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Microhabitat of Rainbow and Cutthroat Trout in the Green River Below Flaming Gorge Dam: Volume I

Jeffrey C. Gosse

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Microhabitat of Rainbow and Cutthroat Trout in the Green River Below Flaming Gorge Dam

Volume I

Jeffrey C. Gosse
Aqua-Tech
MICROHABITAT OF RAINBOW AND CUTTHROAT TROUT IN THE
GREEN RIVER BELOW FLAMING GORGE DAM

Volume I
Narrative Report

by

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The opinions, findings, conclusions, and recommendations expressed in this report are those of the author and do not necessarily reflect the views of the Utah Division of Wildlife Resources or the U.S. Bureau of Reclamation.
EXECUTIVE SUMMARY

Introduction

Flaming Gorge Dam was completed by the U.S. Bureau of Reclamation (USBR) in 1962 and at that time a trout fishery was established by the Utah Division of Wildlife Resources (UDWR) in the tailwater. Initially good trout growth steadily declined as the reservoir filled and the hypolimnetic discharge water cooled. Adjustable penstock modifications were added in 1978 which raised the summer water temperature from 5 to 13°C, and resulted in an improved growth rate in the trout.

The primary objective of this study was to evaluate the potential effects of a proposed peaking power regime on the trout fishery. Specifically, the study was to provide microhabitat data for use by USBR personnel with the fish habitat model developed by the USFW Cooperative Instream Flow Group. This model would then be used to evaluate the physical effects of a proposed peaking power flow regime. Data were collected in 1981 during winter and summer for rainbow and cutthroat trout. The data were stratified by river flow, species and life stage, and activity of the fish. A secondary objective was to collect invertebrate samples and provide vegetation data from the river for use in modeling.

During the winter of 1982, a test was conducted on the effects produced on the trout by sustained high flow releases
(>3600 cfs). Microhabitat data were collected by species, physical activity, and life stage during three time periods: pre-test, high flow test, and post-test.

The study area was defined as the 18 km of river between Flaming Gorge Dam and Red Creek. Most microhabitat data were collected from the first 7 river km below the dam. An intensive study site was located approximately 2.4 km below the dam. Physical, invertebrate, and vegetative data were collected in the intensive study site for use in the hydraulic and habitat models.

Rainbow and cutthroat trout were the most numerous fish species in the study area. Populations for both species were sustained through extensive fingerling stocking by the UDWR.

Brown trout were found in low numbers in the study area, but they were common below Red Creek. All other species of fish observed in the study area were found in low numbers.

Methods

Fish microhabitat is defined as the physical (and occasionally chemical or biological) variables that define (and presumably influence) the exact location occupied by a fish and which change or could potentially change with small changes in the fish's location. Variables which are normally constant over large sections of river (such as temperature, volume of flow, conductivity, dissolved oxygen, etc.) are considered macrohabitat variables. Macrohabitat variables were not measured in this study.
Fish were located and observed by a diver using a modified scuba technique. The diver wore an exorbitant amount of weight to enable him to remain stationary on the stream bottom in the strong currents. An underwater communication system allowed the diver to transmit microhabitat data to the surface personnel.

The diver made microhabitat measurements as nearly as possible to each fish's precise location. Most microhabitat variables could be measured by the diver without assistance and the data were relayed to the surface personnel. Velocity and (initially) light measurements were made by the diver placing the respective probe in position and instructing the surface personnel to read the surface meter.

The six variables used to describe trout microhabitat in this study were: fish velocity, mean column velocity, fish depth, water depth, substrate type, and overhead light. Fish velocity was defined as the water velocity measured at the precise location where the fish was observed. Mean velocity was determined at four-tenths of the water column height occupied by the fish, measured from the river bottom. Velocities were measured with an electronic current meter. Fish depth, the distance of the fish from the stream bottom, was estimated by the diver to the nearest 5 cm. Water depth was measured by using a depth gauge for most of the study. Substrate type was categorized as rock, rubble, gravel, silt or other. Presence or absence of plant cover was also recorded. The level of overhead light reaching the fish was measured with one of two types of electronic illuminance meters.
Both species of fish were grouped by length into two life stages: juvenile and adult. The primary physical activities for both cutthroat and rainbow trout were stationary and random swimming. Stationary swimming was defined as fish maintaining a stationary position by actively swimming against a current. Random swimming was defined as swimming without orientation toward a current that did not produce a net change in general location. Interstitial activity was observed in rare instances. This activity was defined as fish using the interstitial crevices between rocks while random swimming. When fish were observed feeding during any of the activities, this was also recorded.

Vegetative cover was measured in the intensive study site using the same transects established for the IFG-4 hydraulic model. A diver traveled along the transect line and transmitted to surface personnel data on substrate type, plant species, percent of plant cover, water depth, and distance along the cross sections. Measurements of water velocity were made at each plant bed along the cross section.

Benthic samples were collected in the intensive study site to determine invertebrate densities for five substrate types: barren silt, macrophyte beds on silt, gravel, rubble, and rock with Cladophora attached. Samples were collected at depths ranging from 1.4 to 5.8 m by a diver using a special enclosed sampler.
Results

There were seasonal differences in distribution of fish. In the winter, fish were concentrated in the quiet water of pools. The juveniles especially were found in this habitat. The primary activity in pool habitat was random swimming. Fish were distributed three dimensionally from each other. There was little indication of territorial behavior. During the summer fish were usually located in shallower and faster water. The primary activity in the summer was stationary swimming. Fish were distributed in a horizontal plane and established stations or territories were evident.

The average water velocity occupied by the fish ranged from 12 to 41 cm/sec for the activity of stationary swimming and from 7 to 21 cm/sec for the activity of random swimming. Increased flow releases usually resulted in fish occupying higher velocity water during the activity of stationary swimming. For the activity of random swimming, increased flow releases did not consistently result in increased fish velocities.

For the activity of stationary swimming, fish occupied deeper water during the winter than in summer. Random swimming occurred primarily in pools, and seasonal differences in water depth used by the fish were not usually as great for this activity.

Fish depth (distance of the fish from the bottom) was usually greater in winter than in summer. Fish were usually located in the lower one-third of the water column regardless of season.
Fish often moved closer to the stream bottom as flows increased, especially for the activity of stationary swimming and during the summer. The average mean column velocity was consistently higher than fish velocity for the activity of stationary swimming. This resulted from the fact that fish were located below the water depth where mean column velocities are measured. Mean velocities for the activity of random swimming were lower than mean velocities for stationary swimming.

On five occasions, fish were observed during prearranged flow changes. Stationary swimming fish often moved closer to the bottom as flows increased and farther from the bottom as flow decreased. In some cases, juveniles were observed to move closer to shore as flows increased. Feeding rates often increased with increasing flow.

The low water line was the upper limit for establishment of aquatic plants. Water velocities (near the bottom) and substrate both appeared important in determining which species of plant was found in an area. Plant beds on silt substrate consistently had higher densities of invertebrates than the other substrate types.

During the pre-test period in January 1982, fish were observed to choose microhabitat similar to that chosen in January 1981. They were clumped in essentially the same pools as they had occupied the previous year.

During January 1982, juvenile cutthroat were located higher in the water column than the other groups of fish. The juvenile cutthroat trout were physically more isolated from the other groups than they were during January 1981.
High flows (>3600 cfs) were released during most of February 1982. The primary change that occurred during the high flow test was a major emigration of cutthroat trout from the study area. This emigration appears to have occurred during the first week of high flows.

No major changes in microhabitat choices were observed for adult cutthroat trout nor for adult and juvenile rainbow trout. The average fish velocity during the test period for each life stage and activity was lower, with one exception, than fish velocities measured during medium flows in winter and summer 1981.

Post-test observations were made during March and April 1982. During this period, fish began moving out of center pool areas and into shallower, higher velocity areas, usually adjacent to the pools. The number of fish observed, especially juvenile rainbow trout, declined in late March and early April. It appears that many of these fish emigrated below Red Creek and out of the study area.

During the post-test period, some juvenile rainbow trout were observed to use the interstitial crevices in rip-rap banks for microhabitat. Based on their sizes, these fish apparently were naturally reproduced in the river.
Summary

The development and use of tolerance intervals is suggested as an alternative to probability-of-use curves for modeling applications. For the rainbow and cutthroat trout in the Green River, accurate modeling requires data stratification by species, life stage, activity, and season. It is important that predictive models provide accurate velocities at the depths occupied by the fish rather than using average column velocities.

For the activity of stationary swimming, fish velocity tended to increase and fish depth tended to decrease with increased flows. For the activity of random swimming, fish often moved along with changes in sheer edges as flows changed with little resultant change in fish velocity.

There was a large difference between winter and summer distribution of the trout and in the importance of the two activities. Glides and rapids were the primary habitat for trout in the summer. During the winter, fish were heavily concentrated in a few large pools. Random swimming was observed infrequently during summer but was common during winter.

Present low flow levels were the upper limit of plant bed establishment. Plant beds were important in producing high invertebrate biomass, especially Gammarus.

During the pre-test period in January 1982, trout occupied habitats very similar to those occupied during January 1981. Juvenile cutthroat trout were located higher in the water column than the other life stages in 1982 and were physically isolated
by depth from the other fish.

As nearly as can be determined, the juvenile cutthroat trout emigrated from most of the study area during the first week of the high flow test. There was no apparent physical reason for the emigration. The other life stages exhibited no changes during the entire high flow test period. There was no indication of excessive velocities during the high flow test.

During March and April, the months following the high flow tests, there appeared to be a gradual decline in the number of fish, particularly the juvenile rainbow trout. None of the microhabitat variables indicated any reason for the decline.

There was no indication that high flows either forced the fish to swim in velocities above those normally utilized or that they had to utilize marginal habitat to obtain preferred velocities. If high flows play a part in fish emigration, it appears that they are indirectly correlated. Two possible correlations may be that high flows at certain times of the year serve as a trigger to stimulate emigration or that winter high flows result in gas supersaturation or aggrevate other unknown water quality problems. Juveniles were more prone to emigration than adults. It is possible that the size of juveniles is also important in determining whether they will emigrate.
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</tbody>
</table>
ACKNOWLEDGMENTS

This study would not have been possible without the cooperation and support of several agencies and numerous individuals. Source funds for this study were provided by the U.S. Bureau of Reclamation (USBR) and were administered through the Utah Division of Wildlife Resources (UDWR).

Reed Harris (USBR), Jim Johnson (UDWR), and Thomas Burke (USBR) were responsible for much of the original design of the study and provided continued advice as the study progressed. Robert Williams (USBR) guided the week-to-week supervision of the study and its general direction during the final field year and throughout the writing stage. Dave Wegner (USBR) contributed ecological insight and provided information on the preliminary model predictions.

Housing and storage space were provided at the study site by the USBR under the supervision of Robert Simpson. USBR personnel, especially Steve Thompson, Clarence Messenger, and Ron James assisted in coordinating the various flow releases necessary throughout the study and also provided historical flow information. Janelle Pershon's (USBR) friendly and cooperative attitude facilitated many of our activities at the study area.

UDWR personnel at Dutch John assisted in providing and sharing necessary equipment and biological information throughout the study. Richard Kramer, Eric Larson, and Bruce Bonebrake were responsible at various times for the UDWR's study on the Green
River fishery and provided current information. Bruce Schmidt's personal knowledge of the fishery and navigation on the Green River were especially helpful.

The U.S. Forest Service (USFS) granted permission for use of a motorized craft in the restricted area of the Green. Gary Schaffron and Dave Keddy were very cooperative in this aspect. Brian Barber and John Simons of the USFS were helpful in allowing the loan of various tools and materials from their well stocked supply.

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Janlyn Johnson was responsible for most of the clerical and accounting duties which kept us functioning throughout the study. She also was responsible for the preliminary editing and word processing of this report. Field assistants and surface tenders during various parts of the study were Craig Reger, Wayne Mein, and Dennis Cox. My gratitude to Craig and Dennis for preventing a premature cessation of the project and myself can perhaps best be expressed by saying: when that eternal instant arrived, you
performed your jobs perfectly. No higher praise can be given a surface tender.
INTRODUCTION

Historical perspective

Flaming Gorge Dam, Utah was constructed as a hydroelectric project by the U.S. Bureau of Reclamation (USBR) and began operations in 1962. Previously, the Green River had been a turbid, warm-water stream with vast flow fluctuations occurring between the heavy spring runoffs and the low flows encountered during much of the remainder of the year (USDA 1979). As the dam filled, the tailwaters became clear and cold with normal annual temperatures of 4 - 5°C as a result of the hypolimnetic intakes.

When the dam was completed, a trout fishery was established in the tailwater by the Utah Division of Wildlife Resources (UDWR), with initially good rates of growth. As the dam filled, discharge water temperatures decreased, and growth rates for the trout declined (Schmidt et al. 1980). At the request of the UDWR, the USBR constructed a multilevel intake system to allow for release of warmer epilimnetic reservoir water from April to December. This penstock modification became operational in June 1978, increasing mid-summer temperatures from 5 to 13°C. The penstock modification was highly successful in the primary objective of producing increased growth rates for the trout (Larson et al. 1982).

Much of the area surrounding the reservoir and the riparian land for 11 km below the dam has been designated a National
Recreation Area. It is currently administered by the U.S. Forest Service (USFS) which maintains day use areas and a riparian trail between the dam and Little Hole, a distance of 11 km. This area is utilized by an increasing number of people for purposes of camping, river floating, and fishing (USDA 1979 and Larson et al. 1982). The recreation and scenic resources of the area, coupled with its growing popularity, make it imperative that any future changes be considered fully for potential environmental and social impact.

Study objectives

The USBR was evaluating a proposed peaking power regime at the feasibility level for the Flaming Gorge Dam at the beginning of this study (September 1980). This study was initiated to provide biological information for evaluating the effects of a peaking power regime on the tailwater fishery. During the winter of 1982 the peaking power proposal was officially delayed until rewinding and uprating of the existing facilities could be evaluated.

Fish microhabitat

The primary objective of this study was to provide fish microhabitat data to be utilized in the IFG-4 hydraulic simulation and fish habitat model (Bovee and Cochnauer 1977, Bovee and Milhous 1978). The purpose of the data was to determine the impact, if any, of increased or peaking flow releases on fish microhabitat. Summary tables of the data are presented in an appendix.
volume for incorporation by USBR personnel within the model.

Data were collected for rainbow trout (Salmo gairdneri) and cutthroat trout (Salmo clarki). Data were collected by species, life stage (juvenile and adult), and physical activity of the fish for two seasons: winter (January - early April) and summer (June - early September). In addition, data were stratified for three flow levels: low (800 - 1500 cfs) [22.6 - 42.5 m³/sec], medium (2000 - 2800 cfs) [56.6 - 79.3 m³/sec] and high (3600 - 4300 cfs) [101.9 - 121.8 m³/sec]. Flow releases between these defined ranges seldom, if ever, occurred.

**Invertebrate and vegetative data**

A second objective of the study was to quantitatively collect aquatic invertebrate samples from different substrates. A third objective was to provide information to USBR personnel on aquatic vegetation and substrate type for mapping and modeling purposes. The overall purpose of these two objectives was to provide some initial information on potential food sources for the trout fishery.

Both the invertebrate and vegetative data were forwarded to USBR personnel for analysis and incorporation into the aquatic models since our primary responsibility was to collect the data. Some of the summarized findings are presented in this report, however.
High flow test

A fourth objective was added after the first year of study had been completed. This was to monitor the effects on the fish (in terms of microhabitat) during a proposed test of winter high flow releases during 1982.

Fish microhabitat data were again collected by species, life stage, and physical activity as was done in 1981. The data were stratified into three time periods during the winter 1982: prior to high flows (January), during high flows (February), and after high flows (March - April).

Site description

Physical

The study area was defined as extending from the dam downstream 18 km to Red Creek (Figure 1). Microhabitat data were collected primarily from the first 7 km below the dam. Releases from the dam normally fluctuate from 800 to 4300 cfs (22.6 - 121.8 m³/sec). An intensive study site was selected by USBR personnel approximately 0.4 km below Pipe Creek (Figures 1 and 2). They established and mapped ten transects across this site to provide the physical data for the IFG-4 hydraulic model. These same transects were also used to provide vegetative information.

Water temperatures in the river are regulated during the summer to 13°C at the dam by adjustable penstock intakes. During the winter, temperatures drop to a minimum of 4°C at the dam.

The stream banks consist primarily of rock and rubble with little riparian vegetation. The banks are usually stable with
the occasional soil banks exhibiting some erosion. Much of the stream bottom is covered with submersed plants including both macrophytes and attached algae.

Biological

The two dominant fish species from the dam to Red Creek were rainbow and cutthroat trout. Both species are stocked extensively by the UDWR. There was evidence of natural reproduction for rainbow trout.

Brown trout (*Salmo trutta*) were found in low numbers above Red Creek and became more common downstream in the Brown's Park area. Kokanee (*Oncorhynchus nerka*), carp (*Cyprinus carpio*), redside shiner (*Richardsonius balteatus*), channel catfish (*Ictalurus punctatus*), bluehead sucker (*Catostomus discobolus*), and flannelmouth sucker (*Catostomus latipinnis*) were all present but found in very low numbers. Mountain whitefish (*Prosopium williamsoni*), white sucker (*Catostomus commersoni*), and brook trout (*Salvelinus fontinalis*) have all been observed on occasion and northern pike (*Esox lucius*) has been reported in the area.
Figure 1. Flaming Gorge tailwater area.
Figure 1. Continued.
Figure 2. Pipe Creek intensive study site.
METHODS

Fish microhabitat

Microhabitat definition

Microhabitat of fish is normally considered to be those physical (and occasionally chemical or biological) variables which define the precise location occupied by a fish, and which would or could change with small changes in a fish's location. Microhabitat is usually used in this paper to refer to those variables which appear to be used by the fish in determining its location. Variables which are normally constant over a large portion of a fish's environment (such as flow level, temperature, conductivity, etc.) are considered macrohabitat variables, and were not measured in this study. Determination of a species' microhabitat preferences is limited to our human ability to conceive of and measure variables important to a fish.

Observation technique

A modified scuba method was used to observe fish (Gosse and Helm 1979, Gosse 1981, Gosse and Helm 1982). The diver wore an exorbitant amount of weight to facilitate remaining stationary on the stream bottom in the strong currents. The diver moved in an upstream direction to approach the fish from below and behind.

A surface to diver sonic transceiver allowed the diver to communicate with the surface personnel. Variables that could be measured by the diver without assistance were relayed to the sur-
face for recording. Velocity and light readings were made by the surface personnel after the diver had placed the respective probe in the proper location.

An exhaust system vented air bubbles away and downstream from the diver to avoid frightening the fish. Under normal circumstances, fish were not frightened by the diver. Occasionally, fish were attracted to the diver when he had dislodged invertebrates from the substrate. Data were not taken for fish that were disturbed (either attracted or frightened). Fish that were traveling through an area were also not used for data, since they were not truly choosing microhabitat locations. Fish can and will travel through nearly all portions of the river, but they will occupy only certain areas; i.e., their microhabitat.

A modified dry suit and full face mask protected the diver from cold water. The risks posed from the modified diving procedures were reduced with special training dives and safety procedures including: multiple buoyancy systems, a separate emergency air supply, and surface tenders in radio communication with the diver.

Variable measurements were made as nearly as possible to each fish's precise location. When several fish were observed in the same microhabitat, measurements were made in a location representative of the entire area, usually near the middle of the group.
Data stratification

Fish sub-groups

Observations were classified by season, flow, species, life stage, and activity. Length-frequency tables compiled from this study were used to determine the size cutoff between juvenile and adult fish. This cutoff changed slightly between seasons as a result of growth. During the winter, fish ≤ 25 cm were classified as juveniles and larger fish were considered adults. During the summer, 23 cm was used as the division between life stages.

Stationary and random swimming were the two primary activities observed for the study species. The activity of stationary swimming was defined as maintaining a stationary position by actively swimming against a current. Swimming without orientation toward a current (found only in low velocity water) that did not produce a net change in location was defined as random swimming. Fish engaged in one of the above categories that were observed consuming particles were designated as feeding during the respective activity. Resting activity (fish that remain stable with no swimming motion, normally by lying on the river bottom) was not observed for either of the two study species.

Collection schedule

Observations of fish were made primarily in the upper 7 km of the study area. All dives were made during midday periods (0900-1700 h). Data were never taken from the same location twice for the same season and flow. An effort was made to sample the same locations for the different seasons and especially for
the three flow levels within each season.

All major habitat types in the upper 7 km were sampled during winter and summer 1981. Since measurement of microhabitat is dependent on locating fish, efforts were biased towards sampling in locations where fish were predominantly found. Thus, pools were sampled more heavily in winter than in summer and shore areas were sampled more heavily immediately after stocking than they were later in the year.

Statistical analysis

Student's t test was used to test the difference between two means for a variable. Analysis of variance was used to test for differences in average fish velocities among the three flow levels. Fisher's (Ott 1977) least significant difference was used to test between paired means where analysis of variance indicated a significant (P < 0.05) difference among flows.

Microhabitat variables

Thirteen physical variables were measured for each observation: fish depth, distance to the nearest fish, position of the nearest fish, distance to the nearest thigmotactic surface, position of the nearest thigmotactic surface, type of thigmotactic surface, substrate type, water surface condition, fish velocity, mean column velocity, surface incident light, overhead light, and macrohabitat.

Fish velocity was defined as the water velocity measured exactly where the fish was observed. Mean velocity was determined at four-tenths of the water column height occupied by the fish,
measured from the river bottom. Both measurements were made to the nearest 3 cm/sec using an electronic current meter.

Fish depth, the distance of the fish from the stream bottom, was estimated by the diver to the nearest 5 cm. During the first three years of collecting microhabitat data (including the first year of this study), the diver carried a calibrated rod to check his estimation of fish depth. When fish depth was greater than 2 m, the distance was measured with a calibrated rod or depth gauge.

Water depth was measured during winter 1981 using a calibrated rod (<5 m) or a calibrated line (>5 m). During summer 1981 and winter 1982, a depth gauge was used to measure water depth.

Thigmotaxis is defined as a taxis in which contact with a solid body is the directional factor. Fish are often not in contact with any solid body but they may remain in close proximity to one. In this study, the nearest thigmotactic surface was defined as the closest solid object or objects to the fish, which included the stream bottom, attached vegetation, submerged roots and branches, and boulders.

The type of substrate was recorded as rock (>30 cm), rubble (8-30 cm), gravel (0.3-8 cm), silt (<0.3 cm), or other. Presence or absence of plant cover was recorded separately for each substrate type.

The level of overhead light reaching the fish was measured to 0.01% of full sunlight (1.076 X 10^5 lx) on a logarithmic scale using a solar illuminance meter with an underwater probe during
During 1982, a different illuminance meter was used which read directly in luxes and could be taken underwater by the diver. Surface light was measured at the water surface. Macrohabitat was defined using a series of common subjective terms referring to stream habitat. These terms included mid and side pools, glides, back-eddies, rapids and riffles.

Many of these variables were redundant or appeared to be unimportant in defining microhabitat for the two study species. The six most pertinent variables which will be discussed in this report are fish and mean column velocity, fish and water depth, substrate type, and overhead light. Summary tables of these variables are presented in an appendix volume for modeling purposes by USBR personnel. The nearest thigmotactic surface was essentially the same as fish depth since the river bottom was usually the nearest thigmotactic surface.

**Vegetative cross sections**

Vegetative cover was measured in the intensive study area. The same transects (Figure 2) were utilized as had been established by USBR personnel for the IFG-4 hydraulic model.

A cable calibrated in 1.5 m intervals was attached to the starting post on the north side of a cross section. A diver then unreeled the cable along the stream bottom to the south side of the cross section. A surface observer kept the diver in line with the stakes on the south shore. The diver transmitted to the surface personnel: substrate type; plant species (if any); percent density of plant cover along the transect; water depth; and
distance along the cross section. These measurements were made whenever one of the variables changed noticeably. All measurements were made along the transect line, and differences up and downstream from the transect line were not measured.

After a cross section was completed, three velocity measurements were made for each plant bed on the transect line. Two velocity readings were made at a reference point located halfway across the plant bed, measuring along the transect line. One reading was made on the river bottom at this reference point and a second at the maximum height of the plant stalks at this reference point. The third velocity reading was made on the river bottom at the upstream edge of the plant bed, located directly upstream from the reference point.

**Invertebrate samples**

Benthic samples were collected to determine invertebrate density for five substrate types: nonvegetated silt, macrophyte beds on silt, gravel, rubble, and from rock with *Cladophora* attached. Samples were taken from within the intensive study site located below Pipe Creek. Samples were taken only from greater water depths (1.4-5.8 m) than were sampled during earlier studies on the Green River (Holden and Crist 1981) in order to provide a more complete picture of invertebrate populations.

A special enclosed sampler was used which allowed samples to be taken by a diver and returned to the surface without loss of invertebrates. The original prototype sampled an area of 0.07 m² while a later model had an opening of 0.1 m².
RESULTS

Winter and Summer 1981

Seasonal distribution

One of the original purposes in conducting this study was to determine if differences in fish microhabitat choices existed between the winter and summer seasons. During the study, a large difference was observed in the general microhabitat choices of both rainbow and cutthroat trout between the two seasons.

Winter

During the period from January through mid-April (the time of lowest water temperatures, hereafter referred to as winter), the fish were found heavily concentrated in large deep pools and in quiet back-eddies. It was not unusual to observe several hundred or more fish within a pool. Their primary activity within the pools was random swimming, although stationary swimming was observed along sheer edges and in pool thalwegs. (A sheer edge is an area where the velocities change markedly.) While engaged in random swimming, fish were usually distributed three dimensionally with no evidence of territoriality and small distances among fish. Fish engaged in stationary swimming exhibited both three dimensional and vertical two dimensional distribution along sheer edges. The distance among fish was again low and evidences of territoriality were rare.
Juvenile cutthroat trout were found primarily in pools during the winter. They were usually found in the lowest velocity habitat. Juvenile rainbow trout and adult cutthroat trout also were primarily found in this type of distribution. Often the juvenile cutthroat trout would be found nearer the surface of a pool while the latter two groups would tend to occupy the lower parts. It was not uncommon to observe adult rainbow trout in this type of winter distribution, but they were the most likely group to be found in the more typical summer distribution, as described below. This was particularly true of the largest adult rainbow trout. During the winter, fish did not necessarily maintain a fixed position with regard to the river bottom. They often, however, maintained a relatively stable orientation to the current or current edge.

Summer

Observations made from June through November (the period of warm water, hereafter referred to as summer) indicated that the fish were distributed quite differently from the winter. They were found primarily in shallow water areas including riffles, rapids, glides, and to some extent the near shore area. Some fish still occupied the larger pools, but their numbers were greatly reduced, often by an order of magnitude or more.

Stationary swimming was the primary activity observed during the summer. Fish were normally distributed two dimensionally in a horizontal plane and they usually occupied stations or positions, similar to the territories described by other authors.
The average distance between the fish increased over that found in the winter, especially among adults. Juveniles of both species occupied the quiet areas near shore when they were first stocked. Both species appeared healthy and well acclimated from the time of stocking and throughout the summer. As growth occurred the juvenile rainbow trout moved away from the near shore region and dispersed throughout the river. They were found in most areas except the extremely fast rapids. The juvenile cutthroat trout were stocked later and at a smaller size than the rainbow trout. The former occupied the near shore region longer into the summer before moving to midstream, and remained more clumped in their distribution.

Feeding

Feeding was commonly observed during both activities and both seasons, although the number of food particles ingested over a period of time in the winter appeared greatly reduced from that of summer. During the activity of stationary swimming, fish would normally move either vertically or laterally from their original position to engulf a drifting food item and then return to the original position. During the activity of random swimming, the fish did not maintain any permanent position, and food was engulfed whenever encountered.

Adult cutthroat trout were observed to make predatory attempts on both species immediately after stocking. No successful captures were observed, and the frequency of these attempts de-
Microhabitat variables

Water depth

Stationary swimming. The change in location from pools during the winter to shallower water during the summer can be quantified for the two seasons (Table 1). All life stages of fish engaged in stationary swimming occupied significantly (P < 0.05) deeper water during the winter than in summer.

For both species, juveniles inhabited significantly (P < 0.05) shallower water than adults in summer and significantly (P < 0.05) deeper water in winter while stationary swimming. This indicates a somewhat lower use by juveniles of mid-stream areas during summer and a greater percentage of juveniles than adults moving into pools during winter. Many adults were observed stationary swimming in the shallower areas throughout the winter.

Random swimming. Both species of juveniles were found in significantly (P < 0.05) greater water depths during winter than during summer. This again indicates the shifts from shallow water in summer to pools in winter.

Adults of both species differed from juveniles for the activity of random swimming, and were found in deeper average water depths during summer than in winter. This difference between seasons was significant (P < 0.05) for adult rainbow trout but was not significant (P > 0.05) for adult cutthroat trout. Adults were very seldom observed in the activity of random swimming dur-
Table 1. The average water depth (cm) and sample size ( ) for all flows for stationary and random swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary Swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>552 (413)</td>
<td>433 (391)</td>
</tr>
<tr>
<td>Summer</td>
<td>251 (175)</td>
<td>344 (136)</td>
</tr>
<tr>
<td>Random Swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>517 (488)</td>
<td>481 (370)</td>
</tr>
<tr>
<td>Summer</td>
<td>245 (187)</td>
<td>500 (113)</td>
</tr>
</tbody>
</table>
ing the summer. The only habitat where adults consistently engaged in random swimming during the summer was in the largest pools and back eddies. Adults were found random swimming in many pools and back eddies during winter. Thus, random swimming adults occupied a greater mean water depth during summer than during winter.

Fish velocity

Stationary swimming. Increased flows produced increases in fish velocity for all life stages during the activity of stationary swimming in winter (Table 2). Flow increases from medium to high during summer usually produced increases in fish velocity. The average fish velocity for juvenile rainbow trout decreased slightly from medium to high flows during summer, but the change was not significant \( (P > 0.05) \). Fish velocity increased only slightly from low to high flows for juvenile cutthroat trout in the summer. This can be explained by the fact that the juvenile cutthroat trout occupied relatively quiet areas near shore throughout the summer, resulting from their small size.

Adults of both species generally were observed in higher velocities than juveniles. This was most obvious during the summer when the size differences between the life stages were greatest. For all flows combined, adults of both species were found in significantly \( (P < 0.05) \) higher velocities than juveniles during the summer and during the winter for rainbow trout. There was no significant \( (P > 0.05) \) differences in velocities between adult and juvenile cutthroat trout during the winter.
Table 2. The average fish velocity (cm/sec) and sample size ( ) for all flows for stationary swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Cutthroat trout</th>
<th>Rainow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>12 (141)</td>
<td>16 (67)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Medium</td>
<td>25 (167)</td>
<td>23 (238)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>High</td>
<td>30 (80)</td>
<td>28 (83)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>21 (53)</td>
<td>24 (54)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Medium</td>
<td>21 (80)</td>
<td>29 (42)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>High</td>
<td>26 (42)</td>
<td>41 (40)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

Flows for a specific life stage and season which do not share a common letter had significantly (P<0.05) different average fish velocities.
For the same life stage and activity, rainbow trout tended to have higher fish velocities than did cutthroat trout. For all flows combined, juvenile rainbow trout occupied significantly (P < 0.05) higher velocities than juvenile cutthroat trout for both seasons. Adult rainbow trout occupied significantly (P < 0.05) higher velocities than adult cutthroat trout during the winter, but there was no significant (P > 0.05) difference during the summer. Fish velocities tended to be higher (for the same flow) during the summer than in winter with the exception of juvenile cutthroat trout.

Random swimming. For the activity of random swimming, fish velocity did not change consistently with increasing flows (Table 3). Flow changes generally produced little change in fish velocity during random swimming, and increased flows did not necessarily produce increases in fish velocity. For the activity of random swimming, juvenile rainbow trout exhibited the most dramatic increases in fish velocity with flow increases during the winter. However, the number of observations was small (Table 3) and this may be an aberration.

There was a slight tendency for fish to use lower velocities in summer than in winter. Juvenile cutthroat trout chose lower velocities during summer than during winter for all flows. This was again probably a result of their small size and recent stocking.

For all flows combined, adult rainbow trout were found in significantly (P < 0.05) higher velocities than adult cutthroat trout during both seasons. Juvenile rainbow trout were also
Table 3. The average fish velocity (cm/sec) and sample size ( ) for all flows for random swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>13 (127)</td>
<td>16 (107)</td>
</tr>
<tr>
<td></td>
<td>A†</td>
<td>B</td>
</tr>
<tr>
<td>Medium</td>
<td>14 (192)</td>
<td>13 (147)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>High</td>
<td>16 (169)</td>
<td>15 (116)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>8 (56)</td>
<td>12 (36)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A,B</td>
</tr>
<tr>
<td>Medium</td>
<td>8 (68)</td>
<td>10 (34)</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>High</td>
<td>12 (63)</td>
<td>15 (35)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

†Flows for a specific life stage and season which do not share a common letter had significantly (P<0.05) different average fish velocities.
found in significantly \( (P < 0.05) \) higher velocities than juvenile cutthroat trout during the summer, but there was no significant \( (P > 0.05) \) difference between their velocities during the winter.

**Mean velocity**

The activity of random swimming occurred in areas that consistently had lower mean velocities than the areas where stationary swimming was observed (Tables 4 and 5). For all flows combined, this difference was significant \( (P < 0.05) \) for all life stages and during both seasons.

For the activity of random swimming, mean velocities exhibited only slight seasonal differences and did not change greatly with increased flows. During stationary swimming, each life stage occupied areas with significantly \( (P < 0.05) \) higher mean velocities in summer than in winter, all flows combined.

Mean velocities generally increased with increasing flows for adults of both species during stationary swimming. Both species of adults were found in significantly \( (P < 0.05) \) higher mean velocities during medium flow than during low flows for each season. They were also found in significantly \( (P < 0.05) \) higher mean velocities during high flows than during medium flows in the winter. There was no significant \( (P > 0.05) \) difference between high and medium flows in the summer for adults.

Juvenile rainbow trout were found in significantly \( (P < 0.05) \) lower mean velocities during high flows than during medium flows for both seasons, while stationary swimming. Juvenile cutthroat trout were never found in mean velocities
Table 4. The average mean velocity (cm/sec) and sample size ( ) for all flows for stationary swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Juvenile</th>
<th>Adult</th>
<th>Juvenile</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cutthroat trout</td>
<td>Rainbow trout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>19 (141)</td>
<td>24 (67)</td>
<td>36 (51)</td>
<td>35 (192)</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36 (152)</td>
<td>37 (233)</td>
<td>31 (70)</td>
<td>39 (194)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36 (65)</td>
<td>42 (71)</td>
<td>20 (33)</td>
<td>51 (220)</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>33 (53)</td>
<td>39 (54)</td>
<td>32 (96)</td>
<td>46 (83)</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28 (80)</td>
<td>58 (40)</td>
<td>61 (129)</td>
<td>58 (46)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38 (42)</td>
<td>55 (40)</td>
<td>37 (65)</td>
<td>62 (90)</td>
</tr>
</tbody>
</table>

Table 5. The average mean velocity (cm/sec) and sample size ( ) for all flows for random swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Juvenile</th>
<th>Adult</th>
<th>Juvenile</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cutthroat trout</td>
<td>Rainbow trout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>12 (127)</td>
<td>15 (107)</td>
<td>12 (42)</td>
<td>19 (112)</td>
</tr>
<tr>
<td>Medium</td>
<td>14 (192)</td>
<td>12 (147)</td>
<td>15 (25)</td>
<td>23 (84)</td>
</tr>
<tr>
<td>High</td>
<td>19 (169)</td>
<td>20 (116)</td>
<td>17 (44)</td>
<td>19 (112)</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>10 (56)</td>
<td>15 (36)</td>
<td>23 (65)</td>
<td>17 (80)</td>
</tr>
<tr>
<td>Medium</td>
<td>14 (68)</td>
<td>12 (34)</td>
<td>13 (47)</td>
<td>18 (41)</td>
</tr>
<tr>
<td>High</td>
<td>20 (63)</td>
<td>15 (33)</td>
<td>22 (52)</td>
<td>21 (50)</td>
</tr>
</tbody>
</table>
greater than 40 cm/sec.

**Fish depth**

The fish were located a greater distance from the river bottom during the activity of random swimming than during stationary swimming (Tables 6 and 7). For all flows combined, this difference was significant \(P < 0.05\) for each life stage during both seasons. Fish depth was also significantly \(P < 0.05\) greater during the winter than the summer for each life stage and activity, all flows combined.

Fish depth (distance from the bottom) was less for medium than for low flows during summer stationary swimming (Table 6). Fish depth also decreased for adult rainbow trout as flows went from medium to high releases, but not as drastically as from low to medium flows. During the summer, a similar pattern was found for the adults of both species during the activity of random swimming (Table 7). None of the life stages moved closer to the bottom with increasing flow during the winter for either activity.

**Substrate**

Random swimming. The substrate types used during random swimming are indicative that this activity occurs primarily in pools and in quiet water areas (Table 8). Many pools in the Green River, especially the largest ones, have primarily rock substrate along the thalweg and silt substrate in the back waters to the sides of the thalweg. Silt is usually the most common substrate used during random swimming for both seasons and for
Table 6. The average fish depth* (cm) and sample size ( ) for all flows for stationary swimming during summer and winter 1981.

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

*Fish depth is the distance of the fish from the river bottom.
Table 7. The average fish depth* (cm) and sample size ( ) for all flows for random swimming during summer and winter 1981.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>130 (127)</td>
<td>122 (107)</td>
</tr>
<tr>
<td>Medium</td>
<td>192 (192)</td>
<td>221 (147)</td>
</tr>
<tr>
<td>High</td>
<td>267 (169)</td>
<td>147 (116)</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>80 (56)</td>
<td>101 (39)</td>
</tr>
<tr>
<td>Medium</td>
<td>103 (68)</td>
<td>80 (39)</td>
</tr>
<tr>
<td>High</td>
<td>112 (63)</td>
<td>69 (35)</td>
</tr>
</tbody>
</table>

*Fish depth is the distance of the fish from the river bottom.
Table 8. The percent utilization of four substrate types for all flows for random swimming during winter and summer 1981.

<table>
<thead>
<tr>
<th>Substrate Type</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>Rubble</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Gravel</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Silt</td>
<td>59</td>
<td>42</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Rubble</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Gravel</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Silt</td>
<td>65</td>
<td>38</td>
</tr>
</tbody>
</table>
all life stages. Adult rainbow trout during winter were the only exception. They used rock substrate more often than silt. With the exception of juvenile rainbow trout during winter, rock was the second most frequently used substrate. Rock and silt substrate together represented between 63 and 91% of the substrate used during random swimming.

Stationary swimming. During the winter, the activity of stationary swimming also occurred frequently in pools. Rock and silt were both frequently utilized for this activity during the winter (Table 9). The increased use of rock over silt for juvenile cutthroat and rainbow trout could be indicative that this activity usually occurred at the edge of or within the thalweg.

During winter, adult cutthroat trout frequently fed along the top ridge of sandbars while stationary swimming. This may be why they had such a high use of silt substrate in the winter.

In the summer, the shallower areas, such as glides and rapids, were used primarily for stationary swimming. These areas have a high frequency of rubble substrate. This is reflected to some extent by the substrate choices. Rubble is used more often by rainbow trout during summer stationary swimming than at any other time. The frequent use of the other substrate types indicates that the specific microhabitat chosen by the fish often did not contain the predominant substrate (rubble) of the area. Usually the fish were found in a location with a reduced velocity (i.e., behind a rock, in a depression, in a small back eddy) which is often reflected by the presence of finer substrate such as gravel or silt. Rock substrate often indicates high mean
Table 9. The percent utilization of four substrate types for all flows for stationary swimming during winter and summer 1981.

<table>
<thead>
<tr>
<th>Substrate Type</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>51</td>
<td>21</td>
</tr>
<tr>
<td>Rubble</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Gravel</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Silt</td>
<td>18</td>
<td>42</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>22</td>
<td>42</td>
</tr>
<tr>
<td>Rubble</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Gravel</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Silt</td>
<td>55</td>
<td>20</td>
</tr>
</tbody>
</table>
column velocities and a high degree of bottom roughness. The latter provides many spaces of reduced velocity which the fish often occupy.

The predominant use of silt substrate by juvenile cutthroat trout reflected their tendency to remain in quiet water near shore through most of the summer.

Light

**Winter.** Light levels were similar between random and stationary swimming during the winter for each life stage (Table 10). Only juvenile cutthroat trout had a significant ($P < 0.05$) difference in mean light values between the two activities. The 90% range was identical for both activities and all life stages. These ranges indicate that the trout used a wide variety of light values during the midday period. They also indicate that there appeared to be well defined upper and lower limits to the light used by the trout.

**Summer.** Mean light values during summer were significantly ($P < 0.05$) higher than during winter for both activities and all life stages (Table 10). The increase in mean values would be expected from increased light intensity during the summer and the fact that the fish occupied shallower water during the summer.

The lower 90% range value tended to be higher in summer than in winter. But with the exception of random swimming juvenile rainbow trout, the upper 90% range did not show any increase over winter.
Table 10. The average light value (% of full sunlight) and 90%* range ( ) for all flows during winter and summer 1982.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>4.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Swimming</td>
<td>(.5 - 50)</td>
<td>(.5 - 50)</td>
</tr>
<tr>
<td>Random</td>
<td>5.6</td>
<td>5.8</td>
</tr>
<tr>
<td>Swimming</td>
<td>(.5 - 50)</td>
<td>(.5 - 50)</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>10.5</td>
<td>11.7</td>
</tr>
<tr>
<td>Swimming</td>
<td>(5 - 50)</td>
<td>(1 - 50)</td>
</tr>
<tr>
<td>Random</td>
<td>17.9</td>
<td>8.6</td>
</tr>
<tr>
<td>Swimming</td>
<td>(5 - 50)</td>
<td>(.5 - 50)</td>
</tr>
</tbody>
</table>

*Five percent or less of all observations were below or above the given range.
The raw data indicated the upper 90% range for random swimming juvenile rainbow trout (Table 10) was extended because a single group of juveniles were observed six days after stocking in 60% full light. All other observations of juvenile rainbow trout during the summer were at 50% light or less.

Flow change observations

On five occasions, the diver observed fish responses during prearranged flow changes. Three of the observations were made in March 1981 and two in March 1982. These observations, although limited in scope, help explain and substantiate some of the variable changes among flows noted in previous sections.

Vertical adjustments

As flows increased on two occasions, stationary swimming fish were observed to decrease their fish depth (distance to the bottom). Since water velocity is generally lowest near the stream bottom, this reduction in fish depth partially, but not totally, compensated for the increased velocities produced by increased flows. These changes account for both the fact that fish velocity did not increase as much as mean velocity with increasing flows and for the decrease in fish depth with increasing flows.

Fish also were observed to change their stations slightly by relocating behind small (<30 cm in height) rocks and by utilizing depressions in the stream bottom to further reduce fish velocity. In one instance, a fish was observed to change positions as flows began to increase. After the flows had completely increased the
fish velocity at the new position was 34 cm/sec. The position which had been originally occupied by the fish now had a velocity of 67 cm/sec. The latter velocity is much higher than trout in the Green River normally utilize.

Along with reducing their depth, fish were also observed to travel shorter distances (both vertically and laterally) to feed. This meant that they were also reducing their burst energy expenditures. Fish also changed their rheotactic orientation while feeding. At low flows (either before or after a flow change) fish were observed to turn and face downstream while chasing food particles (negative rheotaxis). During medium and high flows, they would consistently face upstream (positive rheotaxis) while feeding or changing positions.

Feeding rates were also observed to change directly with flow changes. Feeding rates were reported on two occasions as infrequent or not observable before flow increases and as high as once every five seconds immediately after a flow increase.

Horizontal adjustments

A different reaction than altering distance from the bottom was observed for some random and stationary swimming fish during flow changes. Some fish changed location to find conditions similar to those found previous to the flow change.

One observation involved a group of random swimming fish located in a pool. These fish were located in quiet water near a location where the water velocity was much higher (a sheer edge). As the flow increased, the sheer edge moved towards shore approx-
imately 2 - 3 m, as did the fish. The net result was a change in absolute location for the fish but no change in velocities nor in relation to the current edge.

In a second case, juvenile and adult rainbow trout were observed engaged in stationary swimming during a flow increase. While the larger adults reacted as described earlier for this activity, the juveniles and smaller adults left their locations and were later found in a back eddy. The velocities in this new location were lower than the ones in which the fish were originally located.

This type of response would help explain why both fish and mean velocities for stationary swimming juvenile rainbow trout decreased as flows went from medium to high (Tables 2 and 4). The fish were relocating to areas (often a back eddy) of greatly reduced velocities rather than remaining in higher velocities.

**Vegetative cross sections**

Vegetative data were collected during three seasons: October - November 1980, March 1981, and August 1981. For the first season, all cross sections except number five were surveyed (Figure 2). For the March and August collections, only cross sections two, four, seven, and eight were surveyed. These four were chosen because they were representative of the different channel and vegetation types in the intensive study site.

The primary plant groups observed were Chara sp., Zannichellia palustris, Cladophora sp., and Ranunculus sp. Diatoms were not recorded although they did exist. Although
never found within the intensive study area, *Potamogeten crispus* was first observed in other parts of the study area during the summer 1981. By the conclusion of the study in April 1982, this species was observed relatively frequently in the study area.

None of the above plants were ever found above the low water (800 cfs) line. This demarcation was very distinct. *Zannichellia* and *Ranunculus* were generally found on fine silt substrate in low (<18 cm/sec) velocity water. *Chara* could be found in similar habitat, but it was also observed in a combination of rubble and silt substrate and in higher velocities (up to 50 cm/sec). *Cladophora* was found exclusively attached to rock and rubble and in moderate to very high velocities (85 cm/sec and more). Often the most luxuriant growth of *Cladophora* was found in rapid areas of very high velocities and low depths.

Utilizing the data from the first series of cross sections, the five substrate types were found in the following percentages: rock, 33; rubble, 43; gravel, 3; nonvegetated silt, 9; and plants on silt, 12. These percentages represent the cross sections only and are not a quantitative representation of either the intensive study area nor the entire river bottom, but they do agree with subjective observations made over the entire study area.

All plants (both macrophytes and algae) appeared to be actively growing during the first sampling in October and November. From mid-December through the March sampling, essentially all plants appeared to be dead or decomposing. By late April, the plants were again actively growing.
Invertebrate samples

Invertebrate samples were taken during three different seasons: December 1980, April 1981, and July 1981. For each season, each substrate type (rock, rubble, gravel, nonvegetated silt, and plants on silt) was sampled three times. The three replicates for each substrate type were taken from three different locations within the intensive study area during the December sample. For the other two seasons, the replicates were made at the same location for each substrate type. The samples were processed by an independent lab (Tables 11 - 13), and have been summarized in Table 14.

Plant beds growing on silt consistently had the highest density by weight of invertebrates (Table 14). *Gammarus lacustris* accounted for 73 to 98% of the invertebrate weight for this substrate. Invertebrate density for this substrate exhibited a great deal of fluctuation, and appeared to lag behind the annual growth and demise cycle of the plant beds. *Gammarus* were also abundant in the other four substrate types during the December and July samples. Chironomids comprised much of the weight in the April sample for nonvegetated silt, gravel, rubble, and rock substrate.

The five types of substrate sampled were a good representation of the available substrate found in the study area, but as mentioned in the previous section, the five types did not occur with equal frequency.
Table 11. Percent species composition by weight and mean total weight (g/m²) of invertebrates for five substrate types from the December 1980 sample.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Barren Silt</th>
<th>Plants on Silt</th>
<th>Gravel</th>
<th>Rubble</th>
<th>Rock (algae attached)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ephemeroptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Baetis</em> spp.</td>
<td>trace</td>
<td></td>
<td>1.2</td>
<td>30.2</td>
<td></td>
</tr>
<tr>
<td>Ephemeralidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ephemerailla inermis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichoptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropsilidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hypoptila</em> sp.</td>
<td>0.2</td>
<td>1.6</td>
<td>1.6</td>
<td>49.6</td>
<td>32.6</td>
</tr>
<tr>
<td>Brachycertridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Brachycentrurus</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Instars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limnophilaidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Psychoglypha</em> spp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Limnophora</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Simulium</em> spp.</td>
<td>trace</td>
<td>trace</td>
<td>1.2</td>
<td>1.3</td>
<td>trace</td>
</tr>
<tr>
<td>Chironomidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupae</td>
<td>0.4</td>
<td>0.7</td>
<td>4.5</td>
<td>2.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Instars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphipoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gammarus lacustris</em></td>
<td>96.1</td>
<td>97.6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oligochaeta</em></td>
<td>3.2</td>
<td>0.1</td>
<td>54.8</td>
<td>2.4</td>
<td>trace</td>
</tr>
<tr>
<td>Turbellaria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planariidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastropoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gyrulus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cladocera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Daphnia</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydracarnia</td>
<td></td>
<td></td>
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<tr>
<td>Mean Total Weight</td>
<td>19.60</td>
<td>116.19</td>
<td>2.86</td>
<td>5.24</td>
<td>1.23</td>
</tr>
</tbody>
</table>

*Data analyzed and provided in tabular form by Bio-West, Inc., Logan, UT for the U.S. Bureau of Reclamation.*
Table 12. Percent species composition by weight and mean total weight (g/m²) of invertebrates for five substrate types from the April 1981 sample.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Barren Silt</th>
<th>Plants on Silt</th>
<th>Gravel</th>
<th>Rubble</th>
<th>Rock (algae attached)</th>
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<tbody>
<tr>
<td>Ephemeroptera</td>
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<td>Baetidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Baetis</em> spp.</td>
<td>0.2</td>
<td>0.6</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemereellidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ephemereella inermis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>Trichoptera</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hydroptilidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hydroptila</em> sp.</td>
<td>19.5</td>
<td></td>
<td>1.5</td>
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<td>19.2</td>
</tr>
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<td>Brachycentridae</td>
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<td></td>
</tr>
<tr>
<td><em>Brachycentrus</em> sp.</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Early Instars</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Limnephilidae</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Psychoglyphia</em> spp.</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Diptera</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Muscidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Limnophora</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simuliidae</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Simulium</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupae</td>
<td>trace</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chironomidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupae</td>
<td>74.5</td>
<td></td>
<td>89.6</td>
<td>34.0</td>
<td>48.1</td>
</tr>
<tr>
<td>Adult</td>
<td>1.9</td>
<td>0.3</td>
<td>4.9</td>
<td>0.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Hemiptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Early Instars</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>Amphipoda</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Gammarus lacustris</em></td>
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<td>0.2</td>
<td>7.1</td>
<td></td>
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<tr>
<td>Ostracoda</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annelida</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
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<td>5.5</td>
<td>63.1</td>
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<td>2.2</td>
</tr>
<tr>
<td>Turbellaria</td>
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<td></td>
<td></td>
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<tr>
<td>Planariidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastropoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyraulus</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cladocera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Daphnia</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydracarnia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean Total Weight 4.84  14.63  0.34  4.05  5.09

*Data analyzed and provided in tabular form by Bio-West, Inc., Logan, UT for the U.S. Bureau of Reclamation.*
Table 13. Percent species composition by weight and mean total weight (g/m²) of invertebrates for five substrate types from the July 1981 sample.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Barren Silt</th>
<th>Plants on Silt</th>
<th>Gravel</th>
<th>Rubble (algae attached)</th>
<th>Rock (algae attached)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ephemeroptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetis spp.</td>
<td>0.2</td>
<td>trace</td>
<td>0.3</td>
<td>18.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Ephemerellidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemerella inermis</td>
<td></td>
<td></td>
<td></td>
<td>trace</td>
<td>1.9</td>
</tr>
<tr>
<td>Trichoptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroptilidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroptila sp.</td>
<td>0.3</td>
<td>0.5</td>
<td>10.0</td>
<td>28.6</td>
<td></td>
</tr>
<tr>
<td>Brachycentridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachycerus sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Instars</td>
<td></td>
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</tr>
<tr>
<td>Limnephilidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychoglypha spp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td>Diptera</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Muscidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limnophora sp.</td>
<td></td>
<td></td>
<td></td>
<td>4.1</td>
<td>4.3</td>
</tr>
<tr>
<td>Simuliidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulium spp.</td>
<td>0.6</td>
<td>2.2</td>
<td>0.2</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Pupae</td>
<td>1.2</td>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chironomidae</td>
<td>22.2</td>
<td>7.6</td>
<td>23.3</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Pupae</td>
<td>0.9</td>
<td>0.1</td>
<td>0.5</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td>0.2</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Hemiptera</td>
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</tr>
<tr>
<td>Early Instars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphipoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gammarus lacustris</td>
<td>6.3</td>
<td>73.2</td>
<td>36.2</td>
<td>37.2</td>
<td>50.2</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>0.3</td>
<td>trace</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annelida</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>69.8</td>
<td>12.7</td>
<td>37.9</td>
<td>18.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Turbellaria</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planaridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastropoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyraulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>Cladocera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daphnia sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace</td>
</tr>
<tr>
<td>Hydracarnia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace</td>
</tr>
<tr>
<td>Mean Total Weight</td>
<td>7.39</td>
<td>21.04</td>
<td>0.21</td>
<td>7.56</td>
<td>3.32</td>
</tr>
</tbody>
</table>

*Data analyzed and provided in tabular form by Bio-West, Inc., Logan, UT for the U.S. Bureau of Reclamation.*
Table 14. Mean total weight (g/m²) of invertebrates and relative density* ( ) (g/m²) by season for five substrate types.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Barren silt</td>
<td>19.6 (1.8)</td>
<td>4.8 (0.4)</td>
<td>7.4 (0.7)</td>
</tr>
<tr>
<td>Plants on silt</td>
<td>116.2 (14.5)</td>
<td>14.6 (1.8)</td>
<td>21.0 (2.6)</td>
</tr>
<tr>
<td>Gravel</td>
<td>2.9 (0.1)</td>
<td>0.3 (0.0)</td>
<td>0.2 (0.0)</td>
</tr>
<tr>
<td>Rubble</td>
<td>5.2 (2.2)</td>
<td>4.1 (1.7)</td>
<td>7.6 (3.2)</td>
</tr>
<tr>
<td>Rock (algae attached)</td>
<td>1.2 (0.4)</td>
<td>5.1 (1.7)</td>
<td>3.3 (1.1)</td>
</tr>
</tbody>
</table>

*Relative density was calculated by multiplying the mean density (g/m²) of invertebrates for a particular substrate with the substrate's percent of occurrence along the transects within the intensive study site.
Winter 1982

Pre-test period

Introduction

Pre-test data were collected during the entire month of January 1982. During this period, flow releases never exceeded medium level (2800 cfs). This flow regime had existed since mid-November, when one of the three generators had become non-functional.

This reduced generating capacity complimented our purpose, which was to observe and monitor the microhabitat of the fish before subjecting them to the test high flow releases. The objective of this period was to determine to what extent fish microhabitat choices differed from the winter of 1981.

Distribution

Both species of fish were found in a seasonal distribution pattern very similar to that of the previous winter; however, they began to change their distribution approximately two weeks earlier than they had the previous year. Early in December 1981 both species were observed to begin concentrating in the large pools, including those that had contained few or no fish during January-March the previous year. By January 1982, the pools which remained occupied were essentially the same as those utilized during the winter 1981. The pools which had been occupied a month before in December 1981, but not in the previous winter, were again unoccupied. Since the majority of fish found in the
pools were juveniles of both species planted the previous spring, this distribution was apparently determined by existing factors rather than any memory function.

Fish velocity

Comparisons of fish velocity were made between the pre-test data and data from January 1981 (Table 15 and Figures 3 and 4). Only medium and low flows occurred during these periods each year. Low flows were predominant in 1981 and medium flows were predominant in 1982. There were not adequate observations to separate the data for the two flows so they have been combined for these comparisons.

Fish velocities were significantly ($P < 0.05$) lower in January 1982 than in January 1981 for each life stage and activity, except for random swimming adult cutthroat trout. Most differences between means for the two years were less than 5 cm/sec, which is a generally smaller difference than was observed between flow changes for the same year (Tables 2 and 3).

Water and fish depth

Most life stage used similar water depths during random swimming and slightly different water depths during stationary swimming (Table 16 and Figures 5 and 6). Part of the shift to deeper water observed for stationary swimming rainbow trout may have resulted from the tendency to concentrate observations in pools during 1982.

Fish depth (distance from the fish to the riverbed) was significantly ($P < 0.05$) greater in 1982 than in 1981 for all groups
Table 15. The average fish velocity (cm/sec) and sample size ( ) for two activities during the month of January in 1981 and 1982 for medium and low flows, combined.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>15.5</td>
<td>19.5</td>
</tr>
<tr>
<td>(171)</td>
<td>(88)</td>
<td>(54)</td>
</tr>
<tr>
<td>1982</td>
<td>11.3</td>
<td>19.9</td>
</tr>
<tr>
<td>(202)</td>
<td>(28)</td>
<td>(187)</td>
</tr>
<tr>
<td>Random swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>13.6</td>
<td>15.6</td>
</tr>
<tr>
<td>(149)</td>
<td>(130)</td>
<td>(42)</td>
</tr>
<tr>
<td>1982</td>
<td>9.1</td>
<td>10.5</td>
</tr>
<tr>
<td>(148)</td>
<td>(30)</td>
<td>(179)</td>
</tr>
</tbody>
</table>
Figure 3. Average fish velocity (cm/sec) ± one standard deviation for the activity of random swimming during January 1981 and 1982.
Figure 4. Average fish velocity (cm/sec) ± one standard deviation for the activity of stationary swimming during January 1981 and 1982.
Table 16. The average water depth (cm) and sample size ( ) for two activities during the month of January in 1981 and 1982 for medium and low flows, combined.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stationary swimming</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>488 (171)</td>
<td>453 (88)</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>455 (202)</td>
<td>429 (28)</td>
</tr>
<tr>
<td>1981</td>
<td>547 (149)</td>
<td>461 (130)</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>496 (148)</td>
<td>473 (30)</td>
</tr>
</tbody>
</table>

*Indicates a significant (P<.05) difference in mean water depth between 1981 and 1982 for the same life stage and activity.
Figure 5. Average water depth (m) and fish depth (distance from the bottom, m) for the activity of random swimming during January 1981 and 1982.
Figure 6. Average water depth (m) and fish depth (distance from the bottom, m) for the activity of stationary swimming during January 1981 and 1982.
during stationary and random swimming (Table 17 and Figure 6). Part of this increase in height, especially for stationary swimming, may have resulted from the tendency to make observations primarily in pools during 1982. All groups chose greater fish depths in 1982 than in 1981, but juvenile cutthroat trout had significantly ($P < 0.05$) greater fish depths for both activities than any other life stage during 1982. This produced a physical separation from the other life stages which was discernable while diving.

This type of spatial separation did not occur in 1981 for random swimming. For stationary swimming in 1981, juvenile cutthroat trout were located higher than other groups in the water column, but the absolute difference was much less than in 1982.

**Substrate**

All life stages and activities utilized similar substrate types between January 1981 and 1982 (Table 18). The predominant substrates used by all groups of fish during stationary swimming were rock and rubble. Silt substrate was used more often during random swimming than during stationary swimming. Gravel was the most infrequently used substrate.

**High flow period**

**Flow schedule**

High flow releases ($>3600$ cfs) were requested and granted through most of February 1982 to determine both the effects on microhabitat variables and on fish distribution. Details of
Table 17. The average fish depth* (cm) and sample size ( ) for two activities during the month of January in 1981 and 1982 for medium and low flows, combined.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stationary swimming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>81</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>(171)</td>
<td>(88)</td>
</tr>
<tr>
<td>1982</td>
<td>262</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>(202)</td>
<td>(28)</td>
</tr>
<tr>
<td><strong>Random swimming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>133</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>(149)</td>
<td>(130)</td>
</tr>
<tr>
<td>1982</td>
<td>288</td>
<td>162</td>
</tr>
<tr>
<td></td>
<td>(148)</td>
<td>(30)</td>
</tr>
</tbody>
</table>

*Fish depth is the distance of the fish from the river bottom.
Table 18. The percent of rainbow and cutthroat trout observed utilizing different substrate types in January 1981 and 1982 at medium and low flows, combined.

<table>
<thead>
<tr>
<th>Substrate type</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td>48</td>
<td>42</td>
</tr>
<tr>
<td>Rubble</td>
<td>46</td>
<td>21</td>
</tr>
<tr>
<td>Gravel</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Silt</td>
<td>7</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>58</td>
<td>34</td>
</tr>
<tr>
<td>Rubble</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Gravel</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Silt</td>
<td>28</td>
<td>13</td>
</tr>
</tbody>
</table>
these releases were taken from the continuous recording chart located in Flaming Gorge Dam (Table 19). The actual timing, duration, and level of flows were a combination of a requested test schedule and the physical limitations based on generating capacities at the time, power demand, and load limits of the transmission lines. During the first two weeks of February, high flows were released from Monday through Friday with scheduled interruptions during the weekend. This allowed the UDWR to sample the fish via electrofishing. Beginning on 16 February, the test was scheduled to run for as many consecutive days as possible. High flows were released over the next 11 days with the exception of 19 February.

From 1 February through 26 February, there were 286 h of high (>3600 cfs) flow releases, for a mean release of 11 h/day of high flows. From 16 February through 26 February, there were 144.75 h of high releases, with a mean release of 13 h/day.

The longest consecutive series of high releases extended for seven days, between 20 February and 26 February, inclusive. There were two calendar days (0 - 2400 h) of continuous high releases and six calendar days with 20+ h/day of high releases.

For comparative purposes, the high flow releases which occurred from 21 February through 6 March, 1979 are also presented (Table 19). This was a time of heavy power demand which produced 14 consecutive days of high flow releases of 8+ h/day. During this period there were a total of 227 h of high flow releases with a mean of 16 h/day. Within this period were 11 days (22 February through 4 March) of 10+ h/day of high flows with a mean
Table 19. Schedule of the high flow test releases from 1 February through 26 February, 1982 and from 21 February through 6 March, 1979.

<table>
<thead>
<tr>
<th>Date</th>
<th>Release (cfs)</th>
<th>Duration (hours)</th>
<th>Date</th>
<th>Release (cfs)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/1</td>
<td>4450</td>
<td>12.50</td>
<td>2/21</td>
<td>4200</td>
<td>8.75</td>
</tr>
<tr>
<td>&quot; &quot;</td>
<td>3600</td>
<td>1.50</td>
<td>2/22</td>
<td>4200</td>
<td>15.50</td>
</tr>
<tr>
<td>2/2</td>
<td>4300</td>
<td>21.00</td>
<td>2/23</td>
<td>4200</td>
<td>21.25</td>
</tr>
<tr>
<td>2/3</td>
<td>4200</td>
<td>16.50</td>
<td>2/24</td>
<td>4200</td>
<td>10.25</td>
</tr>
<tr>
<td>2/4</td>
<td>3900</td>
<td>21.50</td>
<td>2/25</td>
<td>4200</td>
<td>18.75</td>
</tr>
<tr>
<td>2/5</td>
<td>4300</td>
<td>24.00</td>
<td>&quot; &quot;</td>
<td>3600</td>
<td>1.25</td>
</tr>
<tr>
<td>2/8</td>
<td>3760</td>
<td>10.75</td>
<td>2/26</td>
<td>4200</td>
<td>21.50</td>
</tr>
<tr>
<td>2/9</td>
<td>3600</td>
<td>9.50</td>
<td>2/27</td>
<td>4200</td>
<td>20.75</td>
</tr>
<tr>
<td>2/10</td>
<td>4200</td>
<td>3.00</td>
<td>&quot; &quot;</td>
<td>3700</td>
<td>1.25</td>
</tr>
<tr>
<td>2/11</td>
<td>3600</td>
<td>9.00</td>
<td>2/28</td>
<td>4200</td>
<td>11.00</td>
</tr>
<tr>
<td>2/12</td>
<td>4200</td>
<td>12.50</td>
<td>3/1</td>
<td>4200</td>
<td>17.75</td>
</tr>
<tr>
<td>2/16</td>
<td>4200</td>
<td>11.50</td>
<td>&quot; &quot;</td>
<td>3700</td>
<td>1.00</td>
</tr>
<tr>
<td>2/17</td>
<td>4200</td>
<td>12.50</td>
<td>3/2</td>
<td>4000</td>
<td>20.00</td>
</tr>
<tr>
<td>2/18</td>
<td>4200</td>
<td>7.00</td>
<td>3/3</td>
<td>4200</td>
<td>20.00</td>
</tr>
<tr>
<td>2/20</td>
<td>4200</td>
<td>20.00</td>
<td>3/4</td>
<td>4200</td>
<td>18.00</td>
</tr>
<tr>
<td>2/21</td>
<td>3700</td>
<td>10.50</td>
<td>3/5</td>
<td>4200</td>
<td>8.00</td>
</tr>
<tr>
<td>2/22</td>
<td>4200</td>
<td>11.75</td>
<td>3/6</td>
<td>3900</td>
<td>12.00</td>
</tr>
<tr>
<td>2/23</td>
<td>3600</td>
<td>10.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/24</td>
<td>3700</td>
<td>16.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/25</td>
<td>3600</td>
<td>21.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/26</td>
<td>3700</td>
<td>24.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
release of 18 h/day high flows. There were no periods of 24 consecutive hours of high releases but there were a total of five days with 20+ h of high flow releases. Flows prior to and after this period were at considerably lower volumes.

General observations

The last observation of fish prior to the high flow tests was on 20 January. Turbidity was a problem during the first week of tests because no high flows had been released for the previous two months. As a result, only 2 days of observations were made during the first week. During this week, fish were observed but only three of the fish were juvenile cutthroat trout. This in itself was unusual, since the juvenile cutthroat trout were generally observed in large groups.

During the second week of high flows, juvenile cutthroat trout were not found in areas where they had been prevalent during the pre-test period. All other groups of fish were observed in their traditional winter locations. Juvenile cutthroat trout continued to be rare during all diving observations, and only a total of 5 were observed during the last three weeks of the high flow tests. During the high flow test, the UDWR did find a small number of juvenile cutthroat trout in their electrofishing samples (B. Bonebrake, UDWR, pers. comm.).

With the exception of the apparently immediate and almost total emigration of the juvenile cutthroat trout, the other life stages did not exhibit any gross changes in distribution or variable ranges during the period of high flow tests. Fish continued
to be found concentrated in the same pools they had occupied prior to the tests and during the previous winter. Although all three groups (juvenile and adult rainbow trout and adult cutthroat trout) occupied the pools, the adult rainbow trout were found in non-pool, higher velocity areas more frequently than the other two groups. There was no discernable change in the numbers of fish observed by the diver for each of these three groups during the tests. Feeding continued to be a commonly observed activity, with possibly an increased frequency during the test. The general distribution and relative location of the fish in the pools did not change. Location, with regard to the bottom, may have shifted as a result of current shifts and changes in velocity and water depth produced by the higher flows.

Physical variables

**Fish velocity.** During the high flow test, the calculated average fish velocity for each life stage and activity was equal to or lower than fish velocities measured during medium flows in winter 1981 and summer 1981 (Table 20). The single exception was for random swimming juvenile cutthroat trout during the summer, when they were found in significantly ($P < 0.05$) lower velocities, probably as a result of recent stocking. In eleven out of fifteen comparisons, the velocities during the test flows were significantly ($P < 0.05$) less than during medium flows in 1981 (Table 20). For the four other cases, there was no significant ($P > 0.05$) difference between the flows.
Table 20. The average fish velocity (cm/sec) during medium flows in winter and summer 1981 and during the high flow test of 1982.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary Swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter 81</td>
<td>25*</td>
<td>22</td>
</tr>
<tr>
<td>Summer 81</td>
<td>21*</td>
<td>29*</td>
</tr>
<tr>
<td>Test 82</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Random Swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter 81</td>
<td>13</td>
<td>13*</td>
</tr>
<tr>
<td>Summer 81</td>
<td>8†</td>
<td>10*</td>
</tr>
<tr>
<td>Test 82</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>

*Indicates average fish velocity was significantly (P<.05) greater for the 1981 season than during the 1982 test.
†Indicates average fish velocity was significantly (P<.05) less for the 1981 season than for the 1982 test.
Water depth. For the activity of stationary swimming, each life stage occupied significantly ($P < 0.05$) greater water depth during the high flow test compared to the depth utilized prior to high flows (Table 21). For random swimming, each life stage except adult cutthroat trout occupied significantly ($P < 0.05$) shallower water depths during the high flows than they had occupied before the test. For each life stage and activity, water depths between the test period and medium flows from winter 1981 were significantly ($P < 0.05$) different (Table 22). Juveniles were always found in deeper water during 1981 medium flows and adults were usually in deeper water during 1982 test flows.

Fish depth. For the activity of stationary swimming, juveniles of both species had significantly ($P < 0.05$) greater fish depths (distance to the bottom) during the pre-test period than during the test period (Table 23). There was no significant ($P > 0.05$) difference in fish depth for adults between the two periods. For the activity of random swimming, there was a significant ($P < 0.05$) decrease in fish depth during the test, compared to before the test. For the activity of stationary swimming, mean fish depth during the test period was higher than for medium flows in 1981. Fish depth was lower during the test period than during medium flow in 1981 for the activity of random swimming.
Table 21. The average water depth (cm) and sample size ( ) at different times during the winter 1982 for two activities.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cutthroat trout</th>
<th></th>
<th>Rainbow trout</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td><strong>Stationary Swimming</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>455</td>
<td>429</td>
<td>458</td>
<td>443</td>
</tr>
<tr>
<td></td>
<td>(202)</td>
<td>(28)</td>
<td>(187)</td>
<td>(130)</td>
</tr>
<tr>
<td>Test flows</td>
<td>567</td>
<td>494</td>
<td>568</td>
<td>560</td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td>(75)</td>
<td>(136)</td>
<td>(238)</td>
</tr>
<tr>
<td>Post-test</td>
<td>*</td>
<td>347</td>
<td>408</td>
<td>354</td>
</tr>
<tr>
<td></td>
<td>---</td>
<td>(41)</td>
<td>(49)</td>
<td>(131)</td>
</tr>
<tr>
<td><strong>Random Swimming</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>496</td>
<td>473</td>
<td>510</td>
<td>503</td>
</tr>
<tr>
<td></td>
<td>(148)</td>
<td>(30)</td>
<td>(179)</td>
<td>(148)</td>
</tr>
<tr>
<td>Test flows</td>
<td>340</td>
<td>476</td>
<td>470</td>
<td>471</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(35)</td>
<td>(12)</td>
<td>(41)</td>
</tr>
<tr>
<td>Post-test</td>
<td>*</td>
<td>302</td>
<td>599</td>
<td>563</td>
</tr>
<tr>
<td></td>
<td>---</td>
<td>(20)</td>
<td>(21)</td>
<td>(35)</td>
</tr>
</tbody>
</table>

*Juvenile cutthroat not observed after the high flow test.
Table 22. The average water depth (cm) and sample size ( ) during medium flows in winter 1981 and the high flow tests in 1982 for two activities.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>607</td>
<td>429</td>
</tr>
<tr>
<td></td>
<td>(192)</td>
<td>(241)</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>1982</td>
<td>567</td>
<td>494</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(75)</td>
</tr>
<tr>
<td>Random swimming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>484</td>
<td>522</td>
</tr>
<tr>
<td></td>
<td>(192)</td>
<td>(147)</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>1982</td>
<td>340</td>
<td>475</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(35)</td>
</tr>
</tbody>
</table>

*Indicates a significant (P<.05) difference in mean water depth between 1981 and 1982 for the same life stage and activity.
Table 23. The average fish depth* (cm) and sample size ( ) at different times during the winter 1982 for two activities.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>262 (202)</td>
<td>136 (28)</td>
</tr>
<tr>
<td>Test flows</td>
<td>130 (6)</td>
<td>151 (75)</td>
</tr>
<tr>
<td>Post-test</td>
<td>** ---</td>
<td>67 (41)</td>
</tr>
</tbody>
</table>

**Juvenile cutthroat trout were not observed after the high flow test.

*Fish depth is the distance of the fish from the river bottom.
Activity

There was a consistent increase in the ratio of stationary swimming to random swimming during the high flow test compared to before and after the test and during medium flows in winter 1981 (Table 24). The proportion of pool to nonpool habitat sampled during the test was equal to the pre-test proportion and higher than during the post-test and 1981 periods. Increased sampling of pool habitat would tend to bias the activity ratio in favor of random swimming. Thus the observed increase in stationary swimming appears real and not an artifact of sampling.

Post-test period

General distribution

Commencing with the first dive observations (3 March 1982) after the cessation of the high flow test, fish were often observed in generally shallower water, closer to the bottom, and in higher fish velocities than they had been found during the tests. This observation was true for all life stages during stationary swimming. For the activity of random swimming, only the adult cutthroat trout were found in the shallower faster water (Tables 21 and 23). Although the ratio of stationary to random swimming decreased during the period, it still remained higher than during the pre-test period (Table 23).

In general, the fish were leaving the center pool areas they had occupied for the previous three months and moving to somewhat shallower, higher velocity areas often located adjacent to the pools. During this period, higher mean water velocities were ob-
Table 24. Percent occurrence of the two activities, stationary and random (-) swimming during winter 1981 and 1982.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td>Winter 1981</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>53 (47)</td>
<td>39 (61)</td>
</tr>
<tr>
<td>Medium</td>
<td>50 (50)</td>
<td>62 (38)</td>
</tr>
<tr>
<td>High</td>
<td>32 (68)</td>
<td>42 (58)</td>
</tr>
<tr>
<td>Winter 1982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>58 (42)</td>
<td>48 (52)</td>
</tr>
<tr>
<td>Test flows</td>
<td>75 (25)</td>
<td>68 (32)</td>
</tr>
<tr>
<td>Post-test</td>
<td>*</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(33)</td>
</tr>
</tbody>
</table>

*Juvenile cutthroat not observed after the high flow test.
served for both activities and all remaining life stages than had been observed during the test period (Table 25). These increases were significant (P < 0.05) except during stationary swimming for adult cutthroat and juvenile rainbow trout. Juvenile cutthroat trout continued to be totally absent from all diving observations.

The fish were still clumped together in large groups at this time, often near the pools occupied during the earlier part of the winter. They were not distributed uniformly throughout the river, as they were during summer and fall.

The change in location was accompanied by a change in spatial distribution. Fish were commonly distributed in a three-dimensional orientation while occupying the pools. As they moved into the shallower areas, they were more commonly distributed in a horizontal plane, similar to their summer distribution.

This emigration from the pools was similar to the trend observed in late March and early April 1981. In 1982 it occurred earlier, as had the migration into the pools.

Population density

Throughout March, there appeared to be a general decline in total numbers of fish, especially of the juvenile rainbow trout. As scuba observations of fish declined, the technique was altered. Two divers snorkeled sections of the river in an attempt to locate the fish. The divers also watched for any signs of redd excavation, since it was hypothesized that spawning could have caused the fishes' relocation.
Table 25. The average fish velocity (cm/sec) and sample size ( ) during and after the high flow tests in 1982 for two activities.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cutthroat trout</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juvenile</td>
<td>Adult</td>
</tr>
<tr>
<td><strong>Stationary Swimming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test flows</td>
<td>14 (6)</td>
<td>21 (75)</td>
</tr>
<tr>
<td>Post-test</td>
<td>*</td>
<td>24 (41)</td>
</tr>
<tr>
<td><strong>Random Swimming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test flows</td>
<td>12 (2)</td>
<td>6 (35)</td>
</tr>
<tr>
<td>Post-test</td>
<td>*</td>
<td>10 (20)</td>
</tr>
</tbody>
</table>

*Juvenile cutthroat not observed after the high flow test.
The entire stretch of river from the dam to Red Creek was snorkeled at least once, with the majority of this area covered several times. Fish were generally observed in dispersed groups or as single individuals. Between sightings there were often large stretches of river where few or no fish were observed.

The majority of fish sightings were made in relatively shallow, fast, and white water sections of the river. In many cases these sections of the river were heavily strewn with mid-stream boulders. The majority of fish observed were large, healthy looking adults. Rainbow trout were more commonly sighted than cutthroat trout.

No juvenile cutthroat trout were ever observed while snorkeling, and juvenile rainbow trout were observed less frequently than adults. During this period, the UDWR found a small number of all life stages while electrofishing, but the total number of all fish captured declined, especially juvenile trout (B. Bonebrake, UDWR, pers. comm.).

Spawning activity

Redds that seemed to be active were observed at two different locations in the main river. One area was located just above Little Hole and the other was located approximately 2 km below it. In both cases, adult rainbow trout were observed in the vicinity. In the lower area, a pair of adult rainbow trout was observed above the redd on one sighting and a single adult was observed on the same redd at a later date. None of the reds were excavated to confirm egg deposition.
All potential spawning tributaries between the dam and Red Creek were checked for spawning activity. Each one was followed upstream from its mouth to the first barrier to fish access. Often the mouth of the stream was already inaccessible to fish. These streams were Dripping Springs, Gorge Creek, Goslin Creek, Little Davenport, Jackson Creek, and Red Creek. Pipe Creek was not specifically checked for spawning because of its obvious inaccessibility. At the time we observed each of these creeks there were no signs of spawning activity in any of them. Most did not appear accessible or had bottoms composed of substrate too coarse for spawning. Red Creek was too turbid to determine if spawning had occurred in its limited area of accessibility. During periods of heavy spring runoff, some of the streams may have been accessible for a greater distance upstream.

Interstitial activity

A different activity than previously observed in the Green River was discovered while snorkeling for the relocated fish. Juvenile rainbow trout were observed using the interstitial areas of a riprapped bank. The bank was constructed as part of the dam access road, and represents a very unique habitat type along the river.

The fish were observed to swim within the crevices and to occasionally leave the bank and move into the open water. It appeared that there were occasions when the fish ceased swimming and would enter resting activity (remaining stationary without swimming), but this was difficult to ascertain because viewing
them continuously was often difficult or impossible.

The small size of the fish indicated that they probably resulted from natural reproduction. They were considerably smaller than the juvenile rainbow trout which had been planted during the previous spring. This was further supported by observations made by the UDWR while electrofishing in the area (B. Bonebrake, UDWR, pers. comm.).

The juvenile rainbow trout using these interstitial areas occupied significantly \( P < 0.05 \) lower average fish depths, light intensities, and fish velocities than had been previously found for either stationary or random swimming in the Green River (Table 26). The number of fish that were observed in the riprap was low, and this did not appear to be a normal activity for the majority of the population.
Table 26. Average values and sample size ( ) for three variables during three activities for juvenile rainbow trout.

<table>
<thead>
<tr>
<th>Activity and Season</th>
<th>Fish depth* (cm)</th>
<th>Light intensity (% full sunlight)</th>
<th>Fish velocity (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary swimming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter 1981 (176)</td>
<td>82.0</td>
<td>4.0</td>
<td>23 (169)</td>
</tr>
<tr>
<td>All flows</td>
<td>(172)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random swimming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter 1981 (111)</td>
<td>140.0</td>
<td>3.2</td>
<td>15 (101)</td>
</tr>
<tr>
<td>All flows</td>
<td>(111)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstitial activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter 1982 (13)</td>
<td>4.3</td>
<td>0.0016</td>
<td>2 (13)</td>
</tr>
<tr>
<td></td>
<td>(13)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Fish depth is the distance of the fish from the river bottom.
DISCUSSION

Winter and Summer 1981

Modeling application of summary tables

Introduction

Microhabitat data and models are relatively new concepts in fisheries and their application is still in a developing state. This section contains some ideas on how the data might be applied. It is hoped that these concepts will serve as a basis for discussion and to stimulate new ideas, with the eventual goal being the development of uniform standards and techniques.

Habitat rating systems

Probability curves. A practice utilized by the Instream Flow Group (developers of the IFG-4 model) is to develop the summary tables into probability-of-use curves (Bovee and Cochnauer 1977). This technique is preferable to developing normal curves using standard deviations, since most variables have skewed distributions.

Probability-of-use curves may be limited because they adhere too closely to the raw data and because of the vagaries associated with clumped data and limited habitat. For example, distribution of intermediate water depths in a river may be limited by river morphology. Most riffles may be 1 m or less while most pools are 4 to 6 m. Thus the intermediate depths may be found
only at the zone between pools and riffles. This could produce a curve with an artificial dip. A second problem with this methodology is that slight fluctuations in the variable value often cause large changes in the curve. Some critics have questioned whether the curves are truly that precise.

**Tolerance intervals.** To avoid these types of problems, or those caused by highly clustered data, I would suggest the use of tolerance intervals. This would allow the modeler to determine a variable range which is utilized by a defined proportion of the population. The narrower the range, the less likely that undesirable habitat is included. The use of tolerance intervals would have the advantage of not being affected by subtle changes in frequencies of observations and appears to more closely approximate field observations. That is, near the optimum for a specific variable, subtle changes seem to have little effect upon the fish, whereas changes near the outer ranges appear more important.

The preceding statement should not be interpreted as implying that accurate microhabitat measurements are unnecessary. It is imperative that data for microhabitat variables be highly accurate. For example, substituting mean column velocity for fish velocity often produces extremely erroneous results. But once the optimum fish velocity is accurately determined, there will be a range surrounding this optimum that will be essentially as acceptable to the fish as the optimum point.

Generally speaking, I envision a curve drawn from these tolerance intervals as having a relatively flat top (near the op-
timum) with at least one relatively steep side (Figure 7). Since many variables have skewed distributions, the other side often descends more gradually.

Throughout the report, reference is made to the mean of a variable. Other central measurements such as the mode or median could be substituted. All of these are misleading, however, in that they refer to a point value. Biologically, it is more realistic to refer to a preferred range, bordered by an acceptable range and a marginal range, all of which are surrounded by the unacceptable range.

Figure 7 was produced by using incremental tolerance intervals and giving a different preference rating to each. A very simplistic technique which defined only acceptable and unacceptable habitat (essentially a single tolerance interval) was able to predict where up to 84% of the brown trout would be located (Helm et al. 1982). Nonparametric tolerance intervals (Remington and Schork 1970, Somerville 1958) should be used because a fish's use of a variable is seldom normally distributed.

Necessary sub-groups

Microhabitat data has usually been analyzed by species and life stage. Occasionally such data has been separated by season. The data from this study indicates that all of these sub-divisions are important for the study species in the Green River. In addition, differences are found between the activities of random and stationary swimming. Activities are a highly important, yet usually ignored, sub-category in defining microhabi-
Figure 7. Probability-of-use curve and tolerance ranges for stationary swimming adult cutthroat trout during winter (all flows).
tat. Data are never presented in this report with both activities combined, since there is every indication that such combinations would be grossly misleading. For example, if the activities were combined, it would appear that fish velocities of approximately 36 cm/sec are preferred velocities for adult rainbow trout. But this is true only for the activity of stationary swimming, and such velocities are very marginal for the activity of random swimming. The same trend holds true for the other variables and life stages.

Velocity predictions

Error is introduced when mean velocity is substituted in the model for fish velocity because of the large differences between the two. For example, the average mean velocity for stationary swimming adult rainbow trout was 83% higher than the average fish velocity for all flows during the summer. Much of the difference can be explained by examining fish depth. Fish are usually much closer to the stream bottom than the depth for which mean velocity is projected. Additional error is introduced because fish utilize reduced velocities provided by substrate roughness and the edge effect produced by a meandering three dimensional thalweg. Understandably, these are difficult hydraulic variables to model, but a serious effort must be made to do so if accurate velocity projections are to be made. During the interim, limitations of the model should be acknowledged.
Precidence of variables

Six microhabitat variables have been presented in this report. The fish do not appear to give equal importance to these six variables in choosing microhabitat. The model can and should be manipulated to account for these differences, to the extent that the relative importance of each variable can be determined.

Velocity appears to be a highly important variable to the fish. As was discussed in the previous section, fish velocity is a much more relevant variable than mean velocity. Fish velocity data, not mean velocity, should be used to determine microhabitat preferences and fish depth should be used to determine across which plane velocity predictions are made.

The primary importance of fish depth is in determining the distance from the bottom that other measurements and predictions should be made. Another function of fish depth is that very low values, either measured or predicted, can be indicative of excessive velocities.

Water depth appears to be another important variable in determining microhabitat for both rainbow and cutthroat trout. Water depth quantitatively reflects differences in seasonal distributions and activities. There appears to be a moderately wide but slightly different range of acceptable water depths for most life stages, activities, and seasons. There also appear to be fairly distinct upper and lower limits in most cases.

The absence of very low light levels (<0.5%) for the study species is indicative that they do not utilize overhead cover as was observed for resting brown trout (Gosse and Helm 1982).
There appears to be a well defined upper and lower light level for both species, but within this range, light intensities seem relatively unimportant. Unlike water depth, most fish were observed in light values representative of the majority of the river habitat for the particular season. Thus, light is probably less valuable than water depth or fish velocity in defining microhabitat choices for the species. The general avoidance by the fish of very high light values would indicate avoidance of the same habitat defined as unusable by the lower limit of water depth. That is, very high light intensities would be found in the shallowest water, both of which fish avoided during midday periods.

Both species of fish utilized all types of substrate for the various activities and seasons. The shifts in substrate preference that were observed for different activities and seasons appear to be indicative of the velocities and water depths selected by the fish, rather than a positive attraction to any particular substrate type. Two exceptions are discussed below. Neither rainbow nor cutthroat trout were observed to use macrophytes for cover as brown trout did in the Provo River (Gosse and Helm 1979).

Probably the major importance of substrate is in the degree of bottom roughness it provides in higher velocity areas. One important facet of substrate type is that rocks and small boulders can provide areas of reduced velocity which fish will occupy. As mentioned above, this would be important in accurate modeling. Often these areas of low velocity were not much larger than the
fish itself and were usually produced by rocks $\leq 0.5$ m in diameter. Fish seldom positioned themselves behind a boulder if it restricted their upstream vision. The other situation where substrate would be important is for spawning. Although only a little spawning was observed in this study, gravel substrate is known to be used extensively by salmonids for spawning.

Specific applications

For this study, the hydraulic model was used to predict available habitat within the intensive study area. These predictions were then extrapolated to the entire study area on the assumption that the Pipe Creek station was representative of the entire study area. To the extent that the Pipe Creek site was unrepresentative of the study area, these predictions were biased. For example, one-third of the cross sections and approximately one-half of the intensive study site consisted of a large pool, but large pools comprised probably less than 10% of the total study area.

In the summer, when fish utilized pools to only a very limited extent, this habitat was over represented for the study area as a whole. The weighting capabilities of the model should be implemented to reduce pool habitat to a more realistic proportion. Fish were heavily concentrated in pool habitat during the winter, so representing half or more of the stream bottom as large pools may be biologically correct. For example, since the fish, especially the juveniles of each species, were found predominantly in pool habitat during winter, modeling efforts should
be biased towards the pools. The availability or nonavailability of habitat in non-pool areas, according to the model, would have little real meaning since the fish do not use such areas during winter. And conversely, any loss of pool habitat in winter would have an impact far greater than the actual proportion of pool habitat found in the river.

Effects of different flow releases

Fish velocity

The variable with the most potential of being affected by increased flows is fish velocity. Excessive increases in this variable would indicate a major increase in energy expenditure. This could produce a deficit in the fishes' energy balance if drift didn't increase proportionally. Other variable shifts are of concern in that they may indicate utilization of marginal or unsuitable habitat in order to reduce energy expenditure.

The differences in fish velocity among the life stages, seasons, and activities for a given flow indicate that a range of velocities was utilized by the different groups. Adult rainbow trout, for instance, were usually found in higher fish velocities than cutthroat and juvenile rainbow trout.

Optimum fish velocities for trout in streams are above zero. Fish appeared to prefer some velocity, probably because it provided increased food availability in the form of drift. More than 80% of stationary swimming adults for both species occupied velocities at or above 18 cm/sec during the summer. This preference for moving water was further indicated by the fact that few
trout were found in the extremely large, quiet back eddies. They were usually located near areas of moderate velocities, even if not actually in them.

During winter 1981, stationary swimming fish occupied consistently higher velocities with each flow increase. For the activity of random swimming, fish velocities usually remained the same or even decreased with flow increases. Fish were generally concentrated in large pools during the winter, and the habitat utilized for random swimming was seldom more than several meters from the area where stationary swimming occurred. Thus it would appear that the fish could easily have avoided the velocity increases which occurred during stationary swimming with increasing flows. Since they did not, it would seem that the fish were actively choosing the higher velocities, probably because they afforded better feeding opportunities.

One should question when an increase in fish velocity becomes excessive, and at what level it will produce detrimental effects, since not all velocity increases are detrimental nor excessive. Juveniles, especially cutthroat trout, seek lower water velocities than adults, and possibly would be the first to exhibit an indication of excessive velocities. If flows become excessive, they might be the first group to exhibit reactions such as reduced growth, emigration, or mortality.

Juveniles of both species that had attained a length of 15 cm or more appeared to be well distributed throughout much of the river even during high flows. There were certain rapid sections of the river that contained predominantly adult rainbow trout,
but this appeared to be more a function of stream morphology than flow levels. That is, juveniles were never observed in these sections, regardless of flow levels. Juvenile rainbow trout sometimes changed their location to lower velocity areas as flows increased from low to medium. This may have been an indication of velocities above the acceptable range in certain areas of the stream.

Other variables

Except for fish depth (distance to the bottom), there were no major shifts in the other variables as a result of flow changes. Such shifts would have indicated stress and an attempt to reduce velocities by utilizing microhabitat normally considered unacceptable. Most variables remained quite stable, except fish depth, which decreased as flows increased. This decrease in fish depth was consistently observed with increases in stream discharge both in this study and in the Provo River (Gosse and Helm 1979). Changes in fish depth did not appear excessive between medium and high flows nor was fish depth reduced to an extreme limit. The mean fish depth during summer stationary swimming was between 21 - 47 cm for the different life stages and during the two winters it ranged between 43 - 262 cm. In the Provo, Logan, and Blacksmith Fork rivers, fish depth for brown trout was often below 10 cm (Gosse and Helm 1979, Gosse and Helm 1982).

Extreme clumping or concentrations of fish could indicate limitations in available microhabitat. There was clumping during
the winter, but it did not appear to result from flow changes and will be discussed in the following section.

Seasonal differences

A major concern has been that high flows would be detrimental during the winter season, since this was when losses from emigration were suspected to have occurred (Schmidt et al. 1981). It appears from this study that high flows may cause more habitat loss during the summer than the winter. This was because fish were distributed in shallow areas during the summer where flow increases produced more drastic velocity increases than occurred in pools, the predominant winter habitat.

Extensive winter use of pool habitat by the fish did not appear to be flow related. The fish utilized pool habitat during both winters. During December 1980 and 1981, when the fish moved into the pools, high flows were not occurring. Therefore, high flows do not appear to be causing the concentration of fish into pools. Other authors have also observed similar concentrations during the winter. Pettit and Wallace (1975) found mountain whitefish moving downstream and concentrating in large pools during the winter.

Winter use of pools may be a form of energy conservation. When fish velocities from this study were compared between winter and summer for a given activity, winter fish velocity was generally found to be lower. When one considers that most fish changed their activity from stationary swimming in the summer to random swimming in the winter, a greater decrease in fish veloci-
ty becomes apparent.

For the activity of stationary swimming there was also a major decrease in mean velocity during the winter. Fish did not usually maintain positions in these higher velocities, but they often traveled into them for food or to change locations. Thus fish also reduced their burst velocities (the velocities a fish must endure for short periods in order to change locations between their normal locations) in winter.

The net effect of a velocity reduction (either maintenance or burst) is a reduction of energy expenditure. Trout in the Green River effectively reduced their winter energy expenditure by moving to pools and often by occupying parts of pools so quiet that rheotaxis (orientation of the fish towards the water current) was absent or reduced. In addition, the fish's metabolic rates were also reduced because of the decrease in water temperatures during winter (Dickson and Kramer 1971, Rao 1968).

The fish also reduced their ability to obtain food during the winter since they were more concentrated in pools, reducing the feeding area available to individual trout. There is also less drift entering the quieter areas of pools than in areas with faster current (Chapman and Bjornn 1969). Possibly, reduced drift rates occurred before the fish migrated to the pools. There was a large decrease in the density of invertebrates between the December and April collections. If this decrease coincided with either the demise of plant beds or reduction in water temperature, then it would have occurred primarily in December. Such a decrease would reduce the amount of food drift.
and energy available to the fish. As energy became less available, it is conceivable that the fish reacted by reducing or having to reduce their energy expenditure until drift once again became plentiful.

Some of the adult rainbow trout were found in shallow, high velocity locations throughout all seasons. By occupying the most optimum feeding territories, they may have maintained a positive energy balance during the winter.

In summary, it appears that differences in seasonal distribution and between stationary and random swimming are energy related. If the previous statement is true, then the importance of different seasonal distributions and activities becomes apparent. During periods of high food availability, fish would locate in high velocity areas, using stationary swimming, in order to maximize food intake. This would result in high growth rates. During periods of low food availability, fish would locate in areas of low velocity, i.e. pools, as a method of conservation to prevent energy deficits and minimize stress. Location of fish within a pool might also be determined by drift rates. If some drift were available, fish might use stationary swimming to maintain position in or near the thalweg. If little or no drift were present, fish might be observed random swimming in the very low velocity areas.

Vegetative and invertebrate samples

One of the objectives in obtaining vegetative data and invertebrate samples was to determine whether a link existed
between the plant beds, *Gammarus* density, and food utilization by trout. The data obtained indicates that the *Gammarus* were strongly associated with the macrophyte beds and to a lesser extent with *Cladophora*.

The invertebrate data also indicated that at times *Gammarus* represented the bulk of invertebrate density in the river and at other times was a major component. The original hypothesis that plants were important in the trout food chain is therefore supported.

Samples were taken too infrequently to accurately determine seasonal fluctuations in density and periods during which the highest densities of *Gammarus* occur. Moreover, the food habits of trout in the Green River have not been documented. Therefore, there is no documented link between vegetative growth and the sport fishery.

Some informal information from fishermen indicates that *Gammarus* were frequently and often dominantly found in trout stomachs during the summer. No information on food utilization is available from the end of September to the end of May. There are no data on caloric contribution of the various invertebrates to the trout diet or seasonal diet utilization for trout in the study area.
Winter 1982

Pre-test period

Introduction

The purpose of observing the fish prior to the onset of the high flow test was to provide a check to determine whether micro-habitat choices differed from those of winter 1981. There was no way to provide a control during the actual high flows since the entire river is subjected to the same flow regime.

As might be expected in a field study, there were differences between January 1981 and January 1982 which make comparisons between the two years somewhat subjective. Air temperatures were much lower during winter 1982 than during winter 1981. Low flows predominated in January 1981 and in January 1982 medium flows were prevalent. Comparisons can be made for identical times or identical flows, but not for both simultaneously. In addition, fish velocity appeared to increase for both years during increased flows and as the winter seasons progressed, introducing a confounding factor into the comparisons.

Since the fish entered and left their winter distribution earlier in 1982 than in 1981, comparison of the same calendar periods between the two years may not be an exact comparison of the same biological time or season. The juvenile fish, especially the cutthroat trout, were also smaller in winter 1982 than in winter 1981 for the same time period. Comparisons of equal sized fish between the two years was, therefore, not possible.
Finally, the highly clumped winter distribution of the fish provides a potential source of error when comparing the two years. A slight shift in location of the fish or the fluctuations in water current that occur at a given point can both produce minor differences in the data. In the summer, when the fish were dispersed, these fluctuations tended to cancel each other out. But in the winter, when numbers of fish observed was high but variability among them was low, these fluctuations could result in apparent differences between test periods.

Fish velocity

Fish velocities were statistically lower in January 1982 than in January 1981 for most life stages and activities. The most probable reason for the downward shift in velocities is that in 1982, observations were made primarily in areas of heavy fish concentrations, normally pools. This was done because our purpose was to observe as many fish as possible, rather than to determine the total range utilized, as in 1981. The highest winter velocities were observed for individual fish still occupying the fast water areas, which we sampled in 1981 but largely ignored in 1982. The clumped winter distribution of the fish may have also caused some of the differences.

The ultimate question is whether there were biologically meaningful differences between January 1981 and 1982. In order to determine biological differences, the concepts of preferred, acceptable, and total habitat range should also be kept in mind. Near the center or optimum of a particular variable range, small
value changes in a variable probably have little or no biological importance. But near the extremes of a range, or in areas of rapid decrease of utilization (Figure 7), changes of the same order of magnitude may be biologically very important.

For both years, the velocities appear within the preferred or acceptable range of use. That is, although there were shifts in 1982, usually downward, they did not appear to go into areas of marginal uses as determined in 1981. The lower fish velocities observed in January 1982 compared to January 1981 could indicate a slight shift in velocity preferences. This would be most probable for the juvenile cutthroat trout, which were smaller in January 1982 than in January 1981. It is most likely, however, that these shifts represent sampling differences between the two years rather than any real biological change.

Other variables

The variables of water and fish depth, substrate, and percent occurrence of the two activities indicated no major difference between the two years. There were shifts in some cases, but comparing the preferred ranges utilized and the differences between the two years, they did not seem to be biologically excessive. The fact that a majority of the fish occupied the same pools as in the previous winter would help support this conclusion. If there had been major changes in microhabitat choices between the two years, there should have also been major changes in the macrolocation of the fish.
Juvenile cutthroat trout

One exception to the idea of similar habitat choices between the two years was exhibited by juvenile cutthroat trout. There was a major shift in fish depths utilized between the two years. They were physically isolated from the other life stages in January 1982 to a much greater degree than in 1981. Whether this resulted from the smaller size of juvenile cutthroat trout in 1982 or from some other factor is not obvious. This difference might not be considered excessive were it not for the major difference in reaction by this group to the high flows.

High flow period

Introduction

The primary purpose of the high flow test was to attempt to duplicate conditions that occurred in winter 1979. During that period, intensive high flows occurred for a 14 day period. A major loss of fish in the tailwater appears to have also occurred sometime during the winter or early spring of 1979 (Larson et al. 1982).

Comparability of high flows

The 1982 tests were designed to determine whether similar high flows would again cause the fish to emigrate. The high flow periods for 1979 and 1982 were not identical but neither was one obviously more excessive than the other. The greatest daily flow intensities occurred in 1982 with two days of complete 24 h high flows. The longest sustained period of high flow occurred in
1979, with 14 consecutive days of high flows compared to seven consecutive days in 1982. High flows continued over a longer period (26 days) in 1982, resulting in 26% more hours of high flows in 1982 than in 1979. In 1979 and 1982 there were 5 and 6 days, respectively, of 20+ h of high releases.

It is not possible to say definitely whether the 1982 test was an adequate replication of the 1979 conditions, but for each time period when the 1982 test failed to achieve the 1979 level of release, it exceeded the 1979 flows at another time. Given the practical limitations of field studies, I would accept the 1982 test as having adequately (in terms of biological stress) duplicated 1979.

Effects of high flows

If the hypothesis were true that sustained high flows are a direct cause of fish emigration, several changes would be expected. It would be expected that high flows would either subject the fish to increased velocities above their preferred ranges, or that they would maintain or attempt to maintain these preferred velocities by relocating to areas of lower velocity. If these areas were outside of the fish's normal ranges in terms of water depth, fish depth, or substrate, it would be indicative of a reduction in preferred habitat.

There was no indication of any increase in fish velocity during the test period over medium flow from the previous year. It follows that if medium flows are defined as acceptable and non-stressful to the fish, then the velocities the fish encoun-
tered during the high flow test should not have been stressful nor excessive. Generally, fish velocities during the test were somewhat lower than velocities recorded during medium flow the previous year. This decrease was probably due to a seasonal effect (medium flows were recorded into March 1981, when fish were moving into faster water) and to the fact that the 1982 measurements were concentrated more in the larger pools.

Excessive velocities

Sustained or stressful maximum velocities per unit of time are not well defined for any species. Brett (1962) stated that "... velocities of 3.5 to 4.2 lengths/sec represent 1-hour maximum sustained speeds." This would be equivalent to velocities of 70 cm/sec for juvenile cutthroat trout during winter 1982. Dickson and Kramer (1971) exercised fish at velocities ranging from 41-107 cm/sec to produce active metabolic rates. They reported that "... in some instances, fish may respire at active metabolic rates when forced to swim at speeds as low as 1.5 lengths/sec (41 cm/sec)" (underlining added). Webb (1971) lists "cruising speeds" for a series of salmonid species obtained from various studies. These velocities ranged from 47 to 214 cm/sec in all cases where temperatures were at acceptable levels (<20 C).

In the Logan River system, for all seasons combined, adult brown trout chose average fish velocities of 24 and 21 cm/sec while stationary swimming and feeding (during stationary swimming), respectively (Gosse 1981). Juvenile brown trout had aver-
average fish velocities in the Logan River system of 21 and 24 cm/sec for stationary swimming and feeding, respectively. In the Provo River, adult and juvenile brown trout had average fish velocities of 30 and 24 cm/sec, respectively, for winter feeding during stationary swimming (Gosse 1981). Both adult and juvenile brown trout had average fish velocities of 6 cm/sec for random swimming in the Logan River system.

Brown trout are usually considered to prefer lower velocities than either rainbow or cutthroat trout. The velocities listed above for brown trout tend to be lower than the average fish velocities found in this study in 1981 (Tables 2 and 3), but they are very similar to fish velocities observed during the high flow test in 1982 (Table 20). None of the studies discussed in this section had results which would indicate that velocities occupied by the fish during the high flow test would be excessive.

There was certainly no indication that any of the fish groups were being subjected to excessive velocities during the high flow test. There was also no indication that the fish made major relocations in order to maintain these velocities. There were of course the changes in fish depth, readjustments to sheer edges, and some relocations towards shore discussed previously. But there were no relocations to different sections of the river. The fish were found in the same pools and generally the same part of the pool as the previous year and during the pre-test period. The other microhabitat variables also indicate no major value shifts which would indicate a relocation in order to maintain preferred velocities.
Juvenile cutthroat trout

Direct cause of emigration. The immediate and near total disappearance of the juvenile cutthroat trout is a major anomaly to the assumption that high flows were producing no effect on the fish. It is possible that the cutthroat trout emigrated in the 10 day interval between the pre-test and test periods when no observations occurred and was unrelated to the high flow test, but this seems highly coincidental.

If the juvenile cutthroat trout emigrated during the test period, they apparently did it within the first five days of high flows. However, none of the other remaining groups were observed in excessive velocities during the test, and the areas the juvenile cutthroat trout had formerly occupied (usually near the vortex of large back eddies) appeared to have less of a velocity increase than the areas utilized by the other groups. There was therefore no indication that the juvenile cutthroat trout would have had to accept higher velocities with the increased flows. During the high flows in 1981, they exhibited no change in location after two weeks of high flows. Therefore, the emigration of the juvenile cutthroat trout cannot be explained as being caused by excessive velocities from high flows. There does not appear to have been any measurable increase in velocity over medium flows from winter 1981 nor a sufficient amount of time for velocities to have forced emigration. Given the lack of velocity increases, the fact that two weeks of high flows in 1981 produced no reaction, and the short duration of high flows prior to emi-
gration in 1982, high flows do not appear to be a direct cause of emigration.

**Indirect causes of emigration.** If juvenile cutthroat trout emigration was correlated with high flow, an indirect cause would seem more plausible. The physical segregation of the juvenile cutthroat trout observed during the pre-test period may have been an indication that the group was predisposed to emigration, provided the proper environmental cues were present. The onset of high flows may have presented such a cue or trigger.

Juvenile cutthroat trout emigration could be an innate migration behavior triggered by the onset of high flows. If this were true, size may be an important factor in determining whether fish react to the triggering mechanism. Bjornn (1971) postulated that growth (size) was important in determining whether fish react to migration cues.

Other authors have found emigration to be related to both high flows and winter seasons. Moring and Buchanan (1978) found increased downstream migration for two strains of stocked rainbow trout during high flows. Read (1980) reported juvenile bull trout (*Salvelinus confluentus*) emigrating during the winter months and Shetter (1937) found brook trout moving downstream in winter and returning during the summer. Logan (1962) found trout movement highest from December through February.

R. Goede (UDWR, pers. comm.) currently has found histological evidence that gas supersaturation and/or other causes are producing gill damage in the fish at certain times. Winter measurements for gas supersaturation are currently being made. Goede
further speculates that the problem would be most severe with the smallest fish. Nebeker et al. (1978) found differences in susceptibility among steelhead life stages to air-supersaturated water. This scenario could explain the emigration of the juvenile cutthroat trout during 1982, when they were considerably smaller than the other fish and their greater winter survival during 1981, when they were larger and air temperatures were considerably warmer.

No competitive interactions between species were observed in this study, either at the time of planting or later. But possibly there is a species interaction during winter concentration, especially if the juvenile cutthroat trout are considerably smaller than the rainbow trout. Miller (1958) discusses the difficulties in determining the effects of competition. Hanson (1977) was unable to find sympatric populations of juvenile steelhead and cutthroat trout anywhere in central Idaho. In his experimental streams, age 0 cutthroat trout were at a particular disadvantage when stocked after larger steelhead had become established.

Another possible cause of emigration, though perhaps less likely, may be a decrease in certain types of food availability during high flows. Normally drift appears to increase, as does rate of feeding, during high flows for both seasons. Rainbow trout and adult cutthroat trout fed primarily in the lower half of the water column, often near the bottom. Juvenile cutthroat trout fed at or near the surface in 1982, and probably on a different source of food than did the other life stages. High flows
may have decreased the drift rate of this source or decreased its availability. It would, however, be difficult to explain such a dramatic emigration of apparently healthy fish after five days or less of a reduced food supply.

Post-test period

Distribution

The movement out of the winter pools and to higher velocity water by all remaining life stages was similar to the pattern observed in March and April 1981. The triggering mechanism and reason behind these moves is unclear. Daylength increased but water temperature remained constant during this period. Many of the potential hypotheses for this relocation are energy related. The sudden cessation of high flows would probably reduce drift frequency, causing the fish to relocate to areas which provide increased drift (Everest and Chapman 1972), or they may have used the reduced flows to take advantage of the winter hatches of midges. During high flows, feeding on small food items may not be energy efficient. Brown trout in the Provo River moved from heavy concentrations in pools to a more dispersed distribution in glides during artificial reduction of normal winter flows (Gosse and Helm 1979).

In unregulated rivers, spring is often an intense feeding period. Mongillo (1976) found a major increase in food consumption by brown trout in the Blacksmith Fork River during March and April which continued into June. This was also the period of highest growth for brown trout in the same river (Gosse 1978).
During this same period invertebrate densities in the Blacksmith Fork River declined from the highest levels to the lowest (Reger 1980). This would indicate high rates of invertebrate drift and emergence during spring. The dramatic increase in food availability and consumption could produce changes in trout distribution. Possibly a similar increase in food availability is causing the spring relocation in the Green River.

The post-test period was the first time that either rainbow or cutthroat trout were observed under the microhabitat conditions provided by the riprap, but they probably use this habitat throughout the winter. This use of interstitial crevices was similar to the behavior of young salmonids in winter found by Bjornn (1971), Bustard and Narver (1975), Chapman and Bjornn (1969), Gibson (1978), and Hanson (1977).

Emigration

Possible causes. The gradual decrease in numbers of juvenile rainbow trout observed after the test shouldn't have been a direct result of the high flows. There was no evidence of a decrease in numbers until after the test was over. Based on observations of the fish from underwater, they appeared healthy and unstressed throughout the test. If the flows had, either directly or indirectly through supersaturation, produced a stressed condition in the fish, their reaction should have been movement into quieter, rather than faster, water. After examining a series of studies on upstream movement of salmonids, Alabaster (1970) stated that "... the stimulus for movement is not high
flow as such but something closely associated with it, perhaps short-term changes in flow (freshets), together with accompanying changes in concentration of dissolved substances."

Spawning behavior could have been a partial cause for both the relocation and gradual numerical decline of the fish. Within the 22 km of river examined, there was not enough spawning activity nor fish observed to account for the amount of decrease detected.

**Extent.** It should be remembered that the decrease discussed is in the number of fish that were observed or collected via electrofishing. All of the methods used: scuba observations, snorkeling, and electrofishing; indicated a decrease in fish density and all of these methods had previously been used successfully in the Green River to observe or capture fish. Because of logistical problems, quantitative population estimates were not made; therefore, the extent of the numerical decline cannot be quantitatively determined. It does, however, appear that a decline did occur.

**Destination.** It appears that many of the fish emigrated below Red Creek. Brown trout spawning appears to occur primarily below Red Creek. It seems possible that a number of the rainbow and cutthroat trout also utilize this area for reproductive purposes, although this has not been documented.

During the single electrofishing sampling made in the Browns Park area during April, a number of juvenile cutthroat trout were found along with a large number of juvenile and adult brown trout (personal observation by author). Limited access to the area
prevented further electrofishing and poor visibility prevented diving observations in this area.

**Genetic sources.** There is a good deal of evidence to suggest that migratory behavior has a genetic origin. Moring and Buchanan (1978) suggest that as a result of genetic origin, "... a downstream movement tendency may be inherent in a portion of long established hatchery brood fish." Neave (1944), Northcote et al. (1970), and Huzk and Tsuyuki (1974) all found genetically based nonmigratory races of rainbow trout. Diana and Lane (1978) reported on a sedentary subspecies of cutthroat trout. Cargill (1980) suggests that sedentary strains would be a valuable characteristic for stocking programs.

**Possible solutions.** The presence of brown trout and of unmarked rainbow trout observed during electrofishing and in the creel survey indicated that these species have some successful reproduction. The presence of these naturally reproduced fish has some potential management implication.

Possibly either the older stocked fish from the river or naturally reproduced fish could be used as the gene pool for future fingerling stocks. If emigration is due to innate behavioral patterns, it theoretically would be reduced or eliminated if sedentary fish comprised the gene source.

Natural reproduction could possibly be increased by providing or enhancing spawning and rearing areas. If these fish are less prone to winter losses, increasing their reproduction would help increase the total population in the river. Although very little is known about the habitat requirements of emergent fish,
it appears that such habitat is limited in the Green River, and
habitat improvements might increase their survival.

Community stability

The plant community is probably still changing as indicated
by the increase in *Potamogeton crispus* observed during the study.
The invertebrate community has changed since the penstock modifi­
cation (Holden and Crist 1981) and it is probably still changing.
There is some indication that brown trout are becoming somewhat
more common in the river between the dam and Little Hole. All of
these changes dictate caution in predicting the impact of future
flow release programs while the impact produced by the previous
alterations still hasn't stabilized.
CONCLUSIONS AND RECOMMENDATIONS

This section contains conclusions drawn from the study with regard to both the peaking power proposal and general observations on the ecology of the river, with particular emphasis on the fish populations. In addition, suggestions for areas of future studies are made both for continued investigation of the peaking power proposal, should it be actively reconsidered, and for possible solutions to present fisheries problems.

Conclusions

Effects of flow changes

Flow increases produced changes in certain microhabitat variables. Fish velocity tended to increase with increasing flows. This was especially true for the activity of stationary swimming during the summer. For this category, fish were also consistently located nearer the river bottom with increasing flows. Most other variables were either stable with increasing flows or changed inconsistently.

There was some indication of habitat reduction with increasing flows, but it appeared to be slight. The greatest change in available habitat appeared to be between low and medium flows, which agrees with preliminary results obtained from the IFG-4 model (D. Wegner, USBR, pers. comm.). High flows appeared to produce more habitat loss in summer than in the winter because the high flow effects are greatest in the shallower areas which
are utilized more heavily in the summer.

Present low flow levels are the upper limit of plant bed establishment. Any reduction in low flows would decrease the area covered by plants and probably decrease invertebrate production.

**Trout community**

**Seasonal distribution**

Seasonal differences in fish distribution were quite dramatic. These changes were not flow related. A case can be made that these changes were a function of energetics, although other hypotheses are possible and realistic. It is vital that separate seasonal curves be used for modeling of rainbow and cutthroat trout in the Green River.

**Food chain**

Data gathered in this study indicate that plant beds are important in producing high *Gammarus* biomass. *Gammarus* appear to be a vital constituent of the total invertebrate biomass. The importance of *Gammarus* (or other invertebrates) as trout food was not determined. At this level of investigation this information may not be critical, but it will probably be necessary if the project is resumed.

**Spawning**

Apparent redds were observed in the main body of the river with adult rainbow trout occupying positions on them. There are strong indications that natural reproduction is successfully occurring for both brown and rainbow trout, but the current magni-
tude of such reproduction appears low. The potential for successfully enhancing this natural reproduction through habitat improvements is unknown.

**Predicting flow effects**

A comprehensive series of summary tables is provided in a separate appendix volume for use with the IFG-4 model by USBR personnel in predicting future flow changes. Suggestions are made on ways the data might be most accurately incorporated into the model.

The IFG-4 model will be necessary to provide accurate predictions of the effects of increased maximum releases unless special test flows are released. Based on observations made during this study, it appeared that available habitat was maximized at flow releases between 1200 - 1600 cfs. Utilization of the model would provide more specific information by season, life stage, and species. Available habitat appeared to decrease from optimum more rapidly with flow reductions than with flow increases.

Changes in fish and plant species composition indicate that the community structure of the Green River is in a dynamic state, probably as a result of the relatively recent penstock modifications. This indicates that even without a change in the flow release regime, future changes in the fishery are probable. This dynamic state makes prediction of the effects of future changes in the flow regime more difficult.
High flow test

During the pre-test period the fish utilized essentially the same micro and macrohabitat as during the previous year. Juvenile cutthroat trout were an exception. They were physically more isolated by having located higher in the water column.

The high flow test was conducted during the month of February and appeared biologically to be an adequate replication of the 1979 high flows. As nearly as can be determined, the juvenile cutthroat trout emigrated from most of the study area during the first week of the high flow test. There was no apparent physical reason for the emigration since the other remaining life stages were still utilizing acceptable microhabitat. The other life stages exhibited no changes nor outward signs of stress during the entire high flow test period.

During the months of March and April following the high flow tests, there appeared to be a gradual decline in the number of fish, particularly the juvenile rainbow trout, in the study area. None of the microhabitat variables indicated any reasons for the decline.
Recommendations

Flaming Gorge operation

There are several areas which should be investigated to provide a more comprehensive basis for decision making on present and future operations. In terms of the fishery, the area in greatest need of investigation is determination of the fishes' radius of travel on a daily and seasonal basis, both with and without flow changes. The models in use currently evaluate each flow condition independently, without regard to distances between suitable habitat under other flow releases. Although a more dynamic model could probably be designed, the major problem is our lack of knowledge of the distance fish normally travel over short time periods to find suitable habitat.

Most, if not all, existent microhabitat data has been obtained during daylight periods because the collection of such data is a relatively new procedure and because of the added logistical problems of obtaining nighttime data. Collection of microhabitat data during twilight and night periods should be considered. It is more probable that trout alter their activities and/or microhabitat on a diel basis than that their microhabitat remains constant. Kimball (1972), Meyers (1972), and Mongillo (1976) all found feeding rates for brown trout changing diurnally. Just as seasonal changes are important in defining microhabitat, diel changes may also be important.

More information should be obtained on the trout's food chain in the Green River. Stomach samples should be taken on a
diurnal and seasonal basis for caloric content by major groups to determine the importance of the various invertebrate forms found in the stream. If, as is currently suspected, *Gammerus* play a dominant role in the trout's diet, the relationship between *Gammerus* and plants should be more thoroughly investigated, along with the continued existence of the various plant species under the proposed flow regimes. Investigation of the relationship between drift rates and seasonal distribution would also be enlightening.

Winter emigration should be further investigated and its cause(s) determined, if possible. This is important because the flow regime appears to be correlated with, although not a direct cause of, the emigration.

If the current flow regime is altered in any fashion, it would be invaluable to conduct a follow-up study of the effects. Although the IFG-4 model and its predecessors have been used for years to predict the effects of flow alterations on fish populations, few, if any, before and after studies have been conducted to test the reliability of such predictions.

**Fisheries**

The major existent fishery problem under the current flow regime in the Green River is overwinter emigration of fingerling stocks from the previous spring. The cause of the emigration is not apparent. High flows do not appear to be producing excessive velocities or to be forcing the juveniles to emigrate. High flows may be correlated with the emigration, possibly as a
triggering mechanism or by accentuating an existing condition, possibly supersaturation. There was also some indication that the size of the juveniles may be important in determining the severity of emigration. If high flows are serving as a cue for emigration, genetics may be important in finding a solution.

Based on the findings of other studies, there are strong indications that different genetic strains have varying tendencies towards migration. Consideration should be given to mixed strain stocking and evaluation for future years. Along with strains currently used for stocking purposes, consideration should be given to obtaining brood stock from known sedentary populations or possibly from naturally reproduced rainbow trout from the Green River. Alternatively, enhancing natural reproduction may provide a more viable population in the Green River than the stocked population. In such a case some stocking would probably have to be continued to maintain the numerical size of harvest, or the management objective altered towards more of a trophy fishery.
LITERATURE CITED


