LIMITATIONS TO A RAINBOW TROUT POPULATION IN NORTH-CENTRAL MONTANA

by

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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

February 1988

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of a thesis submitted by

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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.

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VITA

Robert William Hitchcock III, son of Robert and Joanne Hitchcock, was born in Loma Linda, California, on April 28, 1957. After graduating from Temple City High School in 1975, he enrolled in the School of Science at California State Polytechnic University, Pomona, from which he received Bachelor of Science Degrees in Biology and Zoology with a minor in Chemistry in 1979. He began graduate studies and research toward a Master of Science degree in August, 1981.

ACKNOWLEDGMENTS

I would like to thank Dr. Robert White for his efforts in directing this study, and critically reviewing the manuscript. I also wish to express my appreciation to the other members of my graduate committee, Drs. Ray White, Dan Goodman, Robert Eng, and the late Gordon Pagenkopf for their assistance in completing this thesis. Kent Gilge of the Montana Department of Fish, Wildlife and Parks, provided guidance for which I am grateful. Employees of the Montana Cooperative Fisheries Research Unit, Montana State Water Quality Bureau, Hill County Conservation District, and Hill County Park Board, assisted in the completion of this project.

I express my most sincere appreciation to my family and friends for their encouragement, support, and patience. For computer knowledge and preparation of figures, I am obliged to George Liknes and Scott Hitchcock. Fellow students Ron Spoon, Tom Carlsen and Chris Randolph were always present when needed. My thanks to Paul Slocombe for diligent efforts in the field. The Montana State Water Quality Bureau, and Hill County Conservation District funded this project through the Montana Cooperative Fisheries Research Unit.

TABLE OF CONTENTS

Page

VITA.. iv

ACKNOWLEDGEMENT.................................... v

TABLE OF CONTENT.................................. vi

LIST OF TABLES....................................vii

LIST OF FIGURES................................... xii

ABSTRACT.. xiv

INTRODUCTION...................................... 1

DESCRIPTION OF STUDY AREA......................... 3

METHODS... 11

Fish Population Sampling.......................... 11
Spawning Habitat.................................. 15
Habitat and Hydraulic Modeling.................... 17
Temperature....................................... 19
Temperature Model................................. 20
Water Storage..................................... 22
Bear Paw Lake Temperature
and Dissolved Oxygen Profiles..................... 22
Specific Conductance and Hydrogen
Ion Concentration................................. 24
Recreation Survey................................. 25
Erosion... 25
Beaver Ponds...................................... 26

RESULTS AND DISCUSSION............................ 28

Species Composition, Distribution,
and Relative Abundance............................ 28

Rainbow Trout Population Characteristics.......... 35

Age Structure, Abundance and Biomass.............. 35
Age and Growth.................................... 41

TABLE OF CONTENTS--Continued

Page

Hatchery Trout.............................. 43

Limitations to Rainbow Trout...................... 44

Fine Sediment................................ 44
Streambed Composition.................... 44
Predicted Spawning Success.............. 46
Stream Flow................................ 49
Habitat Modeling....................... 49
Flow Manipulation...................... 51
Water Temperature............................ 53
Water Temperature Modeling............. 56
Long-term Effects of Hypolimnetic
Discharge on Beaver Creek.................... 60
Effects of Hypolimnetic
Discharge on Bear Paw Lake.................. 64
Applying the Habitat and Temperature
Models to Beaver Creek...................... 69
Contributing Factors......................... 72
Angling and Recreation................. 72
Erosion and Livestock.................. 75
Beaver Ponds........................... 76

Summary and Recommendations...................... 81

LITERATURE CITED.. 85

APPENDICES.. 95

Appendix A - Probability-of-Use Curves............ 96
Appendix B - Explanation of Temperature Model
and Travel Time Calculations......... 100
Appendix C - Tables............................... 105
Appendix D - Sample Recreation Survey Form........ 129

LIST OF TABLES

Table		Page
1.	Parameters of the Beaver Creek study area........	7
2.	Classification of substrate based on a modified version of the Wentworth particle size scale (Spoon 1985)....................................	9
3.	Length of population estimate sections on Beaver Creek in 1981 and 1982....................	12
4.	Fish species collected on Beaver Creek in 1981 and 1982, in order of relative abundance.....................................	28
5.	Average number (fish/km) and biomass (kg/km) of trout and suckers estimated for combined study sections of Beaver Creek in 1981 and 1982. The 95% confidence intervals are in parentheses................................	29
6.	Average number (fish/ha) and biomass (kg/ha) of rainbow trout estimated for Beaver Creek study sections during 1981 and 1982. The 95% confidence intervals are in parentheses......	39
7.	Mean back-calculated lengths and mean increments of back-calculated lengths for rainbow trout collected from Beaver Creek in 1981 and 1982..................................	42
8.	Particle size distribution of potential spawning substrate expressed as cumulative percentages of substrate less than a specified particle size, Beaver Creek 1983................	45
9.	Predicted percent survival of rainbow trout embryo using Irving and Bjornn's (1984) survival equation and substrate data from Beaver Creek, 1982............................	47
10.	Estimates of available water at various drawdowns of Bear Paw Lake (Brown pers. com.)....	52

LIST OF TABLES--Continued

Table Page

11. Translation of water travel time (t) in hours into discharge (m^3/s) necessary for maintaining temperature at T = 16 C for the temperature model of Beaver Creek. T_o = the intial temperature of water released from Bear Paw Lake, T_e = 18 C, the estimated average-maximum water temperature for Beaver Creek at equilibrium, T = 16 C, the expected water temperature in Beaver Creek at end of travel time (t). The three k values represent mean (m = 0.068), upper (u = 0.083), and lower (l = 0.053) equilibrium constants calculated at the 95% confidence level for the stream system....... 58

12. Average-maximum water temperature of Beaver Creek, calculated from thermograph data collected 1.6 km and 7.0 km downstream from Bear Paw Lake, during July and August, 1981 and 1982. Standard deviations are in parentheses.................................... 62

13. Dissolved oxygen in Beaver Creek water, on 15 September 1981............................ 64

14. Means and ranges of pH, hydrogen ion concentration and specific conductance values observed during 4 samplings of Beaver Creek in 1981 and 1982 (standard deviation are in parentheses).................................... 65

15. Comparison of fisherman use and catch on Beaver Creek, 30 June - 11 September 1982..... 73

16. Mean and range of maximum depth, length, width, and surface area of 14 beaver ponds in section 2 of Beaver Creek, 1982 (standard deviation is in parentheses).................. 77

17. Data set used to calculate mean rate coefficient (k_m) for the temperature model of Beaver Creek. T_o = initial water temperature, T_1 = final water temperature, T_e = equilibrium water temperature, Q = discharge, t = travel time from T_o to T_1, and k = rate coefficient.................... 106

LIST OF TABLES--Continued

Table | Page

18. Estimated numbers/km, and biomass (kg/km) of rainbow trout sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses) 107

19. Estimated numbers/km, and biomass (kg/km) of brook trout and brown trout sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses) 110

20. Estimated numbers/km, and biomass (kg/km) of white suckers sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses) 111

21. Estimated numbers/km, and biomass (kg/km) of longnose and mountain suckers sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses) 112

22. Summary of estimated number of trout and suckers per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses 113

23. Summary of estimated biomass (kg) trout and suckers per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses 114

24. Estimated numbers (per km) of rainbow trout by age group in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses 115

25. Estimated biomass (kg/km) of rainbow trout by age group in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses 116

26. Mean total length and mass at time of capture (standard deviation in parentheses) and calculated mean total length and mass at each annulus for rainbow trout collected in Beaver Creek in 1981 and 1982 117

LIST OF TABLES--Continued

Table Page

27. Numbers, totals, and percentages of responses to to recreation survey conducted on Beaver Creek and Bear Paw Lake between 30 June and 11 September 1982.................... 119

28. Comments made by five or more respondents during the recreation survey on Beaver Creek and Bear Paw Lake in 1982........................ 124

29. Length (mm) and mass (g) of rainbow trout sampled from beaver ponds on Beaver Creek in 1982.. 125

30. Length (mm) and mass (g) of rainbow trout sampled from section 2 of Beaver Creek in 1982.. 127

LIST OF FIGURES

Figure		Page
1.	Location of electrofishing, temperature, hydraulic modeling, and thermograph sites in the Beaver Creek study area	5
2.	Geology of the Beaver Creek study area identifying alluvium (Qal), ground moraine (Qgm), and mafic volcanic (Tmv) rock formations (Kerr et al. 1957)	6
3.	Locations of chemistry sampling, substrate sampling, and staff gauge sites in the Beaver Creek study area	16
4.	Depth contours of Bear Paw Lake. Shaded area represents exposed lake bottom resulting from a 2.5 m drawdown	23
5.	Distribution of white, longnose, and mountain suckers in Beaver Creek. Largemouth bass and northern pike collection sites are also included	30
6.	Distribution of rainbow, brook, and brown trout in Beaver Creek	32
7.	Estimated number of rainbow trout (Rt), brook trout (Bk), brown trout (Bt), white sucker (Ws), longnose sucker (Ls), and mountain sucker (Mt) per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval	33
8.	Estimated biomass (kg/km) of rainbow trout (Rt), brook trout (Bk), brown trout (Bt), white sucker (Ws), longnose sucker (Ls), and mountain sucker (Mt) in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval	34

FIGURES--Continued

Figure | Page

9. Estimated number of rainbow trout (per km) by age class in sections 1, 2, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval................ 37

10. Estimated biomass (kg/km) of rainbow trout by age class in sections 1, 2A&B. 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval................ 38

11. Suitable habitat versus discharge from Bear Paw Lake for adult, juvenile, and spawning rainbow trout in section 2 of Beaver Creek........................ 50

12. Daily maximum water temperature in Beaver Creek 1.6 km downstream from Bear Paw Lake during July, August, and September, of 1981 and 1982................................ 55

13. Longitudinal average-maximum water temperature distribution in Beaver Creek between Bear Paw Lake (BPL) and Beaver Creek Reservoir (study section 2), from 3 August to 16 September of 1981 and 1982. Vertical bars represent 95% confidence interval................ 57

14. Temperature (C) versus depth (m) of water in Bear Paw Lake on selected dates during 1981 and 1982............................ 66

15. Dissolved oxygen (mg/l) versus depth (m) of water in Bear Paw Lake on selected dates during 1981 and 1982............................ 68

16. Comparison of length-weight relationship for rainbow trout collected in the Beaver Creek study area during 1982.......................... 78

17. Probability-of-use curves for adult rainbow trout (Bovee 1978)...................... 97

18. Probability-of-use curves for juvenile rainbow trout (Bovee 1978)...................... 98

19. Probability-of-use curves for spawning rainbow trout (Bovee 1978)...................... 99

ABSTRACT

Environmental limitations of Beaver Creek trout populations were studied from August 1981 to March 1983. I attempted to identify primary limiting factors and to determine if timing and quantity of flow released from an upstream storage reservoir (Bear Paw Lake) would improve habitat conditions.

Major limiting factors appeared to be streambed composition, quantity of streamflow, and water temperature. Angling, channel alterations, livestock grazing, and beaver activity contributed to the low rainbow trout abundance below Bear Paw Lake, but did not appear to be major limiting factors.

Throughout the study area, high percentages (>20%) of fine particles (<0.85 mm) were found in streambed materials, reducing quality and quantity of suitable spawning habitat for rainbow trout. Predicted rainbow trout embryo survival to emergence ranged from 0-30% in the study area. Geology of the lower two-thirds of the study section prevents improvement of spawning substrate by manipulating quantity of water released from Bear Paw Lake.

With water temperatures as high as 26 C during summer low flows, Beaver Creek is considered thermally marginal for rainbow trout. Temperature model predictions indicated that releasing 4.4-13.9 C water from the bottom of Bear Paw Lake at a rate of 0.028-1.36 m^3/s, would maintain an average-maximum temperature of 16 C or less for 3.2 km downstream, providing near optimum water temperature for the rainbow trout during most summer months. Releases exceeding the base flow of Beaver Creek by 0.065 $m^3/s/day$ for 60 days, could reduce the recreational value of Bear Paw Lake by exposing 22% (4 ha) of the lake bottom.

Physical habitat simulation model predicted flows of less than 0.34 m^3/s would greatly reduce available adult and juvenile rainbow trout habitat. A discharge range of 0.34-0.86 m^3/s would produce "preferred" velocities and depths for adult rainbow trout in 51-53% of the channel in the 3.2 km section below Bear Paw Lake. In relation to

rainbow trout habitat and optimum water temperature, a minimum flow of 0.28 m^3/s released from the bottom of Bear Paw Lake throughout the year, is recommended.

The 1.6 km of Beaver Creek immediately downstream from Bear Paw Lake was the most heavily fished area on the stream. Rainbow trout of hatchery origin were dominant in this section, having moved down from Bear Paw Lake. By stocking rainbow trout in this 1.6 km section, 99% of the recreational fishing needs for Beaver Creek below Bear Paw Lake would be met.

INTRODUCTION

In north-central Montana, few streams support recreational trout fisheries. Although most streams in this area do not have large trout populations, streams such as Beaver Creek are an important source of recreation.

A study by personnel of Montana Department of Fish, Wildlife and Parks (Needham and Gilge 1980) found large annual variations in rainbow trout (Salmo gairdneri) age class structure in Beaver Creek, suggesting the existence of less than optimum conditions. By monitoring trout abundance and various physical parameters of the stream, I attempted to identify factors that are limiting the trout population.

Numerous limiting factors to trout populations have been identified (Burton and Odum 1945, Call 1970, Raleigh et al. 1984). Those which I hypothesized were the most important in Beaver Creek were streambed composition, reduced stream discharge during late summer, fall, and winter, and high summer water temperatures.

Bear Paw Lake, an impoundment on Beaver Creek, is owned and operated by Montana Department of Fish, Wildlife and Parks and provides a major source of recreation in

Hill County Park. A spillway and penstock provide a means for controlling discharge from the dam and provide opportunity to modify flow and water temperature in Beaver Creek.

Several researchers have demonstrated a good relationship between flow and standing crop of trout (Wesche 1974, Binns and Eiserman 1979, and Schlosser 1982). I sought to identify limiting factors for rainbow trout in Beaver Creek and to determine the extent to which these limitations could be controlled through timing and quantity of flow released from Bear Paw Lake.

The objectives of the study were to:

1. Determine species composition, distribution, and abundance of fish in Beaver Creek between Beaver Creek Reservoir and Bear Paw Lake.

2. Evaluate potential factors limiting the rainbow trout population.

3. Determine recreational use and angler attitudes on Beaver Creek and Bear Paw Lake.

4. Develop a water release plan for Bear Paw Lake, for the purpose of enhancing rainbow trout habitat in Beaver Creek, within the constraints of downstream water rights and recreational demands of Bear Paw Lake.

DESCRIPTION OF STUDY AREA

Beaver Creek is located in north-central Montana, approximately 16 km south of the city of Havre. Mean annual precipitation is 31.95 cm, half of which occurs between May and August (NOAA 1981). Average number of frost-free days is 138, occurring between May and mid-September. Winters are cold with sub-zero temperatures common. Summer air temperatures are warm but seldom hot (less than 35 C). Warmest months are July and August, with mean air temperatures of 20.1 and 19.7 C, respectively. The mean annual air temperature is 5.9 C (NOAA 1981).

Beaver Creek is the main drainage of the Bear's Paw Mountains, which range in elevation from 762 to 1,829 m. The stream drains 127 ha, channeling the water 48 km to its intersection with the Milk River. Beaver Creek runs through the 4,047 ha Hill County Park, reportedly the largest county park in the continental United States. The parkland was placed under stewardship of the county for the purpose of providing a recreation area for visitors and residents of the region. Haying, grazing, and fur trapping in the park help to provide an economic base for the park.

Two reservoirs exist in Hill County Park (Figure 1). Completed in 1973, Beaver Creek Reservoir, located at the northern (downstream) end of the park, is the largest impoundment with a surface area at full pool of 48 ha. The reservoir functions mainly as an irrigation and flood control structure, with a growing potential for recreation. Beaver Creek Reservoir does not influence conditions in the study area, except to block immigration from downstream. The second reservoir, Bear Paw Lake (18 ha), is located 10.0 km upstream. It was constructed in 1952 and serves as one of the area's major recreation sites. Bear Paw Lake has a good trout fishery, supported by stocking of hatchery fish by the Montana Department of Fish, Wildlife, and Parks.

The study area was designated as the 10.0 km of stream between the two reservoirs, as well as 1.6 km upstream from Bear Paw Lake and a similar distance below Beaver Creek Reservoir. Five sections were selected for comparative purposes (Figure 1). All study sections are highly affected by the geology of the region (Figure 2).

Study section 1 is 1.6 km long and is located immediately downstream from Beaver Creek Reservoir (Figure 1; Table 1). In this section, the stream cuts through a thick bed (60 m deep) of ground moraine. This fine-grained glacial deposit makes up much of the substrate in depositional areas of this stream segment. More recent

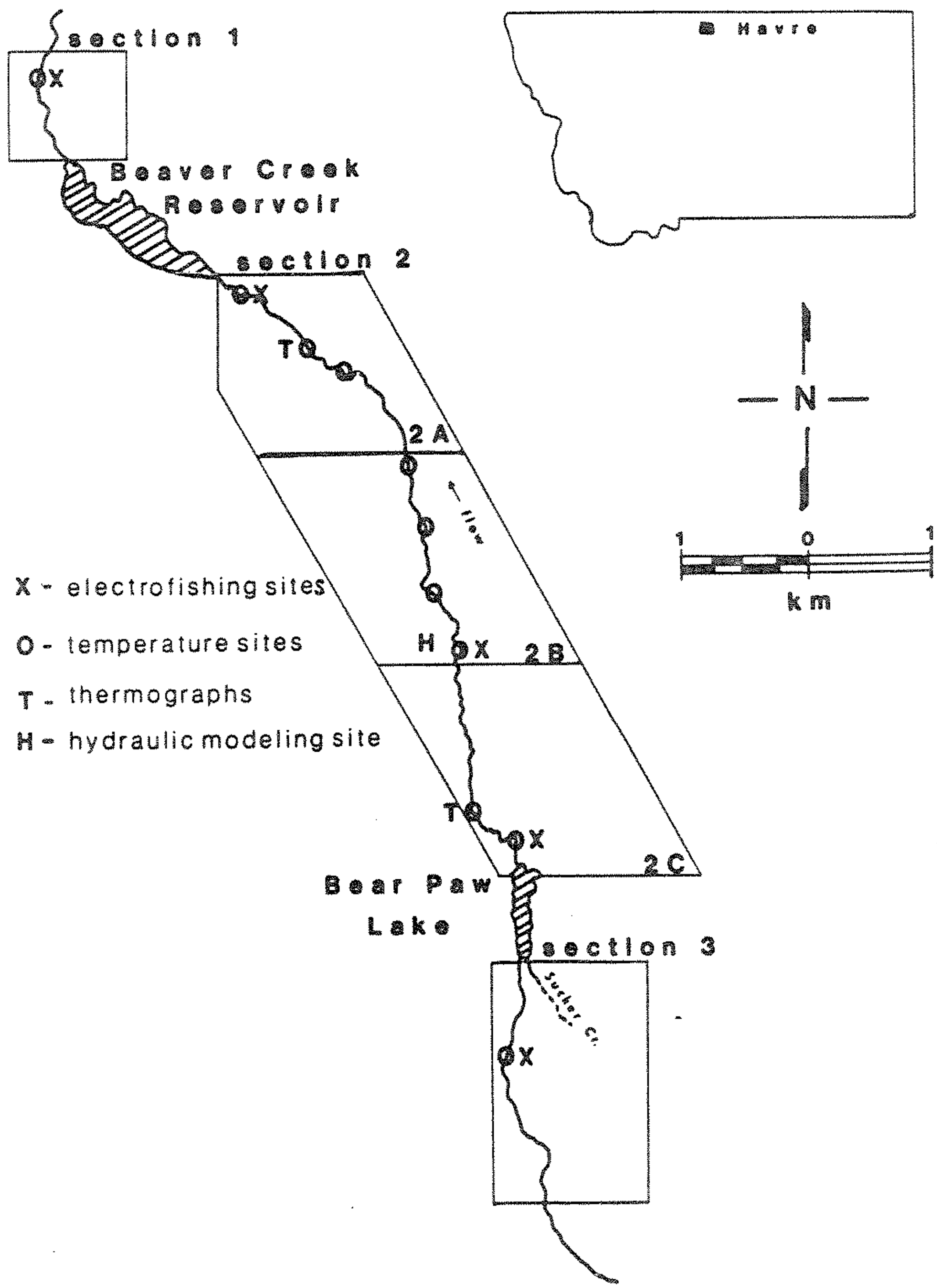

Figure 1. Location of electrofishing, temperature, hydraulic modeling, and thermograph sites in the Beaver Creek study area.

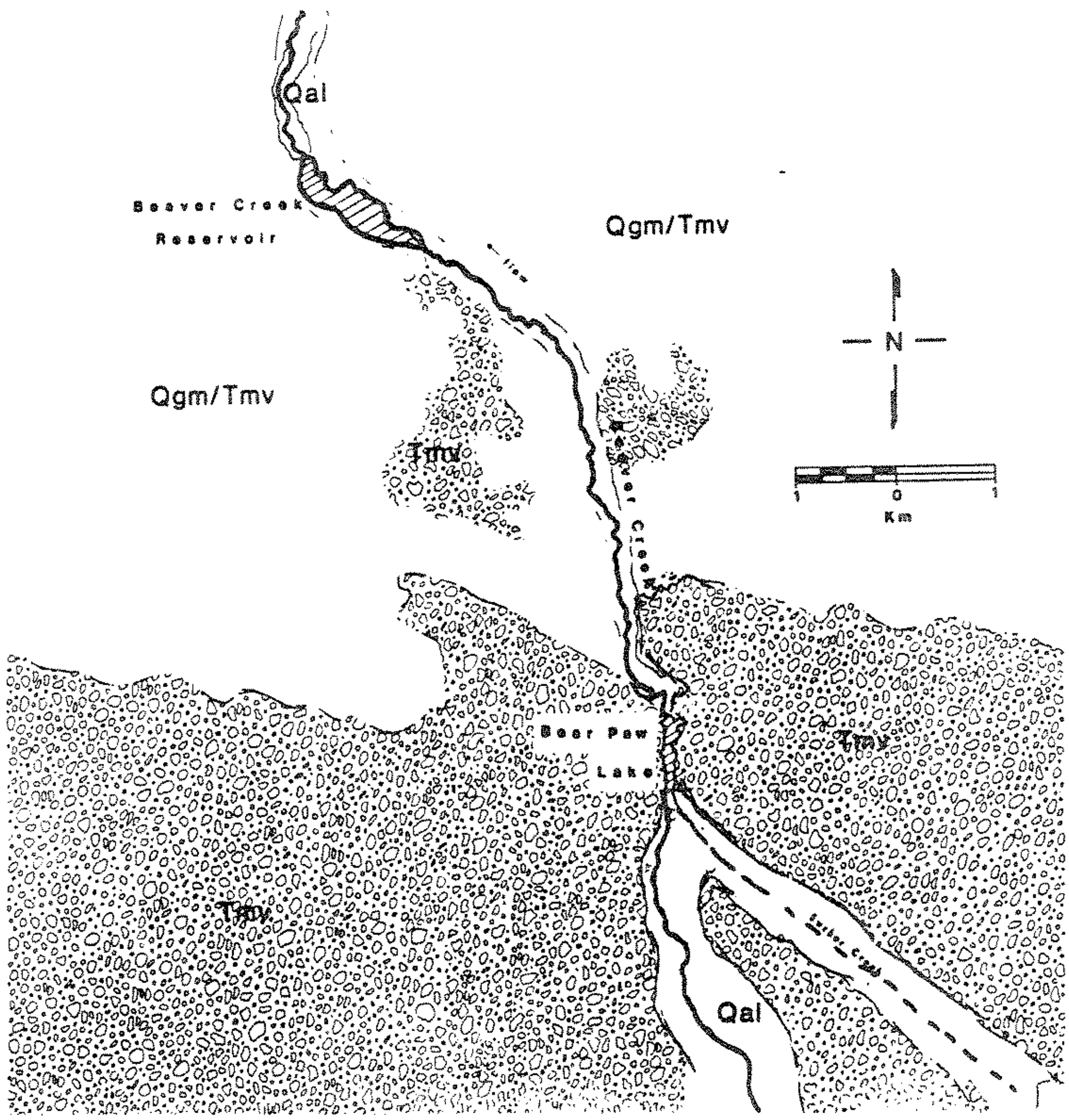

Figure 2. Geology of the Beaver Creek study area identifying alluvium (Qal), ground moraine (Qgm), and mafic volcanic (Tmv) rock formations (Kerr 1957).

deposits of stream alluvium are larger in grain size and are exposed along a narrow margin (50 - 100 m) on either side of Beaver Creek. Section 1 has a lower gradient (7.6 m/km) than the other four sections which adds to the potential for deposition.

Table 1. Parameters of the Beaver Creek study area.

Section	Distance from Bear Paw Lake (upper end of section) (km)	Section length (km)	Streambed gradient (m/km)	Mean width (m)
1	10 km downstream (immediately below Beaver Creek Reservoir)	1.6	7.6	6.2
2A	7 km downstream (immediately above Beaver Creek Reservoir)	3.0	7.6	4.4
2B	3.2 km downstream	3.0	15.2	4.6
2C	immediately downstream	3.2	20.8	5.2
3	immediately upstream	1.6	14.4	4.6

The study area between the reservoirs was divided into three sections, 2A, 2B, and 2C (Figure 1). Section 2A is 3 km in length, beginning 7 km downstream from Bear Paw Lake and terminating at the junction of Beaver Creek and Beaver Creek Reservoir (Table 1). This section is similar in physiography and gradient (7.6 m/km) to section 1, and has cut through the deposited ground moraine, leaving a series of high, unstable silt walls.

Section 2B begins 3.2 km downstream from Bear Paw Lake (Figure 1) and is 3 km long (Table 1). Stream gradient is 15.2 m/km and streambed composition tends toward the larger rubble and cobble (Table 2), which is more typical of stream alluvium.

Section 2C starts at the penstock outlet of Bear Paw Lake (Figure 1), and extends 3.2 km downstream (Table 1). Volcanic benches and slabs make up a large proportion of the streambed. Their presence have produced a series of 1-2 m waterfalls in one reach. Even though section 2C has a substantial gradient (20.8 m/km) that would tend to carry silt away, depositional areas are still very evident.

Section 3, above Bear Paw Lake (Figure 1), is 1.6 km in length (Table 1). The section has a moderate gradient (14.4 m/km) with more alluvium than ground moraine, producing a substrate dominated by cobble and gravel (Table 2), and containing less silt than the other sections.

Table 2. Classification of substrate based on a modified version of the Wentworth particle size scale (Spoon 1985).

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

Average discharge is similar in all sections for all months of the year. Low flows occur between August and February, while the largest discharge is from late April through mid-July. Between 1981 and 1983, flows ranged from 0.056 to 14.0 m^3/s, with average annual discharge between 0.28 and 0.42 m^3/s. The largest flow recorded during the study period occurred in May 1982 and was associated with a spring storm (7.0 m^3/s or approximately 300% of normal). Sucker Creek is the only tributary influencing flow in the Beaver Creek study area (Figure 1). The tributary carries a discharge of less than 0.28 m^3/s, is intermittent, and intersects Beaver Creek at the inlet of Bear Paw Lake.

All study sections have thick riparian vegetation which greatly limits accessibility for humans to the stream, particularly in section 1 and the lower reaches of section 2. Riparian vegetation consists mostly of willow

(*Salix* spp.), water birch (*Betula fontinalis*), and red dogwood (*Cornus stolonifera*), wildrose (*Rosa* sp.), and horizontal juniper (*Juniperus* sp.); various grasses were present in areas with less stable stream morphology. In sections 2C and 3, yellow pine (*Pinus jeffreyi*) and aspen (*Populus* sp.) were also present.

Beaver ponds are found in all sections. Ponds in section 3 are generally active, intact and considered in good condition. Most beaver ponds in sections 1 and 2 are inactive and in poor condition.

METHODS

Fish Population Sampling

Fish population estimates on Beaver Creek were made using the mark-recapture technique described by Vincent (1971). Mark-recapture was chosen to maintain continuity with the MDFWP methods, making a cooperative effort possible through shared equipment, personnel and data. One electrofishing section was established in each of the five study sections (Figure 1); subsampling was necessary because of limited accessibility and manpower. Each electrofishing section was selected to represent longitudinal habitat characteristics of that study section. Electrofishing sections ranged in length from 210 to 375 m and were bounded by natural barriers that would discourage movement of fish into or out of the sampling area (Table 3).

Samples were collected using a direct current bank electrofishing system consisting of a homemade rectifying unit, a 1500-watt generator, a hand-held anode and a stationary cathode. All detectable trout and suckers were captured with dip-nets. Fish were held in live cars until processed. The fish were anesthetised with MS222 (tricaine methano-sulfanate), measured for total length to the nearest 0.25 cm, and weighed to the nearest 0.05 kg using a platform spring scale. Scale samples from rainbow trout were taken from the left side, posterior to the dorsal fin, half-way between the lateral line and the median line of the dorsal surface. Pectoral and anal fin clips were used to provide unique marks for each electrofishing section. After marking, the fish were returned to the live car, allowed to recover, and were returned to their approximate area of collection.

Table 3. Length of population estimate sections on Beaver Creek in 1981 and 1982.

Section	Date	Section length (km)
1	9/81	0.248
	9/82	0.375
2A	9/81	0.375
	9/82	0.365
2B	9/81	0.312
	9/82	0.300
2C	9/81	0.234
	9/82	0.210
3	9/81	0.143
	9/82	0.280

Marking runs were made during the last week of August in 1981 and 1982, and consisted of one upstream and one downstream pass through each section. In 1981, 2 - 5 d were allowed between marking and racapture. In 1982 this period was increased to a minimum of 10 d. Recaptured fish were measured for length while unmarked fish were measured for length and weight, and scale samples were taken from rainbow trout.

Species abundance was estimated using Chapman's modification of the Petersen formula described by Ricker (1975).

$$N^* = \frac{(M+1)(C+1)}{(R+1)}$$

Where N* is the abundance estimate, M is the total number of marked fish, C is the total number of fish captured on the recapture run, and R is the number of marked fish collected on the recapture run. Confidence intervals were constructed using the variance approximation (Ricker, 1975):

$$V(N^*) = (N^*)^2 \; (C-R)/(C+1) \; (R+2)$$

$$SD = SQRT(V(N^*))$$

$$95\% \; CI = t(SD)$$

Where V(N*) represents the variance approximation, SD is the standard deviation, 95% CI is the 95% confidence interval, t represents the t-value for the 0.975 percentile of the t distribution (single tailed), and SQRT identifies the square root operation.

Where it was necessary to combine estimates, confidence intervals were summed using the following formula (Snedecor and Cochran 1980):

$$CI = t[\ SQRT(SUM(SD)^2\ )\ ]$$

Age was determined as described in Bagenal (1978). Heat impressions of rainbow trout scales were made on clear polyvinyl using a hydraulic press and were then viewed under magnification to determine the number of annuli present. Scale radius measurements were made from the scale focus to each annulus and the edge of the scale. These data were used to back-calculate growth of rainbow trout by using the Lea corrected direct proportion method (Bagenal 1978). This method was chosen because it had a higher predictive value (r=0.74 or greater) than other linear and non-linear models attempted in this evaluation. Back-calculated lengths of rainbow trout were analyzed using the FIRE 1 computer program (Hesse, 1977). Calculations were made to determine mean total length at each annulus for each age group of the rainbow trout age I and older. Mean condition factor and standard error were also determined. The analysis was completed for each of the five electrofishing sections and was based on a total sample of 334 rainbow trout.

Spawning Habitat

To determine suitability of streambed gravels for trout spawning, 16 substrate samples from five sections (Figure 3) were taken using a modified McNeil sampler (McNeil and Ahnell 1964). Sites which appeared best suited for trout spawning were selected. Preferred sampling sites were those that had loose gravel of 7 to 77 mm diameter. The tail of a pool, the head of a run or any other morphological feature of the streambed that would enhance intergravel flow, were sought in choosing sampling sites.

Gravel samples were oven-dried, sieved and weighed. Eleven sieve sizes ranging from 0.419 to 50.8 mm were used. The content of each sieve tray was weighed to the nearest 5 g. Percent composition by particle size was then calculated. Cumulative percentage of substrate composition was plotted against particle size to produce a unique curve for each sample. Percentage of substrate smaller than 9.50 mm and 0.85 mm was used to predict rainbow trout embryo survival following the equation described by Irving and Bjornn (1984) relating rainbow trout embryo survival to gravel size compositon.

percent survival =

$$113.58 - 10.77(S_{0.85}) - 0.007(S_{9.5})^2 + 0.301(S_{0.85})^2$$

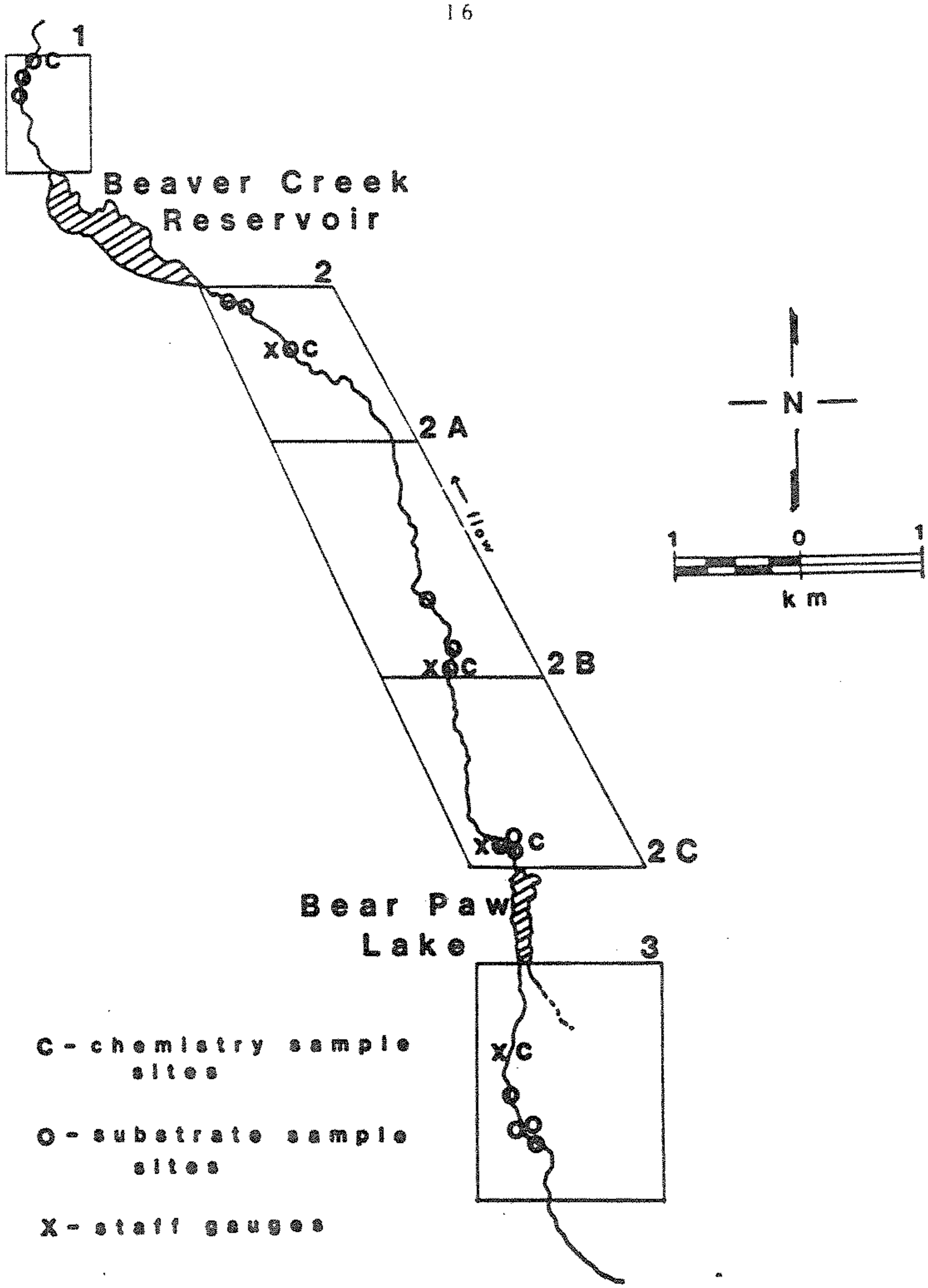

Figure 3. Locations of water chemistry sampling, substrate sampling, and staff gauge sites in the Beaver Creek study area.

where $S_{9.5}$ represents percent composition of the substrate sample with particle size of 9.5 mm or less, and $S_{0.85}$ is the percent composition of the substrate sample with particle size of 0.85 mm or less.

The equation was developed by Irving and Bjornn (1984) using stepwise regression to relate embryo survival to substrate size composition ($r^2 = 0.92$). The rate of fry emergence from two or three replicates for each of 15 gravel mixtures, using 100 trout embryos in each mixture, was determined from experimental troughs. The choice of gravel mixtures was based on a range of gravel size compositions found in salmonid spawning areas of three Idaho streams (Tappel and Bjornn 1983).

Habitat and Hydraulic Modeling

The U.S. Fish and Wildlife Service (USFWS) Instream Flow Group (IFG) model (PHABSIM) was used to predict rainbow trout habitat availability at three discharges. According to Bovee (1982) "The underlying principles of PHABSIM are that each species of fish shows preference for a range of habitat conditions, that these ranges can be determined, and that the area of the stream providing these conditions can be quantified as a function of discharge and channel structure". Bovee and Cochnauer (1977) used habitat-use data reported in the literature to develop preference curves for each rainbow trout life history stage. The functions of these curves are termed the joint preference functions. Parameters used in computation of the joint preference function were depth, velocity, and substrate. Optimum trout habitat is defined as the peak of the preference curve, while either tail represents habitat which is considered less suitable for the trout (Bovee 1978).

To estimate amount of optimum habitat available to rainbow trout at three discharges in Beaver Creek, five transects representative of available habitat were chosen in section 2B of the study area (Figure 1). Depths and velocities were collected at 0.3 m intervals along each transect at high (0.878 m^3/s), medium (0.312 m^3/s), and low (0.065 m^3/s) discharges. Substrate types and percent composition were noted for each transect. Section lengths were measured along the thalweg, and both banks. Water surface and streambed elevations were measured for each transect following the procedures described by Bovee and Milhous (1978).

Staff gauges were placed in four locations along Beaver Creek (Figure 3). A stage-discharge relationship was developed for each site. A Price "AA" current meter attached to a top-setting rod was used to measure discharge (Bovee and Milhous 1978).

Data were entered into the computer in the form compatible with the IFG IV and PHABSIM programs (Main 1978). The information was processed at University of Idaho using IFG IV, PHABSIM, and preference curves for three life stages of rainbow trout (juvenile, adult, spawning). The preference curves used were those developed through the USFWS Instream Flow Group by Bovee (1978)(Appendix A Figures 17-19).

Temperature

Taylor thermographs were used to continuously monitor temperature at two locations (2 km and 8 km downstream from Bear Paw Lake) during June, July, August and September of 1981 and 1982 (Figure 1).

Discharge data were collected throughout the study period at the lower thermograph site and were related to temperature. Water level was read from a staff gauge attached to the inside wall of a parshall flume. This value was then translated to discharge using a stage-discharge curve developed during the study. Accuracy of the staff gauge and the stage-discharge curve was verified at different flows using a Price "AA" current meter attached to a top-setting rod.

To measure water temperature variation within the study area, 11 sampling sites were selected (Figure 1). Sample sites were separated by an average of 1.0 km. One site was below Beaver Creek Reservoir and one was located above Bear Paw Lake. The remaining nine sites were located between the two reservoirs.

Water and air temperatures were measured between 1300 and 1700 h, on 7 randomly selected days between 1 August and 15 September 1981, and 7 d during the same time period in 1982. Sampling times were selected to provide a representative sample of maximum daily water temperatures in the Beaver Creek study area. The average-maximum temperature for each site was calculated and plotted as a function of distance from Bear Paw Lake.

Temperature Model

A temperature model, described by Goodman (1983), was used to predict the influence of various water release strategies from Bear Paw Lake on temperatures in Beaver Creek. Model components are as follows:

$$T = T_e - EXP(-kt)\ (T_e - T_o)$$

where T is the temperature after an elapsed time t, and T_0 is the intial temperature, T_e is the equilibrium constant, and k is the rate coefficient. A detailed explanation of the model is presented in Appendix B.

To determine a range of discharges that would provide a given temperature at a specific site on the stream, the equation was solved twice, once to calculate a suitable rate coefficient (k), and a second time to determine the travel time (t) and discharge (Q).

To calculate the rate coefficient (k), 14 sets of data collected in July-August 1982 were used (Appendix C Table 17). Each data set consisted of four values. Two average-daily temperatures were used to represent T_e (from the lower thermograph) and T (from the upper thermograph). The initial temperature (T_o) was collected from the bottom of the lake using a Kemmerer sampler and thermometer; the travel time (t) was determined following the methodology described by Boning (1974)(Appendix B). Rate coefficients were calculated for each of the 14 data sets. A mean rate coefficient (k_m) and 95% confidence values (k_u and k_l) were then determined for the data set.

To calculate discharges (Q), the equation was rearranged to solve for the travel time (t) and the mean rate coefficient (k_m) was held constant. The equilibrium temperature (T_e) was considered to be the average of the temperatures collected at the lower thermograph site from 1 July to 15 September 1982. Hypolimnetic temperature was used to represent the initial temperature (T_0) of water released from the lake. The initial temperature values are rather robust estimates calculated from data collected biweekly in the summer of 1982. The resulting travel rates (t) were translated into discharge values (Q) using discharge-travel rate curves. This information was used to determine what discharges from Bear Paw Lake would produce a given temperature at a specific distance downstream.

Water Storage

Montana State Water Quality Bureau personnel mapped Bear Paw Lake (Figure 4) to determine surface area and volume, and to develop a discharge rating curve to be used in relating water withdrawal to change in lake surface area. Amounts of water available and area of exposed lake bottom resulting from a 2.5 m drawdown were computed.

Inflow and outflow of Bear Paw Lake were measured using the stage-discharge relationship established at staff gauges located immediately upstream and downstream from the lake (Figure 3). The continuous discharge record of Beaver Creek as recorded by the USDA Soil Conservation Service was used as the main data base for monitoring Bear Paw Lake outflow.

Bear Paw Lake Temperature and Dissolved Oxygen Profiles

To determine effects of hypolimnetic discharge on Bear Paw Lake, changes in temperature and oxygen profiles were monitored in the lake during 1981 and 1982. Seasonal

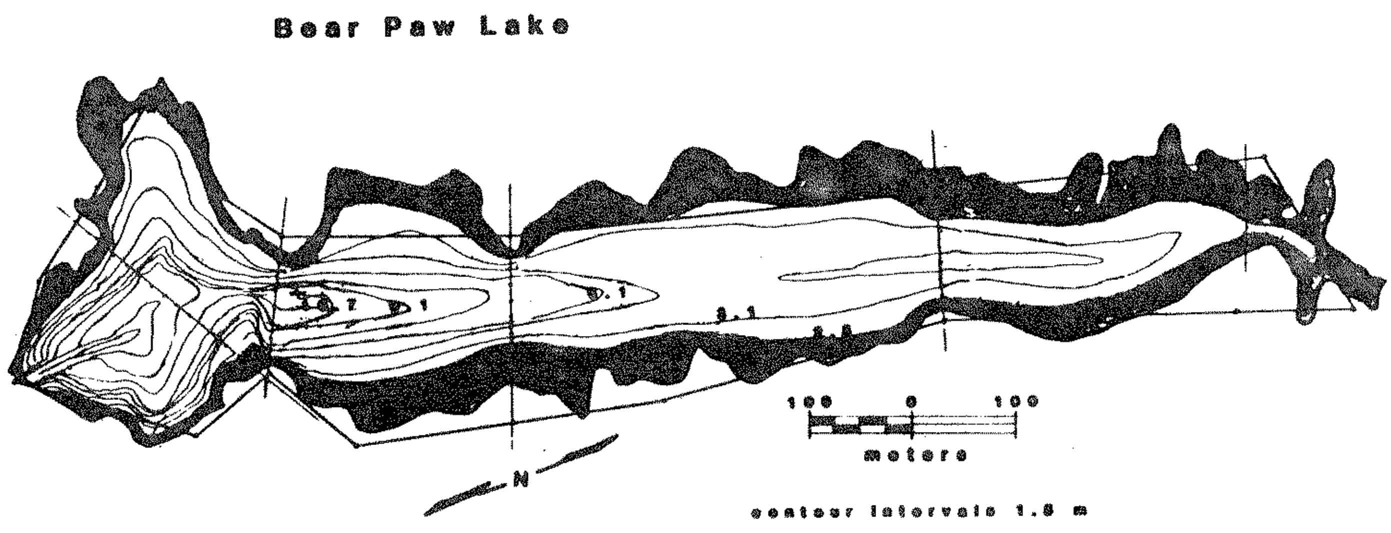

Figure 4. Depth contours of Bear Paw Lake. Shaded area represents exposed lake bottom resulting from a 2.5 m drawdown.

samples were collected, with the most intense sampling during spring and summer, 1982. Summer samples were taken about every 14 d (July-September). Water samples were collected from surface to bottom at 1.3 m intervals using a Kemmerer water sampler. Temperatures were taken from each sample immediately following its removal from the sampler. Dissolved oxygen was then determined in the field following procedures outlined in Standard Methods (1971). Dissolved oxygen and temperature curves were constructed and degree of stratification and effects of discharge strategy (surface, bottom or some combination of both) upon stratification, were determined.

Specific Conductance and Hydrogen Ion Concentration

Specific conductance and hydrogen ion concentration were evaluated seasonally at five sites in the Beaver Creek study area (Figure 3). Measurements of pH were made using an Orion model 407 Specific Ion Meter. Specific conductance was measured with a Beckman RB3-Solu Bridge. Fall 1981 samples were fixed with 0.025 N nitric acid and transported to Montana State University, Bozeman, for analysis. All other samples were analyzed on site.

Water samples were collected near the thalweg. Water and weather conditions were noted as well as factors that might influence water quality (melting snow or cattle in the stream).

Means and ranges were determined for pH and specific conductance. Means for pH were calculated by converting pH to hydrogen ion concentration and then calculating the mean.

Recreation Survey

A recreation survey was conducted from 25 June through 15 September 1982 to determine recreational use and angler attitudes on the study area. Two stratified sampling schedules were used. Seven, 2-week sampling sets were chosen. Eight weekdays (Monday through Thursday) and six weekend-days (Friday through Sunday) in each set were randomly selected for sampling. Eight-hour surveys were carried out for the first four sets (25 June - 9 August), while 4 h surveys were completed for the remaining sets. During a given survey, two round trips were made through the study area. People along the stream and Bear Paw Lake were asked to respond to 19 questions (Appendix D). Numbers of fish creeled from the stream and Bear Paw Lake were recorded. Responses to survey questions were reported as percentages.

Erosion

Annual surveys were conducted along Beaver Creek to document locations of sediment sources. The surveys were conducted on 18 August and 26 July in 1981 and 1982, respectively. Major erosion sources were considered to be those sites which, even at low flows (less than 0.283 m^3/s) contributed silt to the stream system. Most of these sites were large vertical walls (20 - 50 m) of ground moraine. Minor erosion sources were those sites which were potential silt producers. Channelized sections of the stream and banks with minimal cover were the major constituents of this category. Generally, these sites were considered producers of silt at flows greater than 0.283 m^3/s. Soil Conservation Service personnel evaluated the off-stream sources of erosion and condition of the range.

Beaver Ponds

During the 1981 and 1982 stream surveys, beaver ponds in the study area were enumerated and categorized as active or inactive. In 1982, physical characteristics of 14 ponds in section 2 of the study area were documented. Measurements of maximum water depth, length, width, and surface area of the ponds were made.

Rainbow trout populations in beaver ponds were sampled using electrofishing gear. Fish were weighed and measured, and scale samples were taken. A length-weight relationship was calculated for rainbow trout sampled in ponds (N=67) and in the stream (N=87) in section 2 of the study area using the regression program from Statistical Package of the Social Sciences (Nie 1975). Comparison of the two regression lines was made using methods outlined in Neter and Wasserman (1974).

RESULTS AND DISCUSSION

Species Composition, Distribution and Relative Abundance

Fifteen species of fish were collected from Beaver Creek (Table 4). The most common species was the white sucker (*Catostomus commersoni*) which had an estimated abundance of 1882 fish/km and biomass of 131.26 kg/km (Table 5). Rainbow trout, with an estimated abundance of 451 fish/km and biomass of 25.40 kg/km, was the most abundant game fish (Table 5).

Table 4. Fish species collected on Beaver Creek in 1981 and 1982, in order of relative abundance.

White sucker	(*Catostomus commersoni*)
Longnose dace	(*Rhinichthys cataractae*)
Mottled sculpin	(*Cottus bairdi*)
Longnose sucker	(*Catostomus catostomus*)
Rainbow trout	(*Salmo gairdneri*)
Mountain sucker	(*Catostomus platyrhynchus*)
Brook trout	(*Salvelinus fontinalis*)
Brassy minnow	(*Hybognathus hankinsoni*)
Silvery minnow	(*Hybognathus nuchalis*)
Northern redbelly dace	(*Phoxinus eos*)
Brook stickleback	(*Culaea inconstans*)
Lake chub	(*Couesius plumbeus*)
Northern pike	(*Esox lucius*)
Brown trout	(*Salmo trutta*)
Largemouth bass	(*Micropterus saloides*)

Table 5. Average number (fish/km) and biomass (kg/km) of trout and suckers estimated for combined study sections of Beaver Creek where each species was present in 1981 and 1982. The 95% confidence intervals are in parentheses.

Species	Occurrence (number of sections)	Combined section length (km)	Number (fish/km)	Biomass (kg/km)
Rainbow trout	9	2.608	451 (307-606)	25.40 (19.83-30.98)
Brown trout	4	0.623	68 (32-106)	8.48 (3.44-13.52)
Brook trout	4	0.633	562 (352-994)	49.42 (41.14-57.71)
White sucker	10	2.842	1882 (1372-2390)	131.26 (95.84-166.69)
Longnose sucker	6	1.975	810 (562-1059)	98.96 (68.05-129.82)
Mountain sucker	8	2.419	427 (203-583)	10.56 (6.28-15.60)

Three species of catostomids were present in Beaver Creek (Figure 5). White suckers were found in all sections; mountain suckers (*Catostomus platyrhynchus*) were restricted to sections below Bear Paw Lake, while longnose suckers (*Catostomus catostomus*) were found only in sections 1, 2A, and 2B.

Gradient and substrate appeared to be the major factors affecting distribution of catostomids in Beaver Creek. White suckers and longnose suckers were dominant

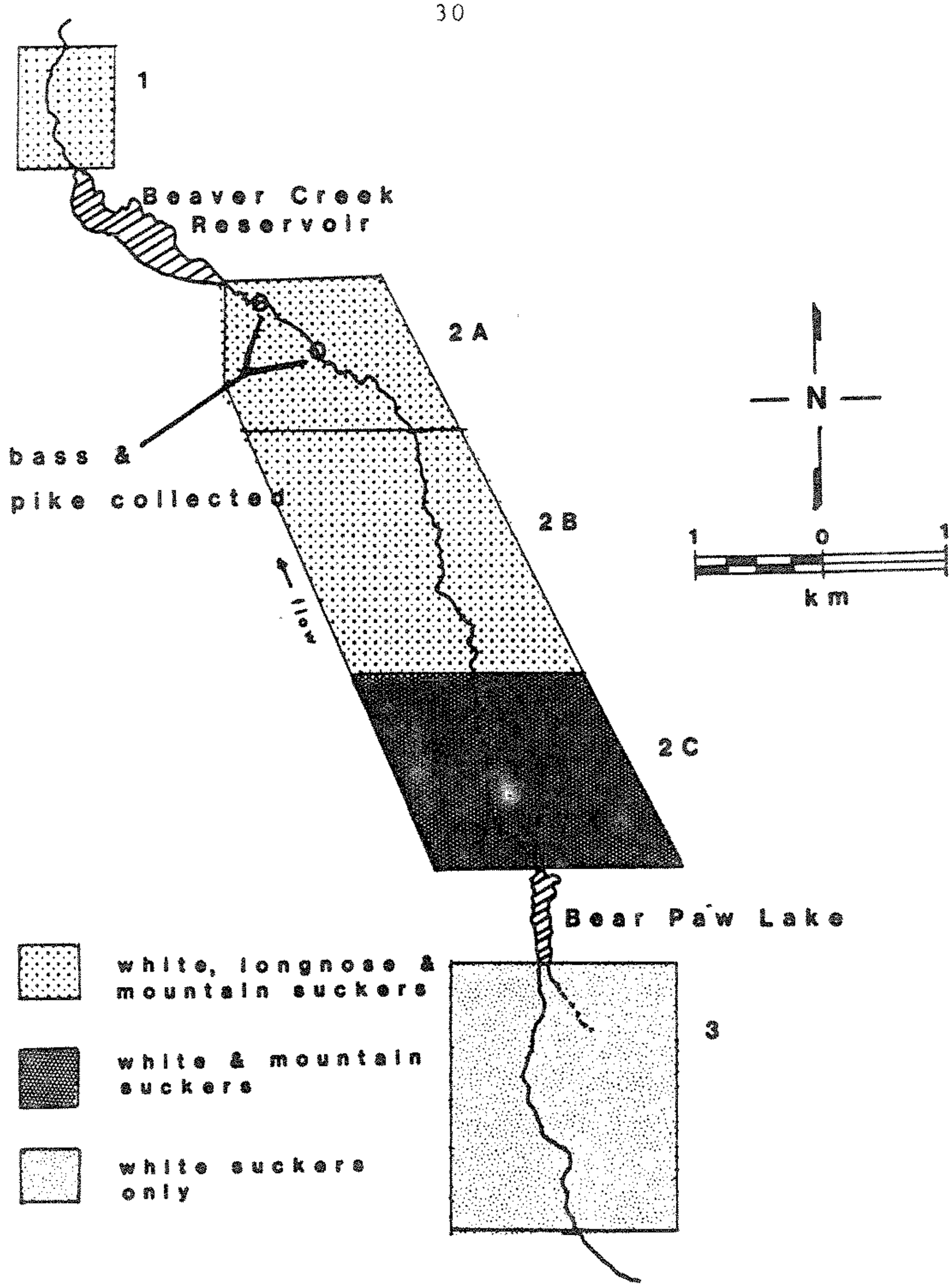

Figure 5. Distribution of white, longnose, and mountain suckers in Beaver Creek. Largemouth bass and northern pike collection sites are also included.

in areas with a gradient of 0 - 8 m/km where substrate was composed of more than 20% fine particles (<0.85 mm). Mountain suckers were found only in steep gradient (8 - 15 m/km) stream sections having cobble (5 - 10 cm) to rubble (10 - 50 cm) size substrate. Brown (1971) and Smith (1978) noted similar trends in habitat selection for these species. Of the three catostomids, the white sucker is considered the least discriminant in habitat preference and has an optimum temperature range of 19 to 21 C (Twomey et al. 1984). This helps explain the broad distribution and large number of white sucker in Beaver Creek.

Rainbow trout were present in all sections of the study area. Brown trout (Salmo trutta) were found below Beaver Creek Reservoir (section 1), while brook trout (Salvelinus fontinalis) were restricted to areas above Bear Paw Lake (section 3) (Figure 6). In 1982, six northern pike (Esox lucius) and two largemouth bass (Micropterus salmoides) were collected in section 2A (Figure 5).

Catostomids were more numerous than salmonids in all study sections except section 3, located immediately upstream from Bear Paw Lake, and above the influence of artifical impoundments (Figure 7 and 8). In sections 1 and 2, rainbow trout and white suckers existed in a ratio of 0.08 to 1 (combined 1981 and 1982 estimates); in section 3 the ratio was 2.61 to 1. The numbers and sizes

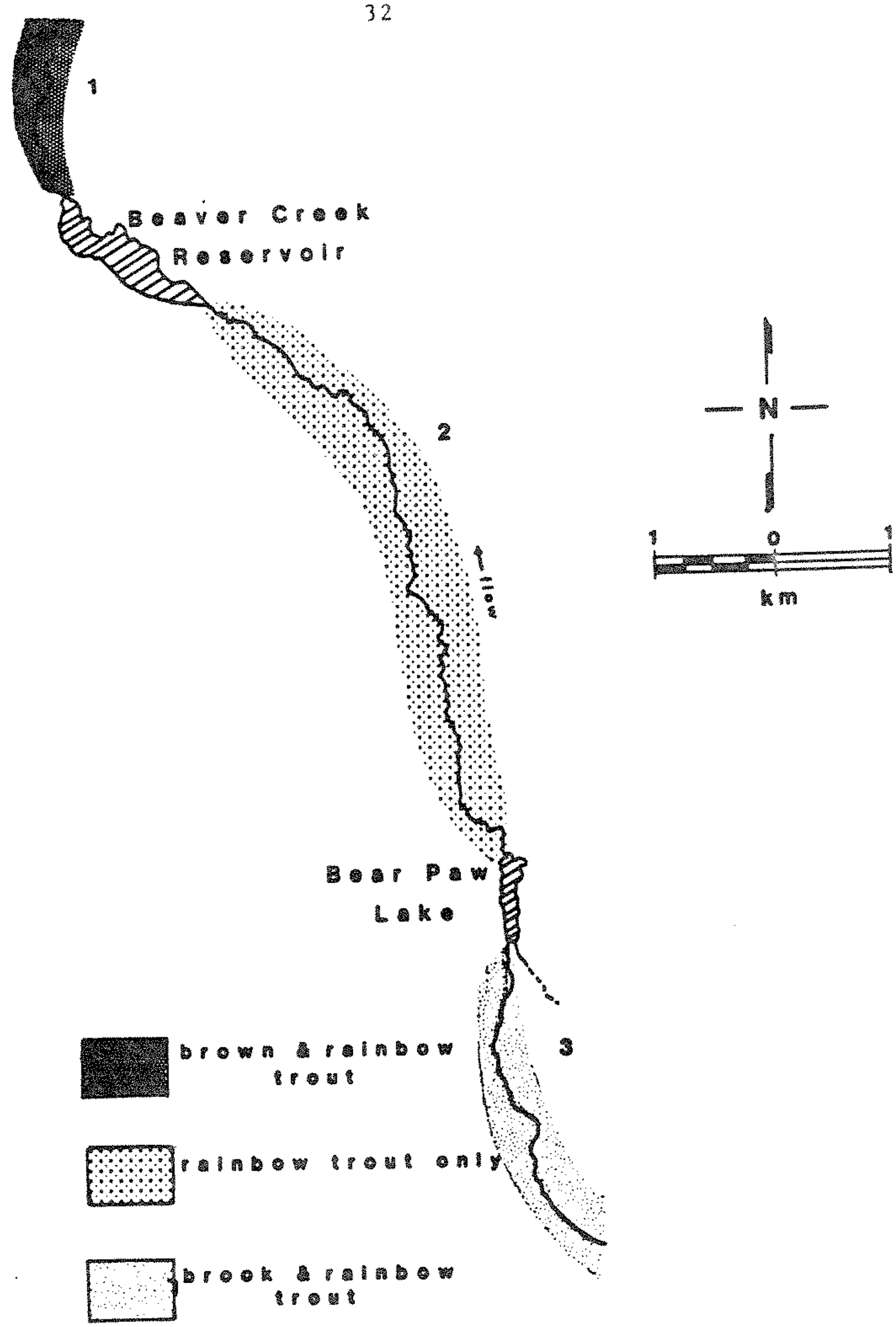

Figure 6. Distribution of rainbow, brook, and brown trout in Beaver Creek.

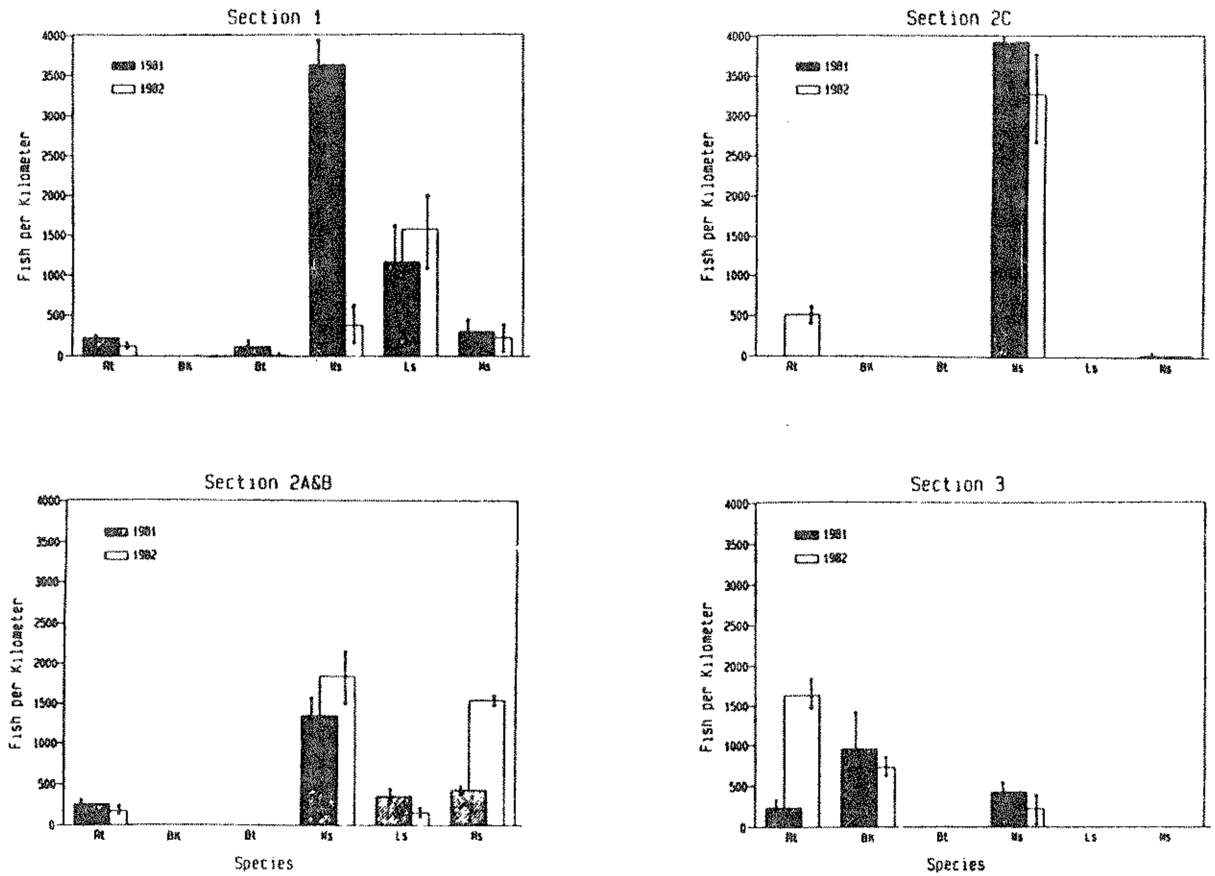

Figure 7. Estimated number of rainbow trout (Rt), brook trout (Bk), brown trout (Bt), white sucker (Ws), longnose sucker (Ls), and mountain sucker (Ms) per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval.

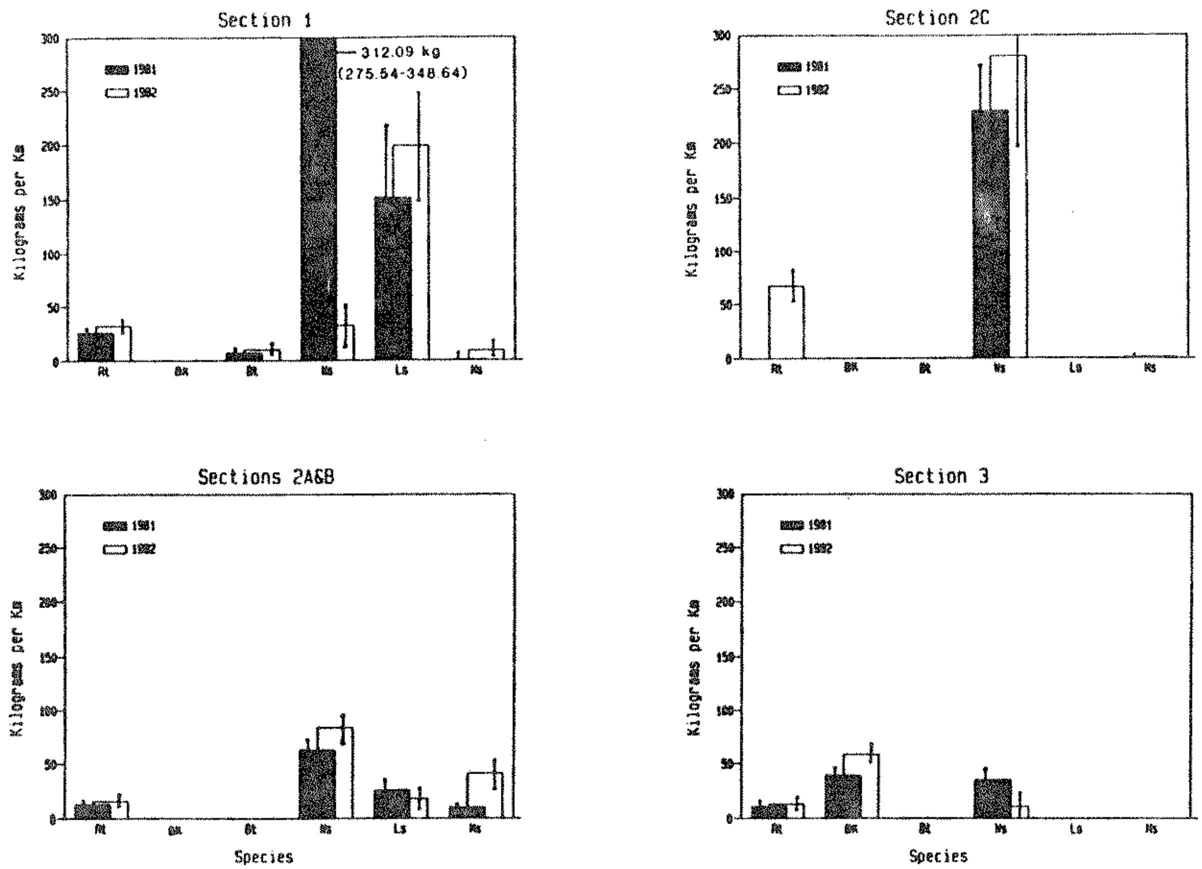

Figure 8. Estimated biomass (kg/km) of rainbow trout (Rt), brook trout (Bk), brown trout (Bt), white sucker (Ws), longnose sucker (Ls), and mountain sucker (Ms) in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval.

of salmonids and catostomids captured by electrofishing in each section are shown in Appendix C Tables 18-21. A summary of these results is given in Appendix C Tables 22 and 23.

Sediment, flow, and temperature conditions in Beaver Creek below Bear Paw Lake result in environmental conditions favorable to warmwater fish species. With average-maximum summer temperatures near 25 C, and a gradient of less than 7 m/km, the lower two-thirds (6 km) of the study area is more typical of a warmwater than a coldwater stream. In a review of warmwater stream literature, Winger (1980) noted that the difference between a warmwater and a coldwater stream is dictated not only by temperature but also gradient, discharge, velocity, stream size, substratum, organic input, and chemical characteristics. He further noted that geology influences these variables. Temperature is the dominant variable; streams with summer temperatures of greater than 20 C are more suited to warmwater fish species (Winger 1980).

Rainbow Trout Population Characteristics

Age Structure, Abundance and Biomass

Rainbow trout sampled in Beaver Creek ranged in age from young-of-the-year to IV+ in 1981 (N=334), and young-of-the-year to 3+ in 1982 (N=164). Few age 0+ rainbow trout were observed in sections 1 and 2 (Figure 9). Age 2+ trout made up 39% of the trout population in these sections, but there were fewer than 100/km (Figure 9, Appendix C Table 24) with an estimated biomass of less than 10.0 kg/km (Figure 10, Appendix C Table 25).

Section 3 had a relatively strong 0+ rainbow trout cohort in 1982, with an estimated 1,588 young-of-the-year/km and an estimated biomass of 9.63 kg/km. Only 63 age 0+ rainbow trout/km with a biomass of 0.38 kg/km, were estimated in 1981. The 2400% increase in age 0+ rainbow trout in 1982 was probably related to an improvement in quality of spawning substrate in spring 1982 due to flushing flows and gravel recruitment associated with a 10 year spring runoff event. In other study sections, 1982 flows did not improve substrate quality because of the geology of the area and the large amount of fine sediment released from over 100 beaver dams which washed out.

Estimated numbers of rainbow trout/hectare in all sections of Beaver Creek ranged from 388 (26.1 kg/ha) in 1981 to 1056 (53.8 kg/ha) in 1982, with an overall average of 722 (40.0 kg/ha) (Table 6). By comparison, standing crops of Sagehen Creek, California during 1952 - 1961, ranged from 384 to 1070 trout/ha with an average of 639 trout/ha. During the same time period the trout biomass in Sagehen Creek ranged from 19.6 - 50.9 kg/ha with an

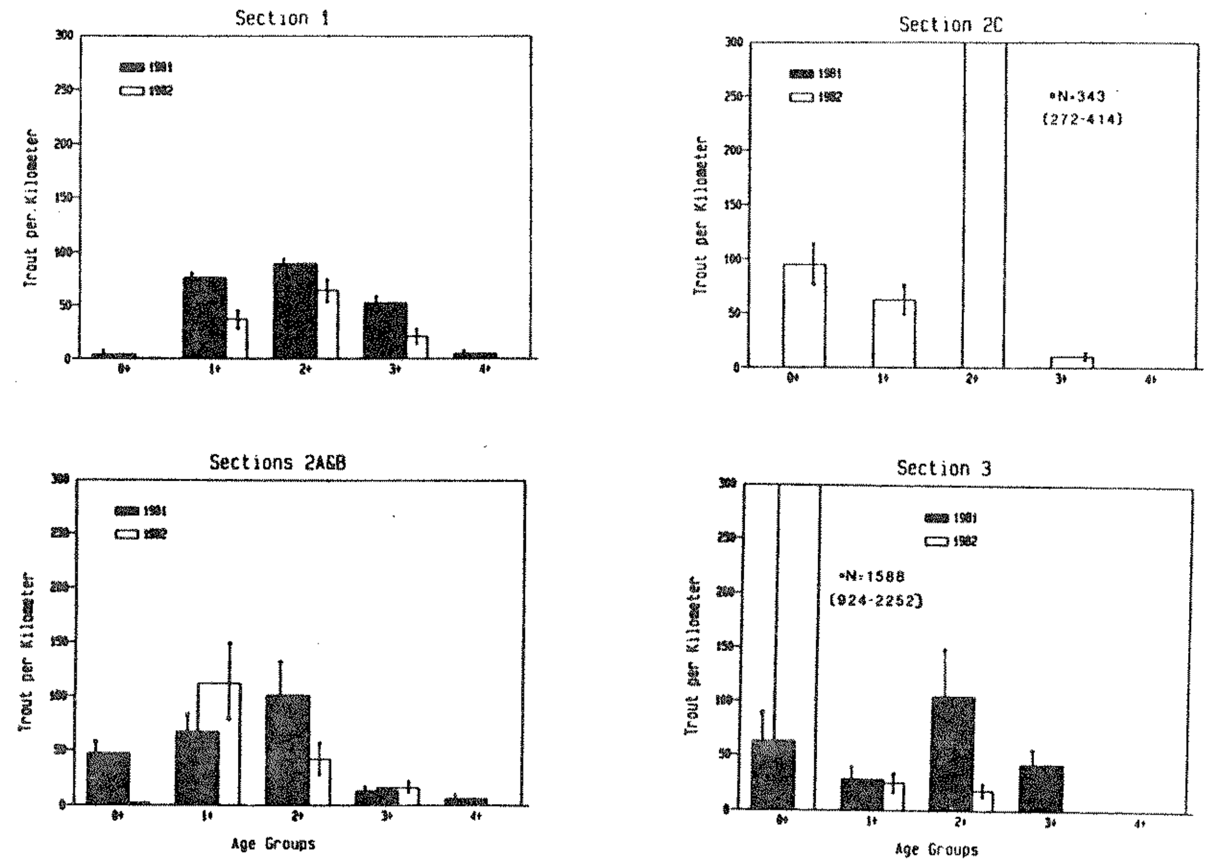

Figure 9. Estimated number of rainbow trout (per km) by age class in sections 1, 2, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval.

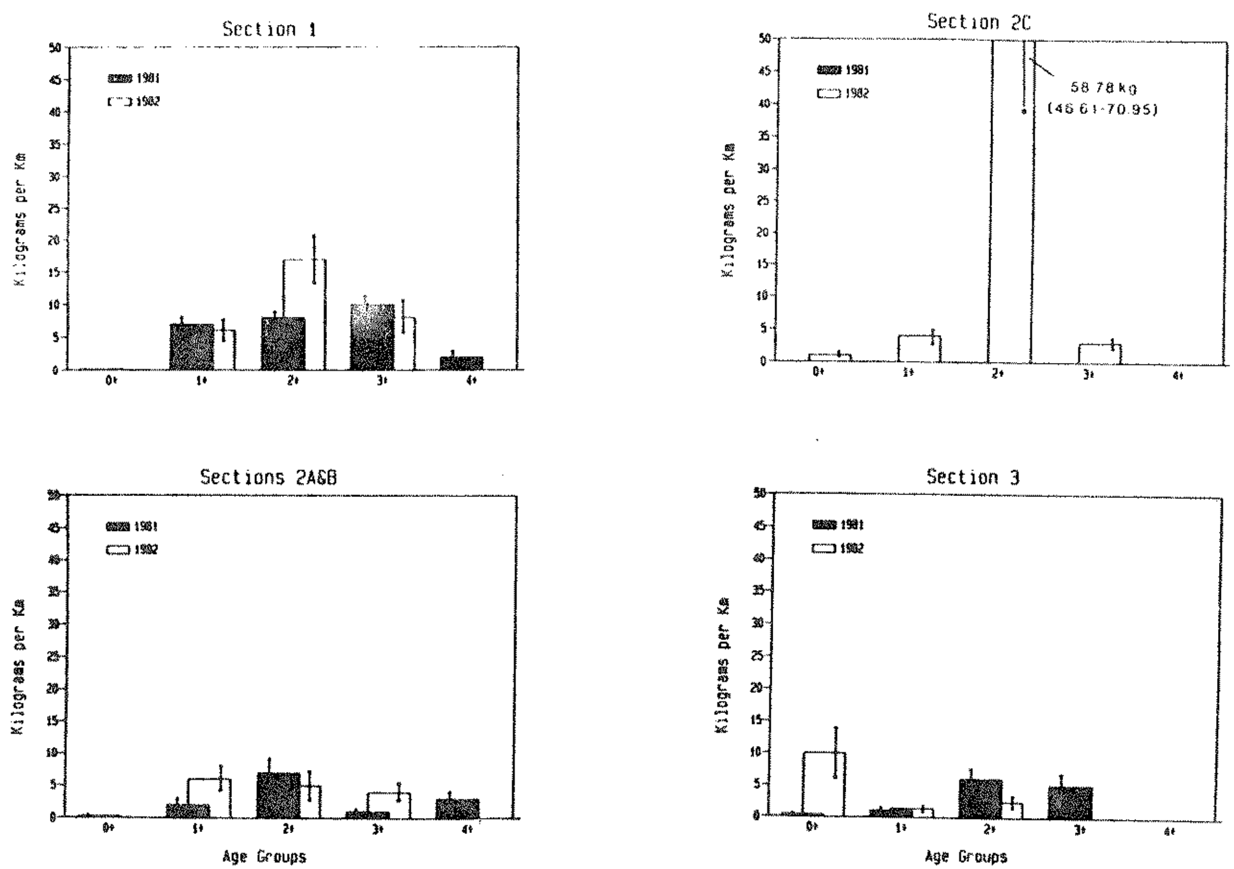

Figure 10. Estimated biomass (kg/km) of rainbow trout by age class in sections 1, 2A&B. 2C, and 3 of Beaver Creek during 1981 and 1982. Bars represent 95% confidence interval.

average of 33.0 kg/ha. In addition to similarities in abundance and biomass, Beaver Creek and Sagehen Creek also have comparable physical characteristics. Sagehen Creek, located in the eastern Sierra Nevada mountains, has an annual discharge of 0.056 - 4.20 m^3/s and water temperatures vary from freezing to greater than 21.1 C for short periods in summer (Gard 1961).

Table 6. Average number (fish/ha) and biomass (kg/ha) of rainbow trout estimated for Beaver Creek study sections during 1981 and 1982. The 95% confidence intervals are in parentheses.

Date	Section	Section length (m)	Section mean width (m)	N*	Average mass (kg)	Fish per hectare	Biomass (kg/ha)
9/81	1	245	6	56 (0)	0.133	376 (0)	50.0 (0.0)
	2A	375	4	68 (19)	0.048	453 (126)	21.7 (3.6)
	2B	312	5	99 (20)	0.058	634 (128)	36.8 (7.5)
	2C	234	5	0	0	0	0
	3	143	5	34 (15)	0.046	475 (10)	21.8 (9.6)
	Average all sections					388 (53)	26.1 (4.1)
9/82	1	375	6	47 (11)	0.183	209 (49)	38.2 (8.9)
	2A	365	4	75 (26)	0.064	513 (178)	32.8 (11.4)
	2B	300	5	41 (6)	0.145	273 (40)	39.6 (5.8)
	2C	210	5	107 (22)	0.130	1019 (209)	132.5 (27.2)
	3	280	5	457 (191)	0.008	3264 (1364)	26.1 (10.9)
	Average all sections					1056 (368)	53.8 (12.8)

N* = population estimate

In comparing Sagehen Creek with other similar streams, Gard and Seegrist (1972) noted that standing crops of trout in Sagehen Creek were above average with respect to numbers and about average with respect to masses. Their data were compared to wilderness streams in New Hampshire which had brook trout biomasses ranging from 26.8 to 70.5 kg/ha (Hoover 1939); to Convict Creek, California where brown trout biomass ranged from 29.4 to 108.0 kg/ha (57 kg/ha average)(Needham et al. 1945); and to Lawrence Creek, Wisconsin where brook trout and rainbow trout biomass ranged from 46.4 to 91.9 kg/ha with 406 to 745 trout/ha (McFadden 1961). Further comparisons were made to Crystal Creek, New York where a 4-year average of 85 brown trout/ha (12.5 kg/ha) was found (Schuck 1945), and Pigeon River, Michigan where a 2-year study reported 130 to 172 brook, rainbow and brown trout/ha (7.1 - 21.4 kg/ha) (Cooper 1952).

Standing crops in both Beaver Creek and Sagehen Creek varied greatly from year to year. Gard and Seegrist (1972) concluded that standing crop fluctuations in Sagehen Creek were associated with flooding, yearly draining, introduced stock, and presence of beaver impoundments in various condition. Most variation was attributed to changes in habitat related to floods and to shifting beaver populations. In Beaver Creek, flooding and shifting beaver populations appear to have affected potential spawning habitat. Introduced stock in study section 2C resulted in variations in standing crop from 0 in 1981 to 510 trout/km (66.5 kg/km) in 1982.

Age and Growth

Rainbow trout back calculated growth in sections 2A, 2B, and 3 was nearly identical (Table 7). Maximum and minimum back-calculated lengths of rainbow trout of the same age never differed more than 2.4 cm (Appendix C Table 26). Annual growth of rainbow trout in sections 1 and 2C was larger, but was biased by the influence of hatchery stock from the reservoirs.

Rainbow trout growth in Beaver Creek was similar to that reported for other streams in the western United States which have large variation in stream discharge and water temperature. In Sagehen Creek, California, rainbow trout growth rates averaged 4.1 cm/yr between their first and third year, with subsequent growth rates of less than 3.5 cm/yr (Gard and Seegrit 1972); this is almost identical to rainbow trout growth rates in Beaver Creek (Table 7). Gard and Seegrist (1972) noted that trout growth rates in Sagehen Creek were near the lower end of the range for similar streams used in their comparison. They suggested that reduced growth rate after age 3 was a result of the lack of suitable stream habitat for older,

Table 7. Mean back-calculated lengths and mean increments of back-calculated lengths for rainbow trout collected from Beaver Creek in 1981 and 1982.

			Calculated length (cm) at each age			
Section	Type of calculation	N	1	2	3	4
1	Mean back-calculated length	74	14.2	19.4	23.4	26.3
	Mean increment of back-calculated length		14.2	5.3	4.9	5.1
2A	Mean back-calculated length	89	11.8	16.2	21.9	25.4
	Mean increment of back-calculated length		11.8	4.9	5.7	5.1
2B	Mean back-calculated length	71	12.7	17.6	21.9	23.5
	Mean increment of back-calculated length		12.7	4.9	4.0	3.4
2C	Mean back-calculated length	68	15.7	21.3	27.4	-
	Mean increment of back-calculated length		15.7	3.6	5.5	-
3	Mean back-calculated length	29	13.0	16.8	20.5	-
	Mean increment of back-calculated length		13.0	3.7	2.9	-

larger trout while the younger, smaller trout had adequate habitat (Gard and Seegrit 1972).

Rainbow trout captured from Beaver Creek appeared to be in good physical conditon. The mean condition factor for 334 rainbow trout sampled in September 1981 and 1982, was 1.036 (SE = 0.027; SD = 0.488). Rainbow trout collected from Ruby Creek, in southwest Montana, had a mean conditon factor of 1.119 and were considered to be in fair to good condition compared to other trout populations in Montana (Randolph 1984). Preliminary studies of aquatic insect populations of Beaver Creek (Needham and Gilge 1980 and 1981) did not suggest that food was in short supply.

Hatchery Trout

In 1981, 1-year after rotenone treatment of Bear Paw Lake, no trout were collected in the 3.2 km of Beaver Creek immediately below the lake (section 2C)(Figure 1). During this period section 2B (6.2 km downstream from Bear Paw Lake) had an estimated 318 rainbow trout/km (18.60 kg/km); one-third of these were young-of-the-year. In 1982, rainbow trout were present in the 3.2 km section immediately downstream from Bear Paw Lake (510 trout/km; 66.49 kg/km)(Appendix C Table 18), primarily as a result of hatchery rainbow trout moving downstream from the lake. The movement was associated with a late May, 1982 flood. Less than one-fifth of these fish were young-of-the-year (Figure 9). Most fish captured were age 2+ and were substantially longer (mean length 24.9 cm) than fish sampled from sections 2A and 2B. Ten specimens of this cohort collected in spring 1983 (age 3) showed no sexual development. On the basis of external appearance (size and coloration), the rainbow trout collected in section 2C closely resembled the hatchery stock found in the reservoirs. To determine if these trout were genetically similar to the hatchery stock, 10 specimens from stream section 2C and 10 from Bear Paw Lake were analyzed by the University of Montana Genetic Laboratory. The results showed that the two samples had similar alleles, indicating that they were from the same stock (Gilge, pers. comm.).

Limitations to Rainbow Trout

Fine Sediment

Streambed Composition. I found few sites in Beaver Creek below Bear Paw Lake where particles smaller than 0.85 mm accounted for less than 20% of the streambed composition, and no sites where particles smaller than 6.4 mm made up less than 20% of the substrate (Table 8). Fine clay sediments are a natural derivative of the geology of the area and are readily deposited in low gradient reaches (<7 m/km). Substrate composition and permeability influence success of spawning, egg incubation and fry emergence (McNeil and Ahnell 1964, Reiser and Wesche 1977, Bjornn 1978, Turnpenny and William 1980, Moring 1982, Tappel and Bjornn 1983).

Table 8. Particle size distribution of potential spawning substrate expressed as cumulative percentages of substrate less than a specified particle size, Beaver Creek, 1982.

Section	Sample	Cumulative percent of the particle size												
	size (mm)	<0.419	0.589	0.85	1.18	2.00	4.75	6.40	9.45	12.7	19.1	25.4	38.1	50.8
1	1	12.13	15.95	16.50	19.67	27.31	36.98	39.06	42.97	52.30	61.82	74.14	86.42	100.0
	2	7.47	10.11	11.00	12.10	15.99	21.87	22.91	24.86	31.78	38.76	56.50	73.34	100.0
	3	12.52	21.41	24.00	26.67	34.95	43.61	45.06	47.80	53.85	57.57	64.22	77.39	100.0
2A	1	9.67	26.95	35.00	41.79	54.82	63.86	65.61	68.90	81.26	92.10	100.0	-	-
	2	6.17	13.44	16.00	19.70	31.08	43.28	45.61	50.00	63.61	73.46	89.00	92.82	100.0
	3	7.30	11.94	14.00	17.05	26.57	35.25	36.80	39.99	47.49	55.16	67.67	79.03	100.0
2B	1	9.84	20.21	24.00	26.58	36.38	44.51	45.38	47.03	53.45	57.68	71.76	83.17	100.0
	2	5.02	9.77	12.00	13.89	20.75	28.96	30.48	33.35	41.60	47.92	61.69	71.20	100.0
	3	4.28	6.78	10.00	10.09	18.29	24.99	26.52	29.39	35.89	43.36	51.56	64.08	100.0
2C	1	7.53	19.52	23.00	27.88	43.35	58.08	60.12	63.94	70.77	77.51	88.80	92.80	100.0
	2	1.55	5.31	9.00	10.76	24.02	38.07	38.99	40.71	50.77	57.78	70.90	83.12	100.0
	3	5.65	10.84	15.00	7.64	33.66	46.30	48.17	51.69	60.00	67.30	80.20	93.00	100.0
3	1	7.38	5.84	9.00	13.29	31.96	46.82	48.82	52.88	64.91	72.94	87.48	96.14	100.0
	2	4.59	9.78	11.00	13.41	21.39	30.77	32.66	36.20	44.58	55.76	74.32	89.45	100.0
	3	4.57	11.28	14.00	17.60	26.99	38.32	40.43	44.40	54.13	62.40	72.22	86.59	100.0
	4	5.19	8.95	11.00	12.51	18.67	25.37	26.56	28.79	34.60	40.35	58.27	69.09	100.0

Several researchers have shown that particles less than 0.85 mm are the most detrimental to salmonid embryo survival (Cederholm et al. 1981, McNeil and Ahnell 1964). Tagart (1976) reported reduced embryo survival in salmonids when 20% of the substrate was made up of particles less than 0.85 mm. Bjornn (1969) showed similar results when more than 20% of the substrate was made up of particles less than 6.4 mm. In all substrate samples collected in Beaver Creek, more than 20% of the particles were less than 6.4 mm in diameter (Table 8).

Predicted Spawning Success. Predicted percentages of rainbow trout embryo survival were calculated and tabulated for 16 sites along Beaver Creek using the Irving-Bjornn (1984) model (Table 9). Predicted embryo survival values ranged from 0 - 29.5%, being lowest at sites immediately above Beaver Creek Reservoir (2A) (mean predicted survival = 3.5%)(Table 9) which corresponds to the second lowest abundance of young-of-the-year rainbow trout observed in the study area (21 fish/km). This section was representative of approximately two-thirds of the study area between Bear Paw Lake and Beaver Creek Reservoir (6 km of stream).

Table 9. Predicted percent survival of rainbow trout embryo using Irving and Bjornn's (1984) survival equation and substrate data collected from Beaver Creek, 1982.

Section	Site	Site description	Cumulative % of substrate <0.85 mm	Cumulative % of substrate <9.50 mm	Predicted % survival	Section mean predicted % survival (standard dev.)
1	1	Head of washed-out beaver pond.	16.5	43.0	4.8	
	2	Tail of large pool, head of riffle.	11.0	24.9	27.2	
	3	Riffle at road crossing.	14.0	47.8	12.5	14.8 (11.4)
2A	1	Head of cement weir.	35.0	68.9	0.0	
	2	Tail of pool, head of riffle.	16.0	51.4	0.0	
	3	Large riffle.	14.0	40.0	10.6	3.5 (5.3)
2B	1	Tail of pool, head of riffle, area receives high livestock use.	24.0	47.0	0.0	
	2	Downstream from bridge, mechanically disturbed area.	12.0	33.6	19.9	
	3	Side of gravel bar.	10.0	29.4	29.5	20.8 (8.3)
2C	1	Mid-channel.	23.0	63.9	0.0	
	2	Mid-channel, gravel bar.	9.0	40.7	29.5	
	3	Mid-channel.	15.0	51.7	1.0	10.2 (16.7)
3	1	Downstream from beaver dam, in side channel.	9.0	52.9	21.4	
	2	Tail of large pool, head of riffle, next to a trout redd.	11.0	36.2	22.4	
	3	Road crossing.	14.0	37.6	11.9	
	4	Trout redd, below beaver dam.	11.0	28.8	25.7	20.5 (5.9)

The highest predicted rainbow trout embryo survival (mean 20.8%; Table 9) and greatest abundance of rainbow trout (Table 5) was observed in the study area above Bear Paw Lake (section 3) and the 4 km immediately below the lake. In these areas, substrate in potential spawning habitat contained less than 15% fines (particles <0.85 mm)(Table 8), and stream gradient was greater than 14 m/km, producing an environment more conducive to successful trout reproduction than lower gradient sections of the stream. Less than 10% of this section was considered potential rainbow trout spawning habitat.

Based upon the small abundance of rainbow trout young-of-the-year (25 fish/km, 0.23 kg/km), and those older than age 3 (20 fish/km, 3.83 kg/km), reproductive success in Beaver Creek below Bear Paw Lake was poor during the study period.

Sexually mature rainbow trout made up only 14% of the population in Beaver Creek. While some age 2+ males were sexually mature, no mature females less than age 3+ were observed. The small number of mature rainbow trout, combined with poor embryo survival, limits the reproductive potential of the population.

Stream Flow

Habitat Modeling. Low discharge during late summer and fall in Beaver Creek below Bear Paw Lake results in reduced rainbow trout habitat. Average monthly flows were as low as 0.09 m^3/s in 1981 and 0.24 m^3/s in 1982. According to the physical habitat simulation model (PHABSIM) (Bovee and Milhous 1978) and the USFWS Instream Flow Group (IFG) preference curves (Bovee 1978), quantity of suitable habitat for adult rainbow trout in section 2 of Beaver Creek was similar at flows ranging from 0.34 - 0.89 m^3/s (Figure 11). At these flows 51 - 53% of the stream channel would be within the "preferred" range of depths and velocities for adult rainbow trout as defined by the IFG preference curves (Appendix A). The model predicted availability of suitable habitat would decrease sharply at flows less than 0.34 m^3/s, reducing suitable adult rainbow trout habitat from 50% (500m/1000m) at 0.34 m^3/s to less than 22% (220m/1000m) at 0.06 m^3/s (Figure 11).

The model predicted that quantity of juvenile rainbow trout habitat in section 2 of Beaver Creek was similar between 0.42 and 0.89 m^3/s, but decreased rapidly when discharge was reduced (Figure 11). Forty-eight percent (480m/1000m) of the stream section was predicted to be suitable juvenile rainbow trout habitat at 0.42 m^3/s,

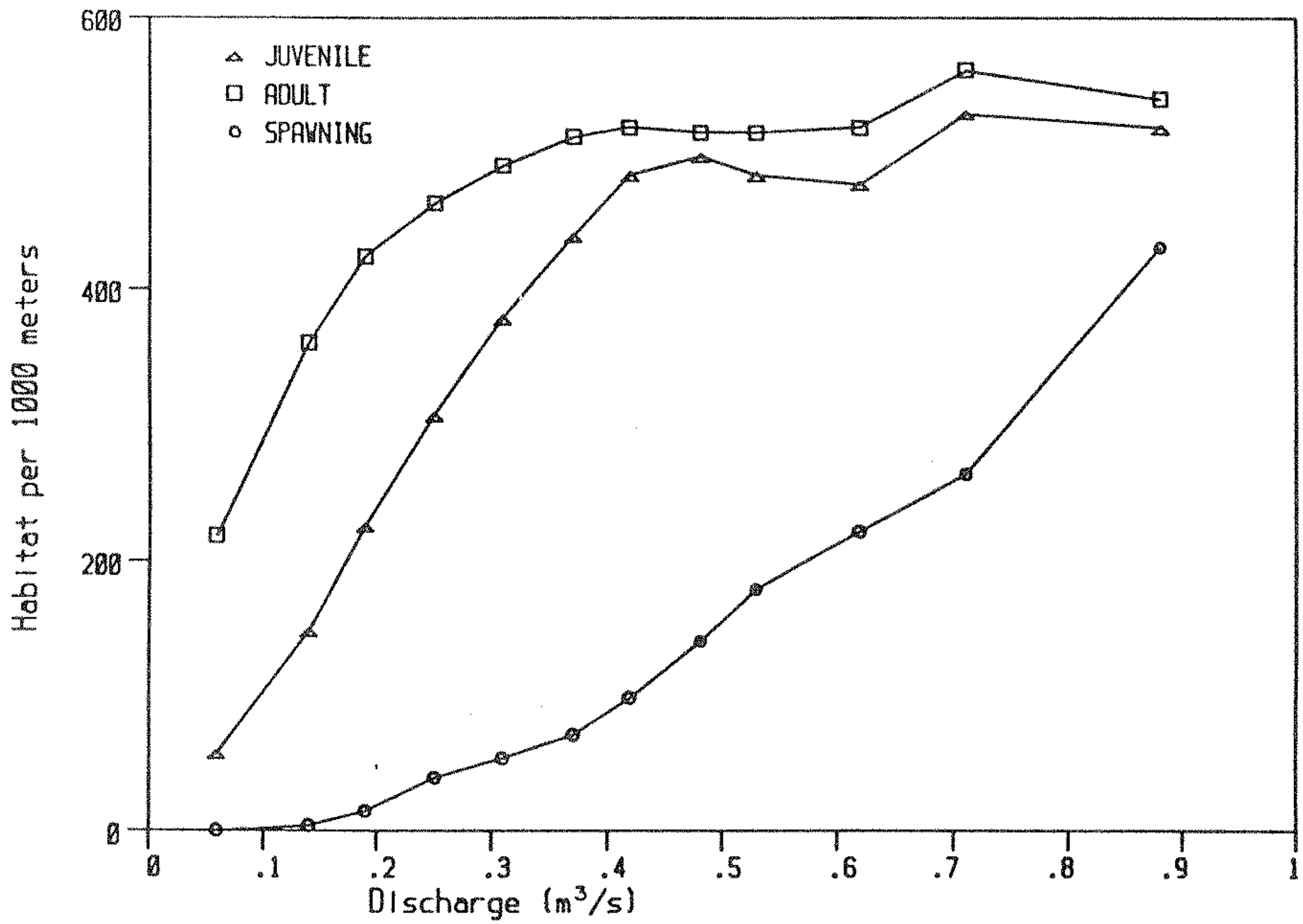

Figure 11. Physical habitat simulation model predictions of quantity of suitable habitat at various discharges in section 2 of Beaver Creek for adult, juvenile, and spawning rainbow trout.

while only 14% (140m/1000m) was useable at 0.06 m^3/s (Figure 11).

Available rainbow trout spawning habitat increased nearly linerally with discharges above 0.38 m^3/s in section 2 (Figure 11). At a discharge of 0.62 m^3/s, average depth in section 2 was 0.55 m and average velocity was approximately 0.60 m/s. At flows ranging from 0.62 m^3/s to 0.89 m^3/s, 20 - 43% of section 2 would provide favorable depth-velocity conditions for rainbow trout spawning. The greatest reduction in available spawning habitat in Beaver Creek would occur when flows were less than 0.38 m^3/s, leaving over 90% (900m/1000m) of the stream unsuitable for rainbow trout spawning. Flow during rainbow trout spawning in 1981 - 1983 (March through May) ranged from 0.62 - 14.0 m^3/s, which suggests that flows did not limit spawning habitat. The large portion of substrate less than 0.85 mm, appears to be the major limitation to rainbow trout spawning success.

Flow Manipulation. The degree to which flow can be manipulated in Beaver Creek is limited by the storage capacity of Bear Paw Lake. The lake has a relatively small surface area (18 ha), with a moderate depth (12 m). Capacity of the lake is 73.3 x 10^4 m^3 at the spillway crest. Estimates of the amount of water that could be released into Beaver Creek for each 0.5 m drop in the level of Bear Paw Lake were calculated by Brown (Montana State Water Quality Bureau, pers. com. 1982) (Table 10). Water can be released from the reservoir bottom at a maximum rate of 4.76 m^3/s; this release rate would empty the reservoir in less than 1 d.

Table 10. Estimates of available water associated with various drawdowns of Bear Paw Lake (Brown pers. com.).

Elevation (m)	Area inundated (ha)	Drawdown (m)	Volume ($m^3 x10^4$)	Available discharge for 60 d ($m^3/s/day$)
1096.5	17.6	1.5	24.21	0.047
1095.0	14.1	1.5	18.69	0.036
1093.5	10.4	1.5	12.12	0.023
1092.0	5.5	1.5	7.03	0.014
1090.5	3.7	1.5	4.56	0.009
1089.0	2.3	1.5	2.90	0.006
1087.5	1.5	1.5	1.95	0.004
1086.0	1.0	1.5	1.17	0.002
1084.5	0.5	1.5	0.56	0.001
1083.0	0.2	1.5	0.16	0.000
		Total	73.3	0.142

2.5 m drawdown = 33.30 $m^3 x10^4$ = 0.06 $m^3/s/day$

Minimum flows usually occur in Beaver Creek in late summer. During this time Bear Paw Lake receives its greatest recreational use, making a full reservoir attractive. Downstream water rights require the outflow of Bear Paw Lake to at least equal inflow.

If the 73.3×10^4 m^3 capacity of Bear Paw Lake was released over a 2-month period, the additional discharge into Beaver Creek would average 0.142 m^3/s, but recreational use of the lake would be lost. A more reasonable drawdown of 2.5 m would release 33.3×10^4 m^3 of water from storage, providing 0.065 m^3/s to Beaver Creek for 60 d (Table 10) while exposing 4 ha of the reservoir bottom (Figure 4). This discharge would be in addition to the normal base flows of the stream.

In 1981, average base flows in Beaver Creek for July, August, and September were 0.29, 0.13, and 0.09 m^3/s, respectively. A 0.065 m^3/s increase in discharge for 60 d would have supplemented the flow by 20 to 70%. Due to the unusual amount of runoff in 1982, average base flows for summer months were high (1.11, 0.41 and 0.24 m^3/s).

From mid-July through mid-September 1981 and 1982, a 0.065 m^3/s flow increase for 60 d in Beaver Creek would have produced average flows within or very near the PHABSIM optimum flow range for section 2 (0.31 - 0.86 m^3/s). Even with this increase in discharge, flow during September 1981 (0.16 m^3/s), would have been below optimum but clearly an improvement over natural flow conditions.

Water Temperature

Mean-maximum summer water temperatures ranging from 19 to 21 C, were associated with low flows in Beaver Creek below Bear Paw Lake from mid-July to mid-September, 1981 and 1982. The tolerance of trout to water temperature is well documented (Brett et al. 1969, Houston 1971, Coutant 1973, and Wedemyer 1973). Coutant (1975) placed the preferred temperature of rainbow and brown trout between 12 and 22 C. He also suggested that the upper avoidance range was from 20-22 C. Kaya (1977) noted similar preferred temperatures in populations of rainbow and brown trout in a thermally heated stream in Wyoming. Hokanson et al. (1977) observed that maximum growth of rainbow trout in a hatchery occurred at 17.2 C. They recorded upper incipient lethal temperatures as 25.6 C for rainbow trout acclimated to 16 C. In a summary of habitat suitability for rainbow trout, Raleigh et al. (1984) concluded that the optimum temperature range is between 12 and 18 C. Based upon the literature, I chose 16 C as the optimum average-maximum summer water temperature for rainbow trout of Beaver Creek.

From 1 July to 15 September 1981 and 1982, maximum daily water temperatures in Beaver Creek ranged from 26.0 to 10 C (Figure 12). Average-maximum water temperature for August and September 1981 and 1982 was 17.3 C, 1 km below Bear Paw Lake and 20.0 C, 7 km downstream (Figure 13). Average-maximum temperature measured immediately upstream from the lake was approximately 17 C for 1981 and 1982 (Figure 13). Average-maximum water temperature for

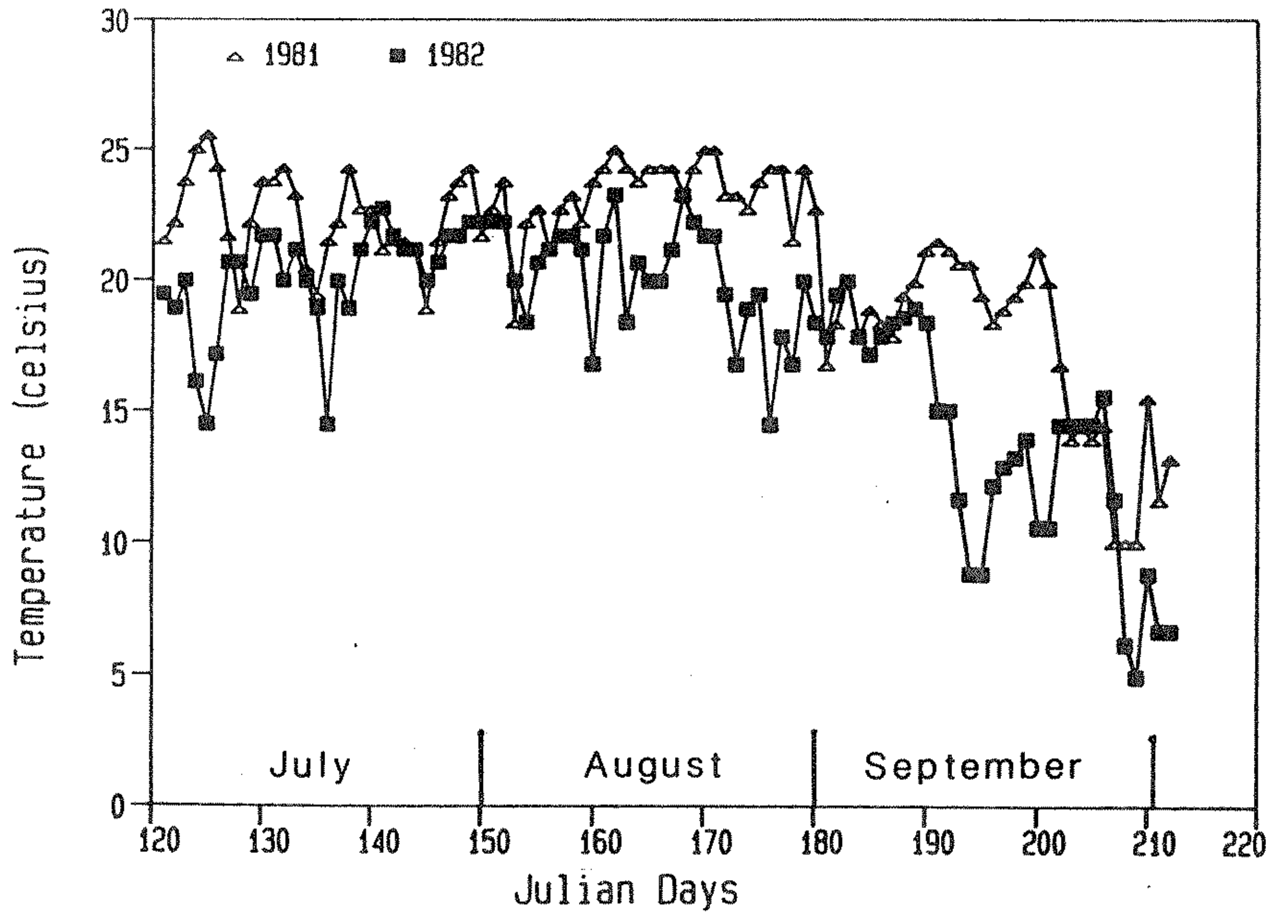

Figure 12. Daily maximum water temperature in Beaver Creek 1.6 km downstream from Bear Paw Lake during July, August, and September, of 1981 and 1982.

August and September of 1981 and 1982 at each temperature measuring site showed water temperature to rise to maximum levels 3.2 - 6.3 km downstream from Bear Paw Lake (Figure 13).

Water Temperature Modeling. For temperature modeling purposes, the optimum average-maximum water temperature for rainbow trout in Beaver Creek (16 C) was used as a desired water temperature. The temperature model predicted that water released from the bottom of Bear Paw Lake at a discharge of no less than 0.504 m^3/s and initial temperature under 12 C, could maintain an average-maximum water temperature below 16 C for 3.2 km downstream from the dam during July and August (Table 11). With an initial temperature of 14-15 C, the same discharge could maintain average-maximum temperature below 16 C for 1.6 km downstream. These would provide near optimum temperatures for the rainbow trout population in the respective areas.

During 1981 and 1982, the hypolimnetic temperature of Bear Paw Lake (or initial temperature) was less than 13 C for all months except September. During September of 1981 and 1982, the maximum hypolimnetic temperatures measured ranged from 14 - 16 C and 17 - 18 C, respectively. With initial temperatures greater than 16 C, the average-maximum temperature in the stream would exceed the optimum

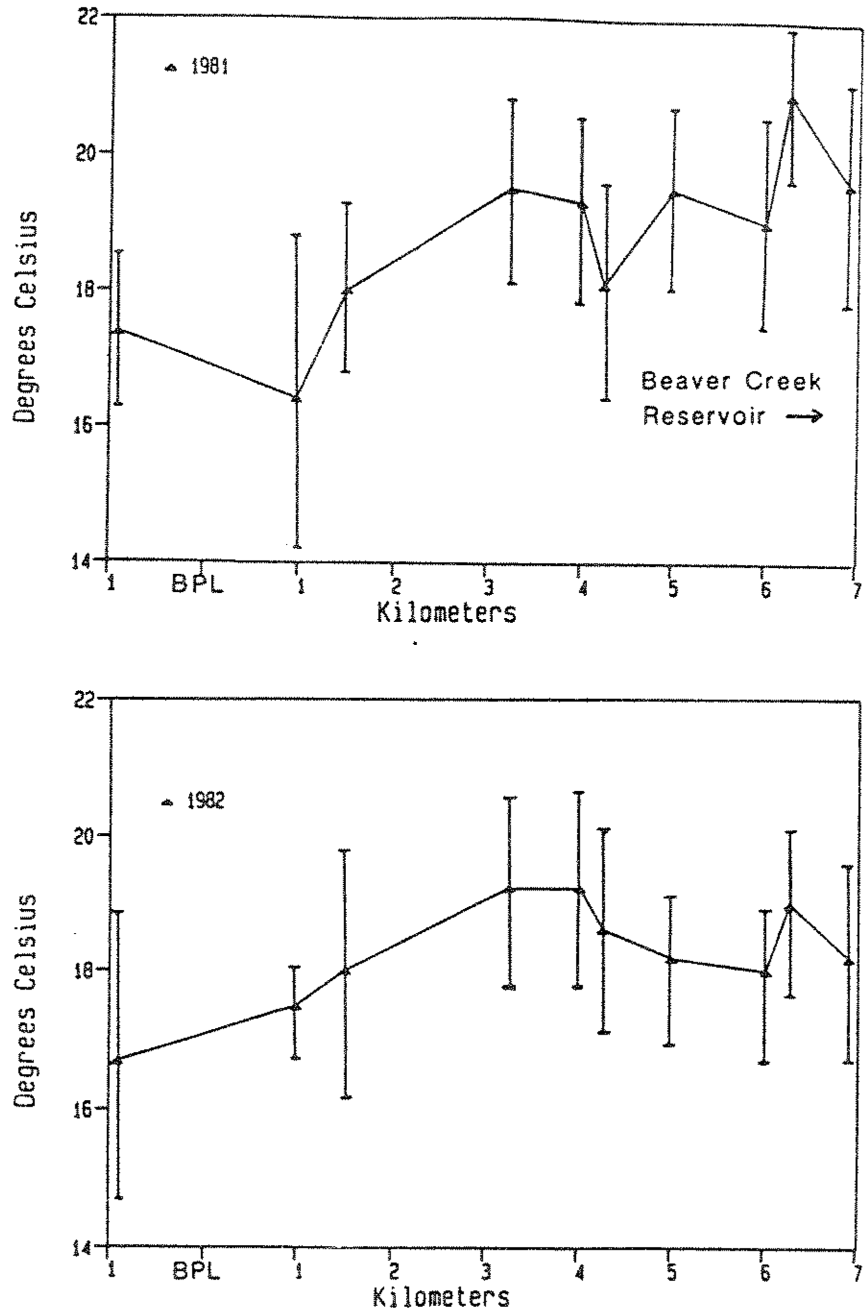

Figure 13. Longitudinal average-maximum water temperature distribution in Beaver Creek between Bear Paw Lake and Beaver Creek Reservoir (study section 2), from 3 August to 16 September of 1981 and 1982. Vertical bars represent 95% confidence interval.

Table 11. Translation of water travel time (t) in hours into discharge (m^3/s) necessary for maintaining temperature at T = 16 C for the temperature model of Beaver Creek. To = intial temperature of water released from Bear Paw Lake, Te = 18 C, the estimate of average-maximum water temperature for Beaver Creek at end of travel time (t). The three k-values represent mean (m = 0.068), upper (u = 0.083), and lower (l = 0.053) equilibrium constants calculated at the 95% confidence level for the stream system.

Initial temperature (C)	Mean-calculated travel time (hr)	Kilometers downstream from Bear Paw Lake					
T_0	tk_m (k_l-k_u)	1.6	3.2	4.8	6.4	8.0	9.6
		Estimated discharge (m^3/s) (range)					
4	10.7 (8.8-13.7)	<0.028 (<0.028-<0.028)	0.042 (<0.028-0.062)	0.116 (0.076-0.187)	0.244 (0.127-0.402)	0.439 (0.224-0.765)	0.790 (0.396-1.36)
7	9.3 (7.6-11.8)	<0.028 (<0.028-<0.028)	0.042 (<0.028-0.079)	0.164 (0.091-0.269)	0.354 (0.176-0.632)	0.651 (0.354-1.08)	1.13 (0.623-1.78)
10	7.4 (6.0-9.5)	<0.028 (<0.028-<0.028)	0.062 (0.042-0.127)	0.297 (0.159-0.430)	0.736 (0.340-0.991)	1.27 (0.623-1.87)	2.21 (1.16-3.40)
12	4.7 (3.9-6.0)	0.042 (0.028-0.079)	0.297 (0.156-0.504)	1.08 (0.510-1.53)	2.38 (1.13-5.10)	5.95 (2.15-11.6)	9.91 (5.10-15.3)
14	3.2 (2.6-4.1)	0.156 (0.071-0.198)	0.906 (0.425-1.36)	3.54 (1.56-6.51)	9.91 (3.12-13.5)	15.6 (8.78-21.2)	21.9 (12.7-28.3)
15	1.3 (1.0-1.6)	1.30 (0.878-2.83)	10.6 (7.93-25.5)				
16	0.0						

(16 C), but would be lower than occurs during present operation of the dam.

The temperature model was originally designed to predict water temperature on the Madison River, in southwest Montana. This river is much larger than Beaver Creek, but application of the model is reasonable. The principle of heat exchange and the dynamics represented by the model's equation should be valid in both stream systems (Appendix B). Size of the hypolimnion in Bear Paw Lake limits amount of cooler water (13 C) available for release, which in turn can limit the accuracy and validity of the model.

To test the effects of hypolimnetic discharge on the temperature of Beaver Creek, water was released from the bottom penstock of Bear Paw Lake at a rate of 0.38 m^3/s, for 3 h on 12 August 1981. With an initial temperature of 10 C, water from the bottom of Bear Paw Lake reduced water temperatures in Beaver Creek by 5.5 C (18.0 to 12.5), 1.0 km downstream, and 4.3 C (19.9 C to 15.6 C), 1.6 km downstream, with no temperature decrease detected 7 km downstream. Increase in water turbidity was observed 3.2 km downstream, but an accurate temperature was not taken. The best estimate of temperature at the 3.2 km site was that it dropped 2 - 3 C (20.0 C to 17 C). Air temperature at this time was 27.0 C.

Although the discharge test was not designed to evaluate the accuracy of the temperature model of Beaver Creek, data indicate that the model has moderate predictive value. The model predicted that a discharge of 0.38 m^3/s with an initial temperature of 10 C, should produce average-maximum stream temperatures of 16 C up to 4.8 km downstream (Table 11). During the test the temperature was reduced to below this level (15.6 C) 1.6 km downstream, but did not appear to decrease to 16 C, 3.2 km and 4.8 km downstream. Discrepancy between model predictions and observed temperature were probably due to the short duration of the test, and the use of point values rather than average-maxima. With a larger sample of input data collected specifically for this model, the predictive value could probably be improved. What the test did show was that hypolimnetic discharge from Bear Paw Lake can effectively decrease water temperature of upper Beaver Creek.

Long-Term Effects of Hypolimnetic Discharge on Beaver Creek

During June - September 1982, as a test of long-term effects of hypolimnetic discharge on the water temperature of Beaver Creek, 95% of the water released from Bear Paw Lake was through the bottom penstock. In July 1981 less than 10% of the discharge from Bear Paw Lake was released in this manner; by late August 1981, 100% of the water was released through the bottom penstock. During July and August 1982 water temperature 1.6 km below the lake exceeded 16 C for less than 5 h/d with an average-maximum of 17.6 C compared to 10 h/d in 1981 which produced an average-maximum of 20.4 C (Table 12). Seven kilometers downstream, during July and August 1982, water temperature was above 16 C for less than 10 h/d with an average-maximum of less than 20.0 C, while in 1981 it exceeded 16 C for 15 h/d, with an average-maximum of 22.8 C (Table 12). During these time periods, discharges ranged from 0.068 - 0.702 m^3/s in 1981 compared to 0.425 - 1.13 m^3/s in 1982. The increase in discharge for 1982 was due to a wetter than normal spring, causing higher natural flows and allowing for the release of more water from Bear Paw Lake.

Hypolimnetic discharges reduced stream temperatures in Beaver Creek 1.6 - 3.2 km downstream from Bear Paw Lake during the months of July and August 1982, producing a more thermally suitable environment for rainbow trout. Average-maximum temperature during this time was reduced to below 16 C, a decrease of approximately 5 C compared to 1981 temperatures.

Alteration of temperature, and accompanying changes in aquatic communities due to reservoir influence have been reported (Briggs 1948, Parsons 1955, Spence and Hynes

1971, Edwards 1978, Kaeding and Zimmerman 1983). All have noted decreases in temperature with hypolimnetic discharge.

Table 12. Average-maximum water temperatures of Beaver Creek, calculated from thermograph data collected 1.6 km and 7.0 km downstream from Bear Paw Lake, during July and August 1981 and 1982. The standard deviations are in parentheses.

	Distance downstream from Bear Paw Lake					
	1.6 km average-maximum temperature (C)			7.0 km average-maximum temperature (C)		
month	1981	1982	difference	1981	1982	difference
July	22.8 (1.82)	16.5 (6.21)	6.3	22.5 (17.2)	20.1 (3.52)	2.4
August	18.1 (3.96)	18.8 (4.06)	0.7	23.1 (2.12)	19.8 (3.31)	3.3
Combined	20.4 (3.06)	17.6 (5.21)	2.8	22.8 (1.91)	20.0 (3.39)	2.8

A number of other changes are associated with hypolimnetic discharge; most center around the release of anerobic, nutrient-laden waters into the stream system. The addition of nutrients to the stream channel can create greater stream eutrophication (Wirth 1970). The extent to which this takes place is dependent on stream morphology and water chemistry. Low dissolved oxygen and hydrogen sulfide gas at the outlet are often produced by hypolimnetic discharge. In most systems enough turbulence occurs near the outlet to oxygenate the water and effectively oxidize excess organic nutrients before they become a problem (Dunst et al. 1974).

In Beaver Creek, hypolimnetic discharge slightly increased turbidity of the stream and some hydrogen sulfide odor was evident at the outlet during initial discharge tests. Due to turbulence of the discharge from the penstock, and to gradient of the stream in this section, dissolved oxygen levels remained near saturation (Table 13). Because of high oxygen levels in the stream, oxidation of organic nutrients continues to take place, indicating eutrophication due to hypolimnetic discharge is not a problem in Beaver Creek.

Other than temperature, water quality parameters measured in Beaver Creek were within acceptable ranges (USEPA 1976) for rainbow trout. Specific conductance ranged from 350 to 789 micro-mhos/cm and had a mean value of 484 micro-mhos/cm at 11.6 C. The range of pH was from 6.29 to 8.35 (Table 14). The lowest values of specfic conductance and pH were found in conjunction with spring runoff. The highest values were found in late summer and fall when flows were low and livestock activity was high.

No pattern of major differences between sampling sites was observed. Random measurements of dissolved oxygen through time in Beaver Creek indicated that the water was saturated. Water quality data from Beaver Creek were typical of north-central Montana streams (Pagenkoph, Montana State University, pers. comm.).

Table 13. Dissolved oxygen in Beaver Creek water during hypolimnetic discharge test, 15 September 1981.

Site (downstream from Bear Paw Lake) (km)	Temperature (C)	Dissolved oxygen (ppm)	Percent saturation (%)
outlet	15.0	4.8	55
0.6	16.5	7.5	85
1.6	13.5	9.9	105
5.5	13.0	11.1	120
7.0	13.0	9.2	100

Effects of Hypolimnetic Discharge on Bear Paw Lake

A prominent thermocline occurred at 6.1 m during August 1981 in Bear Paw Lake (Figure 14). Water temperature ranged from 10.0 C on the bottom to 20.0 C on the surface. Dissolved oxygen concentrations dropped

Table 14. Means and ranges of pH, hydrogen ion concentration and specific conductance values observed on four sampling dates on Beaver Creek in 1981 and 1982 (standard deviation are in parentheses).

Date	Statistical parameter	pH	Hydrogen ion concentration (molar)	Specific conductance (micro mhos/cm)
Fall 10/08/81	Mean	8.13	7.37×10^{-9}	703 @ 8.0 C
	Range	7.90-8.35	($\pm 3.12 \times 10^{-9}$)	589 @ 5.5 C - 789 @ 9.0 C
Spring 03/26/82	Mean	6.24	5.69×10^{-7}	404 @ 5.9 C
	Range	5.55-8.15	($\pm 1.25 \times 10^{-6}$)	340 @ 8.0 C - 450 @ 5.0 C
Summer 07/21/82	Mean	6.49	3.25×10^{-7}	368 @ 19.0 C
	Range	6.29-7.60	($\pm 1.82 \times 10^{-7}$)	330 @ 18.0 C - 400 @ 20.1 C
Fall 09/12/82	Mean	6.79	1.62×10^{-7}	462 @ 13.5 C
	Range	6.25-7.45	($\pm 2.45 \times 10^{-7}$)	430 @ 11.0 C - 480 @ 15.5 C

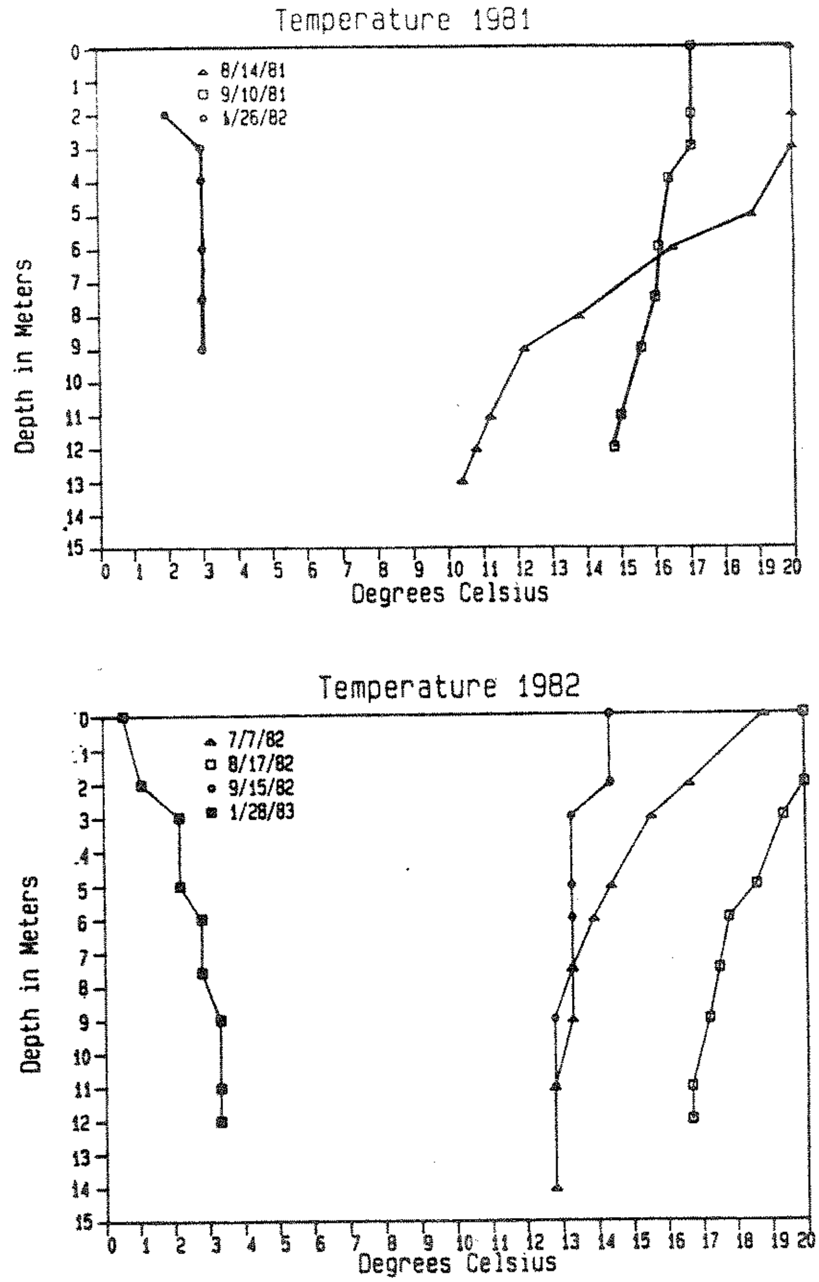

Figure 14. Temperature (C) versus depth (m) of water in Bear Paw Lake on selected dates during 1981 and 1982.

below 5.0 mg/l at depths greater than 4.0 m during August and September, 1981 (Figure 15).

By releasing water from the bottom of Bear Paw Lake, surface and bottom water temperature neared homogeneity in 1982, with temperature varying less than 5 C from surface to bottom; the within-sample range in 1981 was as great as 10 C (Figure 14). Overall, August and September water temperatures ranged from 13.0 to 20.0 C. Temperature in the lower third of the lake averaged 2 C warmer in August of 1982 than in August 1981; the maximum hypolimnetic temperature (17 C) observed during the study was recorded at this time. The volume of lake water affected by low dissolved oxygen was also reduced (Figure 15). Except for mid-August, dissolved oxygen levels remained above 5.0 mg/l at all depths in Bear Paw Lake during the 1982 summer sampling.

The chemical and biological environment of hypolimnetic waters is often unused by fish populations. The consequence of low dissolved oxygen and high hydrogen sulfide levels on fish physiology and ecology are well documented in the literature (USEPA 1976, Doudroff and Shumway 1970, Larkin and Northcote 1970). These studies have shown that such an environment can have adverse effects on the fish in the form of direct toxicity, reduced growth rates, and reduced reproductive efficiency. The presence of hydrogen sulfide at the outlet of Bear Paw

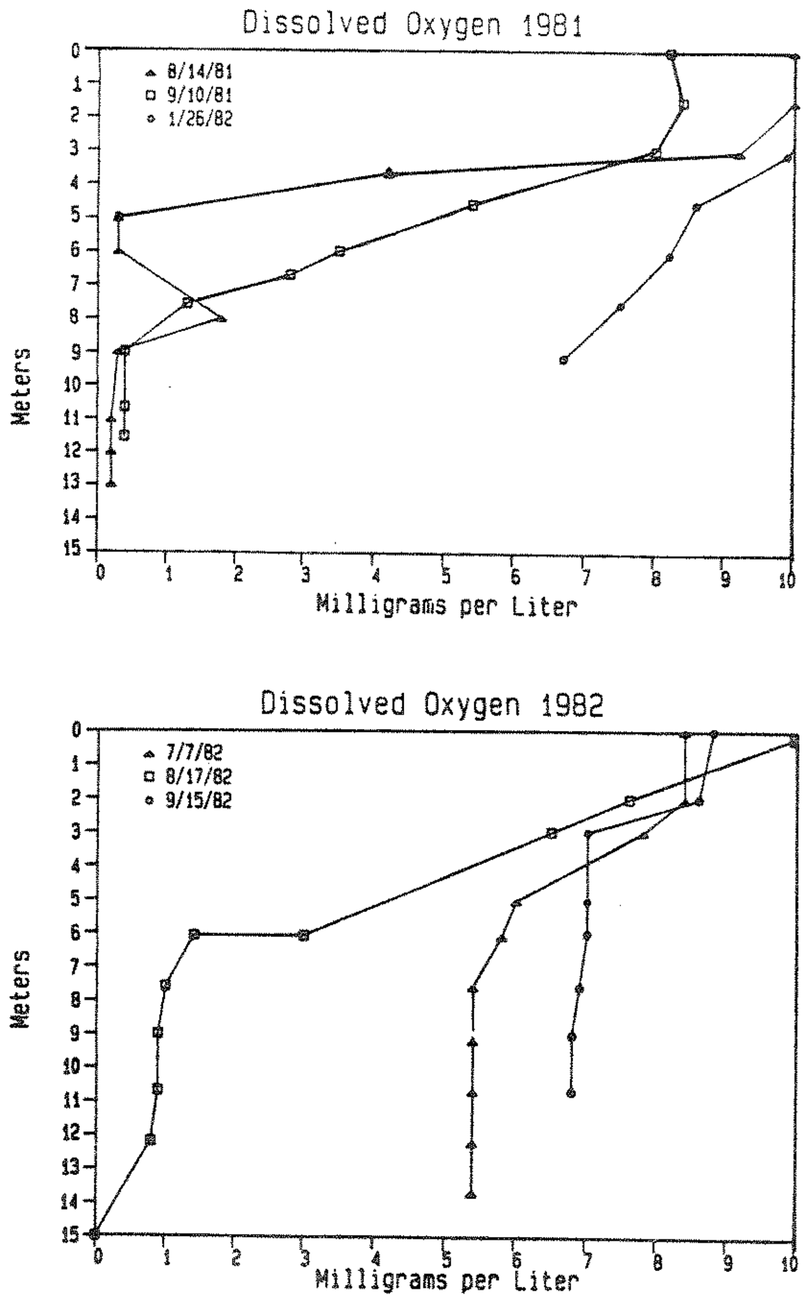

Figure 15. Dissolved oxygen (mg/l) versus depth (m) of water in Bear Paw Lake on selected dates during 1981 and 1982.

Lake and the low dissolved oxygen readings in the hypolimnion in 1981, indicate that portions of the lake were inaccessible to trout.

Dunst (1974) suggested hypolimnetic discharge is a possible method for reducing reservoir eutrophication and some of the resulting effects. Various studies have shown this practice to be effective in the improvement of reservoir water quality. In general these studies denote a reduction in volume of anerobic waters (Johnson and Berst 1965), shortening time of summer dissolved oxygen depletion (Wirth 1970), as well as relations between depth of discharge and dissolved oxygen content (Toetz 1978).

In the case of Bear Paw Lake, water released from the hypolimnion would help reduce stream temperature in the upper portion of Beaver Creek, and increase the volume of oxygenated water in the lake. During July and August, the result would be an increase in useable trout habitat in both environments.

Applying the Habitat and Temperature Models to Beaver Creek

According to the temperature and habitat models, a discharge rate of 0.504 m^3/s could provide an average-maximum water temperature of 16 C and optimum rainbow trout habitat in the 3.2 km section of Beaver Creek immediatley downstream from Bear Paw Lake. In 1981 and 1982, using hypolimnetic discharge, adequate flows could have been provided to satisfy the suggested discharge ranges for the models from March through mid-July. Average monthly discharge of less than 0.504 m^3/s were experienced during August (0.13 m^3/s) and September 1981 (0.09 m^3/s), and September 1982 (0.24 m^3/s). If reservoir storage had been used during this time (60 d), 0.065 m^3/s could have been added to the average-monthly discharge, causing a 2.5 m drawdown of Bear Paw Lake, while increasing discharge to 0.20 m^3/s in all months except September (0.15 m^3/s).

The habitat and temperature models predict that a discharge of 0.20 m^3/s of water with an initial temperature of 10 - 13 C, would provide optimum water temperatures (16 C) and approximately 50% of the useable adult rainbow trout habitat (Figure 11), in the 3.2 km downstream from Bear Paw Lake. By increasing the discharge to 0.28 m^3/s, the projected temperature remains similar, but the predicted useable habitat would increase 30% (Figure 11). The available discharge would be limited by base streamflow, amount of water in the reservoir, and amount of water in the hypolimnion with a temperature of less than 13 C. These factors can vary greatly from year to year.

Stream systems are complex, making it difficult to predict changes in fish habitat and populations due to flow manipulation. Researchers have found that models used to predict the success of fish populations in streams can be of limited value, if applied to streams other than those they were specifically designed for (Bowlby and Roff 1986). In a critque of the instream flow incremental methodology, Mather et al. (1985) noted "(1) a positive linear relationship of weighted useable area (Bovee 1982) and fish biomass has not been well demostrated, (2) the assumption of independence among habitat variables is not valid for depth or water velocity, and leads to unrealistic predictions, and (3) habitat suitability curves should not be treated as probabilty functions" Moyle and Baltz (1985) recognized that fish populations are regulated by many factors besides useable habitat. They suggested that suitabilty curves developed by IFG (Bovee and Cochnauer 1977) should be used in conjunction with population data, and "where possible, macrohabitat variables such as temperature should be incorporated into instream flow analysis". They further noted that habitat use data alone are not enough to construct effective habitat suitabilty curves, and that comparison to habitat availabilty curves and modification based on the researchers experience may be necessary (Moyle and Baltz 1985).

As was noted by Moyle and Baltz (1985), the more information that can be obtained regarding factors that regulate a fish population, the more realistic the model. This was the case with respect to Beaver Creek. By using the results of the habitat, temperature, population and embryo survival models, as well as my personal observations, I obtained a better understanding of Beaver Creek, with respect to rainbow trout habitat. If collected and analyzed on a long-term basis, this type of information would be helpful to resource managers responsible for the well-being of Beaver Creek and its rainbow trout population. With this information, they would be able to set more effective regulations and balance stocking programs to provide more efficient management of Beaver Creek.

Contributing Factors

Angling, channel alterations, livestock grazing, and beaver actvity influenced rainbow trout abundance below Bear Paw Lake, but did not appear to be major limiting factors.

Angling and Recreation. Fishing pressure did not appear to be a major contributor to low trout abundance in Beaver Creek. Most anglers fished Bear Paw Lake (85%); only 15% fished only Beaver Creek, while 42% fished the stream and the lake (Table 15). In 1982, all rainbow trout recorded in the creel below Bear Paw Lake were taken from the 1.6 km immediately below the outlet. The remaining 6.9 km of Beaver Creek below the lake received little fishing pressure due to inaccessibility and poor fishing success.

Table 15. Comparison of fisherman use and catch on Bear Paw Lake and Beaver Creek, 30 June - 11 September 1982.

Section	Total people surveyed	People fishing	Percentage fishing (%)	Trout in creel
Beaver Creek	106	63	59	44
Bear Paw Lake	607	516	85	215
Totals	713	579		259

Population estimates for the five sections of Beaver Creek indicated that the 2+ rainbow trout were the dominant age class in all sections below Bear Paw Lake (Figure 9). Exploited fish populations usually have fewer 2+ and older trout in the population (Hunt 1974, Moyle et al. 1983). Results of the recreation survey and population data suggest that exploitation of the adult members of the trout population in Beaver Creek is not excessive. During the survey only 44 rainbow trout were censused in Beaver Creek. Based on coloration and size, and on the fact that no trout were censused or captured in section 2C in 1981, most of the creeled trout were considered to have been introduced stock. These results indicate that the native population is little affected by angling.

During the 1982 field season (15 June - 15 September), 267 interviews were conducted on Beaver Creek and Bear Paw Lake to determine visitor use patterns and angler attitudes. In 216 h of censusing, 713 people (1 - 5 people in each group) were questioned. Of those interviewed, 85% were at Bear Paw Lake and 15% were along the 12 km study section of Beaver Creek (Table 15). Eighty-one percent of the people interviewed were fishing or were with someone who was fishing. Of the 106 people interviewed along the stream, 63 (59%) were fishing; 516 (85%) of the 607 questioned at Bear Paw Lake were fishing. Of the 259 rainbow trout censused, 215 came from Bear Paw Lake while 44 were creeled from the stream. All 44 trout from the stream were caught in 1982 less than 1.6 km downstream from Bear Paw Lake.

Of the 106 people interviewed in the fisherman survey, 73% were from the Havre area (Appendix C Table 27). Forty-seven percent of respondents said fishing was their main interest in Beaver Creek park. Most fishermen were 19-35 years old, fished for trout in Bear Paw Lake with bait at least once every 2-weeks during summer, and had followed this routine for the last 5 - 10 years. Thirty-seven percent of those interviewed had at some time fished the creek, but only 5% fished Beaver Creek exclusively. Most people had no preference regarding trout species. Recreation, not food, was the main purpose of fishing. Thirty-nine percent believed that the summer of 1982 was the poorest fishing they had encountered in many years.

When asked about lowering the level of Bear Paw Lake 2 - 3 m in late summer and fall to supplement stream flow in Beaver Creek, the majority of people with an opinion, agreed. Forty-one percent considered this as an acceptable management practice, 6.6% were quite hesitant, 30.8% were opposed and 19.7% had no opinion (Appendix C Table 28).

Erosion and Livestock. During 1981 and 1982, 15 major erosion sites were identified in the Beaver Creek study area. The most obvious sites were the large walls of alluvial silt located 8.8 km downstream from Bear Paw Lake. Minor erosion sites were numerous. The most evident minor sites were associated with stream channelization, resulting from road construction through Beaver Creek Park. Unstable stream banks and heavily browsed riparian vegetation were noted in areas of heavy cattle use. A tendency for the cattle to use riparian vegetation for browse and cover was evident. Numerous authors have reported that livestock use and stream channelization reduce the quality of adult salmonid habitat (White and Brynildson 1967, Chapman and Knudsen 1980, Platts 1981, Keller and Burnham 1982, and Schlosser 1982).

The erosion sites in Beaver Creek contribute silt to the stream and reduced the quality of spawning habitat for rainbow trout. The presence of livestock in the stream channel accentuates sediment problems by breaking down channel banks and depleting riparian vegetation which stabilizes streambanks. Beaver Creek has very thick riparian vegetation in many areas, but cattle have taken advantage of open or partially-open areas for crossing, watering and shade. Increased activity in these areas has decreased streambank stability and increased siltation. Loss of riparian vegetation also results in reduced cover for salmonids and can increase temperature variations in the stream environment (White and Brynildson 1967).

Beaver Ponds. In 1981, there were 132 beaver dams in the 10 km between Beaver Creek Reservoir and Bear Paw Lake (section 2). Eighty percent of these dams were considered inactive. Silt in some ponds was as much as 1.2 m deep. After the heavy runoff in June 1982 (7.68 m^3/s at peak), only 14 beaver dams remained. Physical characteristics of the remaining ponds varied greatly (Table 16).

Table 16. Mean and range of maximum depth, length, width and surface area of 14 beaver ponds in section 2 of Beaver Creek, 1982 (standard deviation is in parentheses).

	Maximum depth (m)	Length (m)	Width (m)	Surface area (m^2)
Mean	1.15 ($\pm$0.41)	41.1 ($\pm$25.1)	9.21 ($\pm$4.1)	461.82 ($\pm$424.73)
Range	0.38-1.7	7.0-95.0	4.78-16.2	127.2-1482.0

The largest and oldest rainbow trout collected in the Beaver Creek study area were found in ponds with maximum depths of $\geq$0.8 m. During the 1982 field season, 67 rainbow trout were sampled from the 14 beaver ponds (Appendix C Table 29). The trout ranged in length from 13.5 to 40.1 cm, weighed 24.8 to 655.7 gm, and were age I to VI+. In comparison, the 87 trout collected from Beaver Creek during the 1982 population estimates ranged in length from 12.7 to 37.8 cm, weighed 18.2 to 454 gm, and ranged in age from I to III+ (Appendix C Table 30).

The length-weight regression for 1982 pond and stream-sampled rainbow trout was similar (r = 0.995 and 0.981, respectively); the combined data had a much lower correlation of 0.714 (Figure 16). Analysis of variance showed a significant difference between stream and pond samples at the 95% confidence level (F* = 6065.10). The slopes of the regression lines were not significantly

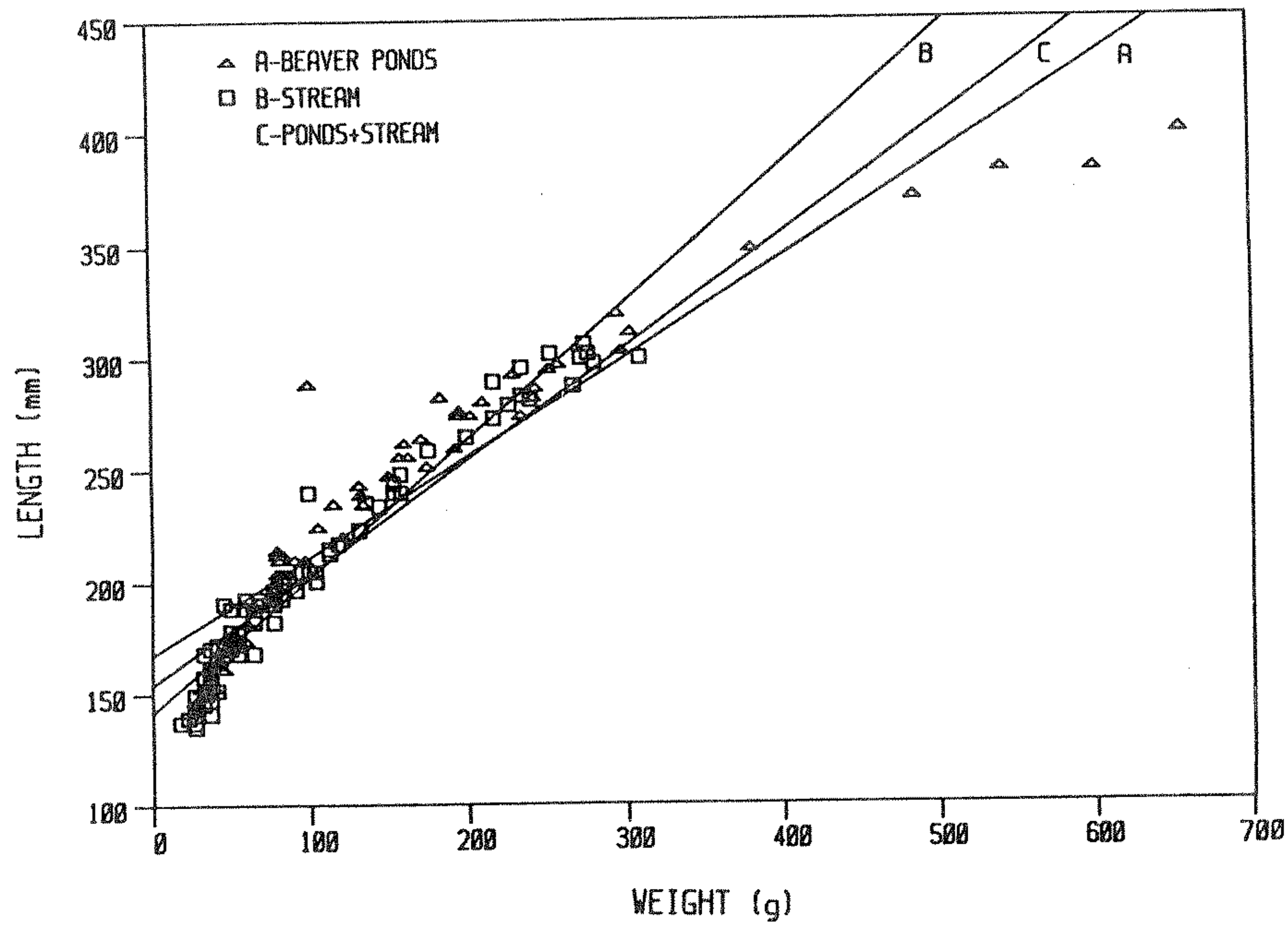

Figure 16. Comparison of length-weight relationship for rainbow trout collected from Beaver Creek study area during 1982.

different, yet their y-intercepts were. Regression lines with similar slopes indicate that both samples have trout with similar length-weight relationships (the trout sampled from the stream were slightly heavier per unit length than those in the beaver pond). The variation in y-intercept indicates that the average trout from the beaver pond sample was significantly longer than those in the stream sample. The variation is related to a greater y-intercept value for the trout sampled from the beaver pond (y=168 g), than the trout sampled from the stream habitat (y=145 g)(Figure 16).

In 1982, the largest estimated abundance of young-of-the-year rainbow trout (1588 fish/km, 9.63 kg/km) was associated with a large beaver dam (2743 m^2) located at the upstream end of section 3. Substrate below the dam contained less than 10% fines (<0.85 mm) and predicted embryo survival (21%) was one of the highest calculated from the study area (Table 9).

At the face of the dam a plunge pool approximately 1 m deep and 10 m long, acted as a holding area for spawning trout. In September 1982, 18 adult brook trout ranging in length from 25.4 - 37.9 cm were electrofished in this area. This was the only such concentration of brook trout observed in the study area. Mature rainbow trout (N=15) were collected in this same area during March 1982 and May 1983. These adult rainbow ranged in length from 18.0 -

28.2 cm, with the youngest mature male being age 2 and the only mature female age 4.

In March 1983, five redds were identified, two located at the base of the dam, and three at the tail of the plunge pool. No other trout redds were found in the study area at that time. During fall 1982, 205 rainbow and 176 brook trout were collected in this area. Of these fish, 193 rainbow trout and 47 brook trout were less than 10 cm in length and were determined to be age 0. Section 3 had the greatest abundance of trout within the study area and habitat associated with the beaver dam was important to age 0 fish as well as mature trout.

Beaver ponds are a source of controversy on Beaver Creek and beaver have been trapped in an attempt to reduce their population. Salyer (1934), Cook (1940), Patterson (1950), Knudsen (1951) and Reid (1952) considered beaver and their impoundments a threat to the quality of the particular stream systems on which their research took place. Others have recognized the positive effects of beaver and their ponds when matched to a suitable drainage (Rasmussen 1940, Tappe 1942, Dalke 1947, Grasse and Putnam 1950, Baily 1951, Rupp 1955, Gard 1961, Call 1970, Munther 1981, and Smith 1981). Most agree that matching a beaver population to a stream system should be done on a case-by-case basis.

After observing over 132 beaver ponds, measuring physical parameters of 35, electrofishing 26, and using a mask and snorkel to observe fish in most, I concluded that ponds with recent beaver activity and depths greater than 1 m were useful to adult trout in Beaver Creek. Rainbow trout may not prefer the pond habitat but they will use the available cover produced by the depth of the pond when cover becomes limited in the stream. After the spring floods of 1982, 23 of the 26 beaver ponds remaining were considered active and provided habitat for adult rainbow trout. Conversely, beaver ponds of less than 1 m in depth were generally lacking beaver activity and provided poor cover and little or no use for adult trout. During dry years, active beaver ponds may provide a potential refuge for trout.

Summary and Recommendations

Beaver Creek between Bear Paw Lake and Beaver Creek Reservoir, is a thermally marginal trout stream. In addition to summer water temperature above the thermal optimum for rainbow trout, major limitations appear to be a lack of suitable spawning habitat and low summer stream flow. In combination, these physical factors result in poor reproductive success and survival of rainbow trout. Trout habitat is further influenced by stream channel instability, livestock grazing, and beaver activity.

The primary goal of this study was to determine if rainbow trout habitat in Beaver Creek below Bear Paw Lake could be improved by modifying water management of the reservoir. Of the three major limiting factors identified, flow and temperature could be modified by changing the existing release pattern. Increased flow and decreased water temperature in summer and fall would improve habitat suitability for rainbow trout in Beaver Creek. Because of the geology of the area, however, poor reproductive success of trout will continue to limit natural recruitment. Maintaining a self-sustaining rainbow trout population above the present level is unlikely.

The 1.6 km section of Beaver Creek below Bear Paw Lake is presently sustained by hatchery fish emigrating from Bear Paw Lake and possibly a small amount of natural reproduction. Since most people interested in fishing Beaver Creek fish this section, annual stocking with fingerling or catchable rainbow trout would provide increased fishing opportunity.

Hypolimnetic release of water from Bear Paw Lake at a rate of 0.28 m^3/s is recommended throughout the year as a preferred minimum flow and should produce an average-maximum summer water temperature 1.6 km below Bear Paw Lake of approximately 16 C, which is near the optimum for rainbow trout. This flow will provide 80% of optimum adult rainbow trout habitat in this section.

Implementation of this recommendation would require frequent monitoring and adjustment of outflow. During dry years when base flows of Beaver Creek are less than 0.28 m^3/s, it would require the lowering of Bear Paw Lake to make-up the flow deficit. By using 0.065 $m^3/s/d$ of the Bear Paw Lake water reserve for less than 60-d, the drawdown of the lake would have negative impact on the recreational value of the lake for some people by exposing 22% (4 ha) of the lake bottom. Most of this would occur at the shallow inlet where the least recreational use occurred during the study. The existing rainbow trout fishery in the 1.6 km downstream from Bear Paw Lake would be benefited by increased available habitat of 20 - 70%.

Livestock grazing in the riparian zone adds further stress to the system by physically deteriorating the quality of the stream as trout habitat. Limiting livestock access to the streambed would help alleviate some streambed structure and erosion problems. Fencing, off-stream water and salting sites, and/or reduced numbers of cattle in the park would reduce such pressure on the stream system.

During this project I made use of several models that, individually, contribute a small portion of the overall understanding of the Beaver Creek system. By combining the results of these models, I was able to predict environmental changes that would take place in Beaver Creek following flow manipulation.

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APPENDICES

APPENDIX A

PROBABILITY-OF-USE-CURVES

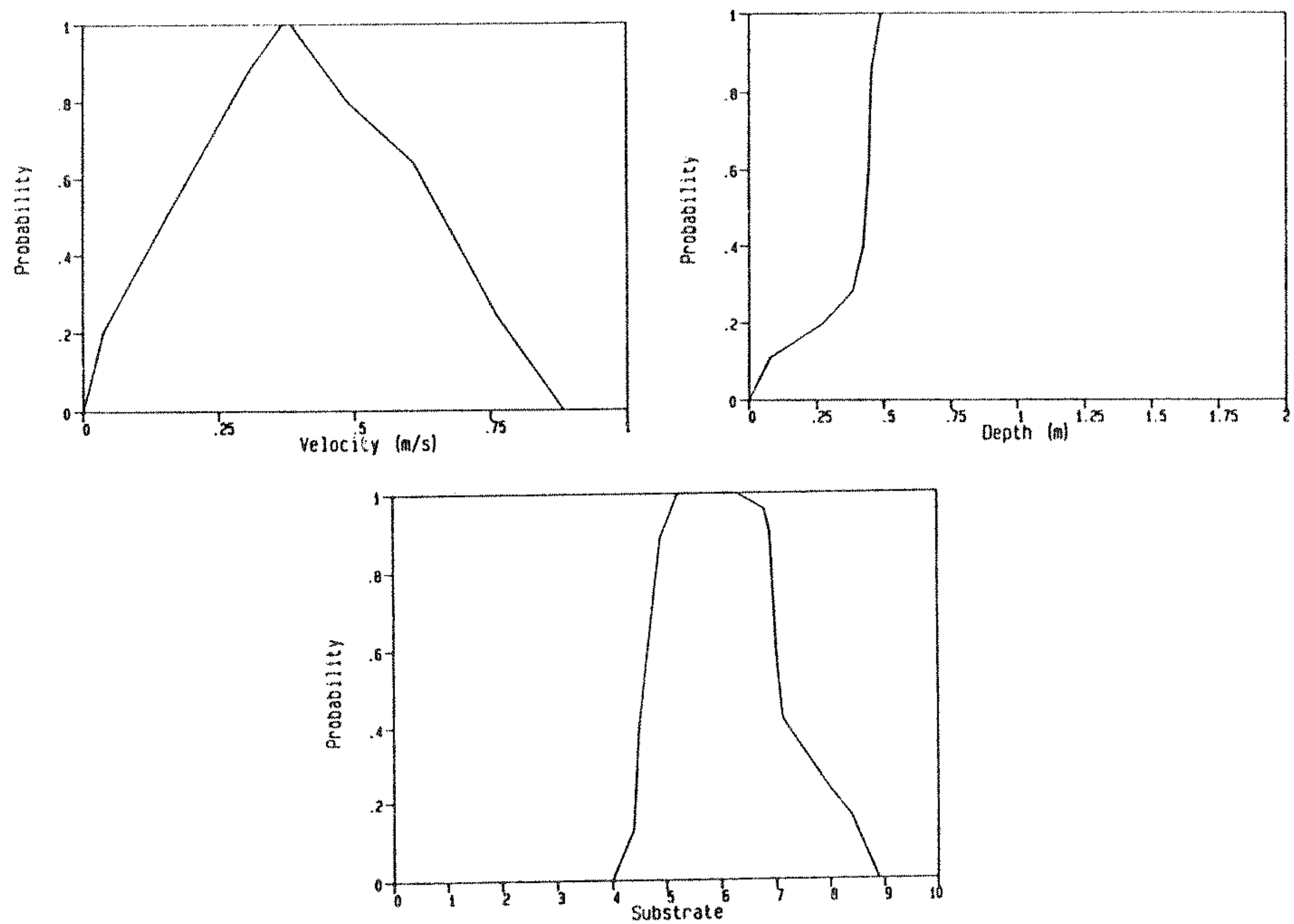

Figure 17. Probability-of-use curves for adult rainbow trout (Bovee 1978).

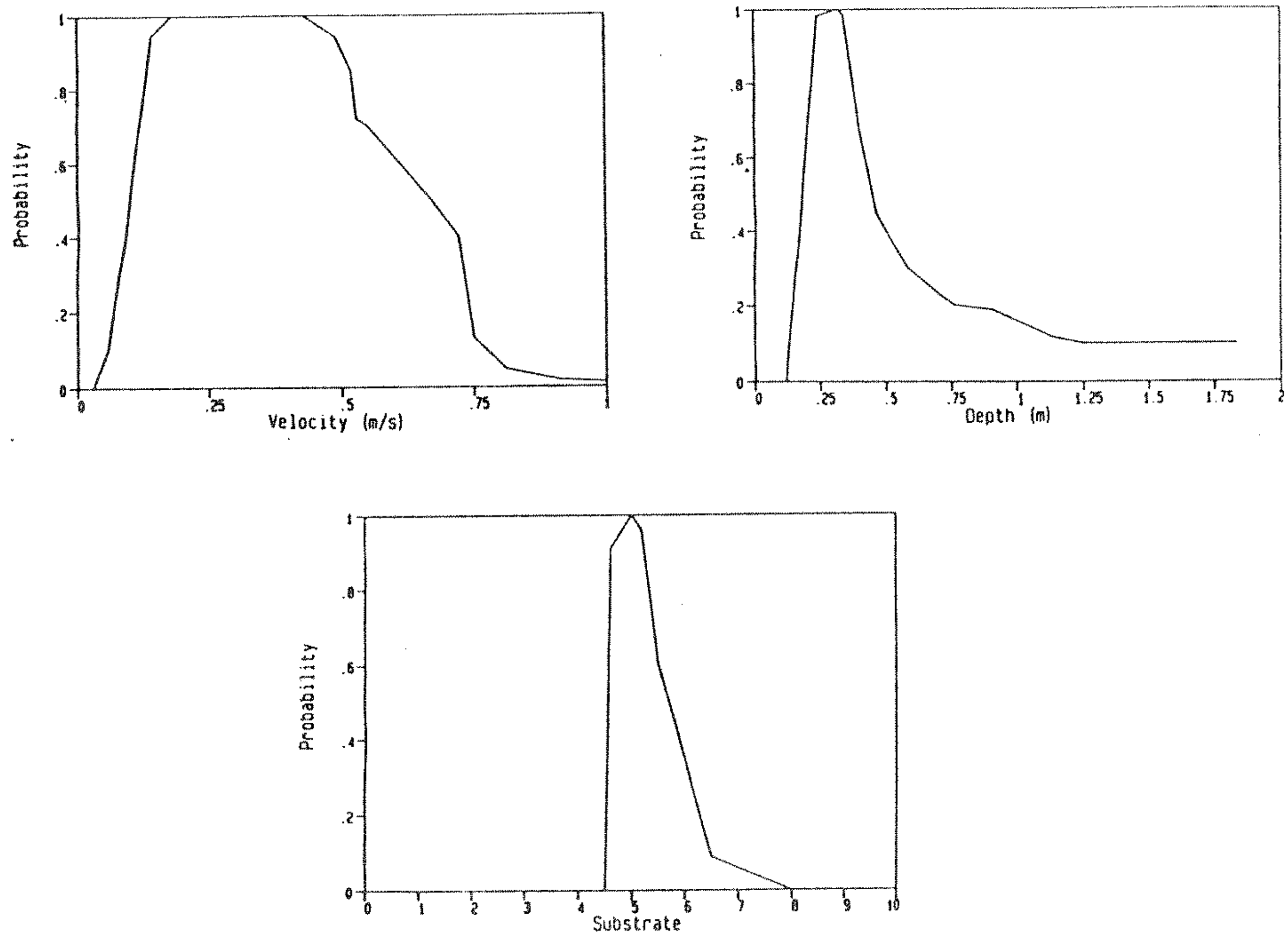

Figure 18. Probability-of-use curves for juvenile rainbow trout (Bovee 1978).

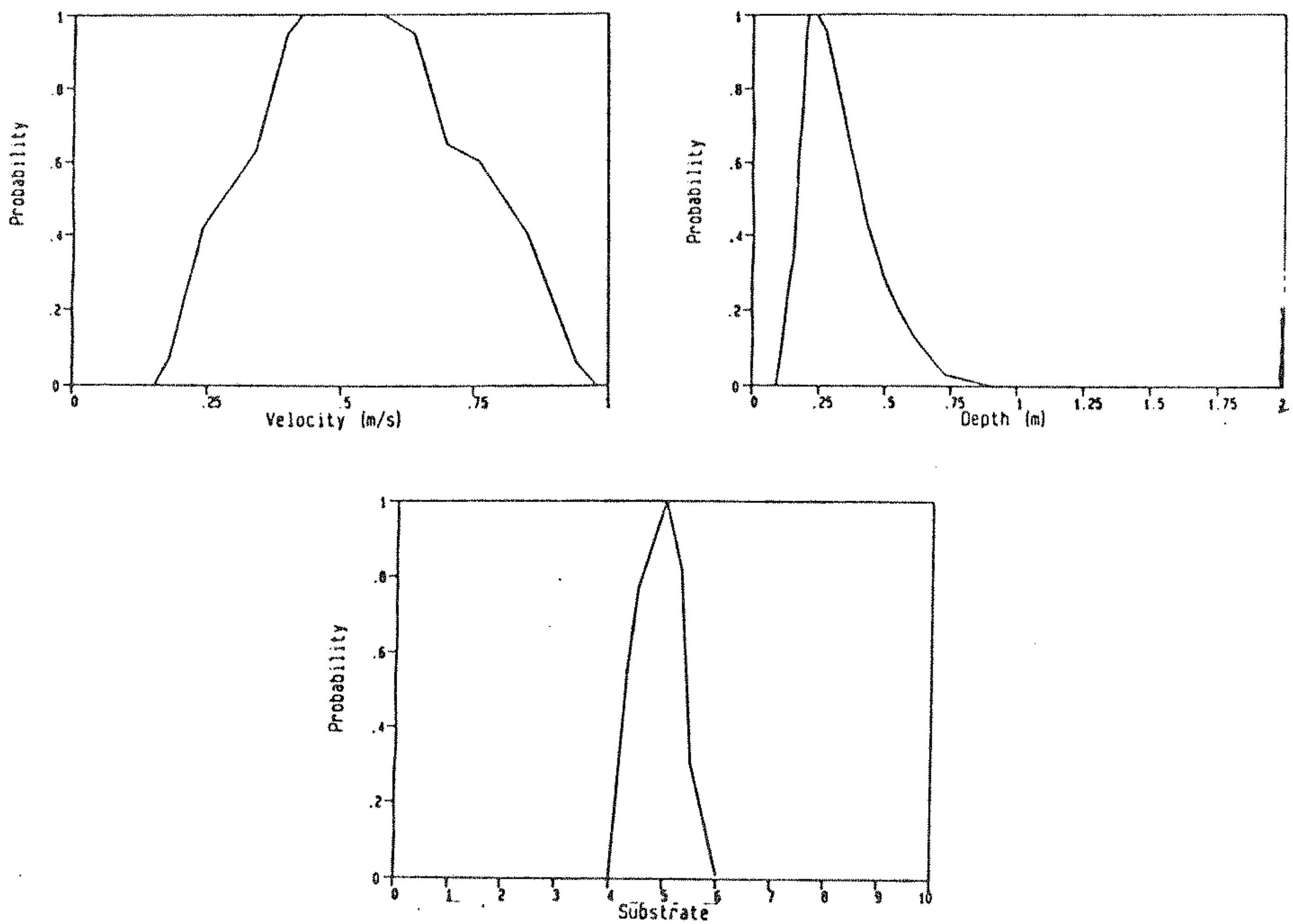

Figure 19. Probability-of-use curves for spawning rainbow trout (Bovee 1978).

APPENDIX B

EXPLANATION OF TEMPERATURE MODEL AND TRAVEL TIME CALCULATIONS

Temperature Modeling Strategy (Goodman 1983)

The rate of heat transfer across an element of a solid material is proportional to the graidient in temperature, with the proportionality constant determined by properties of the material. This gives an equation which, with a different proportionality constant, would be appropriate for representing heat flow owing to mixing in a fluid. This suggests that, even though the numerous mechanisms involved in heat exchange between a river and its environment are very complicated, the overall process could adequately be modeled with a linear form, where the rate of heat transfer to the river is proportional to the difference between the water temperature and the "effective temperature" of the environment. Since the net heat transfer would become zero once the water reached the effective temperature of the environment, the effective temperature of the environment represents an equilibrium temperature of the water. It is the temperature the water would reach after indefinite exposure to constant conditions. Thus the formal equation could be written

$$dT/dt=k(t-T_e) \qquad (1)$$

where T is the water temperature, t is time, T_e is the equilibrium temperature, and k is a rate coefficient which serves as the proportionality constant.

Parameter Fitting

Projecting daily mean temperatures in the river. When the rate coefficient k is a constant, the differential equation, (1), can be solved explicitly in closed form

$$T=T_e-EXP(-kt)*(t_e-T_o) \qquad (2)$$

where Y is the temperature after an elapsed time t, and T_o is the initail temperature. This allows an algebraic solution for the rate coefficient, if the other values are known

$$k=-(1/t)*LOG((T_e-T)/(T_e-T_o)) \qquad (3)$$

Equation (2) represents an exponential decay toward the equilibrium temperature... We may begin by taking the mean temperature (temperature data from the lower thermograph) as an estimate of the equilibrium temperature, and compute a rate coeffiecient directly from substitution of values... in equation (3).

Stream Travel Rates (Boning 1974)

The travel rate of water and the dispersive characteristics of streams can be expected to vary with channel configuration, slope, and discharge. The reaches used... were categorized as pool and riffle, channel controlled or lock, and dam reaches.

Pool and riffle reaches are characterized by a series of pools with relatively low velocity separated by bars or riffles over which the stream flows more rapidly. Water surface slope may vary from minimal in the pools to steep at the riffles. Because of inconsistent pool length for this condition the channel is not as representative of the local hydraulic gradient as in the channel controlled streams.

Channel configuration also varies with length on this type of reach. Discharge in these reaches ranged from 3 to 4,000 cfs. Duration frequencies ranged from 7 to 99 percent and slopes of the reaches ranged from 0.00012 to 0.0057 ft/ft.

Equations	Standard error Log	Standard error Percentages
Pool and riffle reaches: $VL = 0.60\ Q^{0.37}\ S^{0.21}$	0.18	43

The above equation for velocity can also be used to estimate, for a specified stream length, the traveltime of a soluble contaminant. This estimate may be obtained by

$$TL = 1.467L/VL$$

Where TL is the travel time of the leading edge, in hours; L is reach length, in miles; and VL is the velocity estimated by the regression equation, in feet per second. In the equation used to determine the velocity of the leading edge of the contaminate or dye, Q represents discharge, in cubic feet per second, and S represents the slope in feet per feet. TL or travel time of the leading edge of the dye, is equivalent to elapsed time (t) in the temperature model presented by Goodman (1983).

APPENDIX C

TABLES

Table 17. Data set used to calculate mean rate coefficient (k_m) for the temperature model of Beaver Creek. T_o = initial water temperature, T_1 = final water temperature, T_e = equilibrium water temperature, Q = discharge, t = travel time from T_o to T_1, k = rate coeffiecient.

Date	T_o	T_1	T_e	Q (m^3/s)	t (hr)	k
	Degrees celsius					
8/09/81	14.8	17.2	19.7	0.13	3.12	0.22
8/10/81	14.8	17.2	20.0	0.12	3.20	0.18
8/11/81	14.8	17.2	20.0	0.12	3.20	0.20
8/13/81	10.4	14.4	20.3	0.13	3.21	0.17
8/14/81	10.4	15.6	20.3	0.12	3.25	0.23
8/15/81	10.4	15.0	20.1	0.12	3.20	0.18
7/19/82	13.9	14.4	17.5	1.13	1.30	0.13
7/21/82	13.9	15.0	19.2	1.04	1.45	0.17
8/16/82	16.7	17.2	18.9	0.43	1.98	0.13
8/17/82	16.7	17.2	20.6	0.42	2.00	0.07
8/18/82	16.7	17.2	19.7	0.43	1.98	0.09
8/19/82	16.7	17.2	19.7	0.42	2.00	0.08
9/14/82	12.8	10.6	7.8	0.25	2.40	0.22

k_m = 0.158
n = 13

Table 18. Estimated numbers/km, and biomass (kg/km) of rainbow trout sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses).

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	1	0.248	7.6-20.0	14	9	9	0	1.00	0.64	15 (0)	0.0	60 (0)	0.064	3.84 (0.00)
			20.1-22.6	16	6	7	1	0.86	0.38	19 (5)	2.4	78 (20)	0.090	7.02 (1.80)
			22.7-25.1	11	6	6	0	1.00	0.55	12 (0)	0.0	48 (0)	0.114	5.14 (0.00)
			25.2-32.8	9	5	5	0	1.00	0.26	10 (0)	0.0	40 (0)	0.239	9.34 (0.00)
			Total	50	26	27	1	0.93	0.50	56	2.4	226 (20)	0.133	25.63 (2.68)
9/82	1	0.375	20.3-25.2	8	4	5	1	0.80	0.50	11 (4)	1.8	29 (11)	0.142	4.12 (1.56)
			25.3-27.7	7	7	7	0	1.00	1.00	8 (0)	0.0	21 (0)	0.206	4.33 (0.00)
			27.8-35.3	17	8	13	5	0.62	0.47	28 (11)	5.3	75 (29)	0.308	23.10 (8.93)
			Total	32	19	25	6	0.76	0.59	47 (11)	5.6	125 (29)	0.183	31.55 (5.32)
9/81	2A	0.375	5.1-17.5	23	14	30	16	0.47	0.61	50 (18)	8.9	132 (48)	0.032	4.22 (0.13)
			17.6-35.3	9	7	13	6	0.54	0.78	18 (8)	3.8	47 (10)	0.096	4.51 (0.96)
			Total	32	21	43	23	0.49	0.65	68 (19)	9.7	179 (51)	0.048	8.53 (2.54)
9/82	2A	0.365	12.7-17.5	17	8	23	15	0.35	0.47	48 (24)	12.0	132 (66)	0.036	4.75 (2.38)
			17.6-20.0	6	4	9	5	0.44	0.67	14 (9)	4.0	38 (24)	0.051	1.94 (1.22)
			20.1-30.2	6	4	8	4	0.50	0.67	13 (7)	3.4	35 (9)	0.182	6.37 (1.64)
			Total	29	16	40	24	0.40	0.55	75 (26)	13.1	205 (71)	0.064	13.06 (4.54)

M = fish marked on first run C = fish captured on second run
R = fish recaptured on second run U = unmarked fish, captured second run N* = population estimate

Table 18. (continued)

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	2B	0.312	5.1-15.0	17	6	12	6	0.50	0.35	33 (16)	8.0	107 (52)	0.009	0.96 (0.47)
			15.1-17.5	12	7	9	2	0.78	0.58	16 (5)	2.4	52 (16)	0.042	2.18 (0.14)
			17.6-20.1	16	7	8	1	0.88	0.44	19 (4)	2.1	61 (7)	0.064	3.90 (0.45)
			20.2-32.8	22	8	11	3	0.73	0.36	31 (10)	4.8	98 (31)	0.118	11.56 (3.66)
			Total	67	28	40	12	0.70	0.42	99 (20)	9.9	318 (64)	0.058	18.60 (3.72)
9/82	2B	0.300	15.2-22.6	16	8	11	3	0.80	0.50	21 (6)	2.8	69 (19)	0.090	6.21 (1.71)
			22.7-25.1	6	6	6	0	1.00	1.00	7 (0)	0.0	23 (0)	0.153	3.52 (0.00)
			25.2-32.8	10	5	6	1	0.83	0.50	13 (4)	1.8	43 (13)	0.230	9.89 (2.99)
			Total	32	19	23	3	0.86	0.59	41 (6)	3.3	135 (23)	0.145	19.62 (3.83)
9/81	2C	0.234	No rainbow captured in this section during 1981.											
9/82	2C	0.210	5.1-20.1	20	4	6	2	0.67	0.20	29 (13)	6.4	140 (62)	0.018	2.52 (0.11)
			20.2-25.1	25	10	18	8	0.56	0.40	45 (17)	8.4	214 (81)	0.140	29.96 (11.34)
			25.2-35.3	23	21	29	8	0.72	0.91	33 (7)	3.5	156 (34)	0.218	34.01 (7.41)
			Total	68	35	53	18	0.66	0.52	107 (22)	11.1	510 (105)	0.130	66.49 (13.19)

M = fish marked on first run C = fish captured on second run
R = fish recaptured on second run U = unmarked fish, captured second run N* = population estimate

Table 18. (continued)

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	3	0.143	5.1-17.5	14	4	8	4	0.50	0.29	27 (15)	7.3	189 (105)	0.031	5.86 (3.26)
			17.6-27.7	5	5	6	1	0.83	1.00	7 (2)	1.0	49 (17)	0.105	5.15 (1.79)
			Total	19	9	14	5	0.64	0.47	34 (15)	7.4	238 (105)	0.046	11.01 (4.83)
9/82	3	0.280	5.1- 7.4	45	7	51	44	0.14	0.16	299 (47)	91.7	1068 (167)	0.004	4.27 (0.67)
			7.5-12.4	25	14	83	69	0.17	0.56	146 (65)	33.0	520 (231)	0.009	4.68 (2.08)
			12.5-27.7	6	6	11	5	0.55	1.00	12 (6)	2.7	43 (10)	0.100	4.30 (1.00)
			Total	76	27	145	118	0.19	0.36	457 (191)	97.5	1631 (682)	0.008	13.25 (5.46)

M = fish marked on first run   C = fish captured on second run
R = fish recaptured on second run   U = unmarked fish, captured second run   N* = population estimate

Table 19. Estimated numbers/km, and biomass (kg/km) of brook trout and brown trout sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses).

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	1	0.248	No brook trout captured in this section.											
9/82	1	0.375	No brook trout captured in this section.											
9/81	2A&2B	0.687	No brook trout captured in this section.											
9/82	2A&2B	0.665	No brook trout captured in this section.											
9/81	2C	0.234	No brook trout captured in this section.											
9/82	2C	0.210	9.7	1	0	0	0	0.00	0.00	1	-	-	-	-
9/81	3	0.143	5.8-38.9	87	26	41	15	0.63	0.30	137 (29)	15.5	957 (206)	0.041	39.24 (8.45)
9/82	3	0.280	5.6-37.8	122	80	133	53	0.60	0.66	204 (28)	14.1	727 (99)	0.082	59.61 (8.12)
9/81	1	0.248	13.0-34.8	13	6	14	8	0.43	0.46	30 (16)	7.7	121 (63)	0.055	6.66 (3.46)
9/82	1	0.375	23.9-52.1	3	2	3	1	0.67	0.67	5 (3)	1.3	14 (9)	0.736	10.30 (6.62)

No brown trout collected in sections 2A, 2B, 2C, or 3 during 1981 or 1982.

M = fish marked on first run
R = fish recaptured on second run
C = fish captured on second run
U = unmarked fish, captured second run
N* = population estimate

Table 20. Estimated numbers/km, and biomass (kg/km) of white suckers sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses).

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	1	0.248	8.4-39.9	427	145	306	161	0.47	0.34	900 (105)	53.8	3629 (425)	0.086	312.09 (36.55)
9/82	1	0.375	7.4-35.0	292	131	510	379	0.26	0.45	141 (109)	55.8	377 (292)	0.085	32.05 (24.82)
9/81	2A	0.375	6.6-30.0	169	78	276	198	0.28	0.46	596 (110)	56.3	1589 (150)	0.032	50.85 (4.80)
9/82	2A	0.365	7.4-25.2	62	14	101	87	0.14	0.23	428 (194)	98.9	1173 (531)	0.027	31.67 (14.34)
9/81	2B	0.312	8.4-31.2	139	17	76	59	0.22	0.12	599 (234)	120.3	1120 (756)	0.068	76.16 (51.41)
9/82	2B	0.300	6.4-30.7	209	31	114	83	0.27	0.15	755 (219)	111.6	2516 (729)	0.054	135.86 (39.37)
9/81	2C	0.234	5.1-38.1	296	111	345	234	0.32	0.38	918 (310)	158.3	3921 (1326)	0.059	231.34 (78.23)
9/82	2C	0.210	6.1-37.8	70	27	270	243	0.10	0.39	687 (237)	120.8	3272 (1128)	0.086	281.39 (97.01)
9/81	3	0.143	8.4-26.2	32	21	40	19	0.52	0.66	62 (17)	8.7	430 (122)	0.081	34.83 (9.88)
9/82	3	0.280	6.4-29.0	11	7	37	30	0.19	0.64	57 (34)	16.9	203 (236)	0.055	11.16 (12.98)

M = fish marked on first run C = fish captured on second run
R = fish recaptured on second run U = unmarked fish, captured second run N* = population estimate

Table 21. Estimated numbers/km, and biomass (kg/km) of longnose and mountain suckers sampled in Beaver Creek during 1981 and 1982 (95% confidence intervals in parentheses).

Date	Section	Section length (km)	Size group (cm)	M	R	C	U	Efficiency R/C	Efficiency R/M	N*	Standard deviation	Fish per kilometer	Average mass (kg)	Biomass (kg/km)
9/81	1	0.248	9.4-40.9	103	12	35	23	0.34	0.12	288 (120)	61.5	1161 (486)	0.131	152.09 (63.67)
9/82	1	0.375	9.7-40.9	148	48	191	143	0.25	0.32	584 (140)	71.3	1567 (373)	0.127	199.01 (47.37)
9/81	2A	0.375	8.1-31.8	24	10	16	6	0.63	0.42	39 (13)	6.6	103 (36)	0.025	2.58 (0.90)
9/82	2A	0.365	14.5-27.9	15	2	8	6	0.25	0.13	48 (40)	19.6	131 (108)	0.118	15.46 (20.99)
9/81	2B	0.312	12.2-31.5	42	15	70	55	0.21	0.36	191 (80)	40.7	612 (256)	0.082	50.18 (20.99)
9/82	2B	0.300	10.4-30.5	26	2	5	3	0.40	0.08	54 (38)	19.1	180 (127)	0.118	21.24 (30.21)
9/81	2C	0.234	No longnose suckers captured in this section.											
9/82	2C	0.210												
9/81	3	0.143	No longnose suckers captured in this section.											
9/82	3	0.280												
9/81	1	0.248	12.4-21.3	26	2	24	22	0.33	0.31	75 (38)	19.0	302 (153)	0.050	0.76 (7.65)
9/82	1	0.375	7.4-18.8	16	2	9	7	0.22	0.13	57 (47)	23.7	229 (191)	0.041	9.39 (7.83)
9/81	2A	0.375	8.1-20.1	34	9	19	12	0.47	0.26	70 (30)	14.9	187 (120)	0.027	5.05 (3.24)
9/82	2A	0.365	7.6-17.8	43	8	30	22	0.27	0.19	152 (79)	40.4	415 (217)	0.023	9.55 (4.99)
9/81	2B	0.312	8.1-19.0	107	27	54	27	0.50	0.25	212 (54)	27.6	680 (173)	0.023	15.64 (3.98)
9/82	2B	0.300	6.4-17.8	127	6	43	37	0.14	0.05	804 (511)	260.9	2682 (1705)	0.027	72.41 (46.03)
9/81	2C	0.234	10.9-15.8	3	1	2	1	0.50	0.33	6 (5)	2.0	26 (21)	0.028	0.73 (0.59)
9/82	2C	0.210	14.5-17.2	4	1	1	0	1.00	0.25	5 (0)	0.0	24 (0)	0.047	1.13 (0.00)
9/81	3	0.143	No mountain suckers captured in this section.											
9/82	3	0.280												

M = fish marked on first run C = fish captured on second run
R = fish recaptured on second run U = unmarked fish, captured second run N* = population estimate

Table 22. Summary of estimated number of trout and suckers per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses.

Date	Section	Section length (km)	Species (fish/km)					
			Rainbow trout	Brook trout	Brown trout	White sucker	Longnose sucker	Mountain sucker
9/81	1	0.248	226 (247-287)	0 (0)	121 (58-189)	3629 (3204-4054)	1161 (675-1647)	302 (149-455)
9/82	1	0.375	125 (96-154)	0 (0)	14 (5-23)	377 (85-669)	1567 (1194-1940)	229 (38-420)
9/81	2A&B	0.687	255 (198-312)	0 (0)	0 (0)	1354 (1091-1617)	358 (276-440)	434 (372-496)
9/82	2A&B	0.665	170 (123-217)	0 (0)	0 (0)	1844 (1549-2139)	156 (102-210)	1548 (1025-2071)
9/81	2C	0.234	0 (0)	0 (0)	0 (0)	3921 (2595-5247)	0 (0)	26 (5-57)
9/82	2C	0.210	510 (405-615)	1 (1)	0 (0)	3272 (2144-4400)	0 (0)	24 (0)
9/81	3	0.143	238 (133-343)	957 (75-1163)	0 (0)	430 (308-552)	0 (0)	0 (0)
9/82	3	0.280	1631 (949-2313)	727 (628-826)	0 (0)	230 (0-439)	0 (0)	0

Table 23. Summary of estimate biomass (kg) of trout and suckers per kilometer in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses.

			Species (kg/km)					
Date	Section	Section length (km)	Rainbow trout	Brook trout	Brown trout	White sucker	Longnose sucker	Mountain sucker
9/81	1	0.248	25.63 (22.95-28.31)	0 (0)	6.66 (3.20-10.12)	312.09 (275.54-348.64)	152.09 (88.22-215.76)	0.76 (0-8.41)
9/82	1	0.375	31.55 (26.23-36.87)	0 (0)	10.30 (3.68-16.92)	32.05 (7.23-56.87)	199.01 (151.64-246.38)	9.39 (1.56-17.22)
9/81	2A&B	0.687	13.56 (10.53-16.59)	0 (0)	0 (0)	63.50 (51.16-75.83)	26.38 (20.34-32.42)	10.34 (8.86-11.82)
9/82	2A&B	0.665	16.34 (11.82-20.86)	0 (0)	0 (0)	83.76 (70.36-97.16)	18.35 (12.00-24.70)	40.98 (27.13-54.82)
9/81	2C	0.234	0 (0)	0 (0)	0 (0)	231.34 (153.11-309.57)	0 (0)	0.73 (0.14-1.32)
9/82	2C	0.210	66.49 (53.30-79.68)	0 (0)	0 (0)	281.39 (184.38-378.40)	0 (0)	1.13 (0)
9/81	3	0.143	11.01 (6.18-15.84)	39.24 (30.79-47.69)	0 (0)	34.83 (24.95-44.71)	0 (0)	0 (0)
9/82	3	0.280	13.25 (7.79-18.71)	59.61 (51.49-67.73)	0 (0)	11.16 (0-22.32)	0 (0)	0 (0)

Table 24. Estimated numbers (per km) of rainbow trout by age group in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses.

Date	Section	Section length (km)	Age groups (trout/km) 0+	1+	2+	3+	4+	Total
9/81	1	0.248	4 (4)	76 (69-97)	89 (81-97)	52 (48-57)	5 (4-6)	226 (206-247)
9/82	1	0.375	0 (0)	37 (28-46)	64 (49-79)	21 (16-26)	0 (0)	125 (96-154)
9/81	2A&B	0.687	47 (38-60)	67 (55-86)	101 (82-130)	13 (11-17)	6 (4-8)	243 (198-312)
9/82	2A&B	0.665	2 (2)	113 (80-142)	42 (30-53)	16 (11-21)	0 (0)	173 (123-217)
9/81	2C	0.234	No rainbow trout collected in this section.					
9/82	2C	0.210	95 (75-115)	62 (49-75)	343 (272-414)	10 (8-12)	0 (0)	510 (405-615)
9/81	3	0.143	63 (56-91)	28 (16-40)	105 (59-151)	42 (23-61)	0 (0)	238 (133-343)
9/82	3	0.280	1588 (924-2252)	25 (14-36)	18 (10-26)	0 (0)	0 (0)	1631 (949-2313)

Table 25. Estimated biomass (kg/km) of rainbow trout by age group in sections 1, 2A&B, 2C, and 3 of Beaver Creek during 1981 and 1982. The 95% confidence intervals are in parentheses.

Date	Section	Section length (km)	Age groups (kg/km) 0+	1+	2+	3+	4+	Total
9/81	1	0.248	0.22 (0.22)	6.79 (6.16-7.42)	7.86 (7.18-8.60)	9.48 (8.75-10.40)	1.72 (1.38-2.06)	25.88 (23.48-28.16)
9/82	1	0.375	0 (0)	5.98 (4.52-7.43)	17.34 (13.28-21.40)	8.23 (6.27-10.19)	0 (0)	31.55 (24.23-38.87)
9/81	2A&B	0.687	0.34 (0.27-0.43)	2.22 (1.82-2.85)	6.58 (5.34-8.45)	1.18 (1.00-1.54)	2.98 (2.00-3.97)	13.30 (10.84-17.08)
9/82	2A&B	0.665	0.04 0.04)	5.69 (4.03-7.15)	5.24 (3.74-6.61)	4.22 (2.90-5.54)	0 (0)	15.19 (10.80-19.05)
9/81	2C	0.234	No rainbow trout collected in this section.					
9/82	2C	0.210	0.78 (0.62-0.94)	4.23 (3.34-5.12)	58.78 (46.61-70.95)	2.88 (2.30-3.46)	0 (0)	66.67 (52.94-80.40)
9/81	3	0.143	0.38 (0.34-0.55)	1.02 (0.58-1.46)	5.62 (3.16-8.08)	4.57 (2.50-6.64)	0 (0)	11.59 (6.48-16.70)
9/82	3	0.280	9.63 (5.60-13.66)	1.36 (0.76-1.96)	2.43 (1.35-3.51)	0 (0)	0 (0)	13.42 (7.81-19.03)

Table 26. Mean total length and mass at time of capture (standard deviation in parentheses) and calculated mean total length and mass at each annulus for rainbow trout collected in Beaver Creek in 1981 and 1982.

			Mean		Calculated length at each age (cm)			
Section	Age	N	Total length (cm)	Total mass (gm)	1	2	3	4
1	I	11	24.0 (1.8)	151 (30)	15.2			
	II	44	24.5 (4.9)	167 (100)	14.3	19.7		
	III	18	28.6 (4.3)	246 (113)	13.5	18.6	23.5	
	IV	1	-	-	13.0	16.8	21.2	26.3
Mean back calculated length					14.2	19.4	23.4	26.3
Mean increment of back caculated length					14.2	5.3	4.9	5.1
2A	I	61	16.5 (1.9)	50 (50)	12.0			
	II	22	20.4 (4.7)	100 (84)	11.6	16.2		
	III	3	28.7 (1.7)	227 (46)	10.8	17.5	23.0	
	IV	2	31.1 (4.1)	263 (90)	9.3	14.3	20.3	25.4
Mean back calculated length					11.8	16.2	21.9	25.4
Mean increment of back calculated length					11.8	4.9	5.7	5.1

Table 26. (continued)

			Mean		Calculated length at each age (cm)			
Sec-tion	Age	N	Total length (cm)	Total mass (gm)	1	2	3	4
2B	I	20	17.9 (2.2)	61 (28)	12.5			
	II	36	21.4 (3.1)	104 (53)	12.7	17.5		
	III	15	26.1 (3.2)	176 (73)	13.0	18.1	22.0	
	IV	1	--	--	12.0	15.3	20.1	23.5
Mean back calculated length					12.7	17.6	21.9	23.5
Mean increment of back calculated length					12.7	4.9	4.0	3.4
2C	I	10	17.9 (4.7)	95 (38)	16.2			
	II	57	24.9 (2.2)	170 (45)	17.6	21.2		
	III	2	34.0 (5.4)	358 (128)	17.6	21.9	27.4	
Mean back calculated length					15.7	21.3	27.4	
Mean increment of back calculated length					15.7	3.6	5.5	
3	I	10	15.8 (1.2)	51 (15)	12.5			
	II	15	19.7 (3.4)	84 (15)	13.1	16.6		
	III	5	22.9 (1.4)	114 (24)	13.3	17.7	20.6	
Mean back calculated length					13.0	16.8	20.5	
Mean increment of back calculated length					13.0	3.7	2.9	

Table 27. Numbers, totals, and percentages of responses to recreation survey conducted on Beaver Creek and Bear Paw Lake between 30 June and 11 September 1982.

Question	Total	Percent
1. Where are you from?		
Havre, Montana	178	74
Hill County, other than Havre	12	5
Montana, other than Hill County	32	13
United States, other than Montana	17	7
Outside United States	3	1
Total	242	
2. Is fishing your main interest in the Park?		
Yes	112	47
Camping	35	15
Picnicing	12	5
General Recreation	73	31
Cabin owner	5	2
Total	237	
3. How many years have you been coming here?		
First time	39	18
1-4 years	43	19
5-10 years	61	27
11-20 years	33	15
20 or more years	47	21
Total	223	
4. How often do you fish here?		
First time	37	16
Once or twice a year	47	21
Once every 2 weeks	63	28
One or two times per week	64	28
Daily	2	1
Don't fish	12	6
Total	225	

Table 27. (continued)

Question	Total	Percent
5. What season do you fish here most?		
Spring	16	7
Summer	171	71
Fall	4	2
Winter	5	2
Year around	25	10
Spring, summer, and fall	7	3
First time	10	4
Don't fish	4	1
Total	242	
6. Do you fish more on the reservoir or the stream?		
Reservoir	144	62
Both	46	20
Stream	30	13
None	11	5
Total	231	
7. Where do you usually fish on Beaver Creek?		
Above Bear Paw Lake	57	22
Immediately below Bear Paw Lake	40	15
Immediately upstream from Beaver Creek Reservoir	28	11
Above and Below Beaver Creek Reservoir	17	6
Below Beaver Creek Reservoir	5	2
Don't fish the stream	105	40
All parts of the stream	11	4
Total	263	

Table 27. (continued)

Question	Total	Percent
8. What kind of fishing gear do you usually use?		
Flies	32	13
Lures	29	11
Bait	171	67
All	14	5
None	10	4
Total	256	
9. Why do you fish?		
Food	4	3
More for food than recreation	6	4
Both food and recreation	42	29
More recreation than food	24	17
Recreation	60	41
Don't fish	9	6
Total	145	
10. In Beaver Creek, which species of fish would you prefer to catch?		
Rainbow trout	54	22
Eastern brook trout	46	19
Cutthroat trout	24	10
Brown trout	7	3
No preference	115	46
Total	246	

Table 27. (continued)

Question	Total	Percent
11. How has this seasons fishing compared to past years?		
Better	17	8
Slightly better	8	3
About the same	49	22
A little worse	13	6
Poorer	48	22
Don't know	88	39
Total	223	
12. How do you feel about an annual park fee?		
For	95	44
More for than against	55	26
Don't know	27	13
Don't really like it	7	3
Against	31	14
Total	215	
13. Are there improvements you would like to see in the Park?		
More facilities	20	8
Few improvements	3	1
Leave it as it is	94	35
Less facilities	2	1
Comments (Appendix A Table 7)	148	55
Total	267	
14. What are your feelings on lowering Bear Paw Lake in the late summer to supplement flows in Beaver Creek?		
Agree	43	21
Maybe	45	21
Don't Know	42	20
Prefer not, but alright if it helps fish.	14	7
Disagree	66	31
Total	210	

Table 27. (continued)

Question	Total	Percent
15. Estimated ages		
0-12 years	2	1
13-18 years	11	5
19-25 years	64	27
26-35 years	35	15
36-50 years	19	8
Seniors	26	11
Young family groups person in charge under 50	63	26
Older groups person in charge over 50	20	8
Total	240	

Table 28. Comments made by five or more respondents during the recreation survey on Beaver Creek and Bear Paw Lake in 1982.

Comment	Number of Respondents
More and bigger fish.	32
Improve fishing.	13
Clean up garbage and enforce litter laws.	20
Better roads around lake.	17
Happy with it the way it is (the park).	12
Keep cattle out of the park.	6
More restrooms.	19
More trees and shade.	15
More campsites.	8
(58 separate comments made by 232 people)	

Table 29. Length (mm) and mass (g) of rainbow trout sampled from beaver ponds on Beaver Creek in 1982.

Section	I.D. number	Length (mm)	Mass (g)
LBC21	1.	303	297
	2.	164	41
LBC22	3.	183	60
LBC23	4.	190	64
	5.	143	27
	6.	288	244
	7.	148	27
LBC24	8.	225	106
	9.	261	193
	10.	257	158
	11.	205	78
	12.	165	42
LBC25	13.	212	80
	14.	170	47
	15.	153	31
LBC24	16.	175	59
	17.	151	33
	18.	321	295
	19.	401	656
	20.	215	79
LBC23	21.	154	32
	22.	179	51
	23.	204	81
	24.	262	161
LBC22	25.	283	184
	26.	192	68
	27.	172	50
	28.	154	38
	29.	162	45
	30.	175	51
	31.	177	50
LBC21	32.	171	43
	33.	150	32
	34.	194	75
LBC22B	35.	372	486
	36.	278	196
	37.	312	303
LBC32	38.	169	48
LBC33	39.	212	90
	40.	240	133
	41.	213	83
	42.	385	541

Table 29. (continued)

Section	I.D. Number	Length (mm)	Mass (g)
LBC34	43.	275	195
LBC34	44.	213	79
LBC51	45.	290	100
	46.	201	76
	47.	236	134
	48.	198	77
LBC52	49.	205	85
	50.	281	211
	51.	295	252
	52.	349	381
	53.	297	258
	54.	265	172
	55.	235	115
LBC52	56.	293	230
	57.	249	150
LBC53	58.	212	97
	59.	256	164
LBC55	60.	385	600
	61.	245	132
	62.	275	202
LBC81	63.	283	243
	64.	304	297
	65.	252	175
	66.	221	121
	67.	276	234

Table 30. Length (mm) and mass (g) of rainbow trout sampled from section 2 of Beaver Creek in 1982.

Section	I.D. Number	Length (mm)	Mass (g)
2A	1.	295	236
	2.	244	154
	3.	193	68
	4.	279	227
	5.	167	55
	6.	203	83
	7.	216	113
	8.	201	82
	9.	172	54
	10.	178	54
	11.	183	64
	12.	168	54
	13.	168	54
	14.	168	32
	15.	173	41
	16.	170	50
	17.	175	50
	18.	137	18
	19.	173	40
	20.	206	99
	21.	160	36
	22.	168	63
	23.	155	36
	24.	152	40
	25.	157	36
	26.	152	36
	27.	179	54
	28.	168	45
	29.	185	63
	30.	160	36
	31.	150	27
	32.	142	36
	33.	147	36
	34.	145	31
	35.	191	45
	36.	302	277
	37.	170	36
	38.	162	36
	39.	137	27
	40.	157	31
	41.	188	49
	42.	188	59

Table 30. (continued)

Section	I.D. Number	Length (mm)	Mass (g)
2A	43.	178	49
	44.	170	49
	45.	135	27
	46.	170	45
	47.	142	27
	48.	140	22
	49.	160	36
	50.	290	218
	51.	300	309
	52.	236	136
	53.	193	59
	54.	196	77
	55.	239	154
	56.	234	145
	57.	206	95
	58.	284	236
	59.	196	91
	60.	183	64
	61.	300	272
	62.	218	118
	63.	191	68
	64.	287	268
	65.	264	200
	66.	168	45
	67.	206	100
	68.	241	100
	69.	302	254
	70.	193	77
	71.	259	177
	72.	297	281
	73.	213	113
	74.	183	77
	75.	241	159
	76.	305	275
	77.	203	86
	78.	249	159
	79.	201	104
	80.	193	81
	81.	224	132
	82.	282	241
	83.	272	218
	84.	175	54
	85.	259	177
	86.	206	104
	87.	191	77

APPENDIX D

SAMPLE RECREATION SURVEY FORM

Have you been surveyed before?

Date:__________
Time:__________
Location:____
Surveyeor:____

1. Where are you from? ___________.

2. Is fish your main interest in the park?
   Y N other__________.

3. How many years have you been coming here?
   (1st time) 1 2 3 4 5 (20 or more years)

4. How often do you fish here?
   (1st time) 1 2 3 4 5 (daily)

5. What season do you fish here most?
   (Spring) 1 2 3 4 5 (year around)

6. Do you fish more on the reservoir or the stream?
   (reservoir) 1 2 3 (stream)

7. Where do you usually fish on Beaver Creek?
   (above Bear Paw Lake) 1 2 3 4 5 (Below B.C.R.)

8. What kind of gear do you usually use?
   (flies) 1 2 3 4 (all)

9. Why do you fish?
   (food) 1 2 3 4 5 (recreation)

10. Which species of fish on Beaver Creek would you prefer to catch?

Rb	Eb	Ct	Ll	ND
1	2	3	4	5

11. How has this seasons fishing on the creek compared to past years?
    (better) 1 2 3 4 5 (poorer)

12. How do you feel about an annual park fee?
    (It was $3.00 per yr).
    (for) 1 2 3 4 5 (against)

13. Are there improvements you would like to see in the park?
    (more facilities) 1 2 3 4 5 (less) Comments:

14. Feelings on lake lowering in late season.
    (agree) 1 2 3 4 5 (disagree)
    (be sure to explain situiation)

15. Estimated Age:

5-12	14-18	19-25	26-35	36-50	51-seniors
1	2	3	4	5	6

16. Sex M F

17. Number of people in party.

18. Number of hours fished today.

19. Number and species of fish caught today.