Reproductive biology of brown and rainbow trout below Hauser Dam, Missouri River, with reference to proposed hydroelectric peaking
by Ronald L Spoon

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
This study evaluated potential impacts of flow fluctuations on spawning success of brown and rainbow trout (Salmo trutta and S. .gairdneri)in the Missouri River below Hauser Dam. Trout spawning habitat, and its relationship to discharge, was evaluated by using the physical habitat simulation method (PHABSIM) in conjunction with empirical observations. PHABSIM underestimated discharges required to provide maximum available spawning habitat because of biases in depth criteria, and inadequacy of model inputs (depth, velocity, and substrate) in describing preferred spawning habitat.

In the Missouri River and Beaver Creek, physical and hydraulic characteristics of redds were measured to establish spawning criteria. Water velocity appeared to be the most important variable in spawning site selection, and as discharge varied, lateral adjustments in spawning site selection were dictated by water velocity. Dewatering of brown trout redds in the Missouri River occurs at about 60% of the spawning discharge. Spawning of either brown or rainbow trout occurs for at least 5 months of the year. Nocturnal spawning was predominant though fish were observed spawning at all times during a 24-hour period. Duration of brown trout redd construction (Missouri River) ranged from I to 5 days, with most redds being completed in 3 days. Quantity of adequate spawning habitat appears limited for brown trout, which show a high incidence of redd superimposition. Use of Beaver Creek for spawning by river migrants was extensive for rainbow trout but was negligible for brown trout.

/

REPRODUCTIVE BIOLOGY OF BROWN AND RAINBOW TROUT BELOW HAUSER DAM, MISSOURI RIVER, WITH REFERENCE TO PROPOSED HYDROELECTRIC PEAKING

by

Ronald L. Spoon

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

June 1985

APPROVAL

of a thesis submitted by

Ronald L. Spoon

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

19 June 1985 — Date

Robert G. White — Chairperson, Graduate Committee

Approved for the Major Department

19 June 1985 — Date

Robert E. Moore — Head, Major Department

Approved for the College of Graduate Studies

24 June 1985 — Date

H. B. Malone — Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Director of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Ronald Spoon

Date June 19, 1985

ACKNOWLEDGMENT

Successful completion of this study would not have been possible without the sacrifices and dedication of many people other than myself. As committee chairman and principle investigator, Dr. Robert White deserves special thanks for his skillful direction of this study. I can only repay him through my respect. Drs. Calvin Kaya and Ray White reviewed the manuscript and offered valuable comments. Field companions Dan Carty and George Liknes provided countless hours of assistance for which I am grateful. Fellow students Rob Hitchcock, Chris Randolph, and Tom Carlsen were always present when needed. I thank Chris Vitello and Frank Pickett, along with the Montana Power Company employees at Hauser Dam, for their help and tolerance during the many flow tests. For preparation of figures, I am obliged to Sharon Gaughan. Montana Department of Fish, Wildlife and Parks furnished generous amounts of manpower and equipment. I express my most sincere appreciation to my family for their encouragement, support, and patience. Acting as surrogate parents were Doug and Lisa Shoop, and Jodie Canfield provided friendship in its truest form. The Montana Power Company funded this project through the Montana Cooperative Fishery Research Unit.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

ABSTRACT

This study evaluated potential impacts of flow fluctuations on spawning success of brown and rainbow trout (Salmo trutta and S. gairdneri)in the Missouri River below Hauser Dam. Trout spawning habitat, and its relationship to discharge, was evaluated by using the physical habitat simulation method (PHABSIM) in conjunction with empirical observations. PHABSIM underestimated discharges required to provide maximum available spawning habitat because of biases in depth criteria, and inadequacy of model inputs (depth, velocity, and substrate) in describing preferred spawning habitat. In the Missouri River and Beaver Creek, physical and hydraulic characteristics of redds were measured to establish spawning criteria. Water velocity appeared to be the most important variable in spawning site selection, and as discharge varied, lateral adjustments in spawning site selection were dictated by water velocity. Dewatering of brown trout redds in the Missouri River occurs at about 60% of the spawning discharge. Spawning of either brown or rainbow trout occurs for at least 5 months of the year. Nocturnal spawning was predominant though fish were observed spawning at all times during a 24-hour period. Duration of brown trout redd construction (Missouri River) ranged from 1 to 5 days, with most redds being completed in 3 days. Quantity of adequate spawning habitat appears limited for brown trout, which show a high incidence of redd superimposition. Use of Beaver Creek for spawning by river migrants was extensive for rainbow trout but was negligible for brown trout.

INTRODUCTION AND OBJECTIVES

In recent years, Montana Power Company's (MPC) hydroelectric facilities have generated about 400 megawatts annually and met a little over half the total electrical demand for the State of Montana. At the start of this study, Hauser Dam was one of four existing hydroelectric generation sites scheduled for redevelopment. The goal of redevelopment was to "more ecomomically utilize the water available at the existing sites" (MPC 1984).

Hauser Dam is presently operated as a run-of-the-river plant with a generating capacity of 16.5 megawatts. Engineering studies performed for MPC indicate that an additional 25 megawatt powerhouse, combined with a peaking operation, would produce the highest cost-benefit ratio. The flow pattern associated with increasing the generating capacity below Hauser Dam could result in daily discharges ranging between 42.5 and 269.0 m^3/second (1,500 and 9,500 cfs).

The flowing portion of the Missouri River between Hauser Dam and the impounded water of Holter Reservoir is an extremely popular recreation area with fishing for brown and rainbow trout (*Salmo trutta* and *S. gairdneri*) being an important aspect. This reach has been designated as a Class 1, Blue Ribbon trout stream with national importance (Brown et al. 1959). Little information concerning the fish populations in this reach of river and its major tributary, Beaver Creek, was available prior to this investigation.

Spawning, incubation of eggs, and rearing of young-of-the-year trout are the life history features assumed to be most influenced by fluctuating flows in the Missouri River study area. Factors relating to brown and rainbow trout spawning and egg incubation were evaluated in this study.

Selection of spawning sites is not a random process, but rather, depends upon a specific set of physical and hydraulic conditions including particle size of streambed materials, water depth, water velocity, and escape cover for spawners. Each species has evolved to select the combination of these parameters which will result in maximum reproductive success within the environment in which it evolved. In the Missouri River study area, brown trout are entirely self-sustaining and depend on the short, flowing segment of river for spawning. The rainbow trout population, however, is supplemented by hatchery fish. The average stocking rate in Hauser and Holter Reservoirs during recent years has been 200,000 and 300,000 fingerlings, respectively (Berg and Lere 1983).

This stocking probably has a large influence on the resident river population.

The objective of this investigation was to determine the reproductive requirements of brown and rainbow trout and to predict the impact of altering the discharge pattern from Hauser Dam on trout reproduction. The approach taken in assessing impact was to:

1) Determine the importance of Beaver Creek as a spawning tributary.

2) Locate important spawning habitat and describe distribution and abundance of redds.

3) Measure physical and hydraulic characteristics of redds to determine spawning requirements.

4) Monitor timing of spawning runs.

5) Monitor movements of spawning trout

6) Observe general spawning habits that may aid in predicting spawner responses to changes in discharge pattern.

7) Use hydraulic and habitat modeling to examine a series of discharges in relation to spawning habitat.

Results addressing the objective of this study are presented in this thesis, but conclusions and specific flow recommendations can not be published at this time. Recommendations relating to proposed Hauser Dam expansion are available in White et al. (1984) which will be released at a later date.

Information presented in this thesis was collected during 301 field days between 20 October 1981 and 8 January 1984.

DESCRIPTION OF STUDY AREA

Hauser Dam is located on the Missouri River approximately 22.5 km northeast of Helena, Montana. The Missouri River study area included the 6.8 km flowing segment of river between Hauser Dam and Upper Holter Reservoir (Figure 1). The flowing segment becomes increasingly influenced by the impounded water of Holter Reservoir downstream from the island located 4.5 km below Hauser Dam.

The Missouri River flows through a high walled, rugged canyon from Hauser Dam to the mouth of Beaver Creek. The remainder of the study area lies in a narrow floodplain bordered by broad benches or bars. Access to the study area is primarily limited to boat and foot travel by the steep topography of the surroundings.

Hauser Dam is positioned between Holter Dam, which is 43.0 km downstream, and Canyon Ferry Dam which is located 24.9 km upstream (Table 1). These impoundments greatly influence the fishery within the study area. The limnology of Canyon Ferry Reservoir largely governs that of Hauser and Holter Reservoirs (F. Pickett pers. comm.). Holter Reservoir provides an extensive rearing area for fish produced in the flowing segment below Hauser Dam.

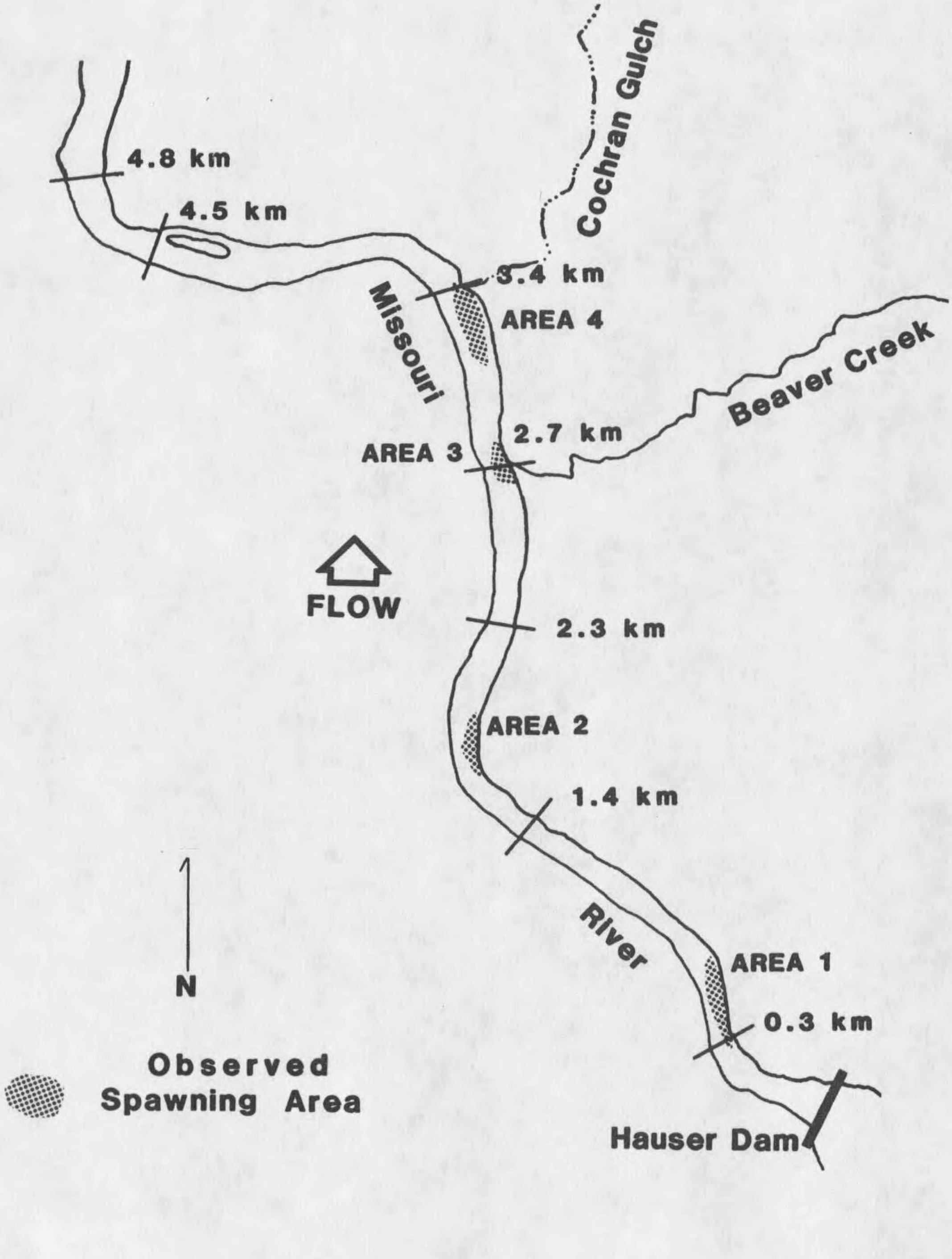

Figure 1. Missouri River study area showing spawning areas and distances below Hauser Dam.

Hauser Dam is a run-of-the-river plant which began operating in 1911. The dam is a concrete gravity structure with a spillway crest 135.6 m long, and an elevation of 1,103.7 m above sea level. The height of the dam above the riverbed is 39.6 m and the intake depth below water surface is 8.2 m at the midpoint. Capacity of water intake is 121.8 m^3/second (4,300 cfs).

Table 1. Date of installation, surface area, electrical capacity, and storage capacity of three impoundments in the upper Missouri River.

	Canyon Ferry	Hauser	Holter
Year Installed	1953	1911	1918
Electrical Capacity (megawatts)	50	16.5	49
Reservoir Storage (million cubic meters)	2530.0	67.8	101.2
Surface Area (ha)	14,238	1,497	1,943

The average annual monthly flow at Hauser Dam is 139.6 m^3/second (4,929 cfs) (MPC flow data for period 1929 to 1978). Flows are above average from April through July. Highest flows occur in June ($\overline{X}$ = 227.6 m^3/second; 8,036 cfs) while September is the month of lowest flow ($\overline{X}$ = 107.8 m^3/second; 3,805 cfs). The drainage area of the Missouri River at the dam is 43,708 km^2.

Beaver Creek, the only perennial tributary in the flowing segment, was also evaluated. This stream, which empties into the Missouri River 2.7 km below Hauser Dam, is approximately 27 km long, with an average gradient of 1.72% (Figure 2). From its source to the town of Nelson, the creek flows through a narrow, limestone canyon. Below this, Beaver Creek meanders through a broader flood plain. Numerous beaver dams are found throughout the length of the stream. Most of the land surrounding Beaver Creek is administered by the U. S. Forest Service (USFS); a USFS road parallels the creek upstream from the mouth for over 19 km.

Severe habitat degradation on Beaver Creek has resulted from alteration of the stream bed for construction of roads and a pipeline, as well as from dewatering and channelization. Prior to 1974, the lower 3.2 km of the stream was under private control and had been completely dewatered for several years during the irrigation season (Hill and Wipperman 1976). The Department of Fish, Wildlife and Parks surveyed the stream in 1973 and found that 24% of a 22.4 km length had been adversely impacted by human activities (Hill and Wipperman 1976).

The Missouri River and Beaver Creek study areas lie within a ponderosa pine - grassland vegetation type. Riparian zones are dominated by red dogwood (<u>Cornus stolonifera</u>) and Willow (<u>Sallix</u> <u>spp.</u>).

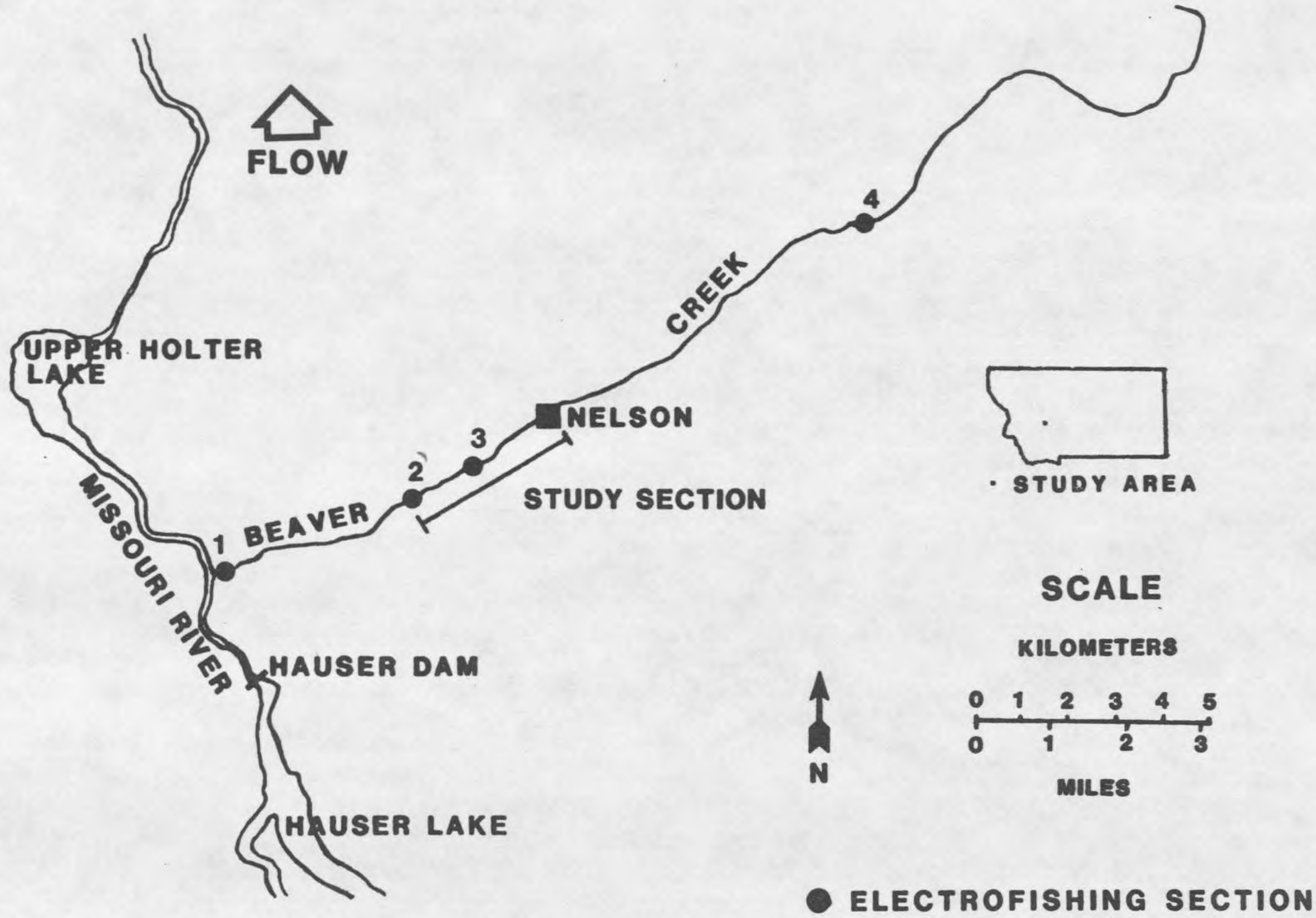

Figure 2. Beaver Creek study area showing locations of electrofishing sections and study section.

METHODS

Fish Sampling

Several aspects of the spawning life history were investigated by electrofishing the Missouri River and Beaver Creek. Four different electrofishing systems were used to meet a variety of sampling situations.

For electrofishing the Missouri River, a fixed-electrode system was suspended from a 4.8 m aluminum boat. The system was powered by a 1500-watt, 115-volt AC generator, and a Coffelt rectifying unit (Model VVP-2C) was used to adjust voltages and convert alternating current to pulsed direct current (60 pulses per second). Most river electrofishing was conducted at night to enhance capture efficiency. Four 120-volt flood lights were attached to the boat to provide lighting for the netter and boat operator.

Three types of mobile electrode systems were used to sample fish populations in Beaver Creek. During low and moderate discharges, battery backpack rectifying units were effective in capturing spawners. A more powerful system was used in Beaver Creek during periods of high discharge. For this system, a 5.2 m aluminum canoe carried the same power source and rectifying unit used in the fixed electrode system, but the positive electrode was hand-held and the negative electrode was suspended from the canoe.

Estimates of fish populations in Beaver Creek were made using a bank electrofishing unit. The components were the same as used in the canoe system, except the hand-held positive electrode was attached to a 152 m length of electrical cord. Beaver Creek electrofishing was primarily confined to sections which were chosen as being representative of the habitat available. Population estimate sections were 305 m long. Section 1 was the lower-most 305 m of Beaver Creek. Sections 2, 3, and 4 were located 4.8 km, 6.4 km, and 17.7 km upstream from the mouth, respectively (Figure 2). Population estimates were calculated using the Chapman modification of the Peterson formula.

During spawning periods, the Missouri River and Beaver Creek study sections were electrofished periodically to determine where spawning fish were concentrated and their stage of maturity. Spawners were classified as: 1) gravid - sex products well developed; small quantities of milt extruded from males when light pressure was applied to abdomen; eggs in females well developed but not released when pressure was applied, 2) ripe - milt and eggs readily released when light pressure was applied to the ventral cavity, and 3) spent - testes and ovaries empty; females in this condition had flaccid abdomens. Secondary sexual characteristics, such as kypes and the degree of scale embeddedness, were also used to differentiate between males and females when they were not ripe. Males tended to have more pronounced kypes and scales more deeply embedded.

Trout Movement

Trout longer than 200 mm total length were marked with individually identifiable Floy T-tags using a Mark II tagging gun. Five thousand fish were tagged from 12 March 1982, to 23 March 1983--4,000 in the Missouri River and 1,000 in Beaver Creek.

Tagged fish captured by anglers and electrofishing were used to monitor movement of brown and rainbow trout. Spawning movement was determined by using recapture data for fish showing sexual maturity when tagged or recaptured. General (non-spawning) movement was evaluated from fish that were not ripe, gravid, or spent when tagged or recaptured.

To determine movement patterns within the 4.5 km study section, the Missouri River study area was divided into four subsections coinciding with frequently used stopping places where fish were tagged and released. The four subsections ranged from 0.8 to 1.4 km in length. Reliable recapture locations were obtained from only 1,264

(81.0%) of the 1,560 recaptures because standard fish processing stops were not always used and fisherman catch locations (received by phone or mail) were often too general.

Movement of trout from the Missouri River to Beaver Creek or from Beaver Creek to the river was also measured. Angler returns from Holter Reservoir, two tributaries of Holter Reservoir, and the Missouri River below Holter Dam provided further movement information.

Redd Distribution and Abundance

Missouri River

The Missouri River between Hauser Dam and the slack water of Upper Holter Lake (approximately 5 km) was monitored regularly to record the progression of spawning activity for brown trout (fall 1981 and 1982) and rainbow trout (spring 1982 and 1983). Redd counts were made by walking the shoreline, by floating, and by observing spawning areas from the surrounding bluffs. Efficiency of counting redds was affected by wind, cloud cover, and turbidity.

The presence (or absence) of deep-water spawning was an important consideration in this investigation. We unsuccessfully attempted to locate and count redds by snorkeling in relatively deep water. On 14 December 1983, river discharge was decreased from 169.5 m^3/second (5,986 cfs) to 42.7 m^3/second (1,506 cfs) for 2 hours. During this time, a helicopter was used to search for and count brown trout redds in deep water areas, and a ground crew examined shallow and dewatered areas. Aerial photographs were taken covering 4.8 km of the Missouri River below Hauser Dam. From these, surface areas of redd aggregates within intensively used spawning areas were determined.

Beaver Creek

Approximately 3.2 km of Beaver Creek from Nelson to the second bridge below Nelson (electrofishing section 2) were selected for periodic redd counts (Figure 2). Redds were counted by wading upstream or walking the shoreline. Fish could occasionally be observed on redds, allowing for species confirmation, and size estimation. From 1981 to 1983, the number of redds was estimated in the lower 11.6 km of Beaver Creek near the end of the brown trout spawning period. Reliable counts of rainbow trout redds were not obtained in Beaver Creek during the spring of 1982 because of turbid water. Rainbow trout redds were counted during 1983.

Physical and Hydraulic Characteristics of Redds

Preferred habitat for spawning in the Missouri River and Beaver Creek was determined by measuring physical conditions at and around brown and rainbow trout redds. Each redd observed was marked with a painted rock so that it would not be counted or measured again. The length of each redd was measured from the upper edge of the pit to the lowermost portion of the tailspill (Figure 3). Three equidistantly spaced width measurements were also taken. From these, an estimate of the surface area of the redd was made using the following formula (Reiser 1981):

$$Area = (1/2L \times Wt) + (1/3L \times Wm) + (1/6L \times Wu)$$

L = length of redd
Wt = width across lower third
Wm = width across midpoint
Wu = width across upper third

Measurements of water depth and point velocity (taken approximately 20 mm above the substrate surface) were made at the upper edge, the pit, and the tailspill of each redd. Mean water velocity (at 0.6 of depth) was measured at the upper edge of the redd (Figure 3). Water depths (nearest 2.0 cm) were measured with a top setting rod and velocities were measured with a Marsh-McBirney (Model 201) electronic current meter. When applicable, I also measured the distance to cover, riffle, and shore, and noted cover type.

Spawning substrate was sampled by using a modified McNeil sampler with a 178-mm-diameter tube (McNeil 1964). The tube was embedded immediately in front of the redd to a depth of 190 mm and the enclosed substrate and suspended solids extracted and stored for later particle size analysis. Thirty-five substrate samples (consisting of bed-material) were collected from brown and rainbow trout

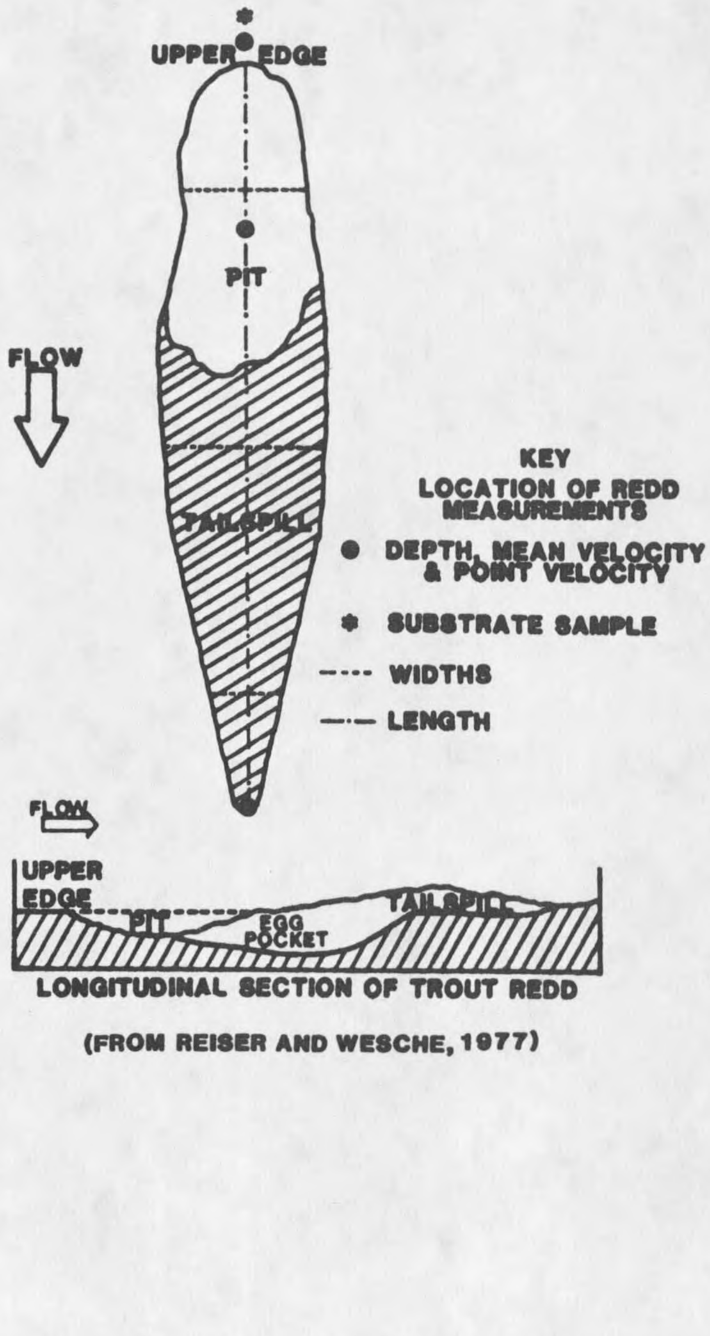

Figure 3. Location of redd measurements.

redds in Beaver Creek, and 50 samples were collected in the Missouri River. At major spawning sites, substrate in the river was observed and photographed during a flow reduction test. During 1983, visual estimates of substrate composition were made at brown trout redds in Beaver Creek.

Substrate samples were dried in a forced air oven for 4 hours at a temperature of 150 C. Sieving was done using a Tyler Ro-Tap sieve shaker and U.S. Standard Testing Sieves in nine sizes of square mesh ranging from 63.50 mm to 0.42 mm. The samples were halved to prevent clogging of sieves, and the shaker was operated for 1 minute per half sample for a total of 2 minutes per sample. The substrate material in each sieve was weighed to the nearest 4.54 gm (0.01 lb) and the percentage of the total sample weight was computed.

Measurements along cross-sectional transects were taken to quantify habitat available for brown trout spawning. Prior to the brown trout spawning period, 65 transects were randomly located along the 3.2 km study section of Beaver Creek. Readings of water depth and mean water column velocity were taken at 0.5-m intervals along cross sections, and substrate composition was visually estimated at 1.0 m intervals using the modified Wentworth scale (Table 2). Stream width and presence of overhead cover were also recorded at each transect.

Table 2. Classification of substrate based on a modified version of the Wentworth particle size scale.

Substrate Type	Particle Size (mm)
Fines	<2.0
Gravel	2.0 - 64.0
Cobble	64.0 - 250.0
Boulder	>250.0

To compare use and availability of spawning substrate, a method was developed to derive a single value representing the mean particle size of a visual observation. The method is explained in Appendix A.

Duration and Pattern of Redd Construction

From 18 October to 12 November 1982, brown trout spawning in the Missouri River was monitored daily to determine the amount of time required for redd construction, and to document daily spawning pattern of individual fish. By placing a painted rock in the pit of the redd, additional spawning at that redd could be detected. Selected redds were observed once or twice each day from the time redd building activity began until it ceased to determine times of the day when fish were on the redd. Some night observations were also made using a spotlight.

Predicted Hatching and Emergence Time

Surface water temperature data from the Missouri River were used to estimate development rates of brown and rainbow trout embryos. Temperature units were calculated from the mean daily temperature (average of maximum and minimum daily temperature), with one temperature unit equaling one degree Fahrenheit above freezing (0 C) for a period of 24 hours. The number of days and temperature units required for eggs to hatch were obtained from the literature (Leitritz and Lewis 1976; Carlander 1969). Hatching dates were calculated for the earliest and latest redds observed in the river to determine the range of hatching times.

Whitlock-Vibert boxes were used to observe egg development for rainbow trout. Eggs and sperm were taken from spawners collected during electrofishing. One hundred fertilized eggs were placed in each box and the boxes were buried 150 to 200 mm (the depth which eggs were observed in natural redds) in the gravel. Three boxes were placed in each of two spawning areas in the vicinity of rainbow trout redds. We had hoped to retrieve the boxes individually at various incubation times, but none could be reached until high spring flows in the river receded.

Physical Habitat Simulation

The U. S. Fish and Wildlife Service physical habitat simulation (PHABSIM) system was used to relate changes in discharge to changes in the quantity of usable spawning habitat. The basic premises of PHABSIM include: 1) each species exhibits preference within a range of habitat conditions it can tolerate, 2) these ranges can be defined for each species, and 3) the area of stream providing these conditions can be quantified as a function of discharge and channel structure (Bovee 1982). The primary output of the model is a measure of usable microhabitat called weighted usable area (WUA)..

The basic model components are: 1) a water surface profile (WSP) model which predicts changes in water surface elevation, depth, velocity, and wetted perimeter along transects, 2) a judgement of the boundaries of suitable spawning substrate within the transect areas (these boundaries were determined during a reduced flow test), and 3) observed spawning preferences for depth, velocity, and substrate presented as probability of use curves. Curves were generated from GOSTAT/GOPLT programs, which perform an exponential polynomial curve fit on frequency data.

Field data required for hydraulic simulation included cross-section survey data (to highwater marks), distances between cross-sections, corresponding water surface elevations at all cross sections at the known discharge. Also recorded were descriptions of substrate, bank and overbank material and vegetation as well as where these change within the cross sections.

During the 3-day period in which transect data were collected, MPC regulated the river at a constant flow of 146.6 m^3/second (5,178 cfs), as determined from the stage-discharge ralationship developed by MPC in 1982. Survey data were collected along four transects in each of three sections of the river; these sections corresponded to spawning areas 1,2 and 4.

Bank and wadable areas (depth $<$ 1.0 m) were surveyed using a level and hand-held stadia rod. Channel profiles in unwadable areas were surveyed from a boat equipped with a constant recording fathometer (Raytheon, model DE-719B). A range finder (Lietz, model SD-5F), operated by a person on shore, was used to determine distance along the transect and to keep the boat on course. To provide targets for the boat operator, two large floats were placed off each bank at the outer extent of the measurements taken by wading. For a more detailed description of field techniques, see Graham et al. (1979).

The PHABSIM model calculates a weighted suitability index which reflects the relative preference of the spawners for the combination of structural and hydraulic characteristics found in each stream segment (or set of four transects). This index is expressed as the percentage of the gross surface area in the stream segment which contains suitable combinations of habitat variables for each life stage of the species for each simulated discharge. For a detailed explanation of how the PHABSIM system functions, see Bovee (1982) and Milhous et al. (1981).

Predicted Dewatering of Utilized Spawning Habitat

In 1982, 77 brown trout redd depths were measured at spawning areas 1 and 2. The number of these redds dewatered at a specific discharge was determined by using predicted changes in water surface elevation. Three inputs were required to use this method: 1) discharge and water surface elevation of the river at the time of spawning; 2) distribution of redd depths at spawning areas 1 and 2; and 3) water surface elevations at numerous discharges from hydraulic modeling.

The number of redds dewatered at areas 1 and 2 was determined at 2.8 m^3/second (100 cfs) increments between 85.0 m^3/second (3,000 cfs) and 70.8 m^3/second (2,500 cfs). The number of redds dewatered at a given discharge was divided by the number of redd depth measurements (77) to determine the percentage dewatered. Spawning areas 3 and 4 were not included in this analysis because hydraulic modeling was not available at area 3, and the backwater of

Holter Reservoir made hydraulic modeling unreliable at area 4. Also, redds at area 4 are not dewatered within the range of flows outlined above.

Reduced-Flow Test - 1982

A reduced-flow test was conducted on 17 August 1982. The purpose of the test was to provide additional information for evaluating potential impacts on spawning habitat of periodic flow reductions from approximately 269.0 m^3/second (9,500 cfs) to 38.5 m^3/second (1,358 cfs). The 38.5 m^3/second (1,358 cfs) flow was based on the stage-discharge relationship developed in 1982 by MPC.

Three major spawning areas of brown and rainbow trout were examined during the 38.5 m^3/second (1,358 cfs) flow to evaluate substrate size in areas known to be used for spawning, to measure depths and velocities of potential spawning areas with suitable substrate, and to determine bottom profiles of spawning areas as far into the channel as possible. Thirteen permanent transects were established at known spawning sites: six transects at the first gravel bar along the right bank 0.2 km below the dam, six at the series of gravel bars along the right bank approximately 1.6 km downstream from the dam, and one at the mouth of Beaver Creek. Along each transect, substrates were sampled and photographed, profiles of spawning areas were made, and depths and mean column velocities were measured.

Reduced-Flow Test - 1983

On 4 August 1983, a reduced-flow test was conducted to evaluate the accuracy of hydraulic modeling predictions at three major brown and rainbow trout spawning areas (areas 1, 2, and 4). Water surface elevations were measured by surveying techniques at four discharges [81.1 m^3/second (2,863 cfs), 66.7 m^3/second (2,357 cfs), 55.4 m^3/second (1,956 cfs), and 143.0 m^3/second (5,048 cfs)]. Water depths and velocities were measured along modeling transects to compare observed with predicted values, and to determine suitability of these areas for spawning and/or incubation at the three lowest discharges.

Temperature and Discharge Monitoring

Water temperatures were recorded continuously with submersible Ryan 90-day thermographs (Model J) that were installed in October, 1981. The thermograph in the Missouri River was located 0.4 km below the dam, while the thermograph in Beaver Creek was placed near the U. S. Forest Service gauging station 2.4 km above the mouth.

Streamflow data in the Missouri River were gathered from a U. S. Geological Survey station 0.3 km below Hauser Dam. Beaver Creek flow data were recorded at the U. S. Forest Service gauging station.

RESULTS

Redd Distribution and Abundance

Brown Trout - Missouri River

During the 3 years brown trout spawning was monitored, spawning began between 11 and 22 October and was completed by mid to late December. Water temperature at initiation of spawning was between 9.4 and 11.1 C (Figure 4). Spawning activity peaked in early to mid November during 1981 and 1982 (Figure 5).

During each field season, most redds (87 to 100%) were observed in four general spawning areas: 1) the large gravel bar immediately below the dam, 2) the series of small gravel bars 1.6 km below the dam, 3) the delta at the mouth of Beaver Creek, and 4) the broad, homogeneous run above Cochran Gulch (Figure 1).

Fifty-five and 160 brown trout redds were observed in 1981 and 1982, respectively. These redd counts were known to be underestimates. Factors contribuing to the low redd counts were: 1) the high incidence of multiple redds and superimposed redds, 2) the presence of redds in relatively deep water that were not visible to the observer, and 3) the inability to distinguish between brown trout and kokanee salmon redds. In areas jointly used by brown