that did not appear to be fully recovering were discarded from the sample. Loss of trout during the recovery period was negligible.

Due to barriers to navigation, sampling from river miles 5 and 6 (as measured from the dam) was not possible. Access into Ladore Canyon and Echo Park, Colorado, was possible only during the winter of 1980. Weather and snow pack prevented access to those areas in other years.

All fish sampled were inspected for dye marks and measured (TL) to the nearest cm. Tag records and return information were stored by species, length group, mark, sample site (river mile) and tag number.

Tagging and tag return data were sorted and analyzed using packaged programs (Statistical Analysis System [SAS]). Unless otherwise stated,

Chi-square tests of tags returned/not returned were employed to evaluate significance of differences between various groups of tagged fish.

Tag return boxes were placed at all major access points along the river. In addition, many tags were returned by mail to the DWR address given on the tags. No reward was offered for tag returns.

## RESULTS -- OBJECTIVE #2

### SPORTFISHERY TRENDS

#### Angler use and harvest

Following peaks in the 1967-1970 period, the Green River experienced declines in use, harvest, mean size of fish creeled, and yield (Table 8). From 1967-1970, use and yield averaged 107,957 hours (hr) and 22,573 kg, respectively. From 1975-1978, estimates of angler use and yield averaged 58,993 hr and 7,205 kg, or only 55% and 32% of the respective 1967-1970 use and yield estimates. This decline was attributed to the colder temperature regime in the tailwater which depressed trout growth and production of the river's ecosystem.

The penstock modification, which became operational on 20 June 1978, appears to be the only reasonable explanation for a recovery in the fishery, which began in 1979. Use and yield from 1979-1982 averaged 126,090 hr and 23,237 kg, respectively, both of which exceeded the 1967-1970 peak. Yield declined sharply in 1983, partly due to flood conditions that discouraged use.

Harvest, creel rate, and yield were sustained at levels higher than otherwise possible by the stocking of catchable sized rainbow trout. Catchables were utilized almost continuously since 1970, especially in



Table 8. Summary of creel survey statistics, Flaming Gorge tailwater, 1964-1984.

Year	Angler Days	Angler Hours	Harvest <sup>a</sup>	Creel Rate	Catch Rate	Mean TL <sup>b</sup> (mm)	Mean Weight (gm)	Yield (kg)
1964	2,900	8,900	8,100	0.91	c	259	227	1,839
1965	8,200	21,300	17,000	0.79	c	272	259	4,399
1966	11,900	39,400	29,200	0.74	c	318	381	11,125
1967	27,800	124,400	71,200	0.57	c	340	459	32,648
1968	34,900	124,500	62,400	0.50	c	345	486	30,313
1969	25,600	79,300	21,300	0.27	0.32	386	636	13,538
1970	29,450	109,630	43,400	0.39	0.58	295	318	13,793
1971	16,867	59,302	22,420	0.38	0.59	312	368	8,245
1972	23,866	92,150	50,365	0.55	0.99	320	418	21,037
1973	17,609	70,565	27,671	0.39	0.81	356	504	13,945
1974	16,731	56,757	36,117	0.64	0.96	284	304	10,986
1975	14,123	69,196	24,094	0.41	c	292	310	7,469
1976	8,471	29,175	12,105	0.41	c	303	301	3,639
1977	20,439	61,681	29,078	0.47	0.66	304	309	8,981
1978	26,451	75,921	40,895	0.54	1.07	242	213	8,731
1979	22,008	81,217	42,023	0.51	0.89	310	379	15,927
1980	33,532	123,474	63,778	0.52	1.04	285	293	18,662
1981	43,316	152,514	91,952	0.60	1.17	311	360	33,049
1982	39,537	147,155	62,459	0.42	1.20	315	410	25,311
1983	---	97,559	52,835	0.54	1.30	307	356	18,859
1984	---	128,891	53,962	0.42	1.00	304	388	20,937

<sup>a</sup> Includes harvest of catchables which were stocked from 1970-1982.

<sup>b</sup> TL = Total Length

<sup>c</sup> Anglers were not questioned regarding catch they returned.



years of particularly poor winter carry over, and their contribution partially obscured trends in success of the trout put-grow-and-take program (Table 9).

It is impossible to surmise what level of angler use would have been experienced had catchables not been stocked during the study period. By subtracting the catchable contribution from the 1979-1984 harvest statistics, however, creel rate becomes a more meaningful indicator of success of put-grow-and-take management (Table 10). This adjusted creel rate was 0.29 in 1979, and reached highs of over 0.5 fish/hr in 1981 and 1983. Creel rate for trout stocked as fingerlings was, therefore, fairly unstable during the period, fluctuating nearly 50% between lowest and highest values. Use peaked with the 1981 peak in catch rate which magnified fluctuations in annual harvest. Harvest increased 119% between 1979 and 1981 and abruptly declined 32% in 1982.

The penstock modification produced a threefold increase in monthly summer growth, with first year growth of cutthroat and rainbow trout stocked as fingerlings now ranging from 25-30 mm/mo during the May-November growing season. The improved growth reduced the period required for stocked fingerlings to grow to catchable size but produced no discernable increase in mean TL of trout creeled (Figure 6).

#### Return to creel of stocked fingerlings

Rainbow trout fingerling size varied from 99 mm to 123 mm at time of stocking (requested size was 125 mm), and stocking date ranged from mid May to late July (Table 11). To facilitate comparisons between years, stocking size was adjusted for the theoretical length each cohort would have been if it had been stocked on 19 May. In doing so, it was assumed

Table 9. Return to creel of catchable-size (approximately 240 mm TL) rainbow trout, Flaming Gorge tailwater, 1978-1982.

Year Stocked	Number Stocked	% Return during the year stocked	Contribution to total harvest during the year stocked (%)
1978	24,582	69.7	41.9
1979	25,029	74.3	44.3
1980	25,757	69.0	27.9
1981	9,142	69.5	6.9
1982	25,158	63.5	25.6
1983	0	—	0

Table 10. Creel statistics with catchables-of-the-year substracted from the harvest, Flaming Gorge tailwater, 1979-1984.

Year	Hours	Harvest	Creel Rate	Mean Length	Mean Weight	Yield
1979	81,217	23,423	0.29	344	531	12,449
1980	123,474	45,997	0.37	288	314	14,430
1981	152,514	85,603	0.56	312	369	31,513
1982	147,155	46,494	0.32	326	455	21,655
1983	97,559	52,835	0.54	307	356	18,859

each cohort would have experienced a mean river growth rate of 1 mm/day between 19 May and the date actually stocked (Tables 11 & 12). This adjusted stocking TL for rainbow trout varied between 28 and 120 mm (Table 11).

The 1978 and 1979 rainbow trout cohorts failed to recruit to the creel during their first summer in the tailwater due to exceptionally late stocking dates, whereas subsequent cohorts contributed substantially during the late season of their respective years of planting.

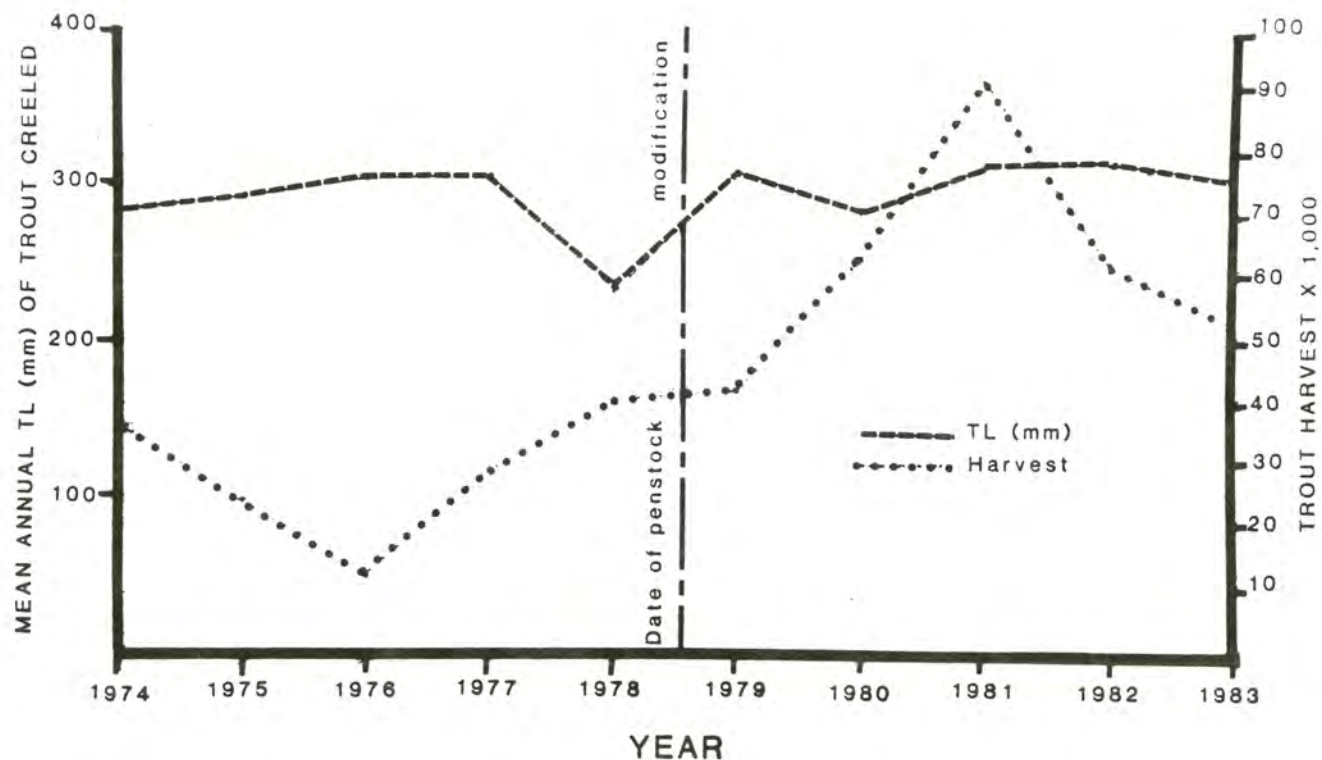


Figure 6. Trends in mean annual harvest and total length of trout creeled from the Flaming Gorge tailwater.

First season harvest of the 1981 year class was probably enhanced by record angler use in that year. Exceptionally high first season harvest of the 1982 rainbow trout year class probably reflects the higher rainbow trout stocking rate that year (Table 11).

Although first season contribution to the creel appeared to stabilize as stocking size approached that requested, second season contributions of each cohort were extremely variable—for rainbow trout ranging from 3.8% to 30.3% of the original cohort size. The high return rate of the 1980 cohort appears to be an exception, since it was never duplicated (Table 12).

Table 11. Stocking data and subsequent harvest of rainbow trout planted as fingerlings, Flaming Gorge tailwater, 1978-1982 cohorts.

Year Stocked	Dates Stocked	TL (mm) when stocked	Adj. <sup>a</sup> TL	Number Stocked	Harvest			
					1st Season	2nd Season	3rd Season	Cumu- lative
1978	11-12 July	123	69	103,751	4,461	5,916	2,001	7,917
1979	27-31 July	99	28	99,695	411	7,642	3,389	11,442
1980	15-22 May	120	120	100,004	13,071	30,321	2,769	46,161
1981	4-5 June	101	84	100,200	17,317	3,817	445	21,579
1982	4-16 June	115	93	175,967	22,005	14,428	176	36,609

<sup>a</sup> Adjusted TL = TL - (1 mm x no. days stocking delayed after 19 May).

Table 12. Stocking data and percent return to the creel of rainbow trout planted as fingerlings, Flaming Gorge tailwater, 1978-1982 cohorts.

Year Number Stocked	Number Stocked	Adj. <sup>a</sup> TL	1st Winter (Jan-Apr) Q <sup>b</sup>	% Return			Cumula- tive Return
				1st Season	2nd Season	3rd Season	
1978	103,751	69	141,025 (2,379)	4.3	5.7	1.9	11.9
1979	99,695	28	114,430 (1,959)	0.4	7.7	3.4	11.5
1980	104,044	120	78,345 (1,321)	13.1	30.3	2.8	46.2
1981	100,200	84	115,700 (1,965)	17.3	3.8	0.4	21.5
1982	175,967	93	158,850 (2,664)	12.5	8.2	0.1	20.8

<sup>a</sup> Adjusted TL = TL (mm) - (1 mm x no. days stocking delayed after 19 May).

<sup>b</sup> Mean monthly discharge for January - April of 1st winter after stocking, in acre feet/month (mean monthly discharge rate as cubic feet/sec in parenthesis).



The role of discharge (Q) on carryover cannot be adequately addressed on the basis of the short span of years since penstock modification for which creel data are available. In 1981, winter Q was unusually low (Table 12, Appendix Table C6, Appendix Figure C1). The carryover of the 1980 cohort was exceptionally high through that winter. The effect of Q on winter habitat is addressed further in subsequent sections of this report.

The adjusted stocking size of the successful 1980 rainbow trout cohort was 31% greater than the 1982 cohort, which was the second most successful cohort of rainbow trout, in terms of second season contribution to the creel. The 1982 cohort was the second largest in TL of the five rainbow trout year classes at time of stocking (Tables 11 and 12).

The 1980 rainbow trout cohort, during its second season, sustained the heaviest angling pressure of the study period, which further increased its return rate. The 1981 and 1982 rainbow trout cohorts experienced relatively heavy harvest during their first year in the tailwater, which may have slightly reduced their second year contribution to the creel (Tables 11 & 12).

Like the rainbow trout, the 1980 Snake River cutthroat trout cohort also returned much better than any other cutthroat trout year class, especially during its second season (Table 13). This cohort, again, was stocked at a larger size and experienced relatively low river discharges during its first winter.

There were no instances when rainbow trout fingerlings were subjected to noticeable stress during handling or stocking. Except for annual variation in size, fish health appeared to be satisfactory at time of stocking. Snake River cutthroat trout, however, never approached the

size requested. In 1981, stocking of cutthroat trout was delayed until July, when daytime water temperatures in Browns Park approached 20 C. The fish were frequently "iced down" at the hatchery; consequently, cutthroat trout stocked in Browns Park in 1981 undoubtedly were thermally stressed. In 1982, a large but undocumented percentage of the cutthroat trout appeared to have deformed, shortened vertebral columns.

The 1980 and 1981 cohorts, both rainbow and cutthroat trout, sustained relatively heavy angling pressure, but only the 1980 cohorts could be considered successful. Annual stocking rates were consistent from 1978-1981. River discharge regime (see below), fingerling size, date of stocking and, for Snake River cutthroat trout, health and handling of the stocked fish, appear to have been the most important determinants of the level of cohort success.

#### Yield

Following penstock modification, rainbow, cutthroat and brown trout yields all increased substantially. Although total yield of the tailwater appeared to have peaked in 1981, brown trout yield continued to increase (Table 14). Brown trout are not stocked in the tailwater, but brown trout yield increased an average of 77% annually after 1979.

#### Cohort longevity

Because population estimates were lacking, the only measure of relative annual recruitment to the creel, rate of mortality, and cohort longevity was trend in creel rates (C/E). After reaching full recruitment to the sportfishery, however, neither rainbow nor cutthroat trout survived in significant numbers more than two years. Estimation of

Table 13. Stocking data and percent return to the creel of Snake River cutthroat trout planted as fingerlings, Flaming Gorge tailwater, 1978 -1982 cohorts.

Year Stocked	Dates Stocked	TL (mm) when stocked	Adjusted <sup>a</sup> TL	Number Stocked	Return to Creel (% of number stocked in parenthesis)		
					1st Season	2nd Season	3rd Season Cumulative
1978	3-4 August	143	62	102,516	0 (0.0)	909 (0.9)	320 (0.3) 1,229 (1.2)
1979	29 June - 13 July	121	73	107,400	4,423 (5.5)	6,148 (5.7)	554 (0.5) 11,125 (11.7)
1980	12-13 June	122	98	100,699	3,081 (3.1)	11,402 (11.3)	687 (0.7) 15,170 (15.1)
1981 <sup>b</sup>	8-9 July	102	52	101,376	322 (0.3)	1,859 (1.8)	451 (0.4) 2,632 (2.5)
1982 <sup>c</sup>	8-11 June	113	92	49,140	427 (0.9)	1,421 (2.9)	54 (0.1) 1,902 (3.9)

<sup>a</sup> Adjusted TL = TL - (1 mm x no. days stocking delayed after 19 May).

<sup>b</sup> Post stocking mortality for fish stocked in Browns Park was probably high: difference in temperature between truck and receiving water exceeded 10 C there in 1981.

<sup>c</sup> High incidence of deformed vertebrae observed among cutthroat stocked in 1982.



annual mortality for individual cohorts should be based upon more than two years of catch data per year class. However, identifying the cause of apparently high mortality (short longevity) in the Green River fishery was a priority concern. Monthly, rather than annual, catch rates from the creel census data were, therefore, used to compare C/E trends between cohorts and to attempt to identify periods of most rapid decline in year class strength among fully recruited (adult) trout.

Specifically, the objective of this analysis was to assess the relative seasonal magnitudes of cohort attrition--summer (angling season) versus winter--and provide some insight regarding the contribution of sportfishery harvest to total mortality among the adult trout population.

Age determination was exclusively on the basis of dye marks. Attrition of marked cohorts was, therefore, a reflection of the combined effects of mortality and loss of the dye mark. It was assumed that dye loss occurred at a constant but unknown rate.

Very few fish older than age III were observed in the creel. This paucity of older marked fish is primarily a reflection of mortality, rather than loss of marks, since even unmarked trout only rarely exceeded 400 mm in either the creel or electrofishing samples.

Attrition of surviving "carryover" during the second and third seasons each cohort was exposed to angling was assessed by plotting adjusted catch curves based upon the monthly sportfishery catch rate of each cohort. This analysis was complicated by an apparent increase in vulnerability to angling during the latter half of the season (Tables 15 & 16). After August, the composition of fishermen shifted from largely family outings to a preponderance of more experienced anglers. Insect emergence, trout food availability, and predominantly low flows typical



Table 14. Total harvest and yield, Flaming Gorge tailwater, 1977-1984.

Year	Rainbow Trout		Snake River Cutthroat		Brown Trout	
	Harvest	Yield (kg)	Harvest	Yield (kg)	Harvest	Yield (kg)
1977	28,181	8,708	824	255	29	9
1978	37,138	7,724	3,376	715	381	292
1979	33,943	11,914	7,532	3,359	477	464
1980	51,131	15,088	11,181	2,839	1,334	695
1981	74,752	27,004	15,918	5,454	1,282	591
1982	53,655	20,700	4,217	2,405	4,534	2,188
1983	42,849	14,140	4,933	2,466	4,145	2,238

of fall may also have altered vulnerability. In any case, plots of monthly catch rates were somewhat curvilinear, even when C/E was transformed to its natural logarithm. Catch curves based upon monthly data, therefore, probably violate the assumption of equal vulnerability and cause underestimation of summer mortality.

Any decline in dye retention over the angling season would, on the other hand, tend to cause overestimation of mortality. Initial mark retention was recorded at time of stocking for rainbow trout in 1979 (green dye) and 1980 (red), and for cutthroat trout in 1979 (green) and 1981 (yellow). The respective mark retention rates were 97% (n = 108) and 100% (n = 116) for rainbow; 99% (n = 107) and 94% (n = 193) for cutthroat trout. These inspections were approximately 2-3 weeks after the mark had been applied. Rate of dye mark loss subsequent to stocking was not determined.

Table 15. Creel contributions for three years following stocking, rainbow trout 1978-1982 cohorts, stocked as fingerlings in the Flaming Gorge tailwater.

	Cohort				
	1978	1979	1980	1981	1982
Number stocked	103,751	99,695	100,004	100,200	175,967
Adjusted <sup>a</sup> TL (mm) of fingerling	69	28	120	84	93
Monthly Creel Rates:					
1st Opening Weekend	b	c	c	0.000	0.000
June	b	0.000	0.011	0.000	0.021
July	b	0.002	0.055	0.011	0.083
August	b	0.006	0.187	0.218	0.280
September	b	0.009	0.292	0.386	0.302
October/November	b	0.017	0.195	0.606 <sup>d</sup>	0.577 <sup>d</sup>
2nd Opening Weekend	c	c	0.259	0.088	0.165
June	0.033	0.051	0.330 <sup>d</sup>	0.041	0.313
July	0.050	0.070	0.171	0.016	0.229
August	0.137 <sup>d</sup>	0.074 <sup>d</sup>	0.114	0.008	0.072
September	0.059	0.052	0.110	0.022	0.058
October/November	0.041	0.042	0.041	0.019	0.063
3rd Opening Weekend	c	0.018	0.038	0.005	0.007
June	0.034	0.042	0.035	0.011	0.001
July	0.014	0.020	0.018	0.004	0.003
August	0.003	0.009	0.006	0.005	0.000
September	0.007	0.004	0.003	0.002	0.000
October/November	0.005	0.007	0.013	0.000	0.000

<sup>a</sup> Adjusted TL = stocking size (mm) - (1 mm x no. days stocking delayed past 19 May).

<sup>b</sup> Equivalent creel data not available for cohort-of-year in 1978.

<sup>c</sup> Opening day strata had not yet been designed into the creel census.

<sup>d</sup> Cohort considered fully recruited by this month.

Table 16. Creel contributions for three years following stocking, Snake River cutthroat trout, 1978-1982 cohorts, stocked as fingerlings in the Flaming Gorge tailwater.

	Cohort				
	1978	1979	1980	1981	1982
Number Stocked	102,516	107,400	100,699	101,376	49,140
Adjusted <sup>a</sup> TL (mm) of fingerlings	62	73	98	52	92
Monthly Creel Rates:					
1st Opening Weekend	b	c	c	0.000	0.000
June	b	0.000	0.001	0.000	0.001
July	b	0.000	0.000	0.002	0.000
August	b	0.051	0.034	0.000	0.001
September	b	0.121	0.066	0.006	0.006
October/November	b	0.315	0.189	0.020	0.036
2nd Opening Weekend	c	c	0.128	0.007	0.012
June	0.019 <sup>d</sup>	0.071 <sup>d</sup>	0.098 <sup>d</sup>	0.010 <sup>d</sup>	0.042 <sup>d</sup>
July	0.004	0.065	0.093	0.014	0.019
August	0.014	0.020	0.037	0.018	0.007
September	0.008	0.024	0.018	0.012	0.007
October/November	0.008	0.033	0.018	0.004	0.006
3rd Opening Weekend	c	0.006	0.012	0.009	0.003
June	0.004	0.008	0.006	0.013	0.000
July	0.002	0.002	0.004	0.006	0.000
August	0.002	0.001	0.003	0.002	0.001
September	0.000	0.000	0.001	0.002	0.000
October/November	0.009	0.000	0.004	0.000	0.000

<sup>a</sup> Adjusted TL = stocking size (mm) - (1 mm x no. days stocking delayed past 19 May).

<sup>b</sup> Equivalent creel data not available for cohort-of-year in 1978.

<sup>c</sup> Opening day strata had not yet been designed into the creel census.

<sup>d</sup> Cohort considered fully recruited by this month.



Table 17. Transformed<sup>a</sup> monthly angler catch rates, second and third angling seasons, 1978-1982 dye marked rainbow trout cohorts.

	Cohort				
	1978	1979	1980	1981	1982
Number Stocked	103,751	99,695	100,004	100,200	175,967
Adjusted <sup>b</sup> fingerling TL (mm)	69	28	120	84	93
<u>Year 2</u>					
June	Not recruited	Not recruited	6.908	6.908	6.908
July	Not recruited	Not recruited	6.250	5.966	6.596
August	6.908	6.908	5.844	5.273	5.438
September	6.066	6.555	5.808	6.286	5.220
October/November	5.434	6.342	4.820	6.138	5.303
<u>Year 3</u>					
June	5.413	6.342	4.663	5.591	1.099
July	4.625	5.598	4.007	4.585	2.303
August	3.091	4.804	2.890	4.804	0.0
September	3.932	3.989	2.197	3.871	0.0
October/November	3.597	4.554	3.664	0.0	0.0

<sup>a</sup> Transformed C/E =  $\text{Log}_e [(1,000 \text{ divided by C/E of 1st fully recruited month in creel}) \times \text{monthly C/E}]$ .

<sup>b</sup> Adjusted TL = Stocking size (mm) - (1 mm x no. days stocking delayed after 19 May).

Table 18. Transformed<sup>a</sup> monthly angler catch rates, second and third angling seasons, 1978-1982 dye marked Snake River cutthroat trout cohorts.

	Cohort				
	1978	1979	1980	1981	1982
Number Stocked	102,516	107,400	100,699	101,376	49,140
Adjusted <sup>b</sup> fingerling TL (mm)	62	73	98	52	92
<u>Year 2</u>					
June	6.908	6.908	6.908	6.908	6.908
July	5.352	6.819	6.855	7.244	6.114
August	6.603	5.642	5.935	7.496	5.112
September	6.043	5.823	5.214	7.090	5.116
October/November	6.043	6.142	5.214	5.991	4.963
<u>Year 3</u>					
June	5.352	4.727	4.111	7.170	Insign-
July	4.654	3.332	3.714	6.397	ificant
August	4.654	2.639	3.434	5.298	3rd yr.
September	0.0	0.0	2.303	5.298	return.
October/November	6.161	0.0	3.714	0.0	

<sup>a</sup> Transformed C/E =  $\text{Log}_e [(1,000 \text{ divided by C/E of 1st fully recruited month}) \times \text{each monthly C/E}]$ .

<sup>b</sup> Adjusted TL = Stocking size (mm) - (1 mm x no. days stocking delayed past 19 May).

The summer catch curves were prepared by equating to 1,000 the catch rate of the month that each cohort fully recruited to the fishery (usually June, approximately one year following stocking), and then adjusting each subsequent monthly C/E proportionately. The adjusted monthly C/E data were then transformed to their natural logarithms, which improved the linearity of their regressions (Tables 17 and 18; Figures 7 and 8).

Rainbow trout of the 1978 and 1979 cohorts apparently did not reach full recruitment to the creel until August of their second year (Table 15). The adjusted stocking size of these two cohorts was the smallest of the 5 study years. Similarly, the 1978 and 1981 Snake River cutthroat trout cohorts were stocked at relatively small adjusted sizes (Table 16), and their irregular catch curves suggest recruitment to the fishery was still developing during their second season after stocking.

Mean monthly attrition of dye marked rainbow trout cohorts ranged from 12% - 52% during their second season in the sportfishery, averaging 32%. The monthly attrition during the third season in the fishery ranged from 32% - 70% and averaged 43% (Figure 7). Total C/E decline for the 6 month angling season averaged 65% and 89% during the second and third years rainbow trout were exposed to harvest.

Mean winter attrition (between October/November of the second angling season and June of the third season), based upon differences in end points of the catch curves, was also highly variable and averaged 41% for rainbow trout (Table 19).

Second and third year catch curves for cutthroat trout nearly paralleled those of rainbow trout (Table 18, Figure 8). Attrition during the second and third angling seasons averaged 65% and 82%, respectively,



for cutthroat trout. Attrition between the second and third seasons (winter) was somewhat higher than for rainbow trout, averaging 61% (Table 19).

Some of the apparent winter loss for both species can be accounted for by harvest which occurred on the opening weekend, a stratum of the creel survey that was not included in the catch curves. Furthermore, June, July and August are months of especially heavy use (Table 20). Heavy use may depress angling effectiveness and depress C/E by almost immediately depleting the fishery. The creel census effort was reduced in 1984, with the end of the field portion of this study, which may in part explain the apparently low third year contributions of the 1982 rainbow and cutthroat trout cohorts. The extremely low numbers of three-year old trout observed in the 1984 creel, however, suggest that survival the previous winter was, indeed, exceptionally low. Discharge levels were unusually high that winter (Appendix Table C6). Winter attrition during the study averaged 41% and 61% for two-year old rainbow and cutthroat trout, respectively. Excluding the winter of 1984, winter attrition of two-year old trout stocked during the study averaged 27% for rainbow and 51% for cutthroat trout.

#### Fish release rates, terminal tackle and hooking mortality

During the 1981 creel census, all anglers interviewed were asked the type of terminal gear used: 1) bait, 2) lures or flies, or 3) both bait and artificials (Table 21). In addition, counts of dead fish, based upon snorkeling surveys, were made immediately prior to the opening of the fishing season, and periodically during the early season

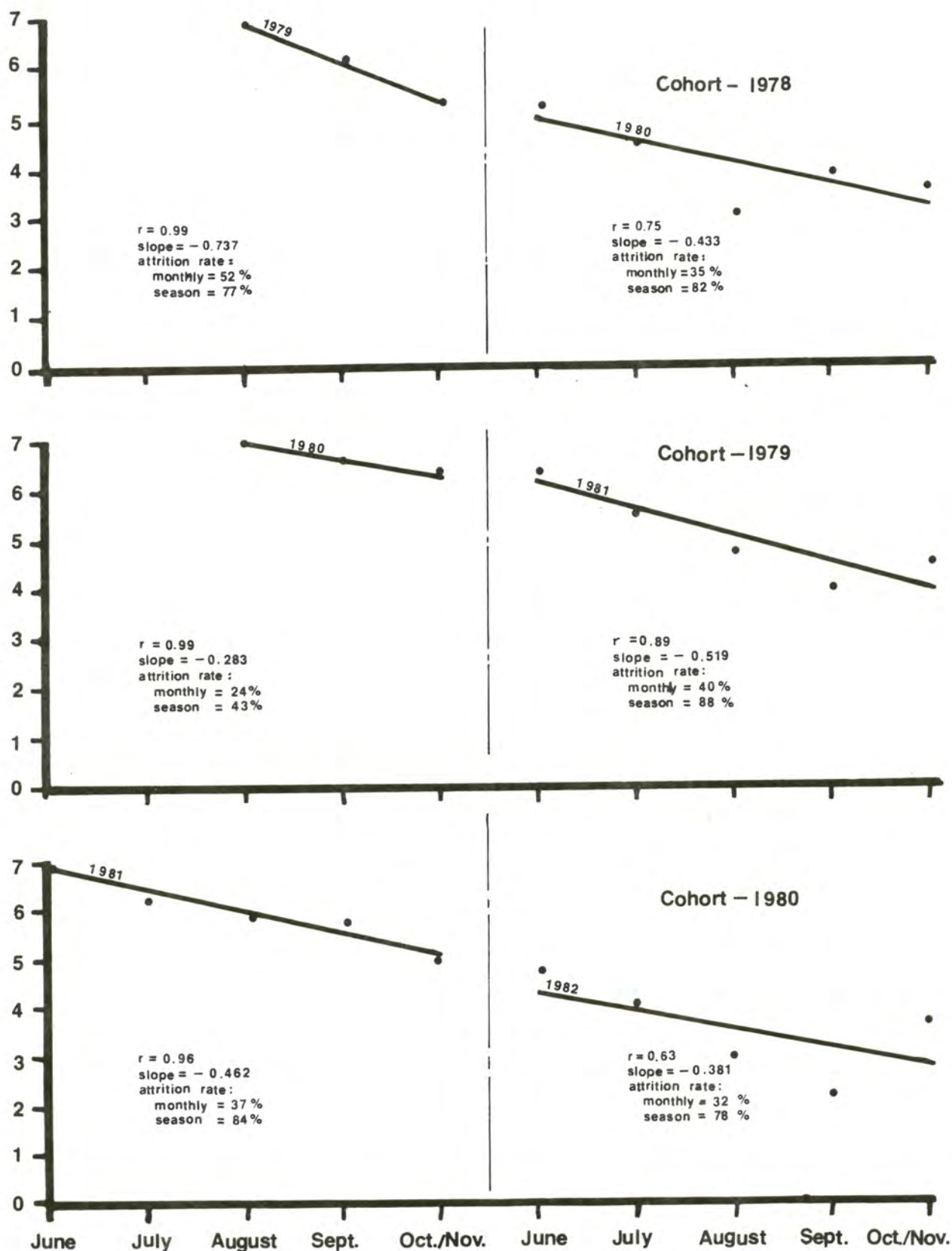


Figure 7.  $\log_e$  adjusted monthly second and third year catch curves from creel census for 1978-1982 dye marked rainbow trout cohorts.

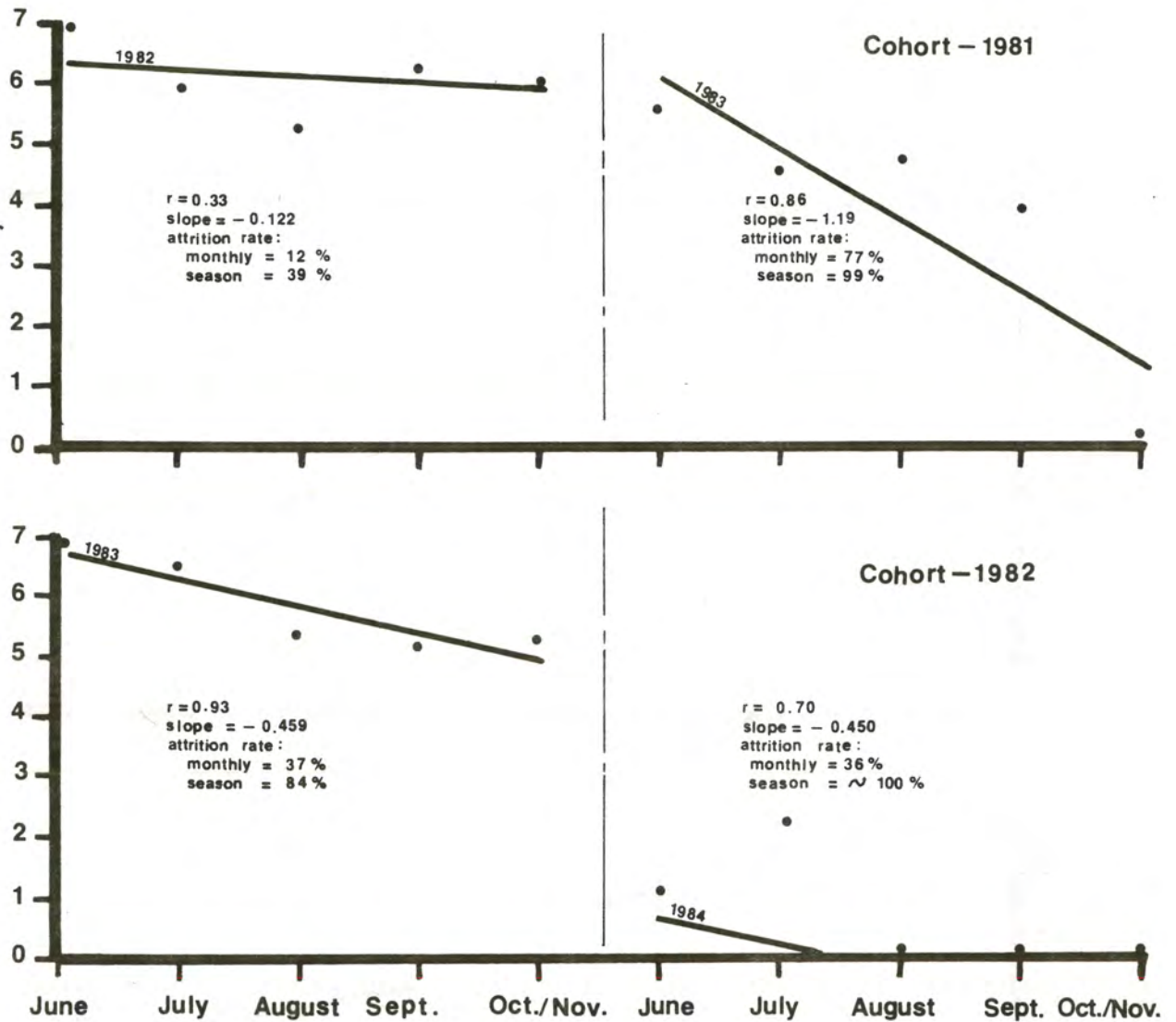


Figure 7. (Continued).



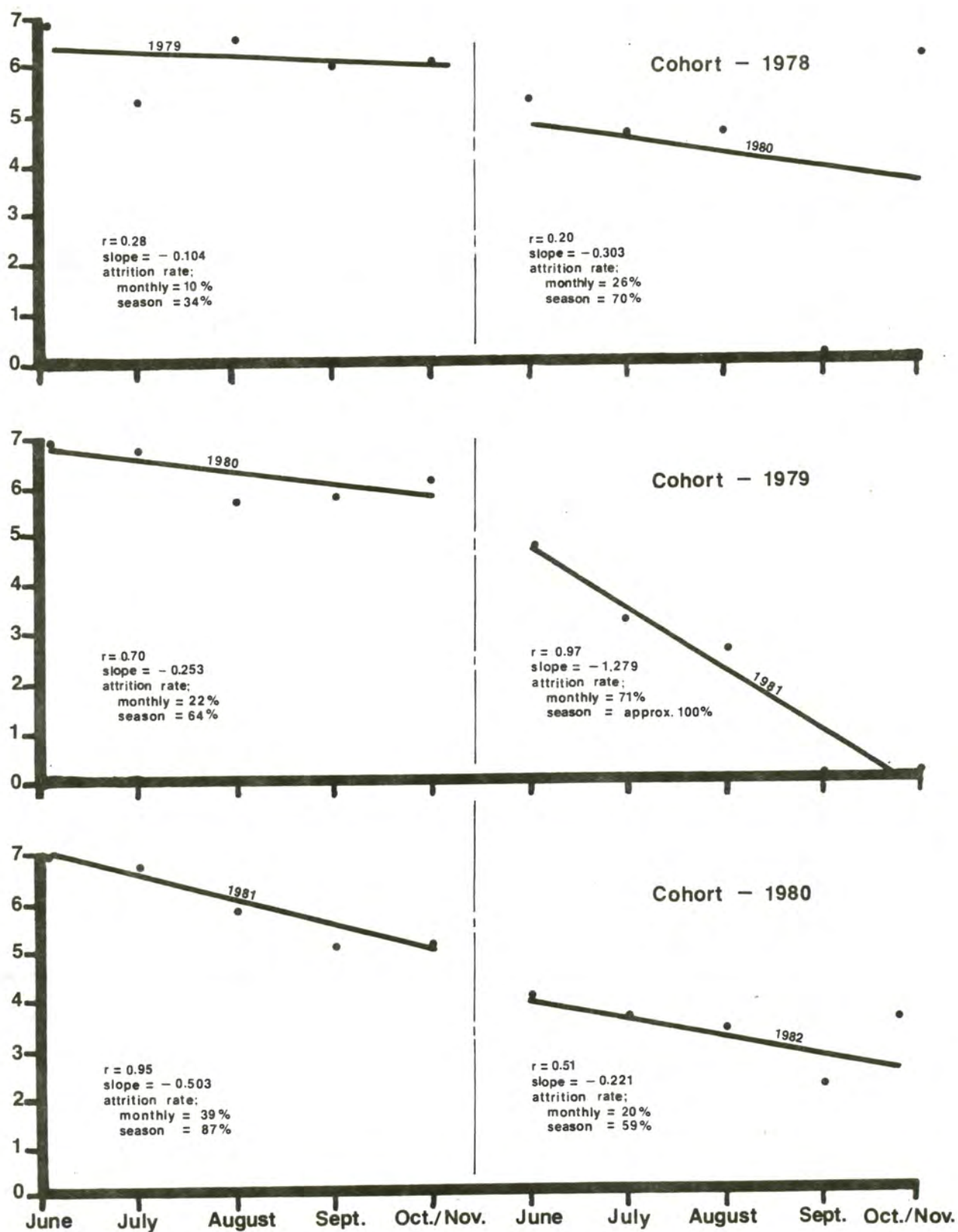


Figure 8.  $\text{Log}_e$  adjusted monthly second and third year catch curves from creel census for 1978-1982 dye marked cutthroat trout cohorts.

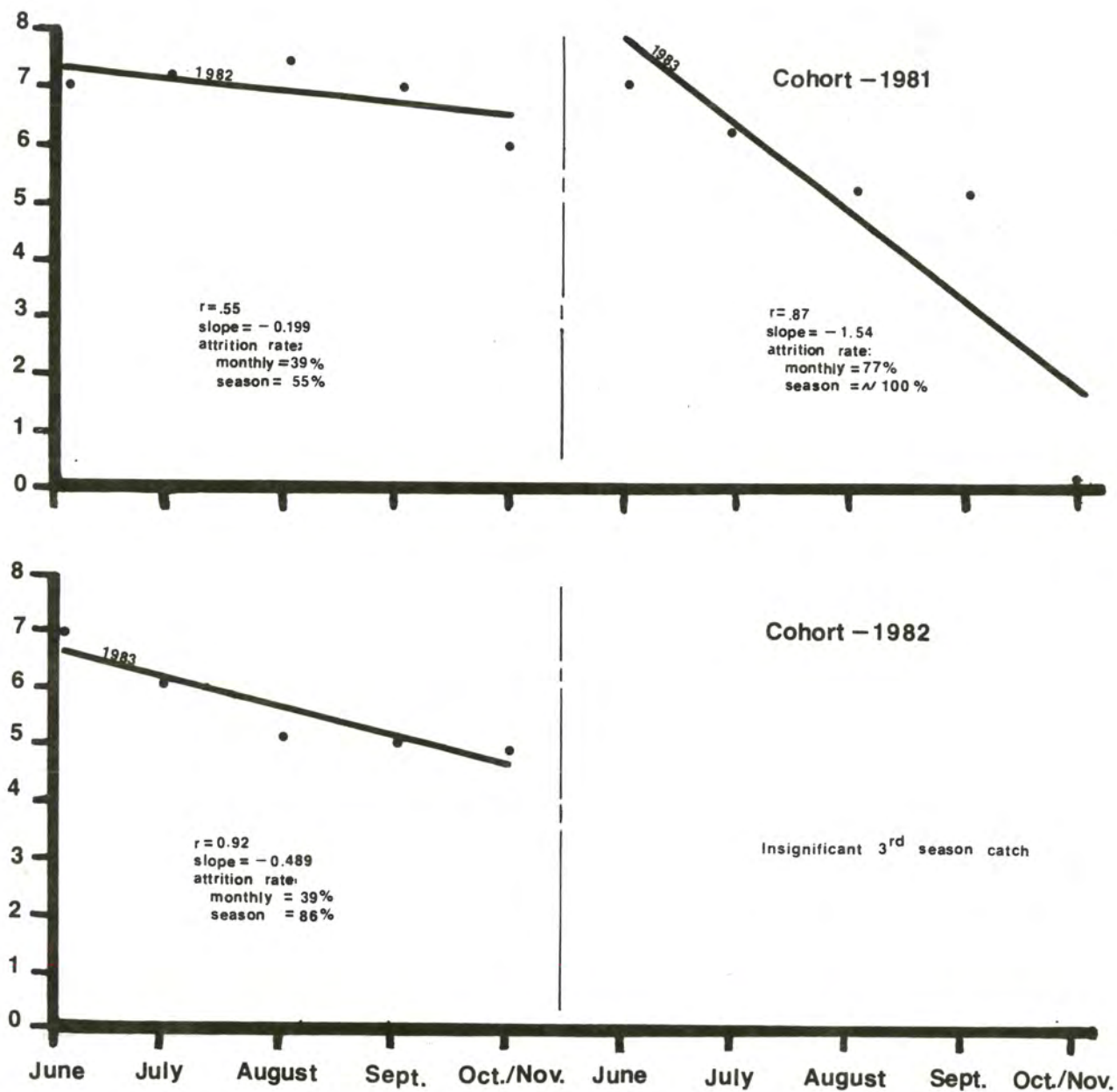


Figure 8. (Continued).

Table 19. Attrition in adult dye marked trout during the second winter following stocking, based upon differences in estimated Oct/Nov and June catch rates from second and third summer transformed catch curves.

Cohort	Winter of:	Rainbow Trout			Cutthroat Trout		
		Log <sub>e</sub> Adj. C/E		Estimated Attrition (%)	Log <sub>e</sub> Adj. C/E		Estimated Attrition (%)
		Oct/Nov	June		Oct/Nov	June	
1978	1980	5.40	5.00	33	5.98	4.77	70
1979	1981	6.32	6.09	20	5.70	4.70	65
1980	1982	5.00	4.25	53	5.02	3.90	68
1981	1983	5.87	6.15	0	6.55	7.92	0
1982	1984	4.99	0.66	Near 100%	4.66	0	100
Mean = 41%					Mean = 61%		

Table 20. Estimated fishing pressure (hours), by month, Flaming Gorge tailwater, 1979-1984.

Year	Opening Weekend	June	July	August	September	Oct/Nov	Total
1979	a	18,003	21,081	24,287	13,426	4,430	81,217
1980	5,113	33,648	34,513	31,994	12,219	5,987	123,474
1981	8,568	45,307	46,443	31,195	12,310	8,691	152,514
1982	11,064	30,950	53,770	30,452	13,536	7,384	147,155
1983	10,929	10,289	26,737	26,232	15,786	7,585	97,559

<sup>a</sup> Opening Weekend pressure estimates had not been designed into the creel census in 1979.



until after the 4 July Holiday weekend, to ascertain whether post-release mortality appeared to be a serious source of loss to the Green River fishery.

Stringer (1967) concluded that from 30-70% of trout caught with bait and released eventually died from associated injuries, but fish released after being caught with artificials experienced less than 10% mortality. To assess the probable incidence of hooking mortality among released fish in the Flaming Gorge tailwater, it was necessary to assume that anglers reporting use of a combination of bait and lures caught half of their throwbacks with each type of gear. Also, because catch rate estimates were not stratified by type of terminal gear, it was necessary to assume that catch rates for all gear types were equal. Anglers using bait or a combination of bait and artificial gear accounted for an estimated 88.4% of angling pressure in 1981; 67.4% of anglers reported using bait exclusively and 21.0% used both bait and artificials. The range of possible hooking losses from 1980 through 1983 is given in Table 22.

It was impossible to ascertain probable age of trout released, but release rate increased sharply in fall (Table 23). During the latter part of the season, recently stocked cohorts first became vulnerable to anglers; thus, except for 1981, released fish were primarily composed of cohorts-of-the-year. In 1981, a considerable number of carryover fish may have been released due to: 1) their relatively high availability, and 2) imposition of a regulation change that year limiting anglers on the opening weekend to only two fish larger than 330 mm (13 in).

Counts of dead fish made during snorkeling (Table 24) are probably conservative. Concentrations of dead fish were found in two deeper pools using scuba equipment. Dead fish in such areas often would escape notice

Table 21. Terminal gear used by anglers fishing the Flaming Gorge tailwater in 1981.

Terminal Gear	% Angler Use						Weighted Mean
	Opener	June	July	August	Sept.	Oct/Nov	
Flies	5.1	3.2	6.0	3.9	3.8	7.2	4.7
Lures	7.7	4.9	4.8	5.2	5.7	15.3	6.2
Combination of Artificials	0.0	0.4	1.6	1.2	1.0	0.0	0.7
Bait	53.6	67.6	61.8	75.3	75.8	59.5	67.4
Bait and Artificials	33.6	23.8	25.8	14.5	13.7	18.0	21.0
Total Artificials	12.8	8.6	12.4	10.2	10.5	22.5	11.6
Total Bait & Bait w/Artificials	87.2	91.4	87.6	89.8	89.5	77.5	88.4

Table 22. Estimated ranges of hooking mortality of trout released by anglers, 1980-1983.

	Estimated <sup>a</sup> number trout released by method			Estimated hooking mortality by method			Total <sup>b</sup>
	<sup>a</sup> Total	Bait	Artificial	Bait		Artificial	
				30%	70%	10%	
1980	64,018	49,869	14,148	14,961	34,908	1,148	16,109-36,056
1981	86,181	67,135	19,046	20,141	46,995	1,946	22,087-48,941
1982	114,061	88,854	25,200	26,656	62,198	2,521	29,177-64,719
1983	74,289	57,289	16,418	17,187	40,102	1,642	18,829-41,744

<sup>a</sup> From expansion of data provided by anglers in creel census.

<sup>b</sup> Total represents range using 30% - 70% hooking mortality rates for bait caught and constant 10% mortality for lure caught fish.

Table 23. Mean weighted creel and catch rates (fish/hr) by month, Flaming Gorge tailwater, 1979-1983.

Year	Opening		June		July		August		September		Oct/Nov	
	Creel	Catch	Creel	Catch	Creel	Catch	Creel	Catch	Creel	Catch	Creel	Catch
1979	--	--	0.43	0.62	0.45	0.60	0.62	0.86	0.47	1.49	0.62	1.75
1980	0.46	0.67	0.41	0.66	0.46	1.14	0.55	1.13	0.75	1.61	0.79	1.21
1981	0.70	1.80	0.73	1.16	0.47	0.82	0.50	1.11	0.66	1.93	0.84	1.61
1982	0.24	0.36	0.30	0.69	0.38	1.29	0.49	1.49	0.56	1.81	0.98	1.65
1983	0.42	0.53	0.74	1.44	0.70	1.39	0.36	1.12	0.44	1.50	0.76	2.08

Table 24. Counts of dead fish observed while snorkeling, Flaming Gorge tailwater, 1981.

Date	Flaming Gorge Dam to Pipe Creek	Pipe Cr. to mile 6.5	River Mile 6.5 to Little Hole	Mean No. Per Mile
28 May	0	a	0	0
3 June	11	a	20	--
15 June	26	38	13	10
2 July	16	15	9	6
7 July	7	82 <sup>b</sup>	10	14

<sup>a</sup> Not Sampled.

<sup>b</sup> This estimate includes 2 pools where counts in deeper areas were made using scuba gear.

Table 25. Raft use and angler participation among raft users, Flaming Gorge tailwater, 1979-1982.

Year	Number rafts	% With at least one angler	Raft Passengers	
			Number	% Angling
1979	9,095	36.0	55,994	20
1980	8,812	50.4	47,074	30
1981	10,334	59.5	56,972	35
1982	11,450	64.6	53,629	38

from the surface. Other fish may have been swept considerable distances downstream or buried under sediment and debris. Some fish may have decomposed or been removed by scavengers between counts. No dead fish



were observed in the counts conducted prior to the opening weekend in 1981 but counts averaged 72 fish, or approximately 10 fish per river mile, during three counts conducted between 15 June and 7 July. Because these counts were neither complete (bottoms of most deep pools were not observed) nor systematic, they cannot be expanded to estimate mortality. The absence of dead fish during the count prior to the opening day suggests, however, that significant mortality occurs that is attributable to angling.

#### Characterization of raft use

Raft use rose during the period of study and angling participation rate of those floating the Green River steadily rose, from 20% in 1979 to 38% in 1982. Angling was engaged in by at least one raft occupant in 65% of rafts floating the Green River in 1982 (Table 25).

#### Summary - sportfishery trends

1. Harvest, use, and yield increased considerably due to warmer water temperatures resulting from modification of the Flaming Gorge penstocks.
2. Record yield of 111.1 kg/ha, reached in 1981, was probably not sustainable.
3. Yield of the sportfishery was limited by survival rates of stocked fingerlings during their first winter in the tailwater.
4. Winter survival of stocked cohorts-of-the-year appeared to be enhanced by stocking of larger (120 mm) fingerlings in May and/or by low (1,320 cubic ft/sec mean monthly) discharges in winter. Rainbow trout survival consistently exceeded that for Snake River cutthroat

trout but the cutthroat trout were disadvantaged in terms of stocking size, stocking date and, occasionally, body condition and handling received.

5. No stocked fingerling cohort during the study contributed significantly to the creel for more than three angling seasons. For all but the 1980 cohorts, combined second and third season return ranged less than 11% of the number of rainbow trout stocked and less than 6.5% of the cutthroat trout.
6. Those trout surviving winter were exposed to relatively high summer mortality. Catch curves of dye marked trout suggest stocked rainbow trout cohorts were depleted at mean monthly rates of 37% and 43% during their second and third seasons in the sportfishery; the total second and third season (6 month) depletion rates for rainbow trout averaged 65% and 87%. Cutthroat trout depletion rates paralleled those of rainbow trout.
7. Sportfishery yield from 1979 through 1983 ranged from 53-111 kg/ha, suggesting the bulk of summer mortality was due to harvest.
8. Based upon differences in monthly catch curves between each cohort's second and third season in the sportfishery, natural winter loss of two-year old (adult) dye marked trout averaged 41% and 61% for rainbow and cutthroat trout, respectively.
9. Hooking mortality of trout released by anglers may have contributed substantially to mortality during the angling season. The bulk of hooking mortality was probably among stocked trout experiencing their first summer in the tailwater.

## SEASONAL MORTALITY AND MIGRATION OF STOCKED FINGERLINGS

### Electrofishing catch trends

Electrofishing catch per effort (C/E) must be considered a highly biased means of trend monitoring, due to changes in efficiency by season. Although standard flows (1,500 cfs) were requested from the Bureau of Reclamation, and all sampling was at night when trout appeared to concentrate in shallower water, seasonal changes in trout distribution and water temperature altered vulnerability. Typically, the trout moved from shallower runs to the deeper pools in December and January and resumed occupancy in the shallower summer habitats during March and April. Thus catch rate was probably depressed in winter due to the greater average depth the trout occupied that time of year. Seasonal changes in water temperature also were likely to affect catch efficiency. Comparisons of C/E trends between years, however, might be expected to reveal major annual trends, if sample dates under comparison are subject to standardized methods and similar seasonal patterns of fish behavior and habitat conditions. The winters of 1980-81 and 1981-82 appear to meet these criteria.

Equipment failures and inclement conditions resulted in the failure to obtain certain scheduled samples, such as the fall 1980 samples at Tailrace and Little Hole. These shortcomings, combined with variation in vulnerability, limited the use of electrofishing C/E to detection of only the most significant changes in trout abundance.

In December, trout moved to predominantly deep pool-like winter habitats where they became less vulnerable to electrofishing. Between March and May, 1981, there was a distinct increase in electrofishing C/E for yearling rainbow trout at both Tailrace and Little Hole (Figures 9

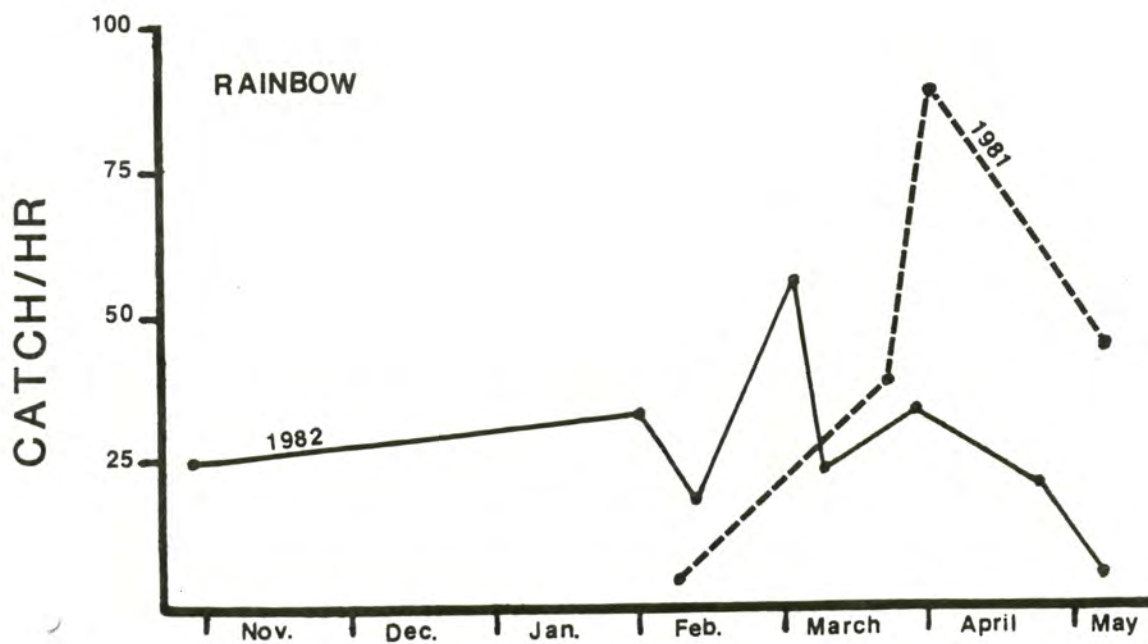
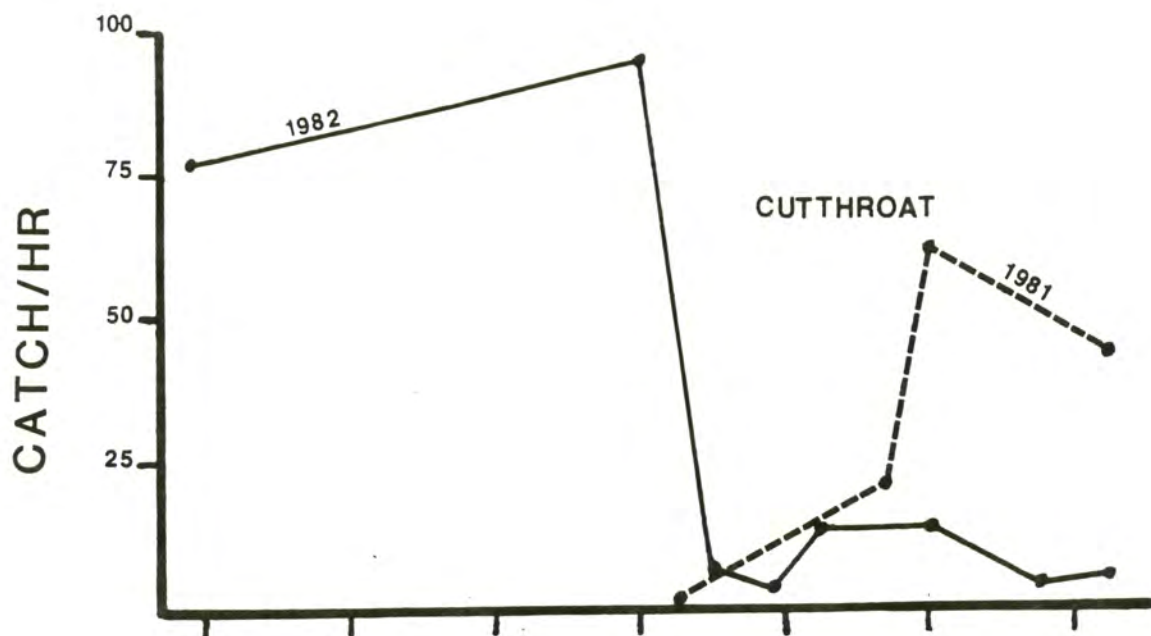


Figure 9. Trends in electrofishing catch rate, February - May 1981 and October - May 1981-82, Tailrace station, for cohorts stocked as fingerlings the previous spring.



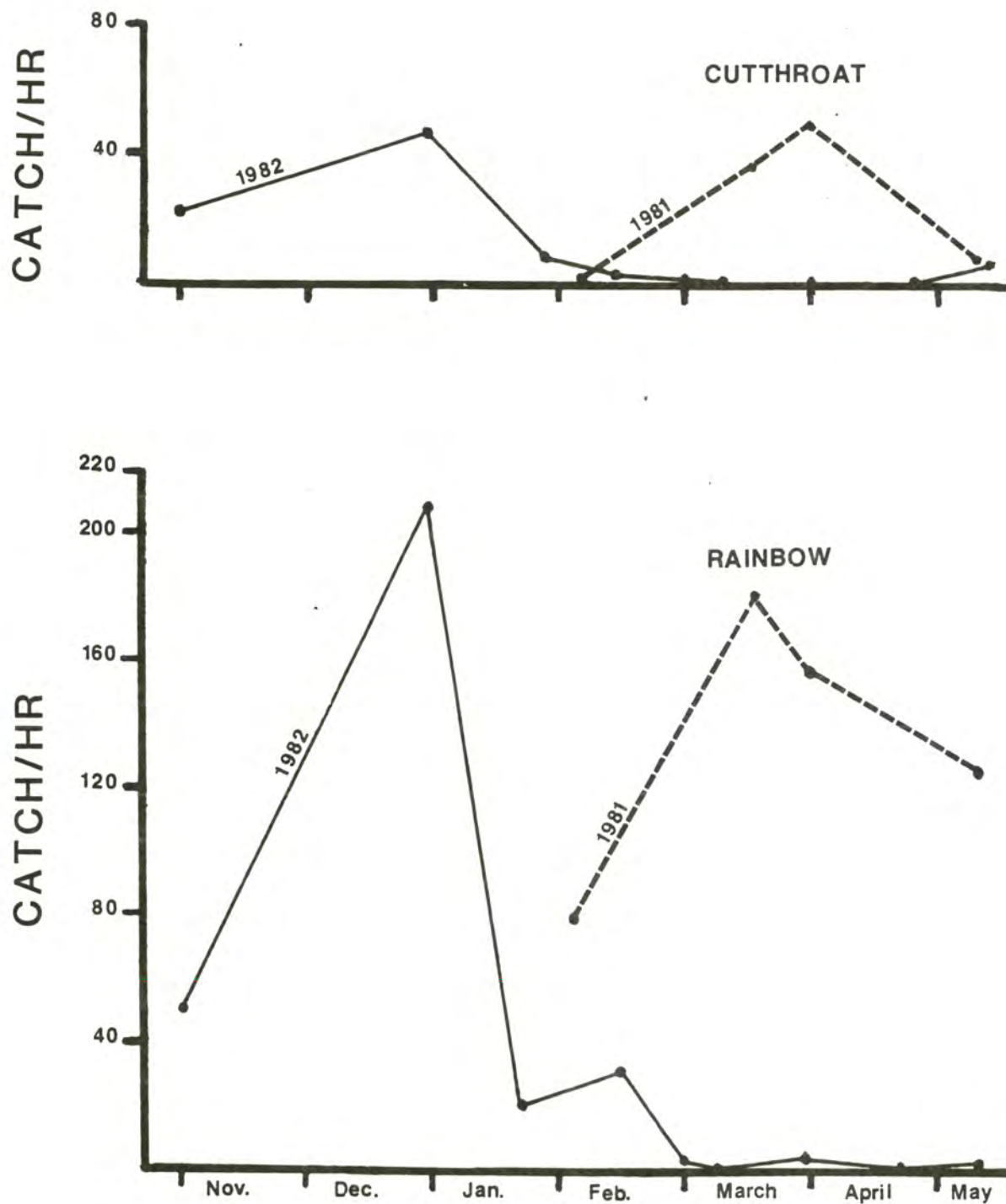


Figure 10. Trends in electrofishing catch rate, February - May 1981 and November - May 1981-82, Little Hole Station, for cohorts stocked as fingerlings the previous spring.

and 10), probably due to the seasonal movement of these fish from deeper winter habitats to shallower waters. In 1982, there was no detectable resurgence in C/E during the March-May periods (Figures 9 and 10), suggesting there had been a substantial decline in numbers of yearling trout in the tailwater since fall 1981. Electrofishing trends, therefore, seem to portray a winter of relatively high yearling trout survival (1980-1981) followed by one of relatively low (1981-1982) survival at Tailrace and Little Hole.

Standardized electrofishing was conducted at Browns Park during the winter of 1980-1981 only. Comparisons of electrofishing C/E trends between years are, therefore, not possible for the lower river. The high catch of yearling cutthroat trout, relative to rainbow trout, at Browns Park (Figure 11) was due to the stocking allocation in 1980, when Browns Park received 66% and 17.4% of the tailwater's cutthroat and rainbow trout stockings, respectively.

Mean winter brown trout C/E at Browns Park was 33.0/hr in 1980-1981 and exceeded that of all other species combined. The brown trout C/E was 0.0 and 16.9/hr at Tailrace and 6.6 and 22.7/hr at Little Hole in the winters of 1981 and 1982, respectively.

Rainbow and cutthroat trout of hatchery origin (displaying fin clips or dye marks) were the predominant catch at Tailrace and Little Hole. The electrofishing data for both winters are given in Appendix Tables B1-B5.

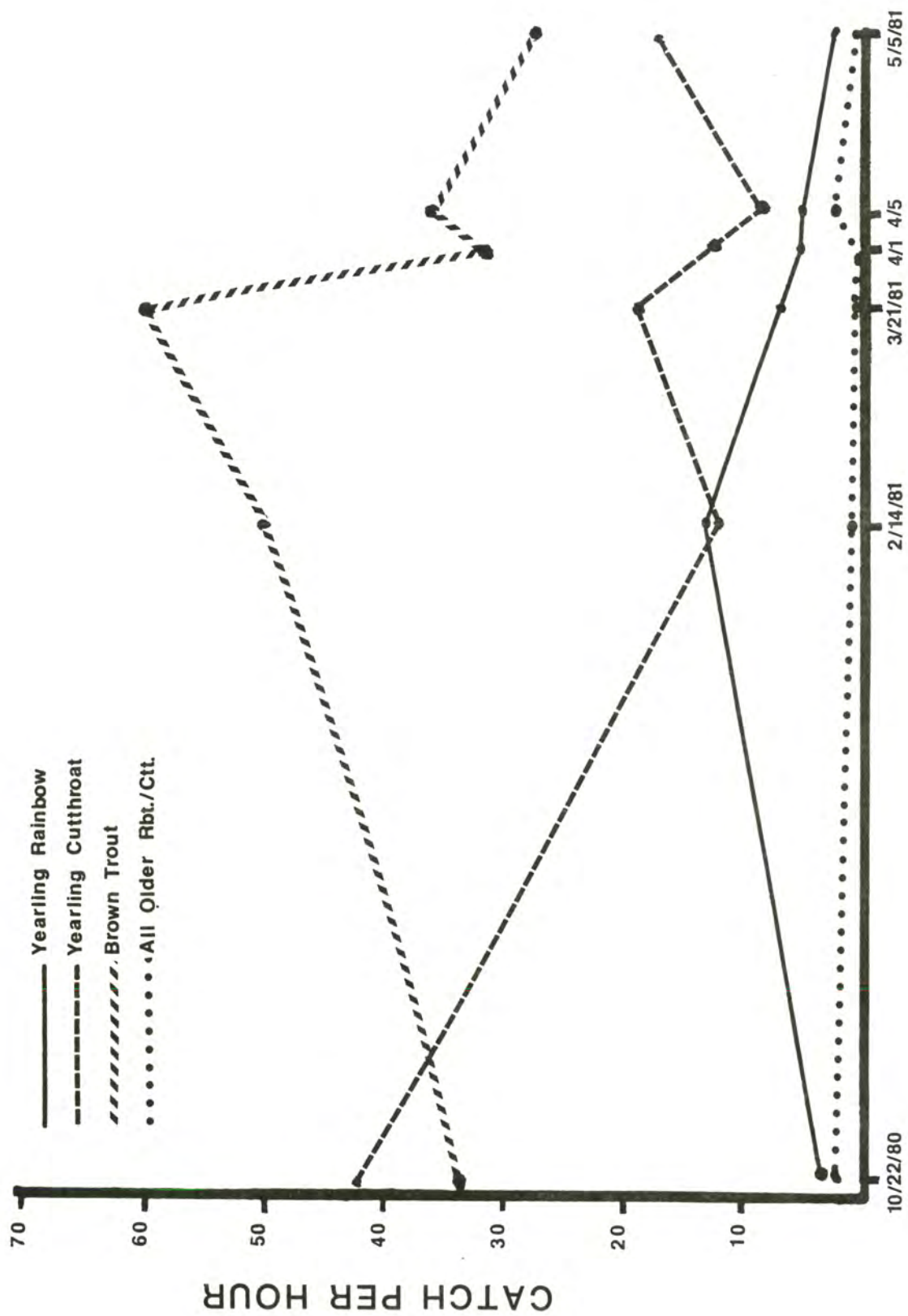


Figure 11. Trends in electrofishing catch rate, October - May 1980-1981, Browns Park Station.

#### Site specific dye marks--movement between stocking sites

During 1979 there was little evidence of movement of double dye marked fish from the stocking sites. Of 55 double dye marked trout observed in the creels of shore anglers during August-November 1979, 89% were taken in the general vicinity of their stocking sites (Table 26). Electrofishing at Tailrace and Little Hole in October of 1979 produced 36 rainbow and 29 cutthroat trout with double dye marks and none had moved between stocking sites.

Electrofishing from January-April 1980 produced a total of 82 rainbow and Snake River cutthroat trout, of which 30.5% had migrated between stocking points (Table 27). During 1980, 54 rainbow and 52 Snake River cutthroat trout with double dye marks were observed in shore angler creels (Table 28). The small number observed is probably the result of poor winter survival. Forty two percent of the double marks were observed at Tailrace, partially a result of the higher rates of angler use and harvest in the upper tailwater. Recoveries at Little Hole, the most heavily fished access point, were surprisingly low. Overall recoveries of both cutthroat and rainbow trout stocked at Tailrace and Little Hole were similar but 100% and 92% of the rainbow and cutthroat, respectively, from the Little Hole stockings were caught at one of the other two access sites. Far less movement of Tailrace stockings was evident. In general, following winter, there was a tendency for rainbow trout to be recovered at or upstream of the stocking sites, whereas Snake River cutthroat trout tended to move downstream.



Table 26. Numbers of double dye marked trout observed in the creels of shore anglers, according to access area, Flaming Gorge tailwater, 1979.

Area of Capture	Dye Mark	Area Stocked	Number Rainbow Trout	Number Snake River Cutthroat Trout
Tailrace	Yellow-Green	Tailrace	4	35
	Red-Green	Little Hole	1	1
Little Hole	Red-Green	Little Hole	5	4
	Yellow-Green	Tailrace	0	3
	Red-Yellow	Browns Park	0	1
Browns Park	Red-Yellow	Browns Park	0	1

The Snake River cutthroat trout plant in Browns Park returned very poorly, accounting for only 7.7% of the number of cutthroat trout recovered. Snake River cutthroat trout were a major component of the harvest in Browns Park but most of the double dye marked fish observed there were stocked at Tailrace or Little Hole.

In summary, it appears that little movement of the 1979 cohort occurred between stocking stations prior to winter 1980, but by the summer of 1980 the double marked trout were mixed throughout the tailwater. The stocking of Snake River cutthroat trout at Browns Park met with relatively poor success. Double marked rainbow trout had moved predominantly upstream, but Snake River cutthroat trout movement was largely downstream.

#### Tagged trout--effect of emigration on tag return

During the winters of 1980-1982 snorkel counts of standard 500 m transects were made on an approximately monthly basis at Tailrace, Little

Table 27. Numbers of double dye marked rainbow and Snake River cutthroat trout captured by electrofishing, Flaming Gorge tailwater, October 1979-April 1980.

Date of Sample	Area Sampled <sup>a</sup>	Rainbow Trout Area Where Stocked			Snake River Cutthroat Trout Area Where Stocked		
		TR	LH	BP	TR	LH	BP
Oct. 1979	TR	15	0	0	18	0	0
	LH	0	21	0	0	11	0
	BP <sup>b</sup>						
Jan. 1980	TR	14	1	1	12	1	1
	LH <sup>b</sup>						
	BP	0	5	5	4	0	1
Feb. 1980	TR	0	1	0	0	0	0
	LH	1	4	2	0	1	0
	BP	0	0	0	0	0	0
Mar. 1980	TR	9	2	0	1	0	0
	LH	1	1	0	0	1	0
	BP	1	0	1	0	0	0
Apr. 1980	TR <sup>b</sup>						
	LH	0	5	1	0	1	0
	BP	0	2	1	1	0	0
Jan. -	TR	23	4	1	13	1	1
Apr., 1980	LH	2	10	3	0	3	0
Totals	BP	1	7	7	5	0	1

<sup>a</sup> TR = Tailrace  
LH = Little Hole  
BP = Browns Park.

<sup>b</sup> Not Sampled.

Table 28. Number of double dye marked trout stocked in 1979 and observed in creels of shore fishermen at each of three access areas during the 1980 fishing season.

Area where caught	Rainbow Trout				Snake River Cutthroat Trout			
	Area where stocked <sup>a</sup>			All Rainbow	Area where stocked <sup>a</sup>			All Cutthroat
	TR	LH	BP		TR	LH	BP	
Tailrace	16	16	7	39	7	7	0	14
Little Hole	4	0	3	7	2	2	1	5
Browns Park	1	3	4	8	14	16	3	33
Total Observed in Creel	21	19	14	54	23	25	4	52
% Movement from Stocking Site	24	100	71		70	92	25	

<sup>a</sup> TR = Tailrace  
LH = Little Hole  
BP = Browns Park.

Hole and Browns Park. These observations suggested that trout abundance was declining during winter. These results could not be quantified, due to the tendency of the trout to relocate to deeper water where they were harder to see in winter, and because many counts were aborted due to high flows, dark overcast weather, turbid water or closure of roads into the various access points. In late March 1980, personnel of Bio/West Inc., Logan, Utah, in an unrelated study, collected 65 rainbow and cutthroat trout from the Green River between Ladore Canyon and Island Park in

Dinosaur National Monument, a distance of 50-80 mi downstream of the lower end of the Utah tailwater. Of 44 fish examined with a portable black light, 33 possessed dye marks identifying them as having been stocked as fingerlings in the Utah tailwater in 1979. The remaining 21 trout were not examined for marks but were similar in size to the examined group. All but two of the rainbow and cutthroat trout captured by Bio/West were less than 300 mm TL. The winter trends in snorkel counts and the findings by Bio/West prompted further study of downstream movement.

To assess the sportfishery implications of downstream movement from the Utah tailwater, trout were collected by electrofishing and tagged during April and May 1981. In addition, a fyke net with floating live cage was set at Little Hole in an attempt to quantify the extent of downstream emigration. The net matted with algae within as little as 5 min., however, and actively migrating trout could not be enumerated. During April 1981, 186 trout were electrofished and tagged in Echo Park, Dinosaur National Monument, Colorado, 64 mi downstream of Flaming Gorge Dam. Nearly 70% of these fish had marks identifying them as stocked fish of Utah tailwater origin. Of the fish with marks, 89% were cutthroat trout stocked the previous summer (Table 29). Winter carry-over of both rainbow and cutthroat trout in 1980-81 was exceptional, but rainbow apparently wintered better than cutthroat trout (See Tables 12 and 13, above). The abundance of cutthroat relative to rainbow trout in the Echo Park sample suggests that differing degrees of downstream migration could have contributed to the difference in carryover between the two species.

An additional 1,119 rainbow and cutthroat trout of the cohorts stocked in 1980 were tagged in the upper tailwater in May 1981. Anglers



voluntarily returned 29.7% of these tags during the 1981 fishing season. Angler return from the 125 trout tagged at Echo Park, on the other hand, was only 5.6%, suggesting downstream migration of the trout substantially reduced their eventual contribution to the sportfishery (Tables 29 and 30). Water temperatures became marginal and silt loads very heavy downstream of the Colorado-Utah state line, and fish that emigrated from the Utah tailwater were very likely subjected to increased mortality during summer. No anglers reported catching tagged fish from waters of Colorado (Dinosaur Monument).

#### Tagging to assess winter survival and time of emigration

During the winter of 1981-82, several more groups of trout were tagged to assess: 1) winter survival by species, tagging location, length, and age at time of tagging, and 2) determine the time of peak movement and the destinations of downstream migrants (Table 31). During November, 3,742 trout were tagged, consisting of all rainbow and cutthroat trout sampled from river miles 1-3 (upper three miles of the tailwater) and only trout with dye marks of the 1981 stocked fingerling cohorts in river miles 4, 7, 8, 9, 10 and 11. (River miles 5 and 6 are inaccessible to jet boats and access below river mile 11, for boats launched from Little Hole, is blocked by Red Creek Rapids). Effective electrofishing time was 2.0 hours per station (river mile) at all but station 1. At station 1, approximately 6 additional hours were spent tagging for study of downstream movement. All 9 stations were to receive 2.0 hours of further electrofishing effort in May 1982 to permit

Table 29. Voluntary tag returns during the 1981 fishing season of trout stocked in 1980 and tagged in Dinosaur National Monument, Colorado, in April 1981.

Species	Number Marked Fish Tagged	Number Returned	Percent Returned
Rainbow trout	10	1	10.0
Snake River cutthroat trout	115	6	5.2
Total	125	7	5.6

Table 30. Voluntary tag returns during the 1981 fishing season of trout stocked in 1980 and tagged in the upper tailwater immediately before the opening of the 1981 fishing season.

Species	Number Marked Fish Tagged	Number Returned	Percent Returned
Rainbow trout	743	231	31.1
Snake River cutthroat trout	376	101	26.9
Total	1,119	332	29.7



comparison of angler return rates of fall versus spring tagged trout of the 1981 cohort, thus allowing an estimation of winter mortality rates. Fish tagged in the "mortality" and "migration" studies received serially numbered Floy tags that were color coded by study objective to facilitate record keeping of tag returns.

Unfortunately, the engine of the electrofishing boat broke down irreparably when only 4 of the 9 stations were sampled during the spring tagging effort. During the 7.75 hours of nighttime electrofishing in the spring, only 92 trout from the 1981 cohorts were sampled (11.9 fish per hour), as compared to the catch of 2,260 fish of the same cohorts (125.6 fish/hour) during 18 hours of equivalent effort (but including nine river miles) the previous fall (Tables 32 and 33). The difference in mean catch rate was highly significant (t test,  $p = 0.001$ ). Clearly, there was a substantial decline in numbers of the 1981 cohorts of rainbow and cutthroat trout between the two sampling periods.

Biweekly electrofishing at Little Hole during January, February, and March failed, however, to capture significant numbers of trout tagged in river miles 1-3. Tagging, therefore, produced little information regarding the timing and magnitude of emigration. Emigration could, in fact, have been a major factor in the disappearance of the 1981 cohort during the winter of 1982, but occurred in such a manner that it was undetected by the intermittent monitoring of the Little Hole electrofishing station. A means of continuous systematic sampling, such as downstream trap netting attempted in 1980-81, is necessary to quantify the extent of emigration. Extremely heavy snowfall the winter of 1982 also prevented access to the entire reach of the Green River in Dinosaur National Monument. It therefore proved impossible that winter to search the lower river for evidence of downstream migration.



Table 32. Trout stocked in 1981 and tagged during the fall of 1981 in the first 11 miles of river below Flaming Gorge Dam.

River Mile <sup>a</sup>	Electrofishing Effort (hr)	Numbers of trout tagged			
		RBT <sup>b</sup>	SRCT <sup>c</sup>	Total	Catch/hr
1	2.00	18	109	233	116.5
2	2.00	58	146	204	102.0
3	2.00	113	32	145	72.5
4	2.00	101	119	220	110.0
7	2.00	235	122	357	178.5
8	2.00	138	180	318	159.0
9	2.00	211	79	290	145.0
10	2.00	191	76	267	133.5
11	2.00	250	82	332	166.0
Total	18.00	1,315	945	2,260	131.4

<sup>a</sup> As measured from the dam. River miles 5 & 6 not sampled.

<sup>b</sup> Rainbow trout.

<sup>c</sup> Snake River cutthroat trout.

Table 33. Trout stocked in 1981 and tagged during the spring of 1982 in the first 11 mi of river below Flaming Gorge Dam.

River Mile <sup>a</sup>	Electrofishing Effort (hr)	Numbers of trout tagged			
		RBT <sup>b</sup>	SRCT <sup>c</sup>	Total	Catch/hr
2	2.00	10	10	20	10.0
3	2.00	8	20	28	14.0
4	2.00	15	22	37	18.5
8	1.75	2	5	7	4.0
Total	7.75	35	57	92 <sup>d</sup>	11.9

<sup>a</sup> As measured from the dam. River miles 1, 5, 6, 7, 9, 10 and 11, not sampled.

<sup>b</sup> Rainbow trout.

<sup>c</sup> Snake River cutthroat trout.

<sup>d</sup> Includes 7 fish carrying tags from the previous fall.

Whether due to emigration, mortality, or a combination of these factors, carryover was poor during the winter of 1981-82. The decline in the spring electrofishing catch and poor return of the 1981 cohorts in the creel (Tables 12 & 13, above) were corroborated by tag return rates for the 1981 rainbow and cutthroat trout cohorts. Voluntary returns of tags by anglers during the 1982-1984 fishing seasons amounted to 40% of the 85 yearling trout tagged during May of 1982, but only 4.4% of the 2,996 trout of the same cohort tagged during the fall of 1981 (Table 34). The lower return rate for fall-tagged fish was highly significant ( $p = 0.001$ ).

The tag return rate for both rainbow and cutthroat trout tagged during fall 1981 was 89% lower than for those tagged during spring 1982, and electrofishing C/E declined 94.0% and 87.5% for rainbow and cutthroat trout, respectively, between the two sampling periods. These indices, when considered together, suggest the probable magnitude of mortality between November 1981 and May 1982 was in the vicinity of 90 percent.

Tag return rates from the sportfishery for trout tagged in fall proved to be functions of species, tagging station, and size at time of tagging. For stocked trout of the 1981 cohorts (Tables 35 and 36), species was a highly significant factor ( $p = 0.001$ ). Tag return rates were 5.8% and 3.1% at all stations combined (Table 35 and 36) and 13.3% and 3.1% for stations 1-3 combined, rainbow and cutthroat trout respectively (Table 37). Returns, however, for older cutthroat and rainbow trout (including rainbow trout catchables stocked in 1981) were very similar (Table 37). For rainbow trout of the stocked 1981 fingerling cohort, length at time of tagging may have been a factor in determining return rate (Tables 35 and 36), but was of marginal

Table 34. Voluntary tag returns<sup>a</sup> during the 1982 fishing season of trout stocked in 1981 and either tagged during the fall of 1981 or during the spring of 1982, in the first 11 miles of the river below Flaming Gorge.

When tagged	Rainbow trout		Snake River cutthroat trout		Total trout	
	No. tagged	% return <sup>c</sup>	No. tagged	% return <sup>c</sup>	No. tagged	% return
Fall 1981	1,473	5.8	1,523	3.1	2,996	4.4
Spring 1982 <sup>b</sup>	30	60.0	55	29.1	85	40.0

<sup>a</sup> Including from outside the study area.

<sup>b</sup> Only river miles 2, 3, 4 and 8 were sampled in spring 1982.

<sup>c</sup> Difference in tag return rates between fall and spring was highly significant ( $p=0.001$ ).

statistical significance ( $p = 0.068$ ). Older rainbow trout cohorts (Table 37) experienced better tag returns than did the 1981 fingerling cohort (22.9% and 13.3% respectively), but again, the difference was not highly significant ( $p = 0.10$ ). Older groups of cutthroat trout, however, returned much better than cutthroat of the stocked 1981 cohort ( $p = 0.001$ ).

For the 1981 cohorts, the statistical significance of size at time of tagging in eventual tag return rates might have been much greater were it not for the low availability of larger individuals. Snake River cutthroat trout were stocked later and at a smaller size than requested in 1981 and, therefore, averaged 33 mm less than the TL of the rainbow trout cohort at the time of the fall tagging, a significant difference (t test,  $p = 0.001$ ). For the rainbow trout 1981 cohort, tag return rate was approximately 3 times higher for those fish that were longer than 305 mm than those less than 305 mm, but only 158 of the larger size group

Table 35. Summary of voluntary angler tag returns from tagging conducted in November, 1981: stocked rainbow trout of 1981 cohort, all stations, with respect to tagging station and size at time of tagging.

Size Group (length range in mm)	Station (with electrofishing effort in parentheses)										
	1* (8.0)	2 (2.0)	3 (2.0)	4 (2.0)	7 (2.0)	8 (2.0)	9 (2.0)	10 (2.0)	11 (2.0)	All Stations (24.0)	
1  (203-229)	Number Tagged	10	0	4	8	3	3	5	14	26	73
	# Retd.	1	0	0	1	0	1	0	0	0	3
	% Retd.	10.0	0.0	0.0	12.5	0.0	33.3	0.0	0.0	0.0	4.1
2  (230-254)	Number Tagged	28	4	31	22	42	24	26	46	69	292
	# Retd.	2	1	4	4	5	1	1	1	1	20
	% Return	7.2	25.0	12.9	18.9	11.9	4.2	3.9	2.2	1.5	6.9
3  (255-279)	Number Tagged	51	25	56	38	123	37	73	65	97	565
	# Retd.	5	1	3	3	4	0	1	2	1	20
	% Tagged	9.8	4.0	5.4	7.9	3.3	0.0	1.4	3.1	1	3.5



Table 35. Continued.

4	Number Tagged	44	26	19	22	58	50	71	48	47	385
(280-305)	# Retd.	6	1	5	1	3	1	3	1	1	22
	% Return	13.6	3.9	26.3	4.6	5.1	2.0	4.2	2.1	2.1	5.7
5	Number Tagged	43	3	3	11	9	24	36	18	11	158
(305+)	# Retd.	15	1	1	2	0	0	1	1	0	21
	% Return	34.9	33.3	33.3	18.2	0.0	0.0	2.8	5.6	0.0	13.3
All Sizes	Number Tagged	176	58	113	101	235	138	211	191	250	1,473
	# Retd.	29	4	13	11	13	3	6	5	3	86
	% Return	16.5	6.9	11.5	10.9	5.1	2.2	2.8	2.6	1.2	5.8

\* Station 1 includes 6 hours electrofishing effort for migration tagging study which followed the standard 2 hour mortality tagging effort.

Table 36. Summary of voluntary angler tag returns from tagging conducted in November, 1981: stocked Snake River cutthroat trout of 1981 cohort, all stations, with respect to tagging station and size at time of tagging.

Size Group (length range in mm)	Station (with electrofishing effort in parentheses)										
	1*	2	3	4	7	8	9	10	11	All Stations	
	(8.0)	(2.0)	(2.0)	(2.0)	(2.0)	(2.0)	(2.0)	(2.0)	(2.0)	(24.0)	
1  (203-229)	Number Tagged	161	30	15	50	32	28	26	44	68	454
	# Retd.	4	1	0	1	3	0	0	0	1	10
	% Retd.	2.5	3.3	0.0	2.0	9.4	0.0	0.0	0.0	1.4	2.2
2  (230-254)	Number Tagged	378	80	14	52	61	101	41	30	13	770
	# Retd.	12	3	1	2	4	4	0	0	0	26
	% Return	3.2	3.8	7.1	3.9	6.6	4.0	0.0	0.0	0.0	4.4
3  (255-279)	Number Tagged	138	35	1	17	28	48	12	2	1	282
	# Retd.	3	0	0	0	1	2	1	0	0	7
	% Return	2.2	0.0	0.0	0.0	3.6	4.2	8.3	0.0	0.0	2.5

Table 36. Continued.

4 (279+)	Number Tagged	10	1	2	0	1	3	0	0	0	17
	# Retd.	2	0	1	0	1	0	0	0	0	4
	% Return	20.0	0.0	50.0	0.0	100.0	0.0	0.0	0.0	0.0	23.5
All Sizes	Number Tagged	687	146	32	119	122	180	79	76	82	1,523
	# Retd.	21	4	2	3	9	6	1	0	1	47
	% Return	3.1	2.7	6.3	2.5	7.4	3.3	1.3	0.0	1.2	3.1

\* Station 1 includes 6 hours electrofishing effort for migration tagging study which followed the standard 2 hour mortality tagging effort.

Table 37. Summary of voluntary angler tag returns received from 1982-1985, from tagging conducted in November, 1981, all marked and unmarked trout, stations 1-3<sup>a</sup>, combined.

Species	Mark					
	Fingerling 1981	Catchable 1981	Fingerling 1980	Fingerling prior to 1980	Unmarked	Older than 1981 finger- ling combined Totals
Rainbow	Tags Returned (%)	46 (13.3)	6 (30.0)	5 (23.5)	1 (9.1)	55 (14.1)
						12 (24.5)
Trout						113 (14.4)
	Number Rainbow Tagged	347	20	17	12	389
						49
						785
Cutthroat	Tags Returned (%)	27 (3.1)	--	22 (24.7)	0 (0.0)	39 (18.1)
						22 (23.4)
Trout						88 (7.5)
	Number Cutthroat Tagged	865	--	89	4	215
						94
						1,173
Total Fish Tagged		1,212	20	106	16	604
						142
						1,958

<sup>a</sup> All trout sampled at Stations 1-3 were tagged.



were tagged. Only 17 cutthroat trout of the 1981 cohort larger than 279 mm were tagged (Tables 35 & 36). For the 1981 cohorts, therefore, the poor return of cutthroat with respect to rainbow trout may be largely an artifact of the smaller size of the cutthroat. The difference in tag returns between species was confined to the 1981 cohorts, of which the cutthroat were much smaller. Had both species been stocked at 150 mm in May, they would have averaged approximately 300 mm in November and, perhaps, a much more sensitive evaluation of the importance of species and size to first-winter survival would have been possible.

Similarly, availability of marked fish older than age I was extremely low. Only 48 older marked rainbow trout and 94 older marked cutthroat trout were tagged in stations 1-3 and tag returns totaled 11 and 22 (22.9% and 23.4%) respectively. Had all older fish captured at stations 4-11 been tagged, rather than only the 1981 cohort, a much more sensitive test of the effect of age on winter survival would have been possible.

Looking at the composite of year classes and marks tagged at miles 1-3, including unmarked trout, tag return rate was clearly a function of length (TL) at time of tagging for both species ( $p = .001$ ). Returns of rainbow and cutthroat trout that were larger than 300 mm when tagged were similar -- 25.3% and 22.1% respectively; returns for those smaller than 276 mm were 8.7% and 2.9%. Between tagging sizes of 276 and 300 mm, intermediate tag return rates were realized for both species (Table 38).

Tagging station was a significant factor in tag returns for rainbow trout of the 1981 cohort ( $p = 0.001$ ) but not for cutthroat trout ( $p$  greater than 0.2). The highest tag return rates for yearling rainbow trout were from stations 1-4 (Tables 35 and 36).

Table 38. Tag returns, with respect to size when tagged in fall 1981, miles 1-3 combined, all marked and unmarked trout, based upon voluntary angler returns in ensuing fishing seasons.

Size Group (TL in mm)	Rainbow Trout			Snake River Cutthroat Trout		
	Number Tagged	Number Returned	% Return	Number Tagged	Number Returned	% Return
200-225	120	15	12.5	212	6	2.8
226-250	129	11	8.5	482	16	3.3
251-275	172	11	6.4	183	3	1.6
276-300	130	17	13.1	25	3	12.0
301-325	90	30	33.3	23	5	21.7
326-350	38	7	18.4	33	7	21.2
351-375	33	5	15.2	67	14	20.9
376-400	29	7	24.1	69	19	27.5
401-425	15	3	20.0	54	12	22.2
426-450	12	4	33.3	15	1	6.7
451+	17	3	17.7	10	2	20.0
Total	785	113	14.4	1,173	88	7.5

A total of 294 returns was received from all cohorts tagged in both the spring and fall sampling. All but 8 of the returns were from fish caught during the 1982 fishing season. Six tags were returned in 1983, one in 1984 and one in 1985.

Summary -- seasonal mortality and migration of stocked fingerlings

Electrofishing catch trends suggested that survival of yearling trout during the winter of 1982 was low relative to that of the previous winter. Brown trout from instream recruitment were the predominant species captured at Browns Park. Rainbow and cutthroat trout of hatchery origin composed the majority of fish captured at Tailrace and Little Hole.

Monitoring of fish that had received stocking-site-specific dye marks revealed little evidence of movement between stocking sites prior to winter, but following the first winter the marked trout were mixed throughout the tailwater. Rainbow trout had moved predominantly upstream but Snake River cutthroat trout movement was largely downstream. The stocking of Snake River cutthroat trout at Browns Park, the lower extent of the trout supporting tailwater, met with particularly poor success. Trout of tailwater origin were found in Dinosaur National Monument in winters of both 1980 and 1981, suggesting that downstream movement into marginal habitats contributed to winter mortality, especially for cutthroat trout.

Tagging studies of 1980 - 1982 suggested:

1. Trout in the Dinosaur National Monument reach of the Green River rarely returned to the creel;
2. Mortality between November 1981 and May 1982 approached 90%, based upon tag return rates and electrofishing C/E;
3. Trout tagged during spring experienced relatively high angler harvest;

4. For trout tagged in fall 1981, angler voluntary tag return rate was a function of fish age -- returns were 72% and 500% higher for older year classes than for yearling, rainbow and cutthroat trout, respectively;
5. Tag return rate was a function of tagging station (river mile) for rainbow but not for cutthroat trout -- rainbow trout return rates were 11.4% and 2.8% for river miles 1-4 and 7-11, respectively;
6. Tag return rates for the 1981 cohorts seemed to be a function of size at time of tagging but this relationship was not highly significant, probably due to their uniformly small size -- Snake River cutthroat trout of the 1981 cohort returned at lower rates than the 1981 rainbow cohort, but this appeared to be due to the smaller size of the cutthroat;
7. For the composite of all trout tagged in fall, 1981, including unmarked trout, tag return rate was a function of TL when tagged -- tag return rate increased sharply for trout larger than 301 mm TL;
8. Rainbow and cutthroat trout longer than 300 mm experienced similar tag return rates;
9. Nearly all tag returns were received within one year of tagging date.



### OBJECTIVE #3

#### DESCRIBE TROUT BEHAVIOR, MICROHABITAT SELECTIVITY AND HABITAT SUITABILITY WITH RESPECT TO SPECIES, LIFESTAGE, SEASON, AND DISCHARGE

#### METHODS -- OBJECTIVE #3

Physical habitat simulation methods employed were from Bovee (1982) and Milhous et al. (1984). Measurement of microhabitat was subcontracted by DWR to Jeffrey Gosse, Aqua-Tech Biological Consulting, Logan Ut. Seasonal microhabitat (depth, velocity, substrate, and light orientation) data were collected from December 1980 - April 1982. Microhabitat parameters were measured by a diver equipped with scuba gear and sufficient weight to enable him to negotiate the stream bottom in strong currents. Microhabitat conditions were measured as nearly as possible to the location of each fish or group of fish. The diver placed the probe of the respective measuring device at the location of the fish and a surface crew recorded meter readings. An underwater-to-surface communication system was used to relay the species, size and number of fish, and other information to the surface crews.

Variables measured included facing velocity, mean column (as measured at 0.4 x water depth measured from the bottom) velocity, fish elevation (distance of fish above bottom), water depth, substrate type, and overhead light.

Microhabitat data were collected at various discharges (Q) for two species and two life stages -- rainbow and cutthroat trout, juvenile and adult -- during summer 1981 and the winters of 1981 and 1982.

Two major swimming activity modes were prevalent for which habitat suitability data were collected. Trout milling about without orienting to the current, an activity which occurred primarily in pool-like areas, was termed random swimming (RS). Orientation to the current, an activity which most frequently was observed in riffle or glide habitats, was termed stationary swimming (SS). A complete description of the methods employed is given by Gosse (1982) and Gosse and Helm (1982).

Habitat suitability was assessed using physical habitat simulation models developed by the Instream Flow Group, United States Fish and Wildlife Service.

### RESULTS - OBJECTIVE #3

#### Life stages

Trout less than 230 mm in summer and less than 250 mm in winter were considered to be juveniles, those larger were termed adults. The size criteria were based upon approximate maximum size of fingerlings of the current year's stocking in summer and fall. By winter, a proportion of the current year cohort would enter the adult category (larger than 250 mm). This was especially true of the 1980 fingerling rainbow trout cohort. Classification of life stage was based upon the diver's judgment and was, therefore, somewhat subjective for fish in the 225-270 mm range.

### Activity modes

The extent to which fish engaged in each activity mode was not quantified. Based upon observations of Gosse (1982) and DWR divers, however, it was apparent that stationary swimming was the predominant activity in summer. Random swimming often seemed to predominate in winter, at least among the juvenile life stages. While engaged in stationary swimming, trout were oriented to the current and, presumably, its invertebrate drift. The SS mode was, therefore, probably related to feeding. Facing velocities for stationary swimming increased with Q, especially during winter (Table 39).

Random swimming behavior, on the other hand, seemed to remove the trout from feeding lanes and into pool-like habitats. Facing velocities were lower than for the SS mode, especially at higher Q, and did not consistently increase with Q (Table 40). The RS mode, therefore, was considered an important means of energy conservation.

### Light intensity, depth, and distance from bottom

Average distance from the bottom was similar for adults and juveniles engaged in stationary swimming in summer, but adults tended to be closer to the bottom than juveniles at medium (approximately 2,200 cfs) and high flows during winter (Table 41). There were no consistent trends in orientation to the bottom for RS activity (Table 42). It is suspected that water column velocity is quite uniform in many pool locations where random swimming predominated.

Except for recently stocked juveniles, nearly all fish observed occupied areas of less than 50% of full light intensity, both during summer and winter. The shade of overhead and instream cover was not a major factor in orientation of either species, juvenile or adult (Gosse 1982).

Table 39. Average facing velocity (cm/sec) and sample size ( ) for all flows for stationary swimming during winter and summer 1981, from Gosse (1982).

Flow	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Winter				
Low	12 (141) A <sup>+</sup>	16 (67) A	17 (51) A	21 (192) A
Medium	25 (167) B	23 (238) B	23 (73) B	27 (206) B
High	30 (80) C	28 (83) C	30 (48) C	30 (242) C
Summer				
Low	21 (53) A	24 (54) A	22 (96) A	27 (83) A
Medium	21 (80) A	29 (42) A	31 (129) B	27 (51) A
High	26 (42) B	41 (40) B	28 (65) B	34 (90) B

<sup>+</sup>Flows for a specific life stage and season which do not share a common letter had significantly ( $p = 0.05$ ) different average facing velocities.



Table 40. Average facing velocity (cm/sec) and sample size ( ) for all flows for random swimming during summer and winter 1981, from Gosse (1982).

Flow	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Winter				
Low	13 (127) A <sup>+</sup>	16 (107) B	11 (42) A	20 (112) B
Medium	14 (192) A	13 (147) A	12 (25) A	17 (84) A
High	16 (169) B	15 (116) B	20 (44) B	15 (112) A
Summer				
Low	8 (56) A	12 (36) A,B	13 (65) B	14 (80) A
Medium	8 (68) A	10 (34) A	7 (47) A	12 (41) A
High	12 (63) B	15 (35) B	12 (60) B	17 (51) A

<sup>+</sup>Flows for a specific life stage and season which do not share a common letter had significantly ( $p = 0.05$ ) different average facing velocities.

Table 41. Average distance of fish from bottom (cm) and sample size ( ) for all flows for stationary swimming during summer and winter 1981, from Gosse (1982).

Flow	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Winter				
Low	86 (141)	57 (67)	43 (57)	45 (192)
Medium	71 (192)	59 (241)	80 (77)	46 (219)
High	118 (80)	55 (83)	127 (48)	62 (242)
Summer				
Low	34 (53)	60 (54)	43 (96)	59 (83)
Medium	37 (80)	30 (42)	20 (130)	29 (53)
High	21 (42)	47 (40)	24 (65)	22 (90)

Table 42. Average distance of fish from bottom (cm) and sample size ( ) for all flows for random swimming during summer and winter 1981, from Gosse (1982).

Flow	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Winter				
Low	130 (127)	122 (107)	143 (42)	82 (112)
Medium	192 (192)	221 (147)	128 (25)	111 (84)
High	267 (169)	147 (116)	144 (44)	138 (112)
Summer				
Low	80 (56)	101 (39)	51 (65)	78 (82)
Medium	103 (68)	80 (39)	147 (47)	69 (45)
High	112 (63)	69 (35)	52 (60)	62 (51)

With ample depths in most river channel areas, water depth was probably not a limiting factor for the fishery. Average daytime occupied water depth (combined averages of seasons, activities and life stages) was 415 cm (13.6 ft) and 465 cm (15.3 ft) for cutthroat and rainbow trout, respectively (Gosse 1982). Trout appeared to avoid depths of less than 2 m during daytime. Night electrofishing demonstrated that depths of less than 2 m were densely populated, however, suggesting that depth suitability data based only upon daytime diving observations are strongly biased.

The predominant substrates over which fish were observed were silt for RS (pools) and rock/rubble for SS (riffles).

Most juvenile fish in winter were engaged in RS activity in pools, where they seldom used substrate features for protection from high water velocities. Only occasionally were juvenile trout observed to inhabit interstices of rocks during winter. However, small trout were commonly taken from bank areas protected with large rock rip-rap and occasionally from other rocky substrate during winter electrofishing. These fish were probably occupying substrate habitats and appeared to be from instream recruitment, based upon their smaller than usual size.

#### Response to flow changes

Gosse (1982) observed fish behavior during two periods of increasing discharge that simulated the routine variation in power generation of Flaming Gorge Dam. In general, Gosse reported that fish engaged in SS activity moved closer to the bottom (an observation not evident from Table 41, at least for winter) and increased their orientation to bottom irregularities in response to increasing Q. These reactions partially,



but not entirely, compensated for increased water velocities. Therefore, as Q increased facing velocity was observed to increase, but at a lower rate than the increase in column velocity. Trout were often located adjacent to the thalweg and the response to intrusion of the thalweg was either: (1) lateral movement of generally less than 3 m to the new location of the thalweg edge or, (2) abandonment of the thalweg edge and selection of a new habitat type, usually involving a lateral movement of several meters or more.

#### Response to high discharge periods

The winter of 1979 was one of low winter carryover for yearling trout. Discharge that winter was relatively high. To test whether Q could explain differences in winter carryover, a period of high discharge that approximated conditions in 1979 (Table 43, Appendix Table C6, Appendix Figure C1) was requested during winter 81-82 from the Bureau of Reclamation. The high Q regime was delivered in February 1982.

Gosse (1982) assessed response of trout to the high Q test by comparing with facing velocities of trout during low discharges that prevailed in the winter of 1981. Facing velocities were lower in January, 1982 than January, 1981, and in some cases facing velocity was substantially lower during the test period of 1982 than during the winter of 1981 (Table 44). However, that comparison was compromised by the fact that the 1980 cohorts were stocked earlier and at larger sizes than those in 1981 (Tables 11 and 13) and, therefore, were noticeably larger during winter. Total lengths in October of 1980 and 1981 were 268.9 mm and 253.6 mm, respectively, for yearling rainbow trout and 238.8 mm and 229.5 mm for yearling cutthroat trout (Table 5). These differences were not

Table 43. Schedule of the high flow test releases of February 1 - February 26, 1982, compared with the high discharge period of February 21 - March 6, 1979, from Gosse (1982).

1982			1979		
Date	Release (cfs)	Duration (hours)	Date	Release (cfs)	Duration (hours)
2/1	4450	12.50	2/21	4200	8.75
2/1	3600	1.50	2/22	4200	15.50
2/2	4300	21.00	2/23	4200	21.25
2/3	4200	16.50	2/24	4200	10.25
2/4	3900	21.50	2/25	4200	18.75
2/5	4300	24.00	2/25	3600	1.25
2/8	3760	10.75	2/26	4200	21.50
2/9	3600	9.50	2/27	4200	20.75
2/10	4200	3.00	2/27	3700	1.25
2/11	3600	9.00	2/28	4200	11.00
2/12	4200	12.50	3/1	4200	17.75
2/16	4200	11.50	3/1	3700	1.00
2/17	4200	12.50	3/2	4000	20.00
2/18	4200	7.00	3/3	4200	20.00
2/20	4200	20.00	3/4	4200	18.00
2/21	3700	10.50	3/5	4200	8.00
2/22	4200	11.75	3/6	3900	12.00
2/23	3600	10.00			
2/24	3700	16.50			
2/25	3600	21.00			
2/26	3700	24.00			

Table 44. Mean facing velocity (cm/sec) during winter and summer, 1981; January, 1982; and high flow test period in February, 1982.

Season	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Stationary Swimming				
Summer, 1981	21.0	29.0	31.0	27.0
Jan. (med-low flow) 1981	15.5	19.5	18.1	22.6
Winter 1981 all months	25.0	22.0	23.0	27.0
Jan. (med-low flow) 1982	11.3	19.9	13.2	18.7
Feb. 1982 (high flow test period)	14.0	21.0	22.0	23.0
Random Swimming				
Summer 1981	8.0	10.0	7.0	12.0
Jan. (med-low flow) 1981	13.6	15.6	11.4	19.3
Winter 1981 all months	13.0	13.0	12.0	17.0
Jan. (med-low flow) 1982	9.1	10.5	9.1	11.7
Feb. 1982 (high flow test period)	12.0 <sup>a</sup>	6.0	7.0	7.0

<sup>a</sup> Sample size = 2

statistically significant ( $p$  greater than .05), probably due to small sample sizes. Gosse (1982) observed that "adult" behavioral traits, including selection of higher velocities and higher incidence of stationary (with respect to random) swimming, were increasingly evident as trout approached 300 mm TL. The duration and intensity of winter weather conditions also differed between the two years, with 1980-81 generally the milder.

Due to these inconsistencies in stocking size (TL) and other factors between years, we also compared behavior of only the 1981 cohorts before (January 1982) and during the high flow test period. In comparing January 1982 to February (high flow test period) 1982 there was a general increase in SS facing velocity, similar to the response of juvenile trout to increasing  $Q$  measured in 1981 (Tables 39 and 44; Figures 12a and 12b).

During the requested high discharges of February 1982, there was a shift of activity pattern from random swimming to stationary swimming (Table 45, Figure 12c). The shift was especially pronounced in juvenile rainbow trout and may have been caused by the high flow tests, since there was a resurgence in juvenile rainbow RS activity during the post-test period. Thus, during the high flow test of 1982 stationary swimming became the predominant activity and facing velocity for stationary swimming increased, especially in the case of juvenile rainbow trout. This change in activity pattern was not observed the previous winter, perhaps due to the shorter duration of high flows and the larger mean TL of the yearling cohorts that winter.

The reason for the change in activity pattern in 1982 is not clear. Possible causes include: 1) loss of slack water areas suitable for RS activity due to high discharges; 2) relocation in response to increased



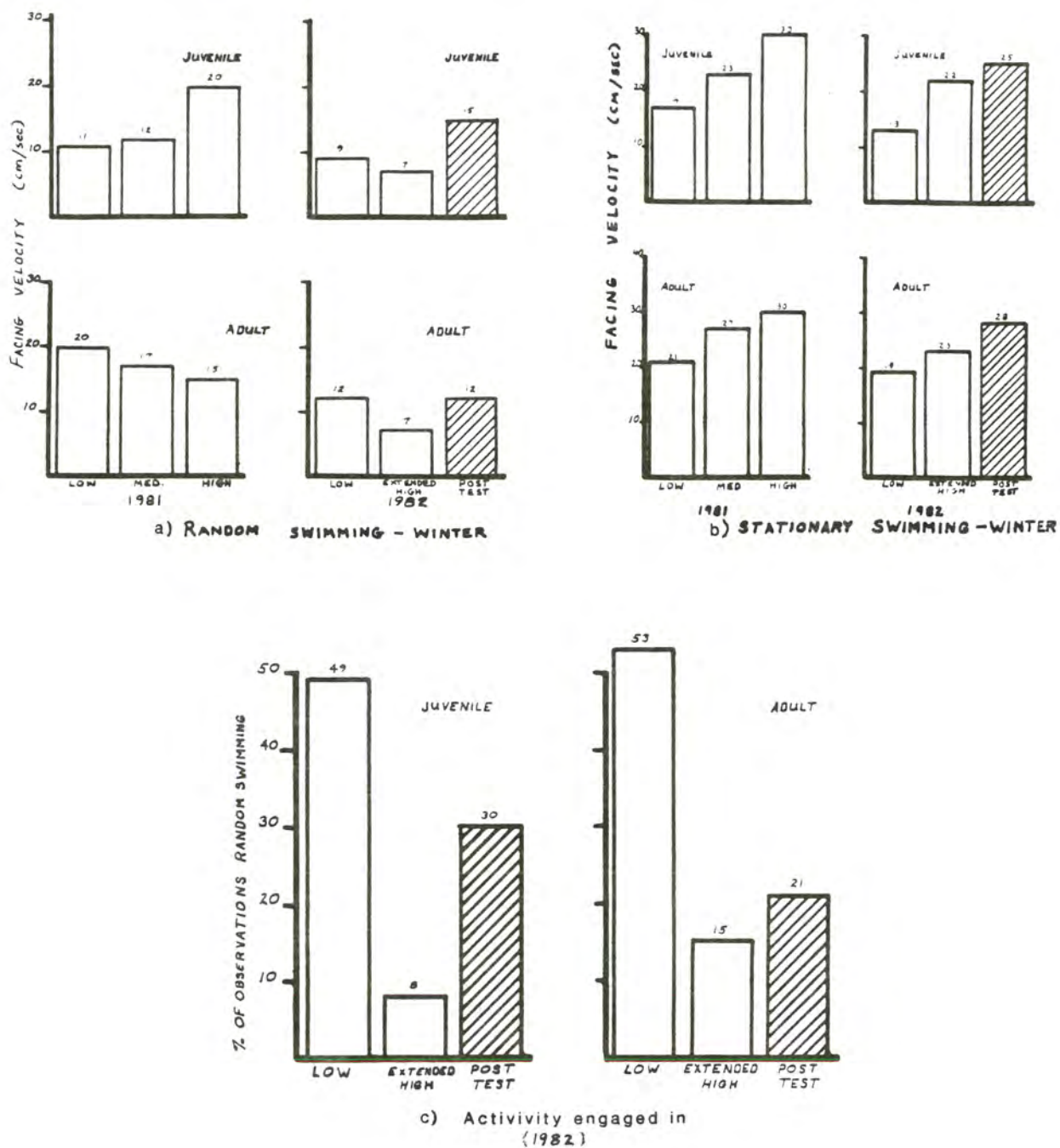


Figure 12. Winter facing velocities during 1981 and 1982 for: a) random swimming; b) stationary swimming; and c) percent of trout observed during 1982 in random swimming activity, at three ranges of discharges, adult and juvenile rainbow trout, Flaming Gorge tailwater.

Table 45. Observations of the two activities, stationary and random ( ) swimming, expressed as percent of total, during winter 1981 and 1982, from Gosse (1982).

Flow	Cutthroat Trout		Rainbow Trout	
	Juvenile	Adult	Juvenile	Adult
Winter 1981				
Low	53 (47)	39 (61)	55 (45)	63 (37)
Medium	50 (50)	62 (38)	75 (25)	72 (28)
High	32 (68)	42 (58)	52 (48)	68 (32)
Winter 1982				
Pre-test	58 (42)	48 (52)	51 (49)	47 (53)
Test flows	75 (25)	68 (32)	92 (8)	85 (15)
Post-test	* ---	67 (33)	70 (30)	79 (21)

\* Juvenile cutthroat not observed after the high flow test.

food availability associated with invertebrate drift during high discharge periods; and 3) behavioral change linked to photo periods and seasonal conditions.

There was an apparent increase in facing velocity of rainbow trout juveniles during March 1982, following the high flow test (Figures 12a and 12b). Gosse (1982) noted that the trout were then changing to more summer-like behavior patterns, which included increased feeding and

orientation to the current. This change in seasonal activity may account for the increase in facing velocity in March 1982. Data collected in March, therefore, probably is representative of a transition to summer habitat.

The magnitude of the shift in activity with changing flow shown in Table 45 should be considered in relative, rather than absolute terms. The study design called for approximately equal numbers of observations of each activity and life stage whenever possible, and did not call for quantitative measures of the extent to which each species engaged in the two activities. The lack of quantitative documentation of the seasonal importance of activity patterns became even more problematical in interpretation of habitat simulation study results.

Cutthroat trout of the 1981 cohort rapidly declined in number at the outset of the test period and were too scarce to permit further observation during the post-test period. Rainbow trout, on the other hand, did not appear to decline during the high flow test and began the seasonal movement from pools to riffle-like summer habitats in late March. During late March through mid April, however, yearling rainbow trout numbers declined. No physical or unusual behavioral changes were apparent in the rainbow trout at the time of their disappearance and there was no indication of unusual mortality within the study reach. By mid-April the paucity of yearling trout caused early termination of underwater observation of fish behavior. Numbers of older trout remained approximately the same throughout the 1982 study period (Table 46).

Table 46. Sample sizes and activity modes of rainbow and cutthroat trout used for measurement of microhabitat, January-March 1982.

Month & Mean Q <sup>a</sup>	Rainbow Trout				Species Total	Cutthroat Trout				Species Total
	Random		Stationary			Random		Stationary		
	Number	% RS	Number	% SS		Number	% RS	Number	% SS	
	Juvenile									
January 1,345	179	48.9	187	51.1	366	148	42.3	202	57.7	350
February 2,651	12	8.1	136	91.9	148	2	25.0	6	75.0	8
March 1,524	21	30.0	49	70.0	70	0	—	0	—	0
	Adult									
January 1,345	148	53.2	130	46.8	278	30	51.7	28	48.3	58
February 2,651	41	14.7	238	85.3	279	35	31.8	75	68.2	110
March 1,524	35	21.1	131	78.9	166	20	32.8	41	67.2	61

a Q = Mean discharge for month in cfs.



### Habitat simulation modeling

#### Description of the PHABSIM stations

Selection of habitat simulation sites represented a compromise between the objectives that modeling sites be representative of the tailwater as a whole and that they represent habitat types utilized during winter. Winter habitat conditions were considered to be limiting to the tailwater fishery. Models must represent limiting conditions if they are to adequately predict fishery responses to changes in physical habitat or fishery management.

Thus, the Pipe Creek station was predominantly pool-like and was selected because it appeared to represent the prevalent winter habitats available to trout between Tailrace and approximately river mile 4.5. The Tailrace station was chosen to represent a habitat known to harbor concentrations of juvenile trout each winter. Snorkel and electrofishing observations suggested pools in this reach supported one of the tailwater's largest winter concentrations of trout. The Indian Crossing station consisted of a wide, open run of moderate depth. Deep slack-water areas were scarce at Indian Crossing and other sites downstream of Red Creek Rapids.

In general, the ratio of runs to pools increases with increasing distance from the dam. Thus, the Pipe Creek and Tailrace stations are probably most representative of the upper tailwater while the Indian Crossing station represents a habitat type more frequently encountered in the lower 18 miles of tailwater below Red Creek Rapids. Riffles with boulder substrate and large boulder obstructed runs, common in the vicinity of Little Hole, are not represented by the three hydraulic simulation stations, nor are large, shallow, sand and gravel filled pool

areas in lower Browns Park. These habitat types may be important to trout in winter, but were not represented due to funding and logistical constraints. Unobstructed riffle habitats were not considered to be extensively utilized by trout in winter and, therefore, were not represented.

Physical habitat differed considerably between the three PHABSIM sites. The Pipe Creek station represented a pool with large eddies on each side of the thalweg. Nearly half of the velocity measurements in certain cross sections at Pipe Creek were negative due to these backflowing eddies. Pipe Creek was the deepest of the three stations. The channel at the Tailrace station was much narrower than at the other sites. This station was on a bend with small, backflowing eddies on the right bank and a point bar on the left. Because of the point bar and its narrow channel, channel surface area and depth at Tailrace were both strongly influenced by discharge (Table 47). The Indian Crossing station lacked eddies (no negative velocities were measured) and was shallower and wider than the other two sites. Velocity was the parameter most sensitive to discharge at Indian Crossing (Table 47). Substrate for all three stations was predominantly cobble and large rock. Coarse gravel was also a significant substrate component at Indian Crossing.

#### Habitat suitability curves

Nearly all habitat suitability data were collected from the upper four miles of the tailwater, where depths were much greater than most downstream reaches. Thus, depth suitability curves reflect the depths prevalent in the pools of the upper tailwater. The probability of use indices for depth rose sharply above depths of approximately 1.5 m and

Table 47. Summary of physical parameters of three PHABSIM stations as measured at two levels of discharge.

Discharge (cfs)	TAILRACE			PIPE CREEK			INDIAN CROSSING		
	Mean <sup>a</sup> Depth (m)	Mean <sup>b</sup> Width (m)	Mean <sup>c</sup> Velocity (cm/sec)	Mean <sup>a</sup> Depth (m)	Mean <sup>b</sup> Width (m)	Mean <sup>c</sup> Velocity (cm/sec)	Mean <sup>a</sup> Depth (m)	Mean <sup>b</sup> Width (m)	Mean <sup>c</sup> Velocity (cm/sec)
800	2.76	34.0	60.4	4.13	42.2	43.9	2.74	49.5	44.7
4,000	5.03	49.8	98.3	7.03	54.4	79.9	4.02	62.2	127.0
Increase	82%	46%	63%	70%	29%	82%	47%	26%	184%

<sup>a</sup> Unweighted mean of cross section cell measurements (usually at 3 meter intervals).

<sup>b</sup> Mean of channel widths taken at each of 6 to 10 cross sections.

<sup>c</sup> Weighted mean of cross section cell measurements.



were maximized at depths of at least 3.5 m (Tables 48 and 49). Maximum depths of the Indian Crossing and Tailrace PHABSIM stations, however, rarely exceeded 3.5 m. During winter, trout were clearly more abundant in deeper pools, at least during daytime in the upper four miles of the tailwater (Gosse 1981). This seasonal change in distribution explains the increase in depth suitability indices for winter (Tables 48 and 49). Few observations were made downstream of mi 4, where boulders and turbulence may have contributed forms of cover not accounted for in our habitat suitability data.

Habitat suitability data collection was stratified by activity (RS and SS) pattern. Seasonal habitat suitability curves were developed for each behavioral mode. This resulted in a total of 8 sets of habitat output from the PHABSIM model for each species. The curves for RS and SS activities were then consolidated, which halved the volume of output. Weighted usable area/discharge (WUA/Q) relationships for the two approaches proved to be basically the same and consolidation of behavioral modes rendered the output to a more comprehensible form. WUA is, therefore, presented in this report based upon the consolidated curves of the two activity patterns (Tables 48 and 49).

Suitability data for RS and SS activities were given equal weight in preparation of the consolidated habitat suitability curves. The tendency for juvenile trout to assume the RS activity mode during winter suggested that suitability criteria for the RS mode could be given greater weight than the SS mode in evaluation of winter habitat quality. Weighting in favor of RS criteria would increase the habitat value of deep, slow, pool-like habitats, while reducing usable area in shallower river reaches. Such weighting would be justified for the upper tailwater, but



data needed to justify extrapolation of our behavioral observations to the lower tailwater were lacking. It was clear that some juvenile trout survived winter in the lower tailwater, although perhaps fewer than upstream. Other physical features, such as large substrate materials in some of the downstream reaches, may enhance habitat stability for trout oriented to the substrate. Further, mid-column velocities were used in the estimation of weighted usable area; consequently microhabitats associated with the substrate (and conducive to SS activity) were seriously underrepresented. Use of midcolumn velocities was probably appropriate for the evaluation of habitat usability in pool-like habitats (conducive to RS activity), where the fish tended to be suspended nearer to the middle of the water column, but could lead to underestimation of WUA for fish engaged in SS or substrate oriented activity in habitats with higher mid-column velocities.

#### Physical responses of PHABSIM stations to discharge

Changes in discharge were reflected at the PHABSIM stations by three physical parameters: 1) depth; 2) channel width; 3) velocity. In the two upstream stations, where channel widths were narrower, channel depth was especially sensitive to discharge level. This was more pronounced at the relatively shallow Tailrace station (Table 47). Mean depths at Tailrace were 82 percent greater at flows of 4,000 cfs than at 800 cfs. The Tailrace station channel width also was relatively sensitive to discharge rate, while mean velocity was less so. Consequently, increasing discharge caused the Tailrace station to ascend the depth suitability curve and increase in total area (Table 47, Figure 13), with the result

Table 48. Habitat suitability data for adult rainbow and cutthroat trout, based upon Gosse (1981), with suitability index to right of velocity, depth, and substrate values.

[illegible]

a Substrate codes and approximate scale: 0.0 = Silt (less than 0.6 mm) 2.0 = Gravel (10-20 mm) 4.0 = Cobble (100-150 mm) 6.0 = Rubble (250-500 mm) 8.0 = Boulder (1,000-2,000 mm) 9.0 = Bedrock (4,000 mm +)

Table 49. Habitat suitability data for juvenile rainbow and cutthroat trout, based upon Gosse (1981), with suitability index to right of velocity, depth, and substrate values.

[illegible]

a. Substrate codes and approximate scale: 0.0 = Silt (less than 0.6 mm) 2.0 = Gravel (10–20 mm) 4.0 = Cobble (100–150 mm) 6.0 = Rubble (250–500 mm) 8.0 = Boulder (1,000–2,000 mm) 9.0 = Bedrock (4,000 mm +)

that weighted usable area increased as a function of discharge (Figure 14 and 15).

Mean depth at Pipe Creek exceeded that at Tailrace and Indian Crossing by 2 and 3 meters respectively. This station also was composed of large, low velocity eddies and backflows, where velocities were not strongly influenced by discharge rate. Mean velocity was relatively low at all flows but more sensitive to discharge than at Tailrace (Table 47). Weighted usable area at Pipe Creek was consistently greater than at the other stations and was maximal at about 800 cfs, declining gradually with flow increases above the current 800 cfs operational minimum.

The channel at Indian Crossing was wider than the other stations and experienced the lowest change in depth in relation to discharge rate. Here, discharge rate was strongly reflected by mean channel velocity (Table 47). Weighted usable area declined sharply with increasing discharge, due to increasing velocities.

#### Habitat suitability

The relationship of WUA to discharge, by season and life stage, was essentially identical for both rainbow and cutthroat trout at all three stations.

Adult habitat was apparently not limiting to the fishery within discharges prescribed by current operating criteria (800-4,200 cfs) at Tailrace or Pipe Creek. Discharge above approximately 1,200 cfs produced sharp declines in WUA at Indian Crossing, however (Figures 14 and 15).

For adult rainbow and cutthroat trout there were no pronounced seasonal differences at any of the three stations in WUA. WUA for juvenile trout, however, dropped in winter to approximately half of its



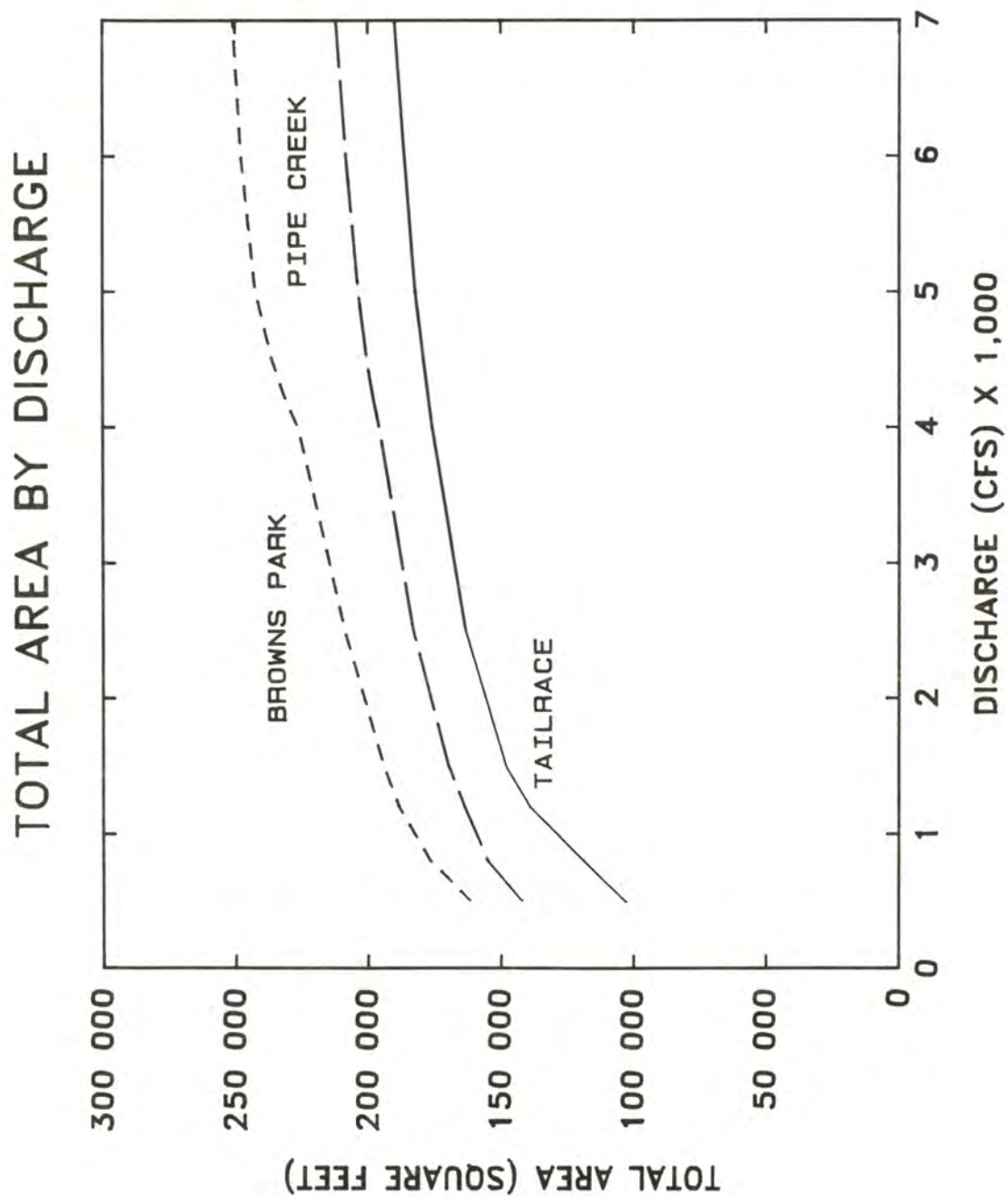


Figure 13. Total watered channel area represented by each of three PHABSIM stations as functions of discharge.

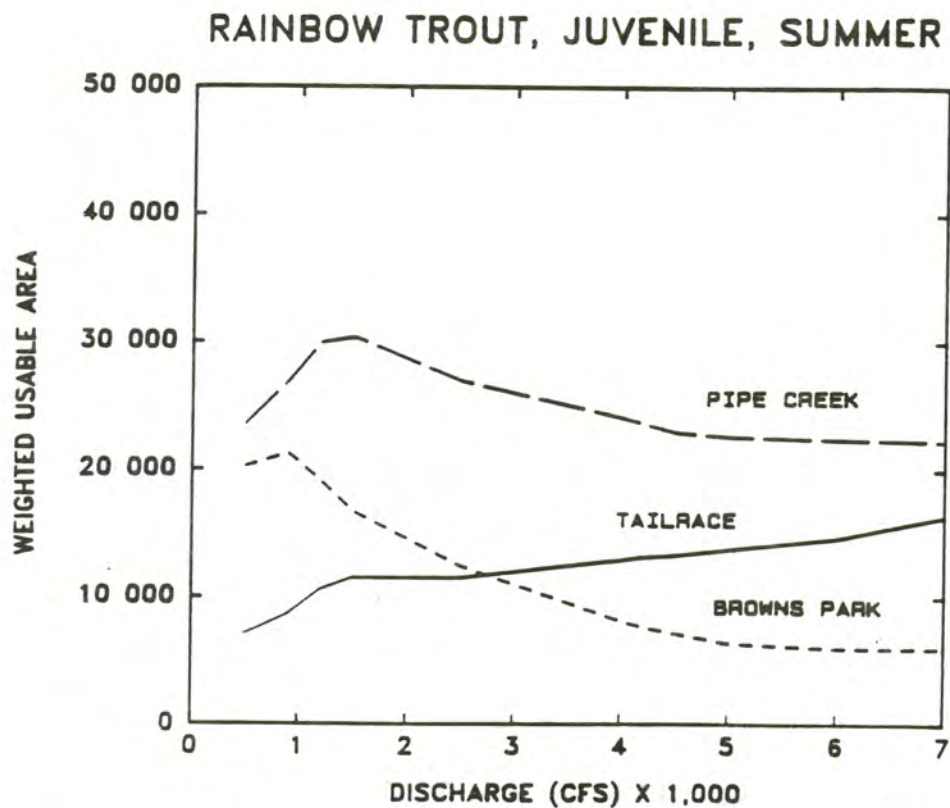
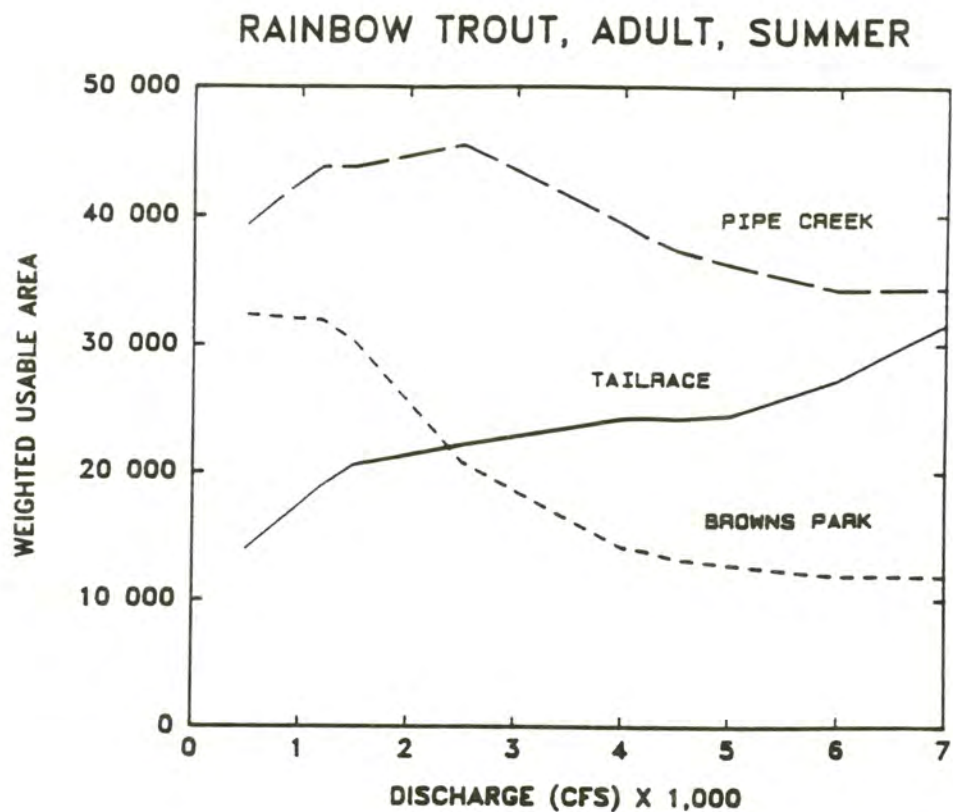


Figure 14. Weighted usable area with respect to discharge for rainbow trout adult and juvenile life stages, summer and winter, at Tailrace, Pipe Creek, and Indian Crossing (Browns Park), based upon microhabitat profiles by Gosse (1982).

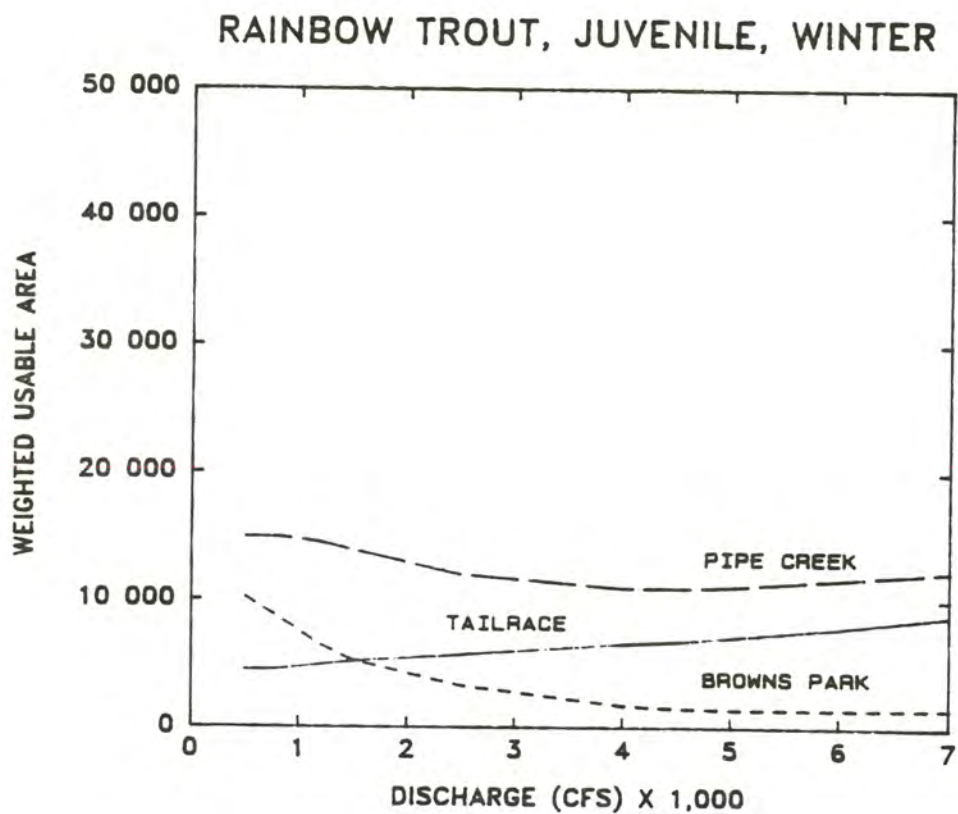
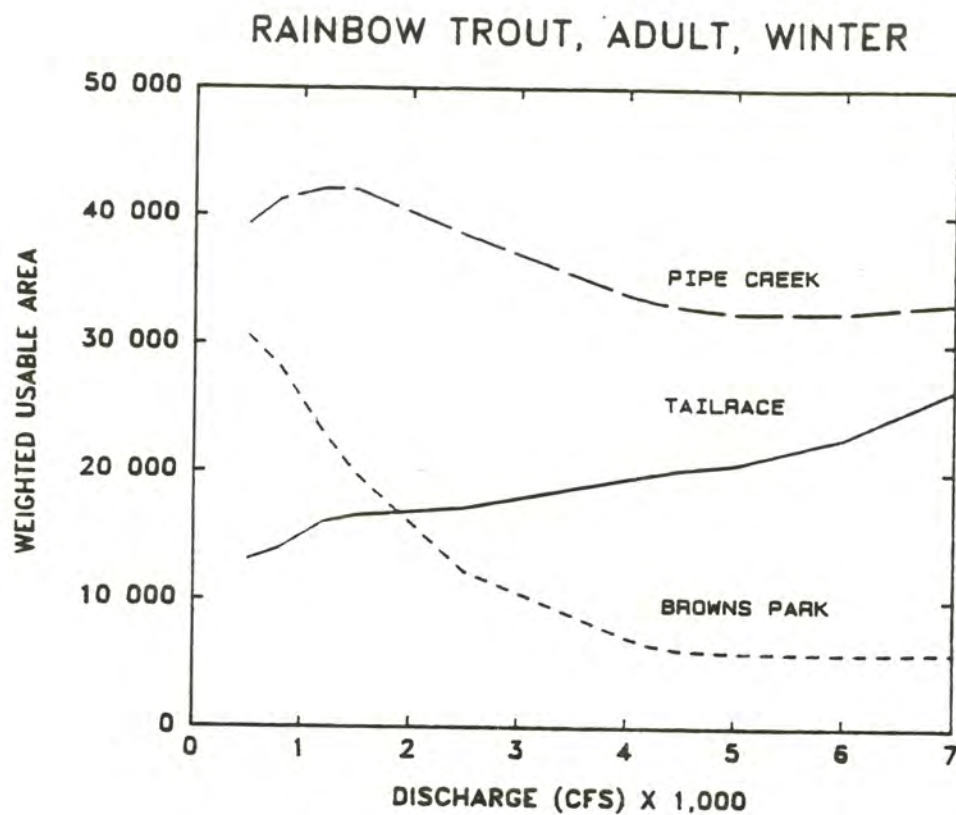


Figure 14. (Continued).

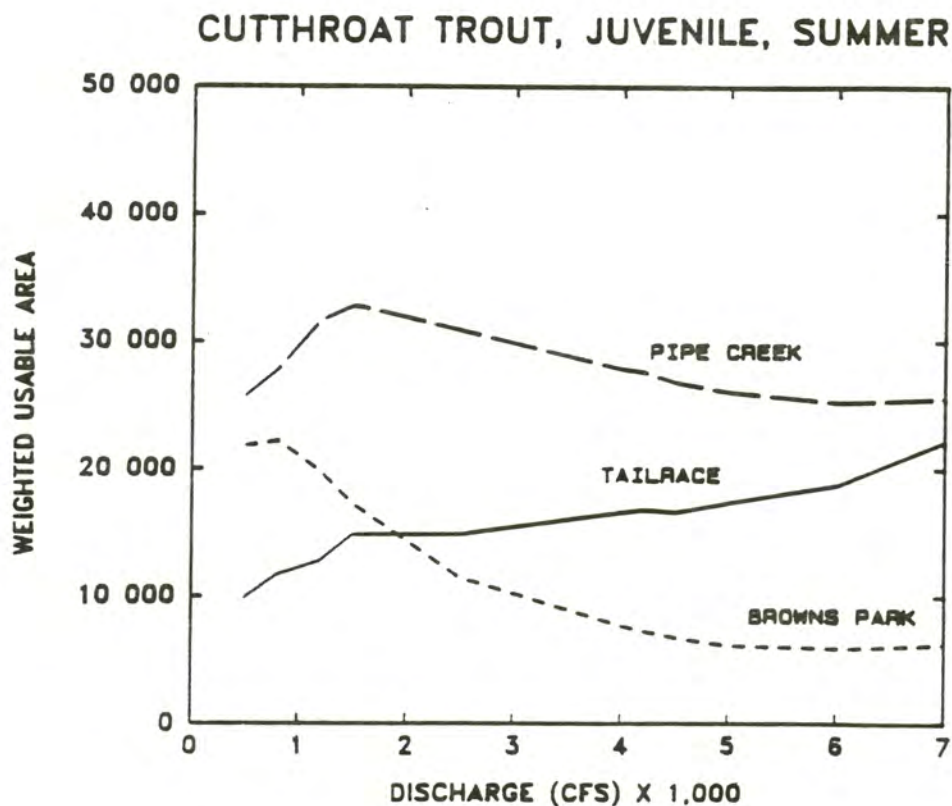
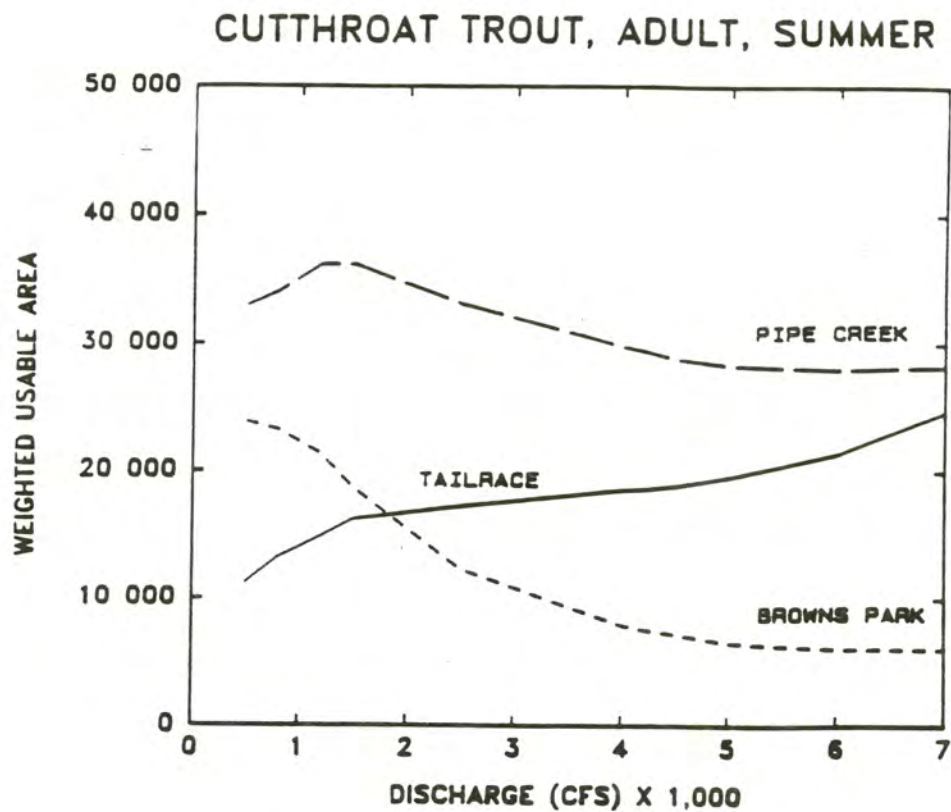


Figure 15. Weighted usable area with respect to discharge for cutthroat trout, adult and juvenile life stages, summer and winter, at Tailrace, Pipe Creek, and Indain Crossing (Browns Park), based upon microhabitat profiles by Gosse (1982).



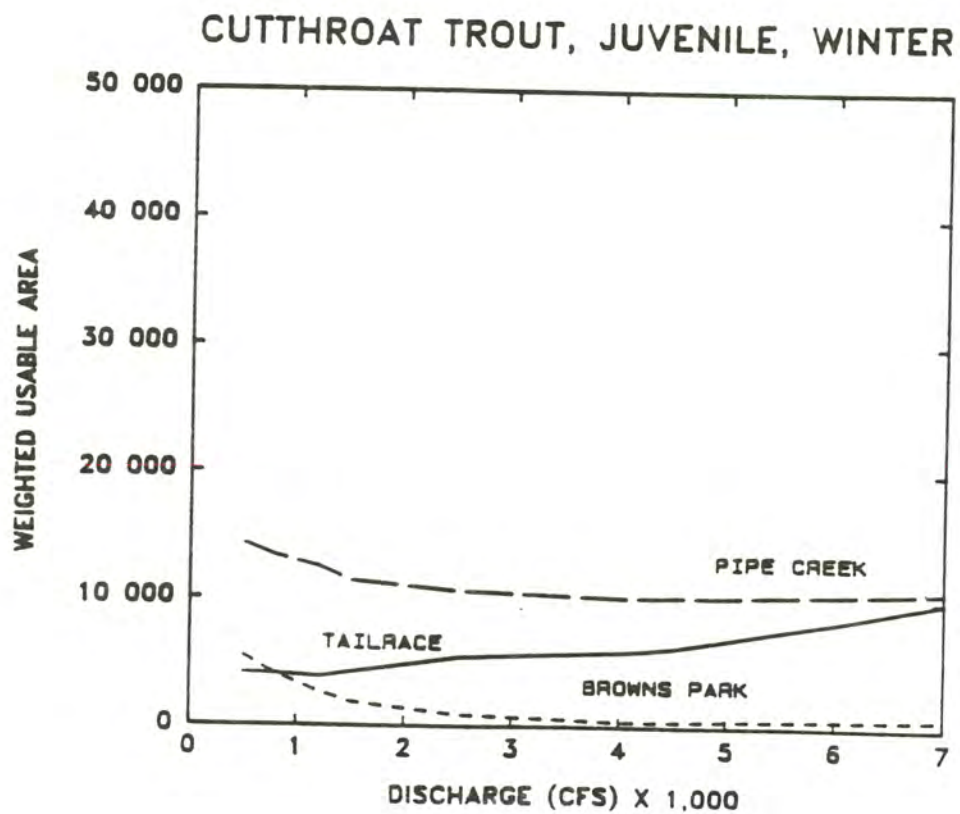
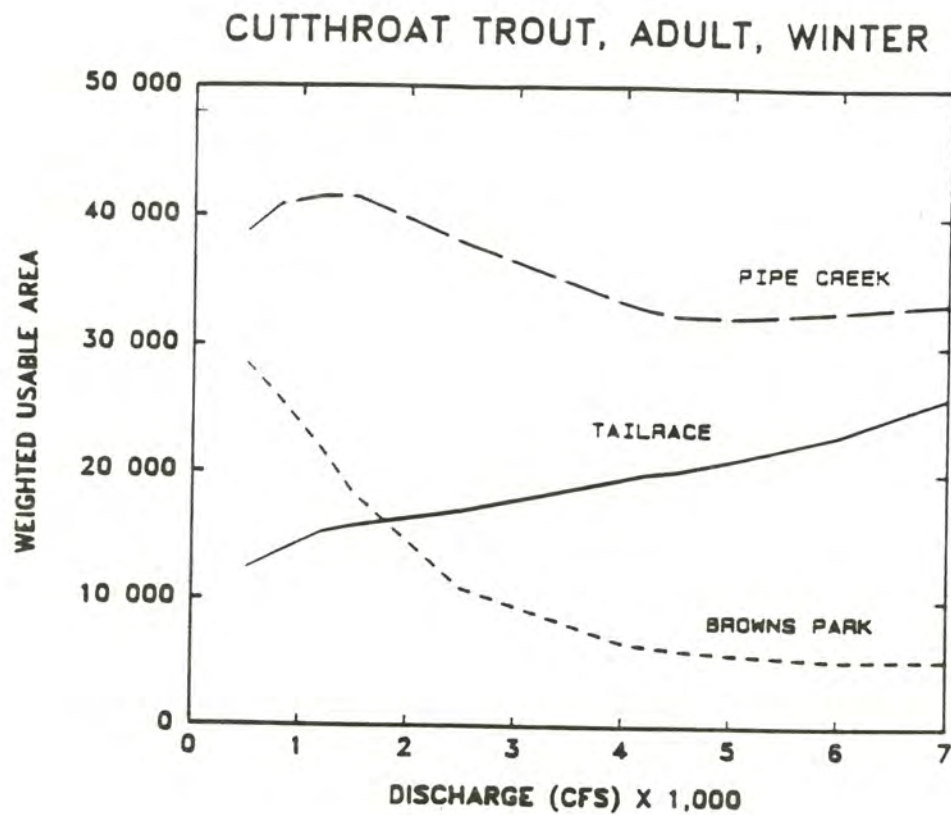


Figure 15. (Continued).

summer magnitude and became almost nonexistent at Indian Crossing at higher discharges (Figures 14 and 15). This seasonal difference is due to the combined effects of two behavioral changes in winter that were most pronounced in trout of the juvenile life stage: 1) an apparent reduction in facing velocity and 2) a shift to deeper habitats.

The decline in juvenile trout habitat during winter at all three stations and the negative WUA/Q relationship at Indian Crossing appear to be two physical variables limiting to populations of trout of the Flaming Gorge Tailwater.

The negative WUA/Q relationship at Indian Crossing was due to the increase in velocity and the relatively small concurrent increases in channel width and depth with increasing flows. Velocities also increased at Tailrace and Pipe Creek but the decline in velocity suitability was apparently compensated for by substantial increases in channel width and depth (Table 47). Bottom velocity profiles for Tailrace and Pipe Creek stations, combined shown in Figures 16 and 17, demonstrate that at higher discharges a considerably smaller proportion of the channel offered velocities suitable to trout, and juvenile trout were especially disadvantaged. The three habitat parameters (depth, velocity, and substrate) were given equal weight in the habitat models. The relative importance of these parameters for the Green River fishery during winter has not been thoroughly addressed and could have considerable bearing on the WUA/Q relationship. For instance, an increase in the weighting factor for velocity (or a decrease in the weighting value for depth) could produce a strongly negative WUA/Q relationship for the Pipe Creek and Tailrace stations. Velocity may, indeed, warrant a greater weighting factor if energy conservation is the principle strategy for juvenile trout in winter (see discussion section below).

Because microhabitat data from the study area were not generated for brown trout, probability of use curves from the Instream Flow Group (IFG), United States Fish and Wildlife Service, were used to generate WUA for this species at Browns Park and Tailrace. The IFG data represent a composite of studies, methodologies, geographical areas and stream habitats. They are not stratified by season and therefore do not apply to the Green River's limiting winter conditions. Size (TL) criteria for definition of juvenile and adult life stages were similar to those used in our study. Habitat suitability curves were available for adult, juvenile, fry, spawning, and egg incubation life stages.

The IFG habitat suitability curves for all life stages of brown, rainbow, and cutthroat trout produced negative WUA/Q relationships when run with the Indian Crossing model. The WUA/Q relationship was also negative for brown trout juveniles and for cutthroat trout adult and juvenile life stages at Tailrace (Appendix Tables C4 and C5). Rainbow trout WUA at Tailrace was low for juveniles at all but the lowest discharges; neither brown trout nor rainbow trout adult WUA varied consistently as a function of Q at this station. The overall relationship of WUA to Q tended to be more negative when the IFG habitat suitability data were employed than with the data derived from Gosse (1982). The difference is largely ascribable to difference in depth suitability curves, with those from the Green River favoring habitats with greater depths.

Use of the IFG habitat suitability curves produced greater WUA estimates for adult than for juvenile life stages for all three species. WUA for brown trout exceeded that for rainbow or cutthroat trout at both stations (Tailrace and Indian Crossing). The IFG curves were not run against the Pipe Creek station.



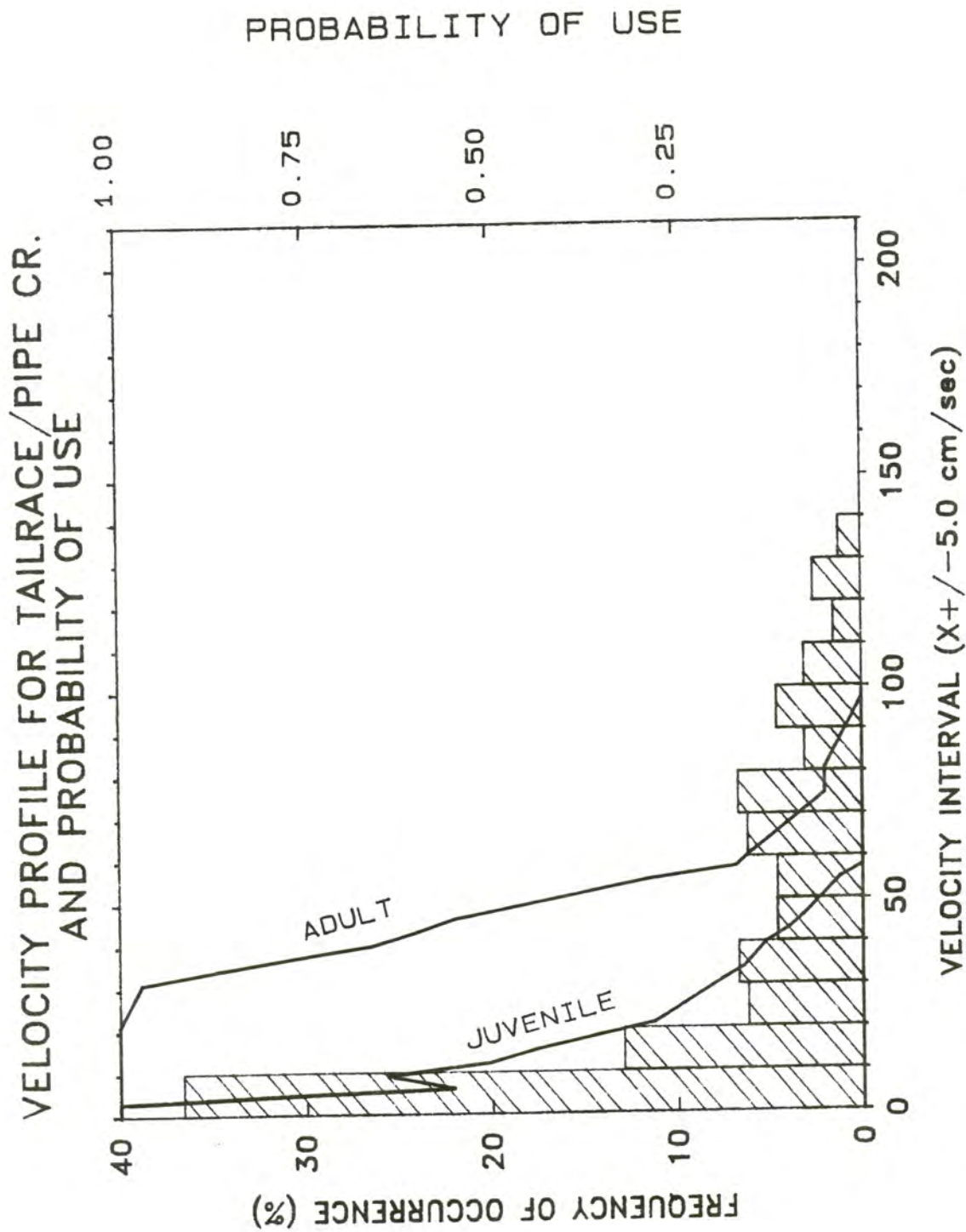


Figure 16. Frequency distribution of bottom velocities from the combined Tailrace/Pipe Creek stations, with respect to velocity suitability curves for adult and juvenile trout (rainbow and cutthroat suitability data combined), 800 cfs.



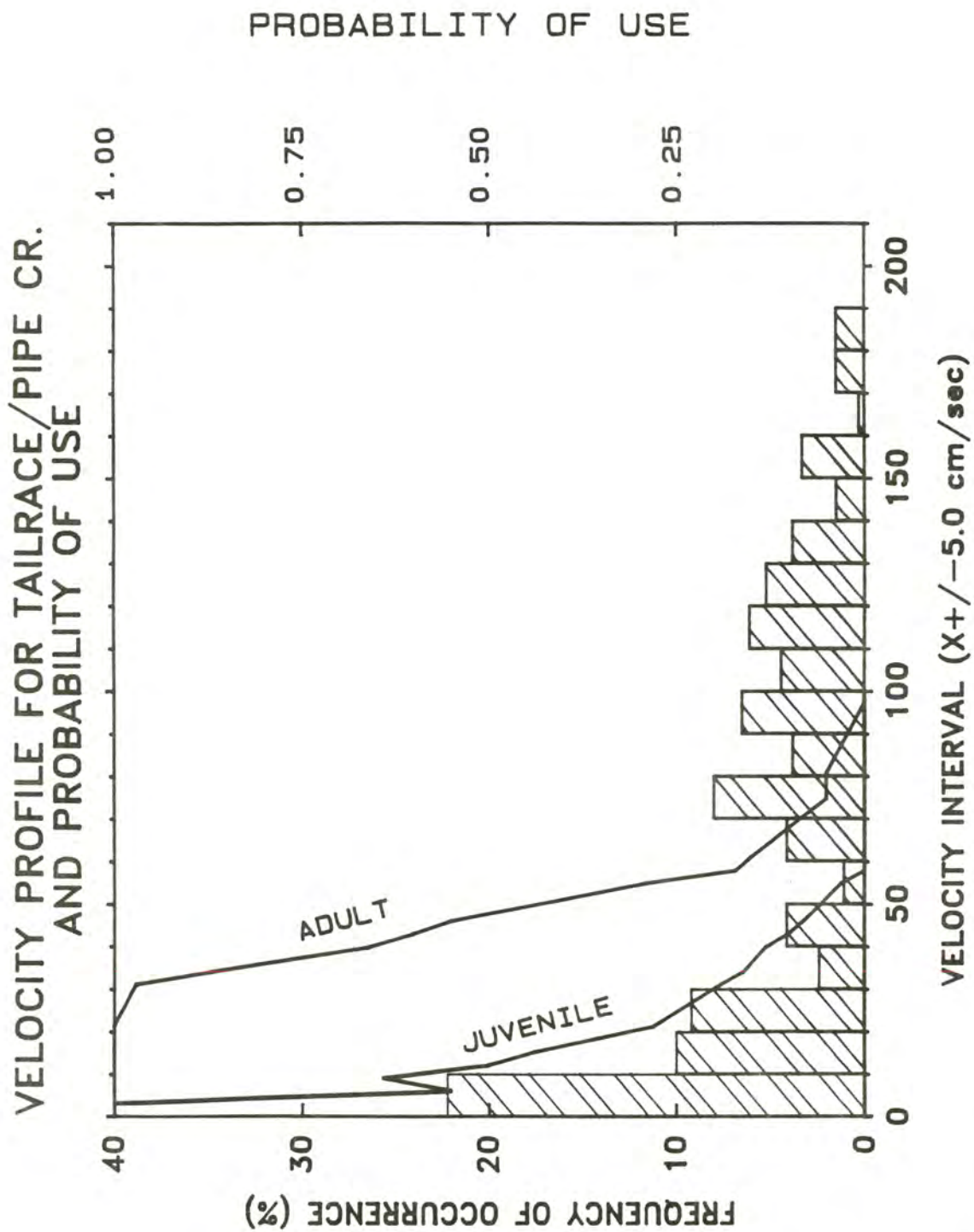
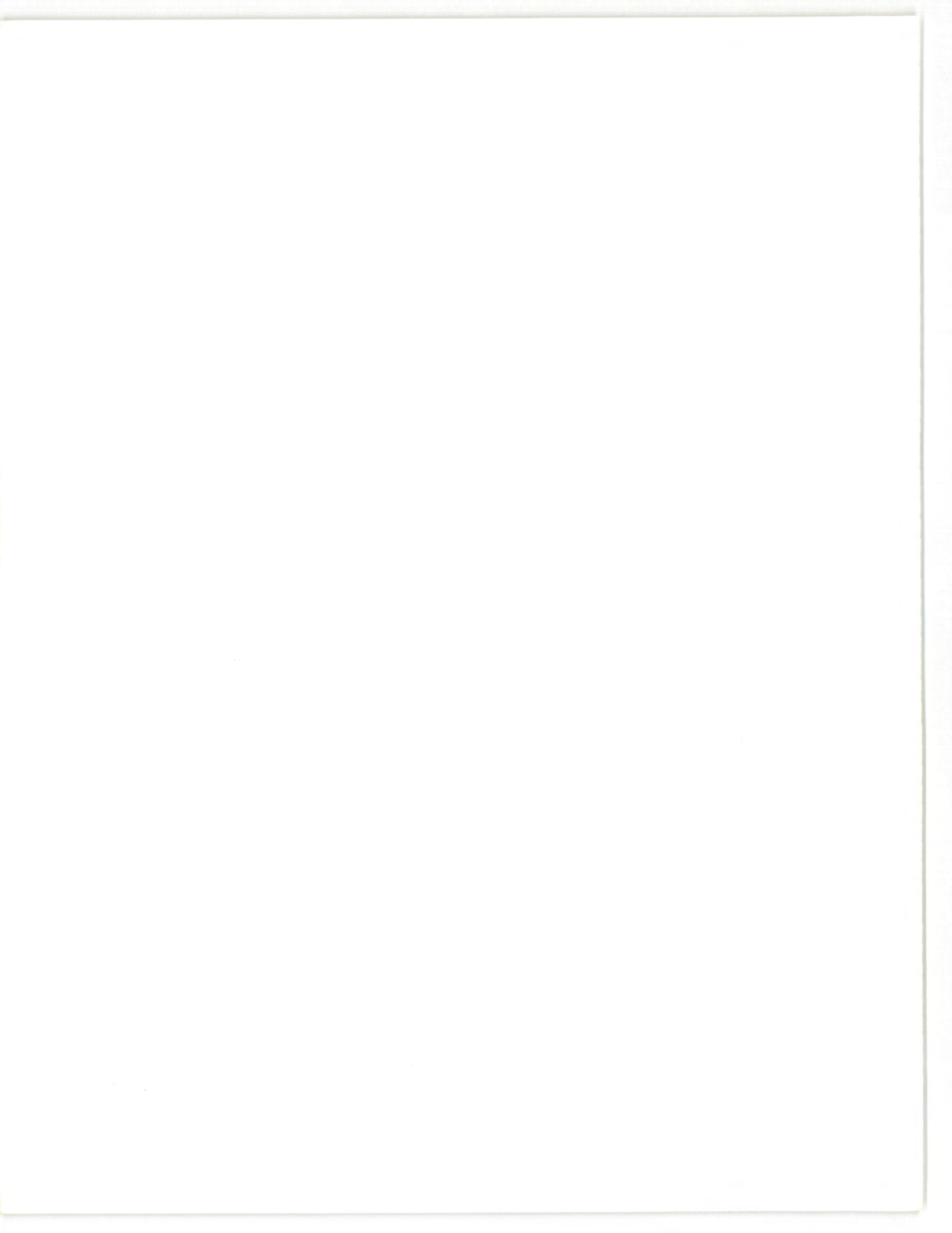


Figure 17. Frequency distribution of bottom velocities from the combined Tailrace/Pipe Creek stations, with respect to velocity suitability curves for adult and juvenile trout (rainbow and cutthroat suitability data combined), 4,000 cfs.



DISCUSSION - TROUT HARVEST, SURVIVAL, MIGRATION,  
AND HABITAT CONSIDERATIONS

OBJECTIVES #2 AND #3

Sportfishery Trends

The increase in use and harvest since 1978 can only be attributed to the modification of the penstocks. Penstock modification produced a three-fold increase in growth which, in turn, allowed fingerlings to reach a size acceptable to anglers in approximately 6 months. Fish that survived their first winter in the tailwater were of highly desirable size and attracted widespread angler interest. In addition the warmer tailwater temperatures undoubtedly attracted recreationists with wider ranges of interests. Previous water temperatures were probably cold enough to discourage some family fishing trips.

Angling participation rate among parties floating the Green River rose steadily during the study, from 20% in 1979 to 38% in 1982. The near doubling in angling participation rate was strongly influenced by the river's continued improvement as a sport fishery.

Total (raft and shore) use peaked in 1981, declining only slightly in 1982. Catch rate and harvest also peaked in 1981 and declined substantially in 1982. The peak in 1981 was the result of the exceptional carry over of the 1980 rainbow and cutthroat trout plantings, and was only sustainable if fingerling plantings continued to winter well. Other cohorts stocked during the study period experienced heavy first winter losses, probably in the vicinity of 90%. Declining angler success rates, in part, contributed to the reduction in use from

1982-1984. The other major contributor to declining use was the exceptionally high runoff and resulting high reservoir releases during the summer of 1983.

A number of findings from this study suggest the harvest level experienced in 1981 was not sustainable. It is clear that, under the stocking plan employed during the study, the carryover rate experienced by the 1980 cohorts could seldom be duplicated. Second year return rates of 30% and 11% were realized from the 1980 rainbow and cutthroat trout fingerling plants, respectively. No other recent plantings produced second year return rates higher than 8.2%. When the previous year's fingerlings failed to carry over well, the fishery was depleted by harvest early in the fishing season, unless catchables were stocked at regular intervals.

Mortality during the fishing season (June - November) of trout stocked as fingerlings the previous year, based upon monthly catch curves, appeared to be in the vicinity of 60-70%. This summer mortality rate was probably underestimated because of what appeared to be a strong increase in trout vulnerability (or angler skill) in the late season. Tag return rates from fish tagged just prior to the angling season ranged from 27% to 40%. Anglers can be expected to voluntarily report less than 40% of tagged fish they encounter (Rawstron, 1971 and 1972). The bulk of each season's harvest was concentrated on the fingerling cohorts stocked the previous year or on catchable stockings. Failure of a single cohort has pronounced effects upon such a fishery.

Survival during the first winter following stocking was the major determinant of cohort success. Winter survival has been shown to be



limiting to trout populations elsewhere (Bjornn 1971, Campbell and Neuner 1985, Kurtz 1980, Needham et. al. 1945).

Rainbow trout larger than approximately 300 mm (12 inches) experienced better winter survival than smaller trout. Rainbow trout larger than 300 mm, tagged in fall 1981, returned to the creel at approximately 3 times the rate of fish smaller than 276 mm (approximately 11 inches). The 1980 cohorts (both rainbow and cutthroat trout) were stocked at larger sizes and survived their first winter considerably better than any other during the study. Analysis of catch curves suggested natural mortality during winter was relatively low for adult trout. Likewise, WUA for adult trout vastly exceeded that for juveniles at all stations during winter. Thus, the river's greatest potential may be in its capacity to provide a diverse fishery composed of several year classes of adult trout.

Winter carry-over could be considerably enhanced by stocking 150 mm (approximately 6 inch) trout no later than mid-May. Growing at 25-30 mm/mo during the period of June-November, TL would average 300 mm by winter. The stocked fingerlings of the year would, theoretically, experience the more favorable survival associated with the adult life stage during their first winter in the tailwater.

However, it was determined that enhancement of first winter carryover would not, alone, be enough to realize the Green River's sportfishery potential. The level of harvest experienced in 1981 demonstrated that harvest could decimate a successful year class in a single season. In 1981, harvest rate was 111 kg/ha for the Utah portion of the tailwater and 311 kg/ha for the upper 11 miles (Dam to Red Creek). By 1982, based upon their contribution to the creel, the

successful 1980 cohorts had been nearly eliminated and their longevity in the creel was little better than the less successful 1981 cohort (Figures 18 & 19). To adequately test the hypothesis that the tailwater's habitat is best suited for older, larger trout, stocking of larger fingerlings must be combined with moderate winter discharge and harvest regulation.

#### Fish behavior, PHABSIM output and supporting biological data

In winter, trout larger than 300 mm (adult) selected a much wider range of habitats than did smaller individuals. It appeared that adult trout facultatively employed the RS and SS swimming modes, but that RS was the dominant and possibly obligate behavior for juveniles of both rainbow and cutthroat trout in pools in winter. Interpreting the probability-of-use curves generated for the three habitat simulation sites, WUA in winter is therefore represented by the composite of RS and SS habitats for adult trout. Winter habitat for the juvenile life stage may be best represented by WUA for RS only. With this interpretation, WUA for juvenile trout is almost nonexistent in winter at all three habitat simulation stations. The scarcity of habitat for juveniles probably reflects their selection of the lowest velocity sites in winter.

Because the major limiting factor in the present study was seasonal (winter) in occurrence, use of habitat suitability curves based on summer observations would have failed to reveal the lack of winter habitat for the juvenile life stage. These results emphasize the necessity of either adequately verifying applicability of curves before applying them to other waters or, preferably, developing electivity curves on site.

The conclusion that habitat for juvenile trout in winter is limiting to the fishery is supported by winter diving and snorkeling observations

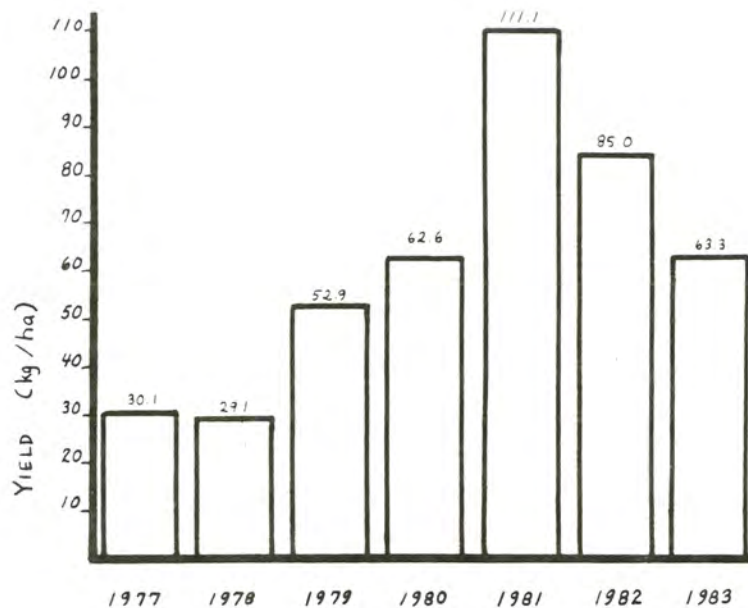


Figure 18. Trends in yield from Flaming Gorge tailwater, 1977-1983.

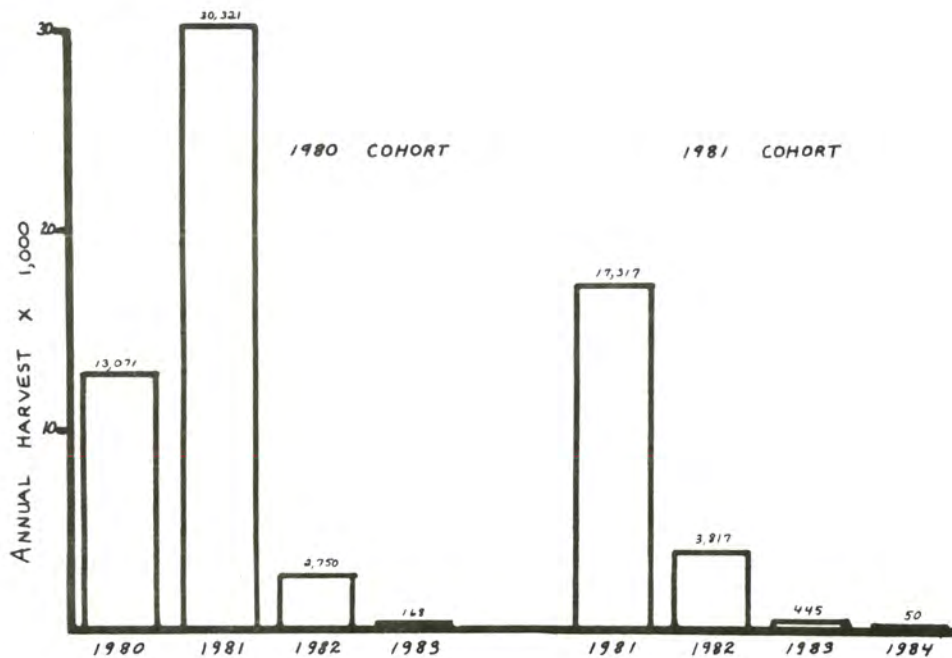


Figure 19. Longevity in the creel of the successful 1980 and less successful 1981 rainbow trout cohorts, stocked fingerlings.



of Gosse (1982) and DWR personnel. Most river areas were sparsely populated, but certain pools were occupied by immense schools of juvenile trout. Juvenile trout appeared to be selecting an extremely small proportion of the tailwater's area during winter. Adult fish, on the other hand, were observed in a much wider variety of areas, including riffles and glides, in addition to pool habitats. These observations are consistent with the differences measured in facing velocities between adult and juvenile life stages (Figures 16 and 17).

Certain pool habitats selected for RS activity may have offered areas of refuge from alterations in velocity, at least within a certain range of discharge. While SS facing velocities seemed to increase as a function of Q, RS facing velocities varied relatively little and were much lower than for the SS mode (Figure 12). Thus, trout in the RS mode probably consumed less energy maintaining their position and, provided they remained in the RS mode, experienced relatively stable water velocities despite the frequent alterations in Q resulting from changing hydroelectric demand.

Yet, during the month-long high flow test in February 1982, both juvenile and adult trout seemed to abandon the RS mode (Figure 12). A likely explanation for the change in activity pattern is that habitats suitable for the RS activity mode either declined in area or alternated in location with increasing Q. In other words, pool habitats may provide stable low velocity areas needed by juvenile trout only within a specific range of discharge, above which facing velocities may increase. Gosse (1982) observed that trout in the Green River only occasionally moved more than a few meters during changes in Q. During the extended high Q period in February of 1982, however, the location and/or total available



area of habitats suitable for random swimming could have changed considerably. WNA for winter RS activity for juvenile trout was very low, relative to that in summer, but there was no discernable relationship between WNA for this activity and discharge.

During February 1982, the trout apparently were unable to locate RS habitats, as evidenced by the high incidence of stationary swimming for both life stages of rainbow trout (Figure 12). Moreover, it was during this period that juvenile cutthroat trout almost entirely disappeared from the study area.

One consistent bias of our microhabitat methodology was limitation of observations to brightly illuminated conditions of midday. This limitation was prescribed to maximize visibility and safety conditions for the scuba diver. Trout were seldom observed in depths of less than 2 m and this probably represents avoidance of full daytime illumination by the trout. It is also likely that during daytime the trout avoided the diver and surface crew by moving into deeper locations. Nighttime electrofishing revealed that trout were heavily distributed in shoal areas and that shallows were especially preferred by juvenile trout.

Basing our habitat suitability curves upon daytime microhabitat observations produced a habitat suitability index of near zero for all depths less than 2 m. It proved necessary to arbitrarily set the index for depths of 0.5 to 2.0 meters at 0.5; otherwise many shallower cells of the three stations, where velocities were relatively low, would have been underrepresented by the PHABSIM models.

Unlike random swimming, SS facing velocity appeared to increase as a function of  $Q$ . Facing velocity for stationary swimming was much more subject to  $Q$  for juvenile trout than that of adults. Between low and

high winter discharges in 1981, SS facing velocity of cutthroat trout juveniles increased 150%, while that of adult cutthroat increased 75%; the rainbow trout increase was 76% and 43%, juvenile and adult, respectively. During the high flow test in February 1982, SS facing velocity increased 24% and 6% for juvenile and adult cutthroat trout and 67% and 23% for juvenile and adult rainbow trout, respectively (Figure 12). Trout in SS positions were observed by Gosse to respond to increasing Q by moving closer to the substrate. This response only partially compensated for the increase in discharge.

In general, for the upper 4 mi of the tailwater at least, the majority of juveniles of both species during winter were found in RS habitats where facing velocities were usually less than 12 cm/sec (0.39 ft/sec). During the high discharges of February 1982, on the other hand, most juvenile trout occupied SS positions. Facing velocities for stationary swimming, for both adults and juveniles, were in excess of 22 cm/sec (0.72 ft/sec) at these higher discharges (Figure 12). Facing velocity for juvenile trout, if expressed in terms of body lengths/second, would undoubtedly have exceeded that of adult trout, suggesting that demands upon metabolism and energy reserves during the high Q test period were probably much greater for the younger life stages. In addition, the rate of standard metabolism in salmonids decreases with increasing body size. The standard metabolism of a 3,000 g sockeye, for instance, is about one fifth that of a 1 g fry (Brett and Glass 1973). Critical (one hour sustained maximum) swimming speed varies directly with both body length and water temperature (Brett and Glass 1973, Fry and Cox 1970). Thus, the longer body conformation of adult trout may enhance their ability to cope with relatively high facing

velocities. Their greater swimming efficiency may also, in part, explain the broader range of elected facing velocities and higher rates of winter survival of adults, with respect to the juvenile life stages.

One hypothesis, therefore, for the disappearance of juvenile trout during and shortly after the February 1982 high flow test is that there was a shift to the SS activity mode and resultant increase in facing velocity. The increase in activity level, in turn, caused depletion in energy reserves of juvenile trout. Energy requirements for maintenance of position may have substantially exceeded energy derived from feeding. Winter is generally a period of relatively low rates of invertebrate drift (Bjornn 1971, Waters 1962), but salmonid digestive tracts have been observed to be relatively full in winter (Bjornn 1971), because digestion rates are reduced at lower temperatures (Reimers 1957).

An alternative explanation for the switch to SS activity during high winter discharges would be that high Q caused increased invertebrate drift, and the SS habitats were more conducive to feeding. The discharges of February 1982 were consistently high. Had increased drift stimulated SS activity, a resumption of RS activity should have occurred following stabilization of invertebrate distribution. Stationary activity was the dominant behavior, however, of juvenile trout during the entire high discharge period.

Hence, the microhabitat data collected from the Green River in winter, especially at higher Q, probably represent the responses of environmentally compromised organisms. Gosse and Gosse (1985), in studies of other Colorado River system tailwaters, demonstrated that there were significant differences between the tailwaters of Glen Canyon (Colorado River), Navajo (San Juan River) and Flaming Gorge (present



study) reservoirs with respect to facing velocities of rainbow trout. The differences seemed to be functions of gradient. SS facing velocities for the San Juan River, the study site with the lowest gradient, were 40% less than in the two higher gradient tailwaters. The authors concluded the differences between these tailwaters reflected Hutchinson's (1957) concepts of "realized" and "fundamental" niches. The realized microhabitat reflects a compromise between optimal (fundamental) and that available. Similarly, Gatz et al. (in press) found that rainbow trout habitat preferences shifted with competition from sympatric brown trout. The microhabitat data collected from the Green River may represent compromises imposed by discharge regime, light intensity, and differences in habitats within the study reach as well as species composition, size structure (hierarchy), and abundance of the trout populations.

WUA for juvenile SS activity in winter was estimated to be high, with respect to that for RS activity. SS activity may, at least for higher discharges, reflect an untenable compromise, energetically, for the juvenile life stage. Habitat for juvenile winter RS activity may be overestimated if this habitat alternates in location with changing Q.

Weighted usable area estimates for the adult life stage, however, suggest that habitat for the adult life stage is not limiting to the trout population of the Flaming Gorge tailwater. The broader range of velocities suitable for adults suggests adult trout can occupy a wider variety of habitats and better accommodate alterations in habitat produced by flow changes than can the juvenile life stage.

Habitat simulation models are, by definition, simplifications of very complex systems, in this case to allow the isolation of limiting habitat variables. The affects of social hierarchy, interspecific and



intraspecific competition, hydrologic affects upon food availability (drift), feeding efficiency, and other factors are not accounted for. Campbell and Neuner (1985) found habitat selection of rainbow trout in small streams to be related to fish size, with larger individuals occupying positions closest to, but protected from, incoming flow, which usually represented feeding focal points. Bachman (1984) proposed that, in his study site, adult brown trout density could be limited by number of feeding focal points. He also demonstrated stocked brown trout were incapable of efficiently utilizing food and habitat resources in the face of a wild brown trout population. Moyle and Baltz (1985) suggested that microhabitat use may be a function of abundance, due to effects of interspecific and intraspecific competition. Although it is probable that the adult life stages of both rainbow and cutthroat trout are considerably better suited to habitat conditions in the Green River than the juvenile life stages, sustainable population size for adults is also a function of social, biological and other factors (Orth 1987). This mix of variables will determine the potential carrying capacity of the adult life stage in the Green River.

Both life stages exhibited a marked increase in RS activity in winter. Gosse and Gosse (1985) hypothesized that RS behavior is a response to low winter water temperatures. In the Glen Canyon tailwater, where water temperature never declined below 8°C, SS was the predominant activity year-round (Gosse and Gosse 1985). Occupation of slower, pool-like, habitats probably represents an attempt to tailor energy requirements to the lower metabolic rate and lower digestive rate experienced by riverine salmonids under typical winter conditions. The shift to pool-like habitats occurred in the Green River as fall

temperatures declined below approximately 6°C in November and December. Summer-like activity patterns, including increased facing velocities and more frequent use of SS habitats, resumed as water temperatures began to exceed 4°C. The change occurred over a period of one to two months during both the spring and fall transitions. Campbell and Neuner (1985) noted a shift to more pool-like habitats, accompanied by occupation of interstitial substrates, for small rainbow trout as temperatures declined in fall from 8°C to 3°C. Chapman and Bjornn (1969) reported a shift to predominantly resting activity and interstitial orientation in steelhead presmolts as temperatures declined below 5.0° - 5.5°C. Hanson (1977) reported substrate orientation for west slope cutthroat trout below temperatures of 4.4°C.

Cunjak and Power (1986) observed that young brook and brown trout formed aggregates in winter, but that these clusters of fish seldom included brown trout larger than 300 mm. Older brook and brown trout maintained higher facing velocities than smaller fish, and facing velocities in winter were slower than for summer. Aggregate behavior increased as water temperatures declined from 5.5°C to 0.1°C. Aggregates occurred in low velocity pools and runs where water temperatures were warmed 2°C to 6°C by entry of spring creeks and seeps. Aggregations of trout were never observed in riffles. The largest aggregates of trout were found in streams with the lowest percentage of pool-like, slack water areas. The authors concluded that the "clumping" of trout in winter reflected an energy conserving strategy, and the "occupation of a limited special commodity" explained the high concentrations of trout involved (Conjak and Power 1986).

Bjornn (1971) suggested the amount of winter cover plays a major role in the number of fish that overwinter in streams that experience temperatures less than 4-5°C, and that fish induced to find cover by lower temperatures may move downstream if unable to locate suitable winter habitats. Thus, low temperature, by stimulating energy conserving behavior, could indirectly stimulate downstream movement. Downstream emigration appeared to be the principal source of winter loss in the Flaming Gorge tailwater.

Influence of anadromous traits from the mixing of various hatchery stocks of rainbow trout was implicated by Moring (1982) as a cause of emigration. The genetic history of the rainbow trout stocked during the study period is similar to the trout used by Moring. The Snake River cutthroat trout, however, were a domesticated but unmixed stock of an inland riverine form of the cutthroat trout subspecies Salmo clarki lewisi. The Snake River cutthroat trout also emigrated from the tailwater. Emigration, therefore, may have been stimulated by a variety of factors and not by genetics alone.

As a rule, natural streams of the Intermountain West experience low stable flows in winter. Winter habitats selected by trout in these streams include: slow velocity areas provided by interstitial spaces (Bjornn 1971, Chapman and Bjornn 1967, Hanson 1977); ice covered shallow pools (Wichers et al. 1982); and shelter of undercut banks, overhanging brush, rockpiles, projecting snowbanks, and exposed roots (Chisholm et al. 1986, Cooper 1953, Needham and Jones 1959,). These attributes of winter cover are largely lacking in the Green River, as are tributaries that might offer winter refuge. Furthermore, unlike unaltered streams,



winter is usually the period of highest Q in the Flaming Gorge tailwater, due to hydroelectric power demand (Appendix Table C6, Appendix Figure C1).

Wintering trout have been reported in relatively shallow water at night (Campbell and Neuner 1985; Needham and Jones 1954). Nighttime occupation of shallows, in combination with low metabolic rate and substrate orientation, could increase vulnerability to discharge alterations, in a manner somewhat analogous to benthic invertebrates and other relatively sessile organisms. Bovee (1985) demonstrated that WUA for sessile organisms under conditions of fluctuating discharge is considerably less than that for streams with stable discharge regimes.

No measurements of microhabitat were made during nighttime during the present study.

Trout were observed in interstitial habitats, but perhaps due to the larger size (TL) of our juvenile life stage classification with respect to studies by others, it was not a prevalent juvenile activity pattern. Interstitial habitats for wintering juvenile trout may also be limited in the Green River by low availability of suitable interstitial areas.



## MANAGEMENT IMPLICATIONS

Considerable variability in habitat and biological conditions was apparent between river locations. Tag return rates for rainbow trout tagged in fall were functions of tagging site (river mile), with return rate generally declining with increasing distance from the dam. The tag return rate for trout tagged at Tailrace (mile 1) was twice that for Pipe Creek (mile 2). Tag return rate for rainbow trout of the 1981 cohort larger than 300 mm was also much higher for those tagged in the upper four river miles than those tagged at river miles 7-11. Growth varied significantly between Tailrace, Little Hole and Browns Park, with the greatest growth rate at Tailrace. The PHABSIM models, in terms of total WUA and stage/WUA curves, also portrayed a general decline in habitat suitability with increasing distance from the dam. Thus, caution must be exercised in drawing generalizations from this study for application to the river as a whole.

Yet, for the purpose of managing its fishery, there are obvious reasons for treating the tailwater as a single unit. Several findings of this study apply to the tailwater in general.

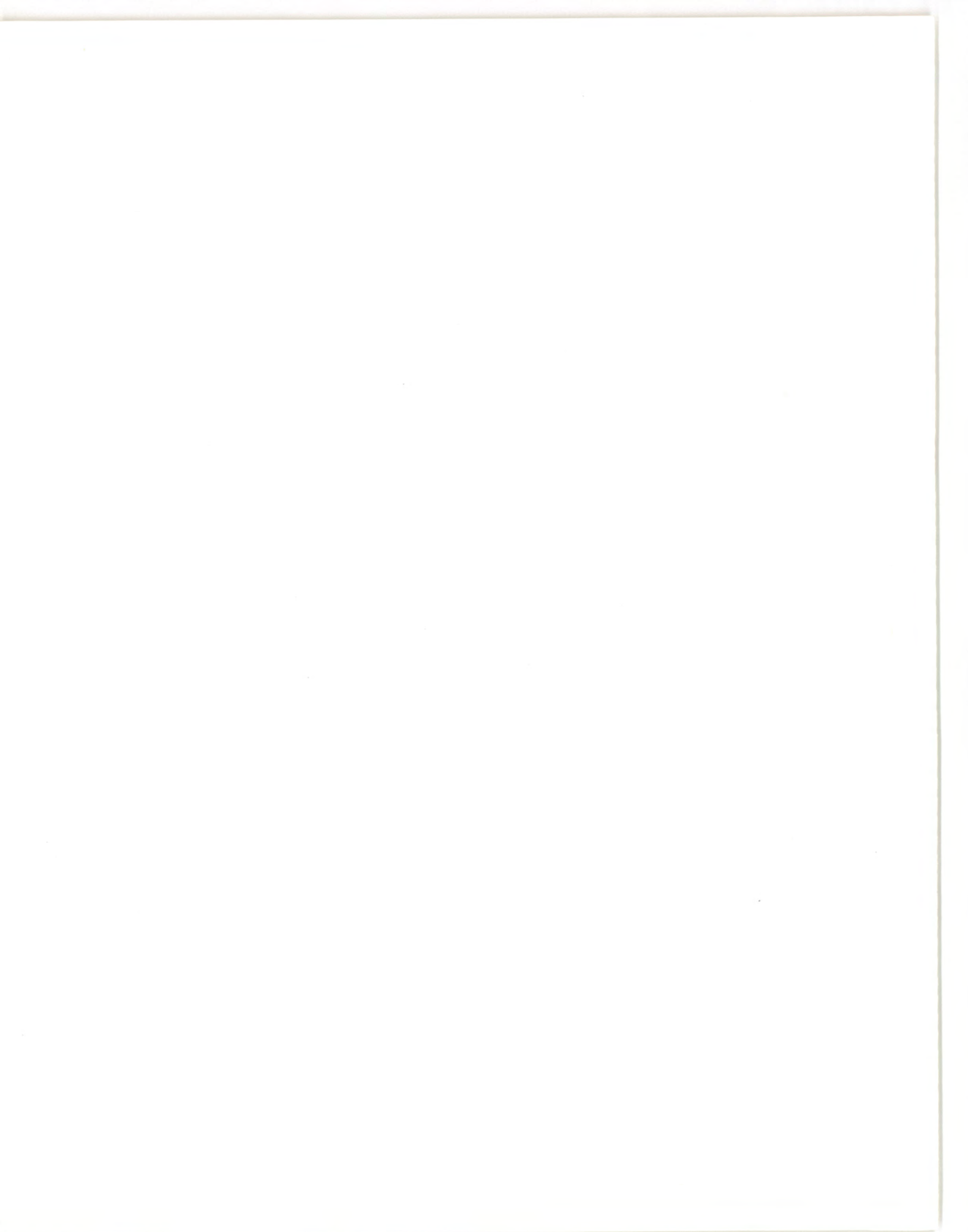
1. Growth rates were exceptional, exceeding 25 mm/mo for yearling trout for the period of May - October at all stations.
2. Natural recruitment of rainbow and cutthroat trout contributed only a small proportion of the harvest during the study.
3. Winter habitat conditions were limiting to survival of stocked fingerlings -- no such habitat limitations were evident for summer.

4. WUA for juvenile life stages of rainbow and cutthroat trout was low relative to that for the adult life stage at all three PHABSIM stations for all discharges. Habitat selected by juvenile trout represented a small proportion of the Green River's total area.
5. Adult trout successfully occupied a much wider range of habitats in winter than juvenile trout.
6. Rainbow and Snake River cutthroat trout appeared to recruit to the adult life stage at approximately 300 mm.
7. Movement of juvenile trout within, as well as emigration from, the tailwater was considerable.
8. Yield ranged from 53 to 111 kg/ha from 1979 through 1983. Angling harvest mortality probably exceeded 60%/year following full recruitment to the sportfishery.
9. Hooking mortality of released trout probably exceeded 30,000 fish annually. Bait fishing was the predominant angling method during the study period.

Based upon these findings a management strategy was synthesized to increase first winter survival of stocked fingerlings, better utilize the growth potential of the tailwater, reduce hooking and angling mortality, provide the angler with a "quality" fishery (in terms of C/E and average TL), and permit occasional harvest of trophy sized trout. In 1985, terminal gear was restricted to lures and flies. Trout between 330 mm and 508 mm (13 and 20 inches) were protected. Two trout less than 330 mm and one trout larger than 508 mm were permitted in the creel. In 1986, to increase winter survival rate of stocked fingerlings, stocking rate was reduced to 100,000 fingerlings annually (from 200,000 fingerlings and

approximately 25,000 catchables during the study period) and, in 1985, fingerling size was increased to 152 mm (from 120 mm or less during the study period). Stocking was scheduled for mid-May. The larger fingerling size resulted in a mean TL of approximately 300 mm for trout entering their first winter. Stocking of catchable-sized trout was eliminated.

Population estimates for two river miles (Tailrace and Little Hole) were conducted during both fall and spring 1985 through 1987, to monitor response of the fish population to the regulation changes and to ascertain trends in winter mortality. Estimates for fall 1985, 9 months after implementation of the management plan, were  $13,776 \pm 1,424$  (95% C.I.) per mile at Tailrace and  $5,618 \pm 675$  at Little Hole. By September of 1987, estimates were  $20,783 \pm 2,546$  at Tailrace and  $12,986 \pm 2,215$  at Little Hole. Substantial increases were also registered in biomass and mean TL of the trout population. These population estimate findings will be published with the final report for the current (1986-1989) tailwater study phase.





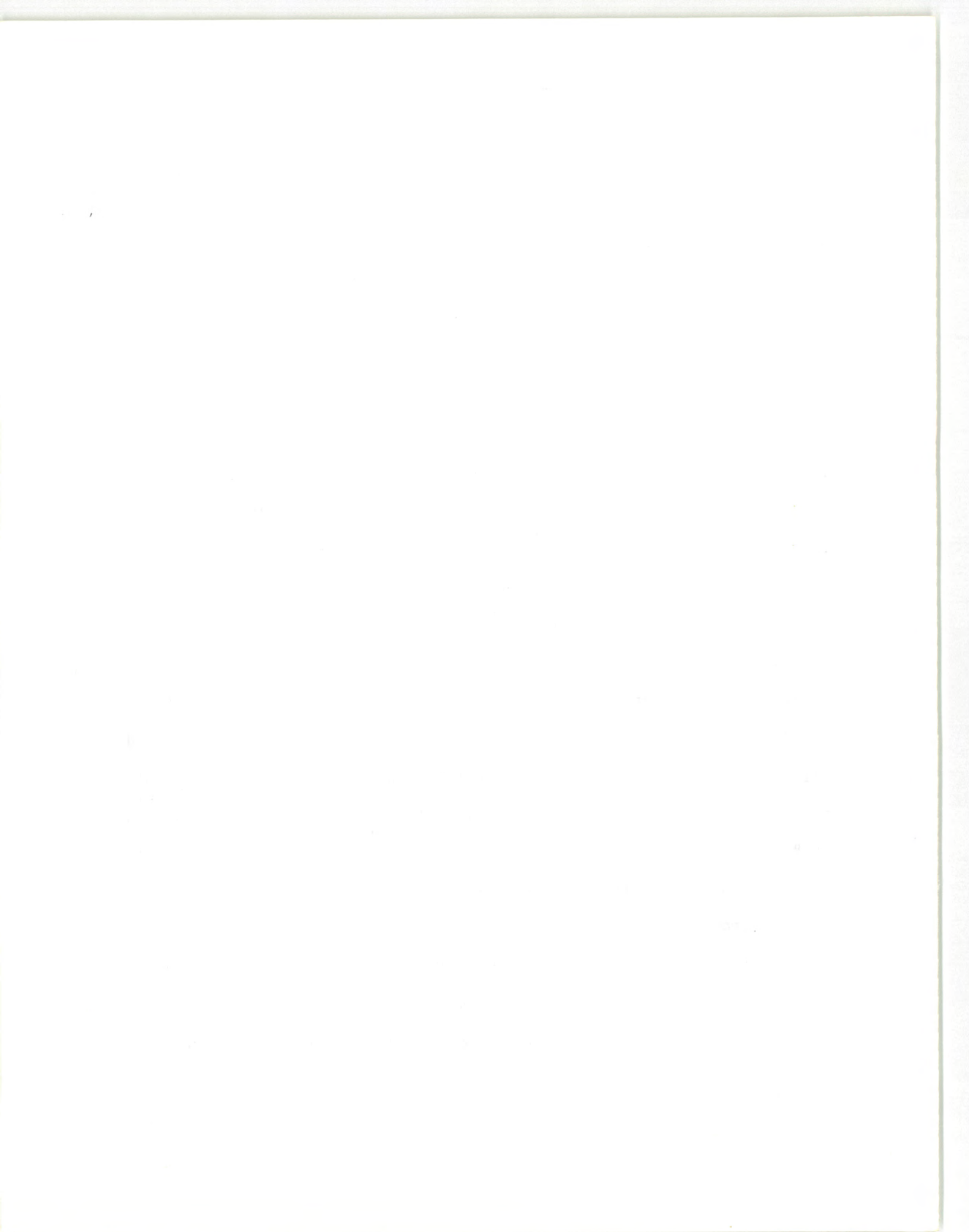
## FUTURE STUDY NEEDS

The change in management outlined above provides the opportunity to verify hypotheses and fine tune certain findings from this study. Specifically, the hypothesis that the Flaming Gorge tailwater is better suited to larger "adult" trout will be tested by assessing population trends. In addition, the size at which trout recruit to the "adult" life stage requires refinement. Size and age probably interact to determine energy reserves available to a trout during winter. Swimming stamina increases as a direct function of body length (Brett and Glass 1973). The TL required to sustain a fish during winter is, therefore, likely to be determined by energy reserves and the facing velocity imposed by conditions of habitat and discharge. The stocking of larger fingerlings may produce better winter carryover in certain river habitats, and not others, or only under certain ranges or durations of discharge.

The Bureau of Reclamation has proposed to rewind and uprate the generators at Flaming Gorge Dam, which will increase maximum Q to 4,900 cfs (from 4,200 during the study period). Increases in winter Q could significantly alter life stage criteria and reduce habitat for adult trout, especially in habitat types represented by the Indian Crossing PHABSIM station. The proposed rewind, therefore, emphasizes the need to better define the roles of Q and fish size and age on winter survival.

The regulation change also permits evaluation of density and social factors that might influence winter survival of the adult life stage. Adult trout were at low densities at all times during the study period.

It is suggested that future investigations incorporate energetics and further microhabitat study, including nighttime observations, with population monitoring to address the questions and opportunities described above.



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APPENDIX A  
OBJECTIVE #1  
TROUT GROWTH

Table A-I. Daily thermograph readings in °C, January-December, 1980, Tailrace.

Day	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	--	--	3.0	3.0	3.8	3.7	3.9	3.9	6.6	6.3	8.2	7.7
2	--	--	3.0	3.0	3.6	3.1	3.9	3.9	7.1	6.7	8.6	7.7
3	--	--	3.0	3.0	3.7	3.6	3.9	3.9	7.7	7.0	8.8	8.5
4	--	--	3.0	2.9	3.6	3.5	3.9	3.9	7.7	7.0	9.6	6.7
5	--	--	2.9	2.9	3.5	3.5	3.9	3.9	7.1	6.4	9.8	8.6
6	--	--	2.9	2.9	3.5	3.4	3.9	3.9	7.4	6.1	10.0	9.5
7	--	--	2.9	2.8	3.5	3.3	4.0	3.9	7.8	6.3	9.6	8.9
8	--	--	2.8	2.8	3.3	3.3	4.0	4.0	8.0	7.1	9.4	8.4
9	--	--	2.8	2.7	3.3	3.3	4.0	4.0	8.2	7.5	9.7	7.7
10	--	--	2.8	2.5	3.3	3.3	4.0	4.0	8.0	7.5	10.0	6.6
11	--	--	2.5	2.5	3.2	3.2	4.2	4.1	8.0	6.3	10.4	7.8
12	--	--	2.5	2.5	3.2	3.2	4.1	4.0	6.6	6.0	10.7	8.7
13	--	--	2.5	2.5	3.2	3.2	4.1	4.0	6.9	6.2	10.7	8.7
14	--	--	3.9	3.5	3.2	3.2	4.1	4.1	7.4	7.0	11.7	8.6
15	--	--	3.8	3.5	4.0	4.0	4.3	4.0	6.0	5.9	11.2	8.6
16	--	--	3.5	3.5	4.0	3.9	4.2	4.1	7.3	7.0	10.6	8.7
17	--	--	3.4	3.4	3.9	3.9	4.2	4.1	8.3	7.0	10.4	8.7
18	3.9	3.5	3.3	3.3	3.9	3.9	4.1	4.1	--	--	10.8	10.2
19	3.6	3.2	3.3	3.3	3.9	3.9	4.1	4.1	--	--	10.9	9.6
20	3.2	3.1	3.3	3.3	3.9	3.9	4.2	4.1	--	--	10.9	10.8
21	3.1	3.0	3.3	3.3	3.9	3.9	5.6	4.2	--	--	11.0	10.7
22	3.0	3.0	3.5	3.4	3.9	3.9	4.9	4.6	--	--	11.0	10.8
23	3.0	3.0	3.5	3.4	3.9	3.9	5.3	4.5	8.5	3.7	12.3	10.6
24	3.0	3.0	3.7	3.5	3.9	3.9	5.8	5.3	7.8	6.6	12.2	9.9
25	3.0	2.9	3.8	3.7	3.9	3.9	5.8	5.6	8.2	7.0	11.8	11.3
26	3.0	2.9	3.8	3.8	3.9	3.9	6.1	5.8	8.1	6.6	12.6	11.1
27	3.0	2.9	3.8	3.8	3.9	3.9	6.1	5.9	8.7	6.7	12.1	10.0
28	3.0	3.0	3.8	3.7	3.9	3.9	6.2	6.0	8.7	8.3	11.8	9.8
29	3.0	3.0	3.8	3.7	3.9	3.9	6.3	5.8	8.6	7.7	11.9	11.3
30	3.0	3.0			3.9	3.9	6.3	6.2	8.3	7.5	13.3	11.5
31	3.0	3.0			3.9	3.9			8.0	6.6		



Table A-1. Daily thermograph readings, 1980, Tailrace, continued

Day	July		August		September		October		November		December	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	12.5	10.2	11.6	11.5	13.0	10.9	11.9	11.5	10.0	9.8	7.2	7.0
2	12.5	10.6	12.6	10.2	13.9	12.9	12.2	11.8	9.8	9.7	7.0	6.9
3	12.6	11.8	14.0	11.8	13.4	11.5	12.4	12.0	10.0	9.6	7.0	6.9
4	12.1	11.9	12.8	11.1	13.0	10.5	12.7	12.4	10.1	10.0	6.9	6.8
5	12.9	12.0	12.9	11.1	13.1	11.1	12.5	11.9	10.1	9.6	6.8	6.5
6	13.2	12.5	13.2	11.0	13.2	10.9	12.1	9.9	9.9	9.2	6.5	6.4
7	12.8	12.3	13.0	10.2	13.1	11.1	12.6	10.9	9.9	9.8	6.4	6.3
8	13.0	10.7	11.8	10.3	13.1	11.1	12.8	11.5	9.8	9.3	6.3	6.3
9	12.9	12.2	12.4	10.2	12.9	10.9	12.9	12.2	9.8	9.7	6.3	6.2
10	13.7	10.9	12.5	11.4	12.8	11.0	13.0	12.5	9.8	9.3	6.2	6.0
11	13.4	9.6	12.3	11.2	13.0	12.4	12.6	12.5	9.6	9.0	6.1	6.1
12	13.3	10.8	12.6	11.2	13.0	11.0	12.6	12.4	9.6	9.6	6.0	6.0
13	14.0	13.2	13.0	11.2	12.5	10.8	12.6	12.4	9.6	9.5	6.0	5.9
14	14.0	7.0	12.5	10.9	12.8	11.0	12.8	12.4	9.5	8.5	5.9	5.8
15	13.5	8.6	12.4	10.9	12.7	11.5	12.5	12.0	8.8	7.8	5.8	5.8
16	13.5	12.8	12.1	10.1	12.0	11.6	12.8	12.0	8.6	8.5		
17	13.9	13.2	12.7	10.9	12.3	11.8	13.1	12.8	8.6	8.3		
18	13.6	11.3	12.7	10.2	12.3	10.9	—	—	8.4	8.2		
19	13.1	11.1	12.0	10.2	12.4	11.0	—	—	8.3	8.2		
20	13.6	10.6	12.4	10.0	12.4	10.1	—	—	8.4	8.2		
21	13.6	11.0	12.2	10.2	12.3	12.0	—	—	8.2	8.0		
22	12.3	10.1	12.8	9.8	12.3	10.0	11.5	11.0	8.0	7.9		
23	13.0	10.2	13.0	10.2	12.4	10.8	11.5	10.9	7.9	7.8		
24	12.9	10.2	12.1	10.1	13.0	10.8	11.3	10.8	7.8	7.6		
25	12.2	10.2	12.2	9.8	12.6	11.0	11.2	10.6	7.6	7.5		
26	11.9	8.3	12.5	10.5	12.4	9.9	10.7	10.4	7.5	7.4		
27	12.6	11.2	12.9	10.0	12.5	11.3	10.6	10.3	7.5	7.3		
28	12.6	11.2	13.1	10.3	12.3	12.0	10.5	10.2	7.3	7.3		
29	12.6	11.4	12.6	10.0	12.2	11.9	10.4	10.1	7.3	7.3		
30	12.2	9.2	13.0	10.9	12.0	11.6	10.3	10.0	7.3	7.2		
31	12.0	9.0	13.0	12.4			10.2	9.9				

Table A-2. Daily thermograph readings in °C, January-December, 1980, Little Hole.

Day	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	3.9	3.8	2.3	1.5	4.2	2.8	3.4	2.3	8.1	5.8	9.6	8.4
2	3.9	3.8	2.8	2.0	4.2	2.7	3.1	2.3	8.1	6.0	10.4	8.3
3	3.9	3.3	2.7	2.4	4.1	3.1	3.6	2.1	9.3	8.2	12.2	8.9
4	4.1	3.9	2.8	2.4	3.2	2.9	4.8	2.3	9.2	7.0	12.0	9.0
5	4.1	3.9	2.8	2.0	3.1	2.9	4.2	3.1	9.0	6.5	12.8	9.8
6	3.9	3.0	2.8	2.4	3.1	2.9	5.2	3.1	7.5	6.2	12.3	10.0
7	3.5	3.0	2.7	2.3	3.2	2.8	4.1	2.6	7.9	7.0	13.0	10.0
8	3.5	3.4	2.5	1.5	3.1	2.6	4.3	3.0	9.7	7.3	13.0	9.8
9	3.8	3.5	2.5	1.2	3.8	2.7	4.6	3.0	8.0	7.7	11.3	10.0
10	3.9	3.9	2.4	1.2	3.8	2.7	4.5	3.4	9.9	7.6	13.7	10.3
11	3.9	2.5	2.5	1.5	3.5	2.7	4.0	3.2	7.9	6.0	12.6	10.4
12	3.3	3.0	2.7	1.6	3.0	2.3	4.2	3.0	7.3	5.8	12.7	11.0
13	3.5	3.4	2.5	2.0	3.8	2.0	5.5	2.6	7.5	6.3	13.0	11.3
14	3.8	3.8	3.0	2.2	3.2	2.2	4.9	3.2	9.1	6.9	13.7	10.6
15	3.8	3.5	2.8	2.7	3.2	2.2	5.4	3.2	9.1	7.0	13.4	11.5
16	4.4	3.2	3.9	2.7	2.6	1.7	--	--	8.9	7.4	13.2	11.2
17	3.3	3.2	3.7	3.2	3.5	1.4	--	--	8.3	7.5	13.4	10.8
18	3.5	3.2	3.2	3.2	4.2	1.6	--	--	10.1	7.4	12.0	10.8
19	3.3	2.9	3.4	3.0	4.0	2.1	--	--	8.7	7.9	12.6	11.4
20	2.8	2.2	3.3	3.3	4.5	2.2	--	--	11.5	8.2	13.7	11.3
21	3.0	2.4	3.0	2.9	3.4	2.3	--	--	11.4	8.2	14.9	11.9
22	3.0	2.6	3.2	3.0	2.8	2.4	6.9	4.0	10.7	8.1	15.0	12.0
23	3.0	2.2	3.1	2.9	4.6	2.1	6.1	3.9	10.1	8.6	13.6	11.8
24	3.0	2.7	3.9	2.5	3.5	2.8	5.3	4.3	8.8	8.0	14.7	12.0
25	3.0	2.1	3.2	2.2	3.1	2.5	7.5	5.0	9.6	7.6	14.4	12.8
26	2.3	1.3	4.2	2.5	4.0	2.3	7.7	4.9	9.5	7.9	14.4	12.8
27	2.0	1.2	4.3	2.8	3.9	2.5	8.4	5.5	11.2	7.7	14.4	12.8
28	2.3	1.7	3.8	2.8	3.6	2.7	8.5	5.5	12.0	9.5	14.3	12.8
29	2.1	1.6	3.5	3.0	3.8	2.7	6.6	5.3	10.2	8.6	14.3	12.8
30	2.6	1.8			3.2	2.2	6.4	5.3	10.0	8.5	14.3	12.8
31	2.6	1.5			3.2	2.2			10.1	8.5		

Table A-2. Daily thermograph readings in °C, 1980, Little Hole, continued.

Day	July		August		September		October		November		December	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	14.0	13.3	14.4	12.9	14.2	12.1	12.0	10.9	10.6	10.0	7.2	6.7
2	14.0	13.1	14.6	12.9	14.2	12.1	12.4	11.2	10.6	10.1	7.8	6.6
3	14.4	12.4	15.7	12.9	14.1	13.0	12.9	10.8	10.6	10.0	--	--
4	15.5	12.5	16.5	13.7	14.0	12.7	12.0	10.9	10.6	9.4	--	--
5	14.4	12.2	14.8	13.3	14.0	12.3	12.2	10.7	10.1	9.8	--	--
6	14.4	12.7	16.1	13.9	13.9	12.6	12.0	10.7	10.0	9.6	--	--
7	14.4	13.2	15.0	13.4	13.9	13.2	11.7	10.7	10.0	9.4	--	--
8	14.4	12.8	14.6	13.3	13.5	13.0	12.0	10.4	10.0	9.4	--	--
9	14.4	13.3	14.5	13.3	13.5	12.5	10.9	10.6	9.8	8.9	--	--
10	14.5	13.3	14.9	13.0	13.5	13.0	12.0	10.5	10.0	8.9	--	--
11	14.7	13.3	15.1	13.2	13.8	12.5	11.0	10.0	10.0	9.4	--	--
12	13.9	13.3	14.5	13.3	14.0	12.9	10.3	9.5	10.0	9.8	--	--
13	14.4	13.8	13.9	14.6	13.1	12.5	9.9	9.8	9.8	9.1	--	--
14	15.4	14.0	14.9	13.9	13.6	12.0	12.8	12.2	9.0	8.9	--	--
15	14.6	13.5	14.0	12.0	12.5	10.7	12.2	11.7	11.0	10.5	--	--
16	15.5	13.4	12.6	11.5	12.1	10.7	11.9	11.6	11.1	10.2	--	--
17	15.6	13.3	13.0	11.4	12.4	10.8	11.7	11.1	10.9	10.0	--	--
18	15.3	14.3	13.7	11.8	12.0	11.2	11.7	11.1	10.8	10.1	--	--
19	14.7	14.1	12.3	11.8	13.1	11.0	12.2	11.1	10.5	10.1	--	--
20	15.3	13.3	13.4	11.3	12.4	10.5	12.2	11.1	10.4	9.9	--	--
21	15.3	14.1	14.4	11.8	12.0	10.4	12.2	11.1	10.3	10.2	--	--
22	15.3	13.4	13.8	11.4	12.1	10.5	12.1	11.4	10.3	10.2	--	--
23	14.9	13.3	13.8	12.7	12.6	11.0	11.7	11.0	10.3	9.8	--	--
24	14.4	13.1	13.1	12.2	11.3	10.9	11.5	10.7	10.1	9.8	--	--
25	15.2	12.9	12.4	12.0	12.4	10.9	11.1	10.6	10.1	9.9	--	--
26	15.7	12.8	13.1	12.1	12.4	11.0	11.1	11.0	10.1	9.9	5.0	4.1
27	14.9	12.4	13.4	12.2	12.4	10.9	11.1	10.4	7.7	7.3	4.5	3.8
28	15.3	13.3	13.9	12.4	12.1	10.7	11.1	10.5	7.6	6.8	4.3	3.8
29	14.2	13.1	13.5	12.7	12.7	10.6	11.1	10.1	7.2	6.7	3.8	3.4
30	14.3	12.9	12.9	12.3	12.4	10.5	11.1	10.0	7.3	6.9	4.1	3.5
31	14.7	12.9	13.0	12.0			10.6	10.0			4.0	3.6



Table A-3. Daily thermograph readings in °C, January-December, 1980, Browns Park, 22 river miles from Flaming Gorge dam.

Day	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	4.1	3.4	4.0	1.8	6.5	3.0	5.7	3.0	--	--	13.1	10.3
2	3.9	3.3	4.6	2.0	6.3	3.3	5.7	2.5	--	--	14.2	9.6
3	4.4	2.9	4.5	3.0	5.0	4.2	5.8	2.3	--	--	15.4	10.5
4	5.2	3.5	5.3	3.8	5.2	3.4	6.9	4.0	--	--	15.8	12.0
5	5.4	4.0	4.7	2.5	4.9	3.3	7.9	4.6	13.7	11.1	16.2	10.9
6	5.1	2.4	4.8	3.1	4.7	3.6	8.4	4.6	11.0	8.7	15.5	11.4
7	3.3	2.4	4.0	3.6	5.0	3.2	7.3	3.8	11.4	8.1	16.1	10.5
8	3.9	2.6	4.3	1.9	5.0	2.9	5.8	3.3	11.9	8.8	16.5	11.8
9	4.4	3.3	3.9	1.7	6.3	3.0	7.3	3.7	10.7	8.7	16.4	12.0
10	4.6	3.9	4.0	1.8	6.0	3.0	7.8	4.5	11.2	8.2	17.1	10.7
11	4.0	1.5	4.2	1.7	5.6	3.2	7.2	3.6	10.1	8.5	16.6	11.0
12	3.0	1.5	4.3	1.9	4.8	2.5	4.5	2.9	8.5	7.5	16.4	12.2
13	4.2	2.8	4.5	2.5	6.2	2.3	6.2	2.9	9.3	7.5	16.7	12.0
14	5.3	4.0	5.7	3.9	7.0	3.9	8.7	3.4	11.0	7.1	16.5	11.8
15	5.2	4.4	5.9	4.3	6.8	4.8	7.8	3.8	11.4	9.1	15.5	11.8
16	5.3	4.1	5.8	4.2	4.8	1.3	8.5	3.8	12.2	9.2	17.5	12.4
17	5.3	4.7	5.9	4.3	5.3	1.0	--	--	9.2	8.0	16.7	11.9
18	4.7	4.0	--	--	6.1	2.4	--	--	11.7	7.3	16.8	12.6
19	3.5	2.9	--	--	6.6	3.3	--	--	12.4	8.7	15.4	12.4
20	3.7	1.9	--	--	7.2	2.6	--	--	14.6	8.5	17.1	12.1
21	4.5	2.0	--	--	5.8	4.2	--	--	15.2	11.5	17.4	13.2
22	4.7	3.3	--	--	5.3	3.8	--	--	14.5	9.7	17.4	13.6
23	4.1	2.5	--	--	6.6	1.7	--	--	13.1	10.6	17.7	13.6
24	4.9	2.0	--	--	5.8	4.3	--	--	11.8	9.7	17.1	12.5
25	4.7	2.3	--	--	5.0	3.1	--	--	11.1	7.5	16.0	12.2
26	2.2	1.9	--	--	6.7	2.3	--	--	13.7	8.2	14.7	14.1
27	2.8	1.6	--	--	6.7	2.9	--	--	13.7	8.7	18.1	13.0
28	3.6	1.6	--	--	6.6	2.8	--	--	15.4	11.3	16.3	12.0
29	3.2	1.3	4.1	3.8	5.5	3.1	--	--	13.3	11.7	16.3	12.6
30	4.1	1.5	--	--	5.8	3.6	--	--	14.8	9.7	17.1	13.9
31	3.8	1.5	--	--	4.4	1.5	--	--	13.7	9.9	--	--



Table A-3. Daily thermograph readings in °C, 1980, Browns Park, 22 river miles from Flaming Gorge dam continued.

Day	July		August		September		October		November		December	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1	16.6	14.1	15.8	13.0	--	--	14.4	11.0	10.4	8.6	7.1	6.1
2	18.1	13.4	18.2	13.2	--	--	13.9	11.0	10.8	8.5	6.3	5.3
3	15.9	12.7	17.0	13.1	--	--	14.3	11.2	12.5	8.3	6.0	5.6
4	17.5	13.9	17.9	13.0	--	--	15.0	11.5	9.9	8.3	6.9	5.7
5	18.1	14.0	17.3	13.6	--	--	14.8	11.5	11.5	8.3	7.9	6.4
6	18.0	13.5	18.4	13.1	--	--	13.7	11.0	10.7	8.2	6.9	6.3
7	17.8	13.9	18.7	13.0	--	--	13.9	10.9	10.0	8.2	6.5	6.0
8	15.4	13.2	18.1	12.7	--	--	13.1	10.8	10.2	8.2	6.3	5.3
9	18.1	13.4	15.5	12.3	--	--	13.4	10.4	10.1	8.0	5.5	3.4
10	17.5	13.1	15.7	12.1	--	--	13.3	10.0	9.8	7.8	4.6	3.4
11	17.3	13.8	17.5	12.2	--	--	12.0	10.6	9.5	7.5	5.2	3.8
12	19.1	14.4	16.0	12.8	--	--	13.5	10.8	9.5	8.5	5.2	3.9
13	15.6	13.9	15.4	13.0	--	--	12.2	10.5	10.0	8.8	5.5	4.0
14	13.8	13.1	17.4	12.8	--	--	10.7	9.5	10.3	8.4	5.5	3.5
15	18.7	13.6	17.1	13.0	--	--	9.6	9.3	8.4	8.2	4.5	3.0
16	18.5	13.6	13.0	12.2	--	--	10.0	9.0	8.4	7.0	--	--
17	19.2	15.4	--	--	--	--	11.5	9.2	7.9	6.5	--	--
18	19.8	14.8	--	--	--	--	9.6	9.3	7.9	6.1	--	--
19	16.3	13.2	--	--	13.5	13.0	10.2	9.0	7.7	6.2	--	--
20	18.0	13.1	--	--	15.0	11.5	10.2	9.0	7.8	6.2	--	--
21	19.3	13.7	--	--	13.3	10.9	10.2	9.0	8.3	7.1	--	--
22	18.4	13.8	--	--	14.0	10.0	10.2	9.0	8.3	6.5	--	--
23	17.6	13.1	--	--	14.3	10.8	10.2	9.0	7.9	7.4	--	--
24	15.3	12.5	--	--	14.3	11.3	12.1	9.0	8.2	7.7	--	--
25	18.0	12.4	--	--	14.5	11.5	11.0	8.8	8.2	7.5	--	--
26	17.8	12.9	--	--	14.0	11.1	10.8	8.7	7.5	4.8	--	--
27	16.0	13.0	--	--	15.0	11.2	9.4	8.7	6.6	6.1	7.1	5.2
28	18.5	12.9	--	--	15.0	11.2	10.0	8.7	6.5	6.2	5.8	4.1
29	16.3	13.0	--	--	14.9	11.2	10.4	8.6	6.7	6.0	5.0	3.5
30	17.0	12.9	--	--	14.7	11.0	10.1	8.6	7.0	6.4	4.8	3.0
31	17.6	12.8	--	--	--	--	10.3	8.6	--	--	4.9	3.2

Table A4. Density of Green River macroinvertebrates, in samples from December 3-4, 1980<sup>a</sup>.

Taxa	Station Density (#/m <sup>2</sup> , 3 replicates)				
	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.	4.3			990.5	5271.4
Ephemerellidae					
<u>Ephemerella inermis</u>					
Trichoptera					
Hydroptilidae					
<u>Hydroptila</u> sp.	47.1	1004.3	152.4	6685.7	1061.9
Brachycentridae					
<u>Brachycentrus</u> sp.				19.0	
Early instars				38.1	295.2
Limnephilidae					
<u>Psychoglypha</u> sp.					
Diptera					
Muscidae					
<u>Limnophora</u> sp.			9.5		
Simuliidae					
<u>Simulium</u> spp.	10.0		28.6	838.1	28.6
Pupae					
Chironomidae	338.6	942.9	652.4	2533.3	3623.8
Pupae					
Adult					
Hemiptera					
Early instars				95.2	5714.3
Amphipoda					
<u>Gammarus lacustris</u>	614.3	2814.3	219.0	666.7	257.1
Ostracoda	32.9	90.0			4.8
Annelida					
Oligochaeta	342.9	510.0	2509.5	1085.7	19.0
Turbellaria					
Planariidae			4.8		9.5
Gastropoda					
Gyraulus		4.8			
Cladocera					
<u>Daphnia</u> sp.					
Hydracarnia				152.4	38.1
Total	1390.1	5366.3	3576.2	13,104.7	16323.8
Standard Deviation	824.88	3257.7	1773.4	1773.4	4781.0
Coefficient of Variance	0.59	0.61	0.49	0.49	0.29

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah

Table A5. Density of Green River macroinvertebrates in samples from March 30-April 4, 1981<sup>a</sup>.

Taxa	Station Density (#/m <sup>2</sup> , 3 replicates)				
	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.		28.6		14.3	114.3
Ephemerellidae					
<u>Ephemerella inermis</u>					57.1
Trichoptera					
Hydroptilidae					
<u>Hydroptila</u> sp.		909.5		57.1	857.1
Brachycentridae					
<u>Brachycentrus</u> sp.		4.8			
Early instars					
Limnephilidae					
<u>Psychoglypha</u> spp.					
Diptera					
Muscidae					
<u>Limnophora</u> sp.					
Simuliidae					
<u>Simulium</u> spp.		19.0			
Pupae	4.8				
Chironomidae	1833.3	428.6	233.3	1914.3	7085.7
Pupae	85.7	161.9	23.8	42.9	704.8
Adult					
Hemiptera					
Early instars					
Amphipoda					
<u>Gammarus lacustris</u>	166.7	771.4		4.8	76.2
Ostracoda	33.3	9.5			19.0
Annelida					
Oligochaeta	147.6		52.4	876.2	228.6
Turbellaria					
Planariidae					
Gastropoda					
Gyraulus					
Cladocera					
<u>Daphnia</u> sp.					
Hydracarnia					
Total	2271.4	2333.3	309.5	2909.6	9142.8
Standard Deviation	1756.2	344.7	119.8	1225.4	1459.1
Coefficient of Variance	0.77	0.15	0.39	0.42	0.16

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah

Table A6. Density of Green River macroinvertebrates in samples from July 7-8, 1981<sup>a</sup>.

Taxa	Station Density (#/m <sup>2</sup> , 3 replicates)				
	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.	26.7	16.7	3.3	3341.0	102.7
Ephemerellidae					
<u>Ephemerella inermis</u>		3.3		12.3	
Trichoptera					
Hydroptilidae					
<u>Hydroptila</u> sp.	13.3	136.7		1115.7	924.0
Brachycentridae					
<u>Brachycentrus</u> sp.					
Early instars					
Limnephilidae					
<u>Psychoglypha</u> spp.		16.7			
Diptera					
Muscidae					
<u>Limnophora</u> sp.				13.3	13.3
Simuliidae					
<u>Simulium</u> spp.		66.7	3.3	35.6	13.3
Pupae		60.0		83.3	
Chironomidae	6160.0	857.0	116.7	1384.3	2737.3
Pupae	240.0	20.0		51.3	94.6
Adult				71.0	16.0
Hemiptera					
Early instars					
Amphipoda					
<u>Gammarus lacustris</u>	1320.0	1560.0	60.0	842.3	1057.3
Ostracoda	13.3	10.0			
Annelida					
Oligochaeta	8640.0	3300.0	273.3	136.7	46.7
Turbellaria					
Planariidae					
Gastropoda					
Gyraulus					13.3
Gladocera					
<u>Daphnia</u> sp.				2666.6	1333.3
Hydracarnia			3.3	250.0	46.7
Total	16413.3	6047.1	459.9	10003.4	6398.5
Standard Deviation	6684.5	4045.9	45.8	2600.6	3147.3
Coefficient of Variance	0.41	0.67	0.10	0.26	0.49

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah



Table A7. Species composition (%) by weight, Green River macroinvertebrate samples from five substrate types, December 3-4, 1980<sup>a</sup>.

Taxa	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.	trace			1.2	30.2
Ephemerellidae					
<u>Ephemerella inermis</u>					
Trichoptera					
Hydroptilidae					
<u>Hydroptila</u> sp.	0.2	1.6	1.6	49.6	32.6
Brachycentridae					
<u>Brachycentrus</u> sp.				trace	
Early instars				trace	trace
Limnephilidae					
<u>Psychoglypha</u> spp.					
Diptera					
Muscidae					
<u>Limnophora</u> sp.			7.7		
Simuliidae					
<u>Simulium</u> spp.	trace	trace	1.2	1.3	trace
Pupae					
Chironomidae	0.4	0.7	4.5	2.6	6.9
Pupae					
Adult					
Hemiptera					
Early instars				trace	1.2
Amphipoda					
<u>Gammarus lacustris</u>	96.1	97.6	30.2	42.5	29.1
Ostracoda	trace	trace			trace
Annelida					
Oligochaeta	3.2	0.1	54.8	2.4	trace
Turbellaria					
Planariidae			trace		trace
Gastropoda					
Gyraulus		trace			
Cladocera					
<u>Daphnia</u> sp.					
Hydracarnia				0.4	trace
Mean Total Weight (g/m <sup>2</sup> )	19.60	116.19	2.86	5.24	1.23

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah

Table A8. Species composition (%) by weight, Green River macroinvertebrate samples from five substrate types, March 30- April 4, 1981<sup>a</sup>.

Taxa	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.		0.2		0.6	2.0
Ephemerellidae					
<u>Ephemerella inermis</u>					2.7
Trichoptera					
Hydroptilidae					
<u>Hydroptila</u> sp.		19.5		1.5	19.2
Brachycentridae					
<u>Brachycentrus</u> sp.		trace			
Early instars					
Limnephilidae					
<u>Psychoglypha</u> spp.					
Diptera					
Muscidae					
<u>Limnophora</u> sp.					
Simuliidae					
<u>Simulium</u> spp.		0.2			
Pupae	trace				
Chironomidae	74.5	6.2	89.6	34.0	48.1
Pupae	1.9	0.3	4.9	0.6	5.9
Adult					
Hemiptera					
Early instars					
Amphipoda					
<u>Gammarus lacustris</u>	21.2	73.5		0.2	7.1
Ostracoda	0.1	trace			0.3
Annelida					
Oligochaeta	2.2		5.5	63.1	2.2
Turbellaria					
Planariidae					
Gastropoda					
Gyraulus					
Cladocera					
<u>Daphnia</u> sp.					
Hydracarnia					
Mean Total Weight (g/m <sup>2</sup> )	4.84	14.63	0.34	4.05	5.09

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah

Table A9. Species composition (%) by weight, Green River macroinvertebrate samples from five substrate types, July 7-8, 1981<sup>a</sup>.

Taxa	Barren Silt	Plants on Silt	Gravel	Rubble	Rock (Algae Attached)
Ephemeroptera					
Baetidae					
<u>Baetis</u> spp.	0.2	trace	0.3	18.7	2.0
Ephemerellidae					
<u>Ephemerella inermis</u>		trace		1.9	
Trichoptera					
Hydroptilida					
<u>Hydroptila</u> sp.	0.3	0.5		10.0	28.6
Brachycentridae					
<u>Brachycentrus</u> sp.					
Early instars					
Limnephilidae					
<u>Psychoglypha</u> spp.		3.9			
Diptera					
Muscidae					
<u>Limnophora</u> sp.				4.1	4.3
Simuliidae					
<u>Simulium</u> spp.		0.6	2.2	0.2	0.9
Pupae		1.2		3.7	
Chironomidae	22.2	7.6	23.3	3.2	6.8
Pupae	0.9	0.1		0.5	1.4
Adult				0.2	0.3
Hemiptera					
Early Instars					
Amphipoda					
<u>Gammarus lacustris</u>	6.3	73.2	36.2	37.2	50.2
Ostracoda	0.3	trace			
Annelida					
Oligochaeta	69.8	12.7	37.9	18.7	1.1
Turbellaria					
Planariidae					
Gastropoda					
Gyraulus					2.8
Cladocera					
<u>Daphnia</u> sp.				trace	
Hydracarnia			trace	1.5	1.6
Mean Total Weight (g/m <sup>2</sup> )	7.39	21.04	0.21	7.56	3.32

<sup>a</sup> Gosse (1983); identification by Bio-West Inc., Logan, Utah

# LENGTH FREQUENCY IN GROWTH STUDY, CUTTHROAT TROUT

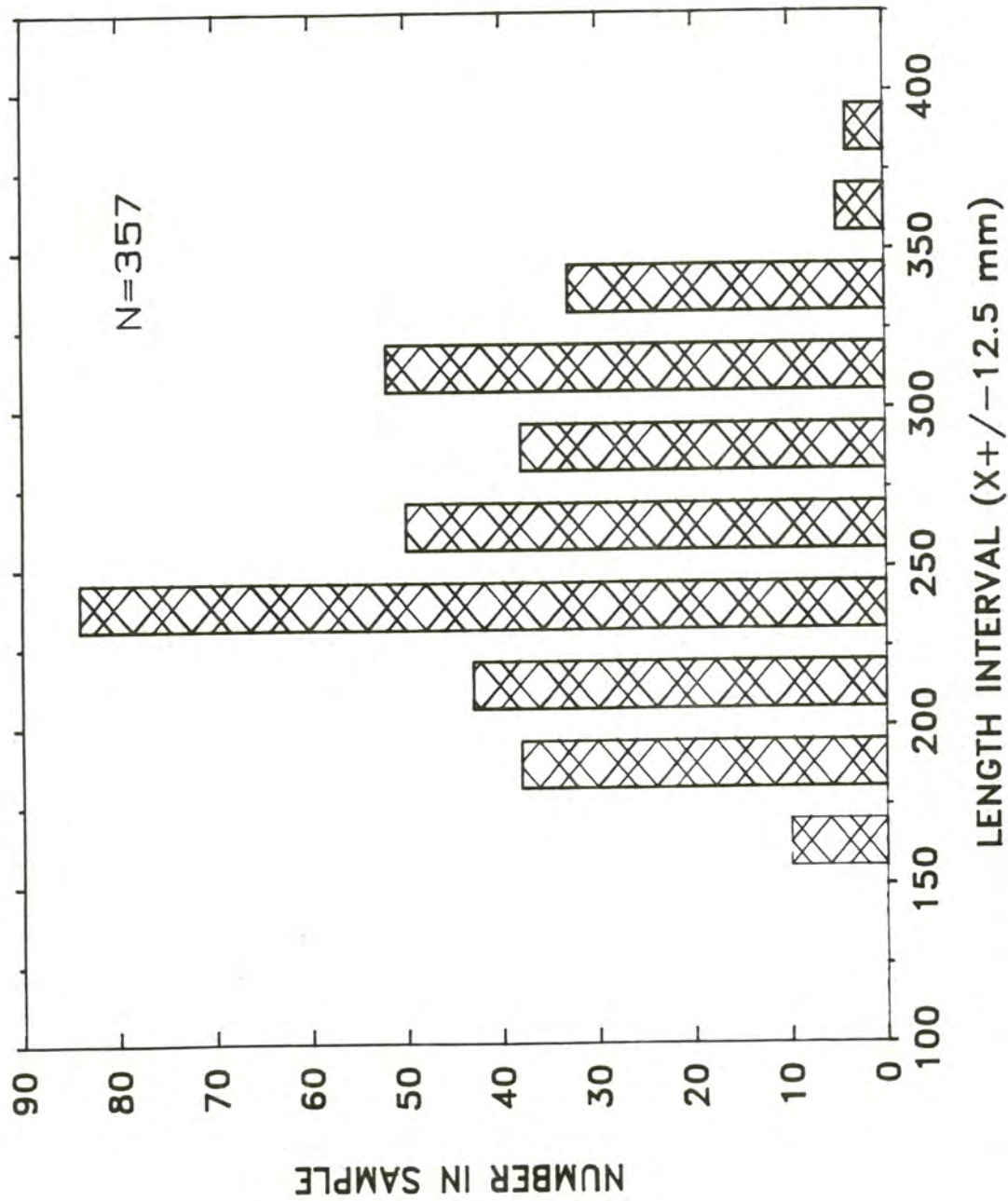


Figure A1. Length frequencies in electrofishing samples used for age and growth - cutthroat trout.



# LENGTH FREQUENCY, AGE AND GROWTH, RAINBOW TROUT

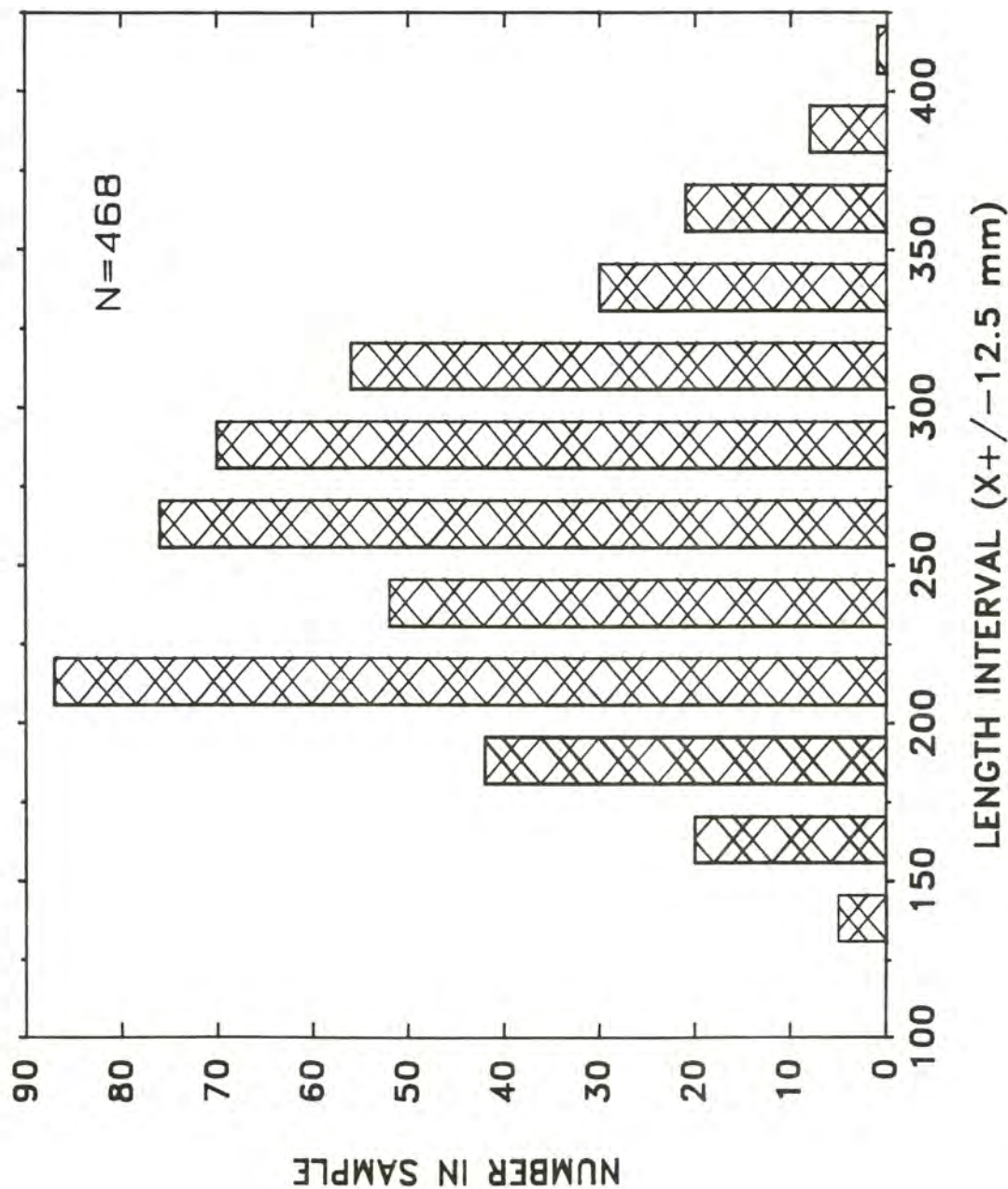
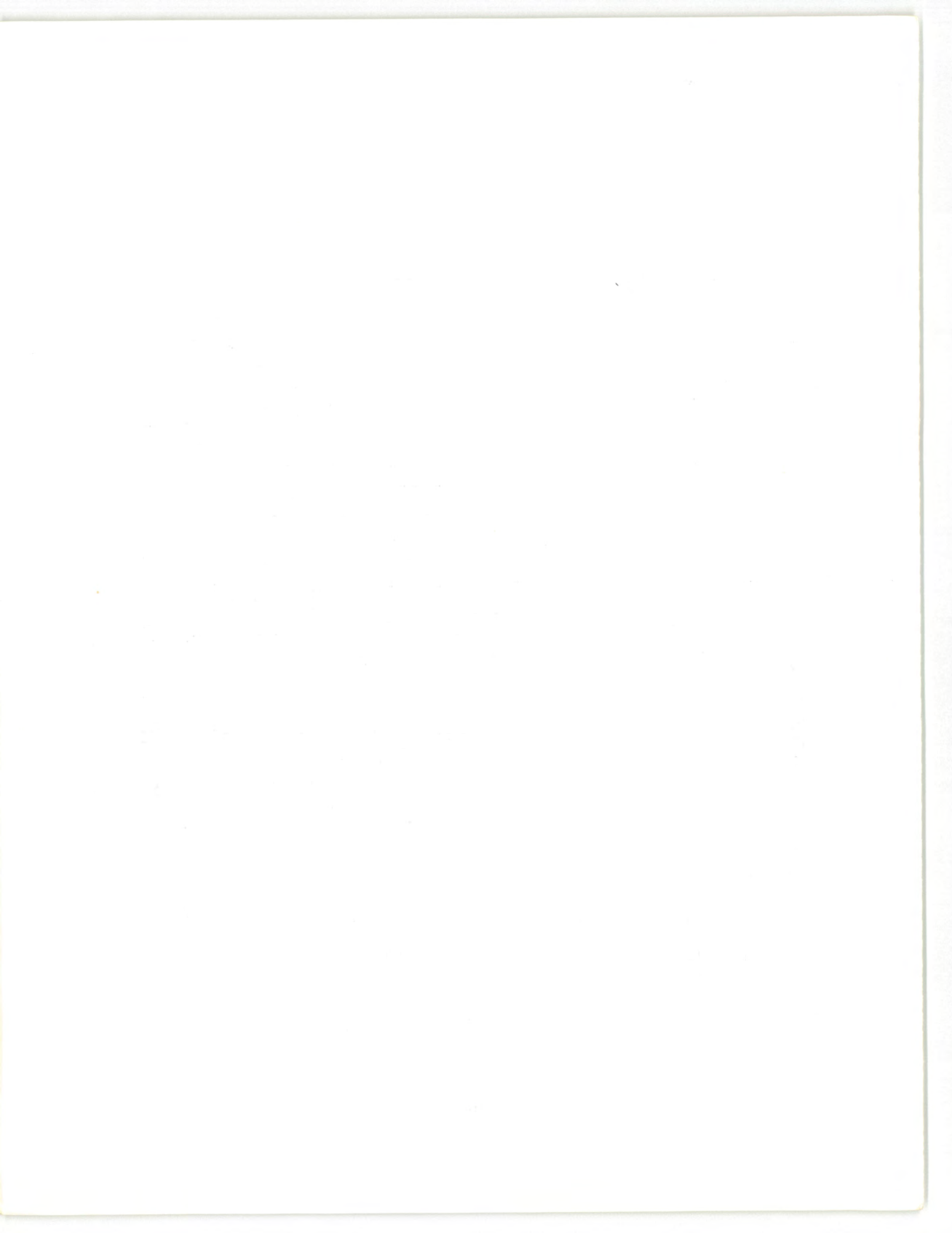


Figure A2. Length frequencies in electrofishing samples used for age and growth-rainbow trout.



APPENDIX B

OBJECTIVE #2

ANGLER USE, HARVEST TRENDS, TROUT  
MIGRATION, AND MORTALITY

Table B1. Electrofishing catch per hour, February - May, 1981, Tailrace Station.<sup>a</sup>

Date	Effort (hrs)	Catch - Per - Unit - Effort (catch/hr)									
		Rainbow Trout					Cutthroat Trout				
		I Marked (1980)	II Marked (1979)	III Marked (1978)	UM <sup>b</sup>	NR <sup>c</sup>	I Marked (1980)	II Marked (1979)	UM <sup>b</sup>	NR <sup>c</sup>	Brown Trout
2/05/81	3.0	5.0	2.7	0	18.0	1.7	1.7	0.7	3.3	0	0
3/19/81	0.33	33.0	18.0	0	66.1	21.0	21.0	6.0	42.0	6.0	0
3/30/81	0.58	84.5	15.5	0	46.6	12.1	62.1	6.9	25.9	0	0
5/04/81	0.67	45.0	9.0	3.0	51.0	6.0	39.0	6.0	40.5	0	0

<sup>a</sup> Standard late October sampling was conducted but effort (hours fished) was inadvertently not recorded.

<sup>b</sup> UM = No detectable mark, age unknown.

<sup>c</sup> NR = Presumed instream reproduction.



Table B2. Electrofishing catch per hour, February - May, 1981, Little Hole Station.<sup>a</sup>

Date	Effort (hrs)	Catch - Per - Unit - Effort (catch/hr)									
		Rainbow Trout					Cutthroat Trout				
		I Marked (1980)	II Marked (1979)	III Marked (1978)	UMB <sup>b</sup>	NRC	I Marked (1980)	II Marked (1979)	UMB <sup>b</sup>	NRC <sup>c</sup>	Brown Trout
2/06/81	2.0	79.0	4.0	0.5	19.0	0.5	0.5	1.0	1.0	0	0
3/20/81	0.40	187.5	12.5	0	47.5	12.5	37.5	0	2.5	0	12.5
3/31/81	0.55	156.4	21.8	0	30.9	16.4	49.1	1.8	3.6	0	12.7
5/05/81	0.83	126.5	8.4	0	18.1	2.4	7.2	1.2	4.8	0	0

<sup>a</sup> Standard late October sampling was conducted but effort (hours fished) was inadvertently not recorded.

<sup>b</sup> UM = No detectable mark, age unknown.

<sup>c</sup> NR = Presumed instream reproduction.

Table B3. Electrofishing catch per hour, October 1980 – May 1981, Browns Park Station.

Catch - Per - Unit - Effort (catch/hr)										
Date	Effort (hrs)	Rainbow Trout				Cutthroat Trout				
		I Red (1980)	II Green (1979)	UM <sup>a</sup>	NR <sup>b</sup>	I Red (1980)	II Green (1979)	UM <sup>a</sup>	NR <sup>b</sup>	
10/22/80	1.12	3.6	1.8	2.7	0	42.0	0.89	0	0	33.9
2/14/81	1.08	13.0	0.9	2.8	1.9	12.0	0	0	0.9	49.1
3/21/81	1.42	7.0	0	4.2	0.7	19.0	0	0.7	2.1	60.0
4/01/81	0.58	5.2	0	1.7	0	12.1	0	0	0	31.0
4/05/81	1.00	5.0	2.0	1.0	3.0	8.0	0	1.0	0	36.0
5/05/81	2.00	2.5	0.5	5.5	0	17.0	0	6.0	0	27.5

<sup>a</sup> UM = No detectable mark, age unknown.<sup>b</sup> NR = Presumed instream reproduction.

Table B4. Electrofishing catch per hour, October 1981 - May 1982, Tailrace Station.

Date	Effort (hrs)	Catch - Per - Unit - Effort (catch/hr)									
		Rainbow Trout					Cutthroat Trout				
		I Marked (1981)	II Marked (1980)	III Marked (1979)	UM <sup>a</sup>	NR <sup>b</sup>	I Marked (1981)	II Marked (1980)	III Marked (1979)	IV Marked (1978)	Brown Trout
10/27/81	0.75	25.3	1.3	0	44.0	0	72.0	10.7	1.3	0	13.3
1/30/82	0.83	38.5	1.2	0	45.7	33.7	89.2	14.5	1.2	0	14.5
2/13/82	1.08	19.4	0.9	0	27.8	13.9	6.5	2.8	0	0.9	8.3
2/27/82	0.92	56.5	3.3	0	37.0	25.0	3.3	12.0	0	0	2.2
3/06/82	0.92	22.8	1.1	0	24.0	10.9	13.0	3.3	0	0	9.8
3/29/82	0.91	29.3	1.1	2.2	67.4	48.9	13.0	3.3	0	1.1	29.3
4/19/82	0.75	21.3	4.0	0	41.3	22.7	4.0	9.3	1.3	0	26.7
5/05/82 <sup>c</sup>	2.00	3.5	N/A	N/A	N/A	N/A	5.0	N/A	N/A	N/A	N/A

<sup>a</sup> UM = No detectable mark, age unknown.

<sup>b</sup> NR = Presumed instream reproduction.

<sup>c</sup> The standard Tailrace Station was not sampled due to mechanical failures of equipment. Data from river mile 2, where only marked yearlings were sampled, is substituted for the Tailrace Station.

Table B5. Electrofishing catch per hour, October 1981 - May 1982, Little Hole Station.

Date	Effort (hrs)	Catch - Per - Unit - Effort (catch/hr)									
		Rainbow Trout					Cutthroat Trout				
		I Marked	II Marked	III Marked	IV Marked	UM <sup>a</sup>	NR <sup>b</sup>	I Marked	II Marked	III Marked	UM <sup>a</sup> NR <sup>b</sup>
10/28/81	0.75	54.7	34.7	1.3	0	65.3	4.0	22.6	9.3	1.3	4.0 0
12/30/81	0.53	211.0	22.6	3.7	0	83.0	18.9	45.3	5.7	1.9	20.8 0
1/25/82	0.75	20.0	4.0	0	0	4.0	25.3	9.3	8.0	1.3	4.0 0
2/14/82	0.67	32.8	37.3	0	0	16.4	10.4	3.0	9.0	0	9.0 0
2/28/82	0.67	3.0	7.5	1.5	0	6.0	23.9	3.0	6.0	0	3.0 0
3/07/82	0.67	0	13.4	0	0	7.5	26.9	1.5	4.5	0	1.5 0
3/29/82	0.75	4.0	28.0	2.7	1.3	10.7	45.3	0	8.0	0	5.3 2.7
4/19/82	0.75	1.3	32.0	4.0	0	20.0	36.0	1.3	8.0	0	6.7 4.0
5/08/82	0.75	2.7	34.7	2.7	0	21.3	74.7	6.6	6.6	0	8.0 2.7
											41.3

<sup>a</sup> UM = No detectable mark, age unknown.

<sup>b</sup> NR = Presumed instream reproduction.



APPENDIX C

OBJECTIVE #3

TROUT BEHAVIOR, MICROHABITAT  
SELECTIVITY, AND HABITAT SUITABILITY

Table C1. Weighted usable area by species, season, and life stage (RS and SS activities combined), for various levels of discharge at Indian Crossing Station, (Browns Park) based upon electivity data collected by Gosse (1982).

Discharge (cfs)	SUMMER				WINTER			
	Adult <sup>a</sup>		Juvenile <sup>a</sup>		Adult		Juvenile	
	RBT <sup>b</sup>	SRCT <sup>c</sup>	RBT	SRCT	RBT	SRCT	RBT	SRCT
500	32,340	23,780	20,234	21,806	30,556	28,449	10,168	5,428
800	32,057	23,154	21,276	22,217	28,088	25,734	8,628	4,003
1,200	31,898	21,256	19,071	19,802	22,975	21,684	6,408	2,624
1,500	30,216	18,621	16,662	17,249	19,727	18,172	5,217	1,846
2,500	20,752	12,218	12,351	11,415	12,143	10,808	3,265	888
4,000	14,117	7,844	8,108	7,650	7,021	6,576	1,706	405
4,200	13,855	7,478	7,632	7,242	6,489	6,336	1,595	438
4,500	13,175	7,112	7,121	6,720	6,049	6,040	1,503	489
5,000	12,742	6,475	6,332	6,115	5,865	5,713	1,405	561
6,000	11,849	6,022	5,965	5,918	5,792	5,283	1,459	680
7,000	11,788	6,042	6,051	6,279	5,948	5,316	1,568	814

<sup>a</sup> Gosse (1982) defined juvenile trout to be those less than 230 mm in summer, 250 mm in winter.

<sup>b</sup> Rainbow trout

<sup>c</sup> Snake River cutthroat trout

Table C2. Weighted usable area by species, season, and life stage (RS and SS activities combined), for various levels of discharge at Pipe Creek Station, based upon electivity data collected by Gosse (1982).

Discharge (cfs)	SUMMER				WINTER			
	Adult <sup>a</sup>		Juvenile <sup>a</sup>		Adult		Juvenile	
	RBT <sup>b</sup>	SRCT <sup>c</sup>	RBT	SRCT	RBT	SRCT	RBT	SRCT
500	39,302	33,007	23,564	25,748	39,283	38,736	14,946	14,271
800	42,023	34,071	26,913	27,761	41,224	40,802	14,902	13,240
1,200	43,810	36,188	29,936	31,643	42,090	41,498	14,452	12,414
1,500	43,797	36,113	30,336	32,775	41,946	41,418	13,837	11,346
2,500	45,488	33,018	26,894	30,800	38,421	37,905	11,954	10,580
4,000	39,363	29,768	24,059	27,807	33,805	33,333	10,913	10,116
4,200	38,411	29,426	23,618	27,569	33,380	32,853	10,923	10,140
4,500	37,340	28,773	22,924	26,755	32,911	32,342	10,935	10,211
5,000	36,226	28,292	22,583	26,003	32,436	32,235	11,107	10,224
6,000	34,223	27,962	22,360	25,205	32,513	32,744	11,674	10,445
7,000	34,398	28,227	22,240	25,577	32,275	33,395	12,312	10,736

<sup>a</sup> Gosse (1982) defined juvenile trout to be those less than 230 mm in summer, 250 mm in winter.

<sup>b</sup> Rainbow trout

<sup>c</sup> Snake River cutthroat trout

Table C3. Weighted usable area by species, season, and life stage (RS and SS activities combined), for various levels of discharge at Tailrace Station, based upon electivity data collected by Gosse (1982).

Discharge (cfs)	SUMMER				WINTER			
	Adult <sup>a</sup>		Juvenile <sup>a</sup>		Adult		Juvenile	
	RBT <sup>b</sup>	SRCT <sup>c</sup>	RBT	SRCT	RBT	SRCT	RBT	SRCT
500	13,984	11,209	7,121	9,887	13,088	12,342	4,514	4,162
800	16,784	13,209	8,648	11,706	13,980	13,604	4,557	3,997
1,200	18,910	14,867	10,565	12,808	16,014	15,206	4,930	3,814
1,500	20,571	16,230	11,501	14,857	16,546	15,742	5,197	4,262
2,500	22,140	17,240	11,457	14,884	17,166	16,975	5,762	5,469
4,000	24,257	18,546	12,923	16,600	19,482	19,529	6,606	5,918
4,200	24,311	18,613	13,134	16,795	19,784	19,910	6,679	6,026
4,500	24,168	18,868	13,299	16,554	20,217	20,172	6,796	6,267
5,000	24,492	19,574	13,765	17,391	20,648	21,038	7,137	6,916
6,000	27,265	21,422	14,643	18,765	22,730	23,023	7,870	8,330
7,000	31,591	24,704	16,392	22,209	26,502	26,035	8,860	10,000

<sup>a</sup> Gosse (1982) defined juvenile trout to be those less than 230 mm in summer, 250 mm in winter.

<sup>b</sup> Rainbow trout

<sup>c</sup> Snake River cutthroat trout



Table C4. Weighted usable area by species and life stage for Indian Crossing (Browns Park), using electivity curves provided by the Instream Flow Group.

Discharge (cfs)	L I F E S T A G E				
	Adult	Juvenile	Fry	Spawning	Incubation
<u>Rainbow Trout</u>					
500	13,728	3,203	2,660	1,000	9,259
800	13,039	3,626	2,226	1,233	12,742
1,200	11,476	2,651	1,704	626	16,125
1,500	9,910	2,175	1,425	705	17,886
2,500	6,632	1,818	1,105	1,425	20,888
4,000	2,395	994	452	793	17,716
4,200	2,282	850	366	685	17,106
4,500	2,108	600	235	515	16,248
5,000	1,773	399	159	312	15,139
6,000	1,219	369	179	180	13,160
7,000	980	300	115	120	11,008
8,000	797	189	63	71	9,152
<u>Cutthroat Trout</u>					
500	8,347	5,402	3,412	698	12,795
800	9,562	6,329	3,358	631	14,494
1,200	8,114	4,680	2,795	240	14,702
1,500	6,357	4,248	2,768	376	14,814
2,500	4,725	2,541	1,235	846	13,973
4,000	1,462	1,131	645	136	9,184
4,200	1,674	1,064	586	117	8,705
4,500	1,699	885	482	18	8,003
5,000	1,374	654	340	47	7,105
6,000	734	392	253	158	5,630
7,000	591	340	203	30	4,331
8,000	558	302	162	0	3,585
<u>Brown Trout</u>					
500	23,841	17,253	16,549	1,265	12,795
800	22,183	13,673	14,493	1,254	14,494
1,200	20,185	12,560	12,867	700	14,702
1,500	19,347	11,107	11,717	813	14,814
2,500	13,554	7,400	8,867	1,382	13,973
4,000	8,985	4,720	5,731	583	9,184
4,200	8,527	4,474	5,488	473	8,405
4,500	7,825	4,055	5,159	406	8,003
5,000	6,837	3,631	4,894	298	7,105
6,000	5,665	3,460	4,481	209	5,630
7,000	5,267	3,282	3,850	92	4,331
8,000	4,687	3,190	3,542	43	3,585

Table C5. Weighted usable area, by species and life stage for Tailrace Station, using electivity curves provided by the Instream Flow Group.

Discharge (cfs)	L I F E S T A G E				
	Adult	Juvenile	Fry	Spawning	Incubation
<u>Rainbow Trout</u>					
500	5,962	1,495	957	261	3,411
800	6,642	1,492	1,354	136	9,933
1,200	8,188	1,733	1,119	103	11,742
1,500	9,086	1,521	857	46	12,726
2,500	7,368	912	471	4	11,971
4,000	6,401	610	272	201	9,554
4,200	6,500	653	303	330	9,141
4,500	6,466	781	479	518	8,512
5,000	7,326	982	443	625	7,792
6,000	7,967	602	193	283	7,296
7,000	7,908	542	253	193	6,990
8,000	7,504	566	323	199	6,628
<u>Cutthroat Trout</u>					
500	4,007	2,750	1,550	83	7,966
800	4,817	3,025	1,824	8	8,247
1,200	4,862	3,697	2,502	29	9,567
1,500	5,205	3,131	1,824	1	9,308
2,500	3,132	1,729	1,383	32	5,765
4,000	1,974	843	650	181	4,439
4,200	1,663	739	670	223	4,276
4,500	1,654	722	699	287	4,000
5,000	1,512	735	578	151	3,802
6,000	1,665	603	337	14	3,455
7,000	786	379	269	137	3,145
8,000	793	333	233	44	2,719
<u>Brown Trout</u>					
500	7,576	7,719	6,713	494	7,966
800	8,637	8,393	7,309	432	8,247
1,200	9,927	8,466	7,649	485	9,567
1,500	9,761	7,873	7,735	406	9,308
2,500	10,135	7,687	6,824	75	5,765
4,000	10,174	5,581	4,816	225	4,439
4,200	10,120	5,298	4,898	329	4,276
4,500	10,137	5,401	5,056	500	4,000
5,000	10,693	5,281	4,554	601	3,802
6,000	11,298	4,898	3,635	242	3,455
7,000	11,242	4,146	3,233	227	3,145
8,000	10,872	3,539	2,878	164	2,719

# MONTHLY FLOW IN ACRE-FEET

GREEN RIVER BELOW FLAMING GORGE DAM, WATER YEARS 1978 - 1982

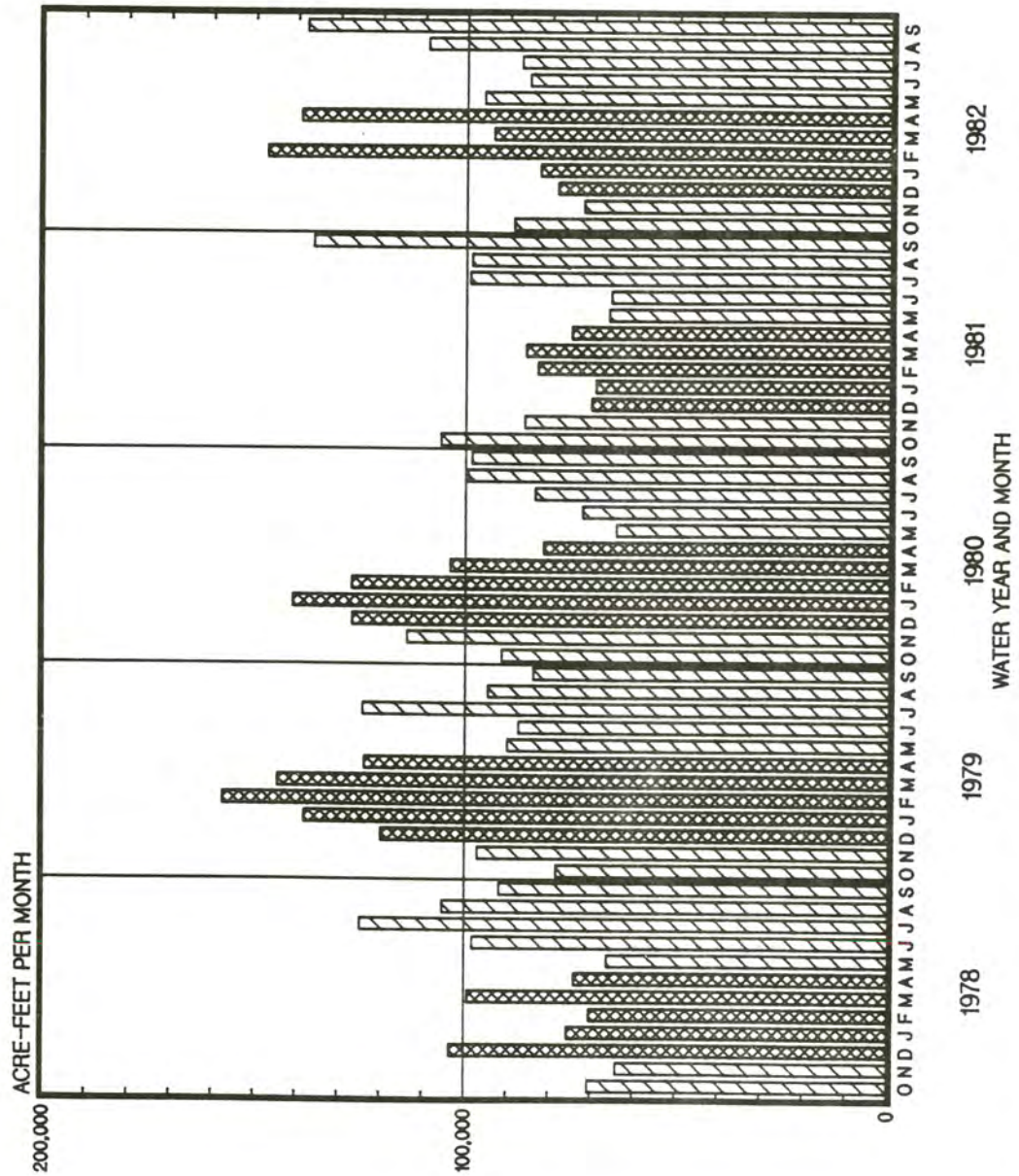


Figure C1. Monthly discharge in the Green River below Flaming Gorge Dam during the 1978-82 study period (winter flows are denoted by cross-hatched bars).



Table C6. Monthly discharge data for Green River below Flaming Gorge Dam, for water years 1978-84.

DISCHARGE (CUBIC FEET/SECOND) NORMAL MONTHLY MINIMUMS (ALL DAYS)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	ANNUAL
1978	949	934	934	920	929	925	941	821	930	903	908	953	821
1979	874	876	893	1,150	1,930	924	1,230	1,210	1,220	1,210	1,220	1,210	874
1980	889	895	863	902	1,000	876	869	850	863	824	843	934	824
1981	877	882	875	882	879	873	874	880	869	876	912	869	869
1982	864	870	858	864	936	864	882	894	942	908	857	1,440	857
1983	779	2,612	865	2,034	1,653	2,071	2,002	1,448	3,983	7,204	2,997	2,583	779
1984	750	1,807	1,449	2,590	3,427	2,822	2,793	3,370	1,486	1,684	2,136	1,275	750
7 Yr	750	870	858	864	879	864	869	821	863	824	843	869	750

DISCHARGE (CUBIC FEET/SECOND) NORMAL MONTHLY MEANS (ALL DAYS)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	ANNUAL
1978	1,149	1,075	1,038	1,229	1,266	1,613	1,243	1,075	1,649	2,030	1,713	1,542	1,386
1979	1,274	1,630	1,951	2,248	2,836	2,350	2,083	1,464	1,468	2,022	1,539	1,410	1,850
1980	1,487	1,913	2,064	2,292	2,286	1,687	1,371	1,047	1,216	1,360	1,618	1,657	1,664
1981	1,723	1,448	1,144	1,128	1,496	1,397	1,261	1,077	1,105	1,612	1,606	2,288	1,439
1982	1,445	1,265	1,277	1,345	2,651	1,524	2,340	1,560	1,432	1,417	1,776	2,317	1,686
1983	3,910	3,655	2,926	2,985	2,376	2,452	2,840	3,076	7,964	10,127	5,056	3,729	4,270
1984	3,159	3,181	3,186	3,739	4,089	3,774	3,911	5,309	2,294	3,591	3,428	2,217	3,493
7 Yr	2,021	2,024	1,941	2,138	2,436	2,114	2,150	2,087	2,447	3,166	2,391	2,166	2,256



Table C6. Continued.

## DISCHARGE (CUBIC FEET/SECOND) NORMAL MONTHLY MAXIMUMS (ALL DAYS)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	ANNUAL
1978	1,320	1,320	1,410	1,940	3,000	2,600	1,960	1,670	2,650	2,770	3,140	2,510	3,140
1979	1,960	2,440	2,610	2,620	3,960	3,820	3,790	2,650	2,340	3,300	2,880	2,320	3,960
1980	3,500	3,980	3,410	3,650	3,710	3,340	2,230	1,940	1,770	1,890	2,090	2,040	3,980
1981	3,340	2,160	1,990	2,090	2,090	2,500	2,500	1,840	1,620	2,410	2,330	3,550	3,550
1982	2,300	2,000	1,940	1,920	4,140	2,290	3,600	2,530	2,160	2,100	3,200	3,320	4,140
1983	5,316	3,944	3,946	3,847	3,794	2,717	3,969	3,999	10,135	12,300	7,741	4,079	12,300
1984	3,890	4,046	4,170	4,178	4,277	4,194	4,236	8,426	3,371	4,243	4,213	2,981	8,426
7 Yr	5,316	4,046	4,170	4,178	4,277	4,194	4,236	8,426	10,135	12,300	7,741	4,079	12,300

## MONTHLY ACRE-FEET DISCHARGES

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	ANNUAL
1978	70,650	63,970	103,540	75,570	70,310	99,180	73,960	66,100	98,120	124,800	105,300	91,760	1,043,260
1979	78,330	96,990	119,960	138,200	157,500	144,500	123,950	90,020	87,350	124,300	94,630	83,900	1,339,630
1980	91,430	113,800	126,900	140,900	126,960	103,700	81,580	64,380	72,360	83,620	99,490	98,600	1,203,720
1981	105,900	96,160	70,640	69,360	83,080	85,890	75,030	66,220	65,750	99,120	98,750	136,150	1,052,050
1982	88,850	72,270	78,520	82,700	147,230	93,710	139,240	95,920	85,210	87,130	109,200	137,880	1,217,860
1983	240,400	217,500	179,900	183,500	131,960	150,770	168,990	189,100	473,900	622,700	310,900	221,900	3,091,520
1984	194,200	189,300	195,900	229,900	227,100	232,100	232,700	326,400	136,520	220,800	210,800	131,900	2,527,620

