Limitations to a rainbow trout population in north-central Montana
by Robert William Hitchcock

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

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^/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 mr/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^/s released from the bottom of Bear Paw Lake throughout the year, is recommended• The 1.6 km of Beaver Creek immediately downs t ream 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.

LIMITATIONS TO A RAINBOW TROUT POPULATION IN NORTH-CENTRAL MONTANA

by

Robert William Hitchcock III

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APPROVAL

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Robert William Hitchcock III

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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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.

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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

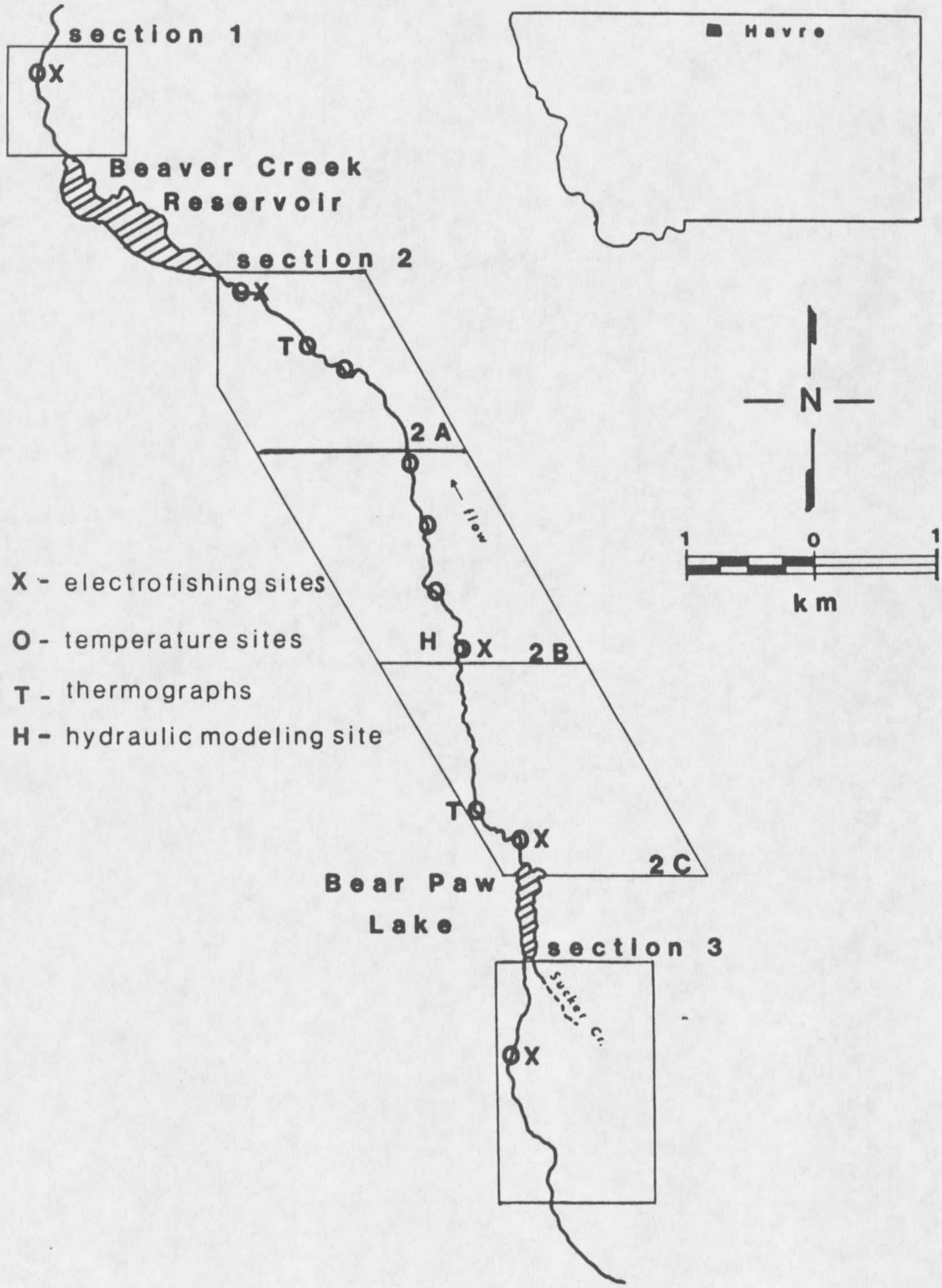

Figure 1. Location of electrofishing, temperature, hydraulic modeling, and thermograph sites in the Beaver Creek study area.

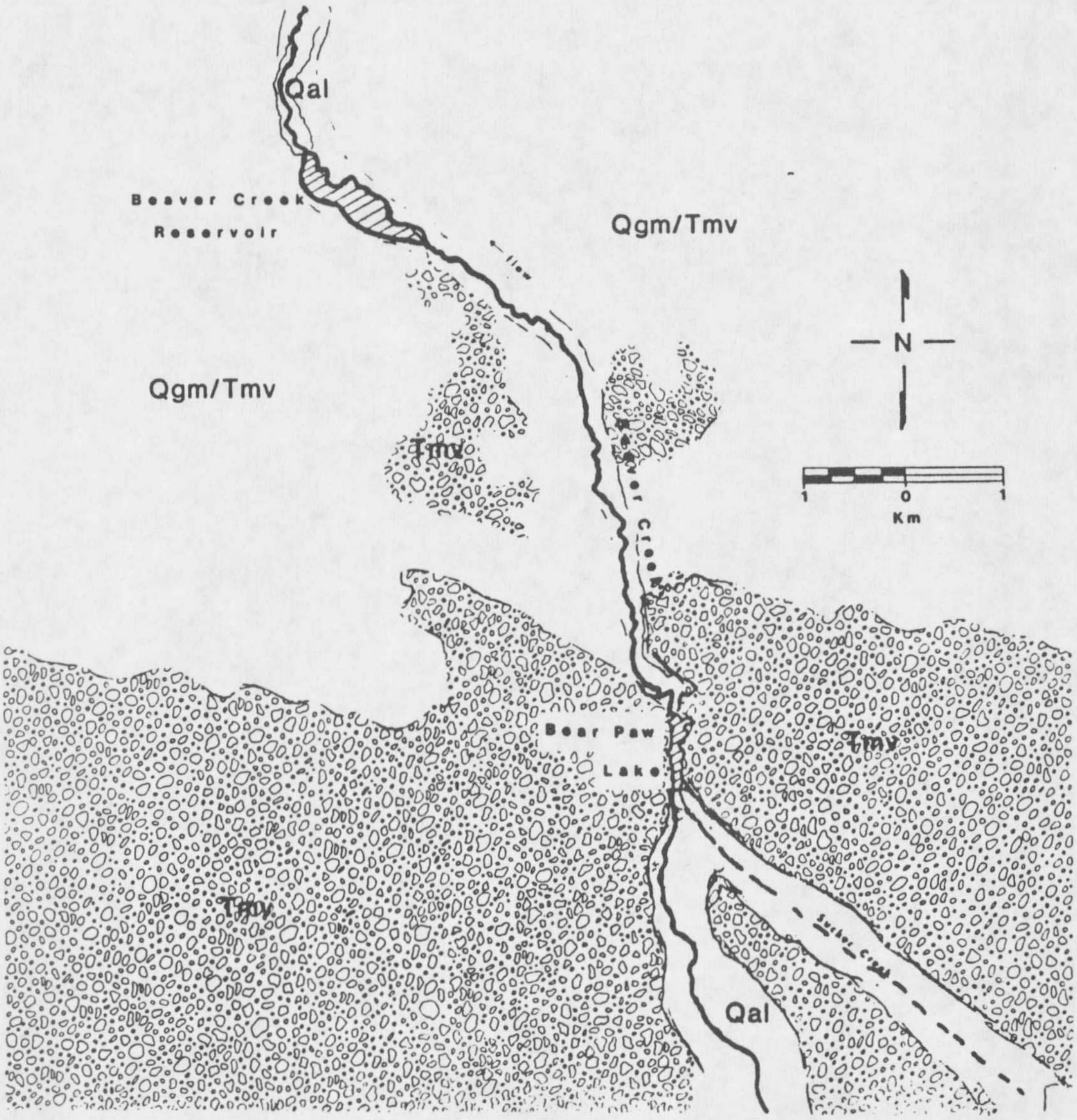

Figure 2. Geology of the Beaver Creek study area identifying alluvium (Qal), ground moraine (Qgm), and mafic volcanic (Tmv) rock formations (Kerr 1957).

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 =

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

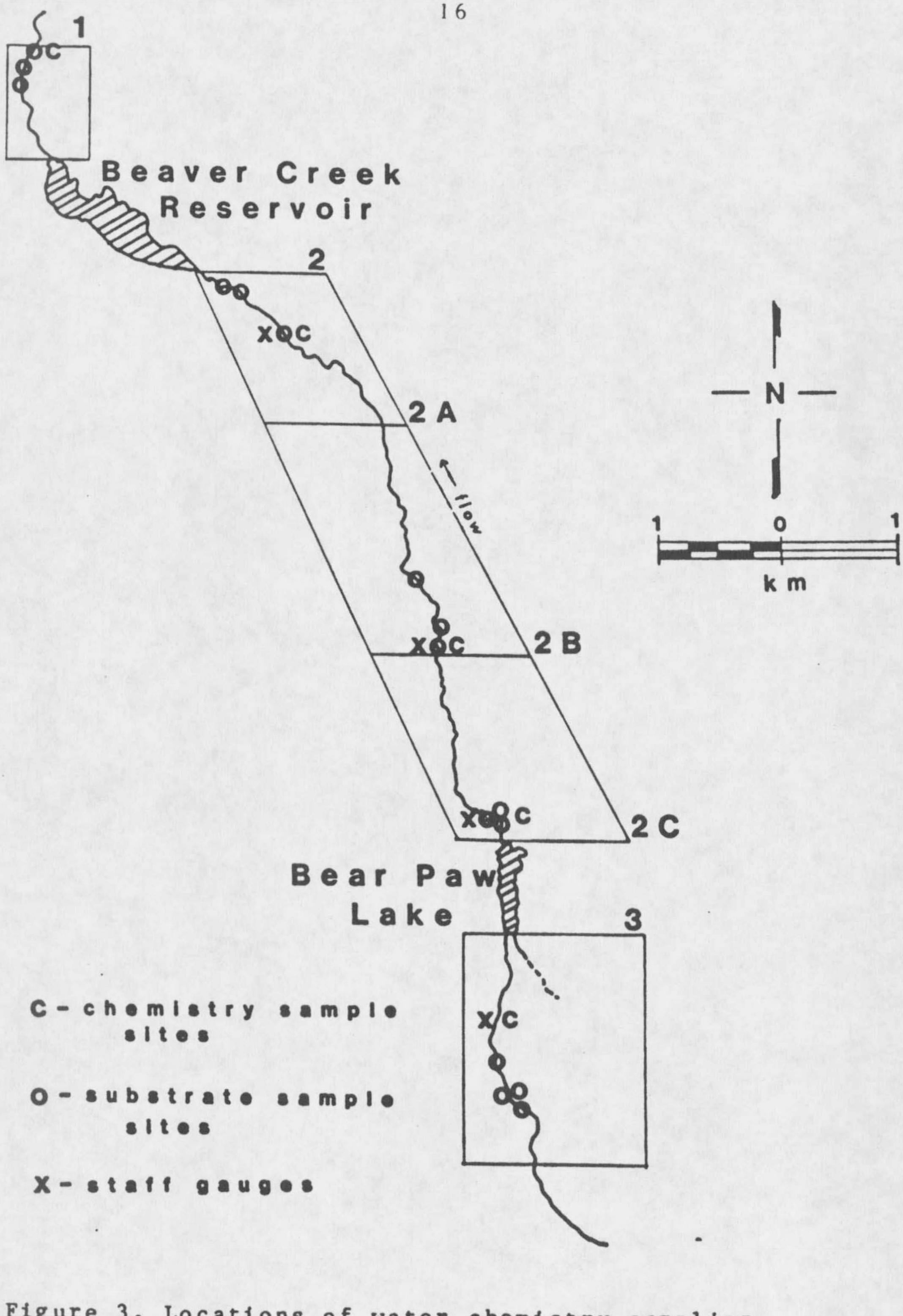

Figure 3. Locations of water chemistry sampling, substrate sampling, and staff gauge sites in the Beaver Creek study area.

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

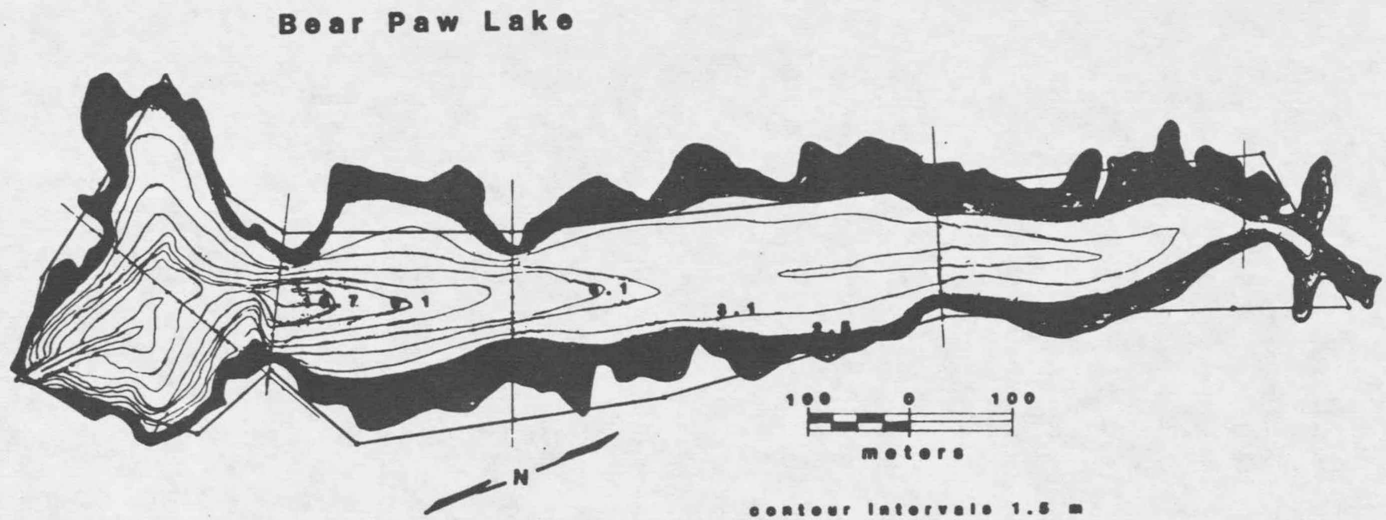

Figure 4. Depth contours of Bear Paw Lake. Shaded area
represents exposed lake bottom resulting
from a 2.5 m drawdown.

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 (<u>Catostomus platyrhynchus</u>) were restricted to sections below Bear Paw Lake, while longnose suckers (<u>Catostomus catostomus</u>) 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

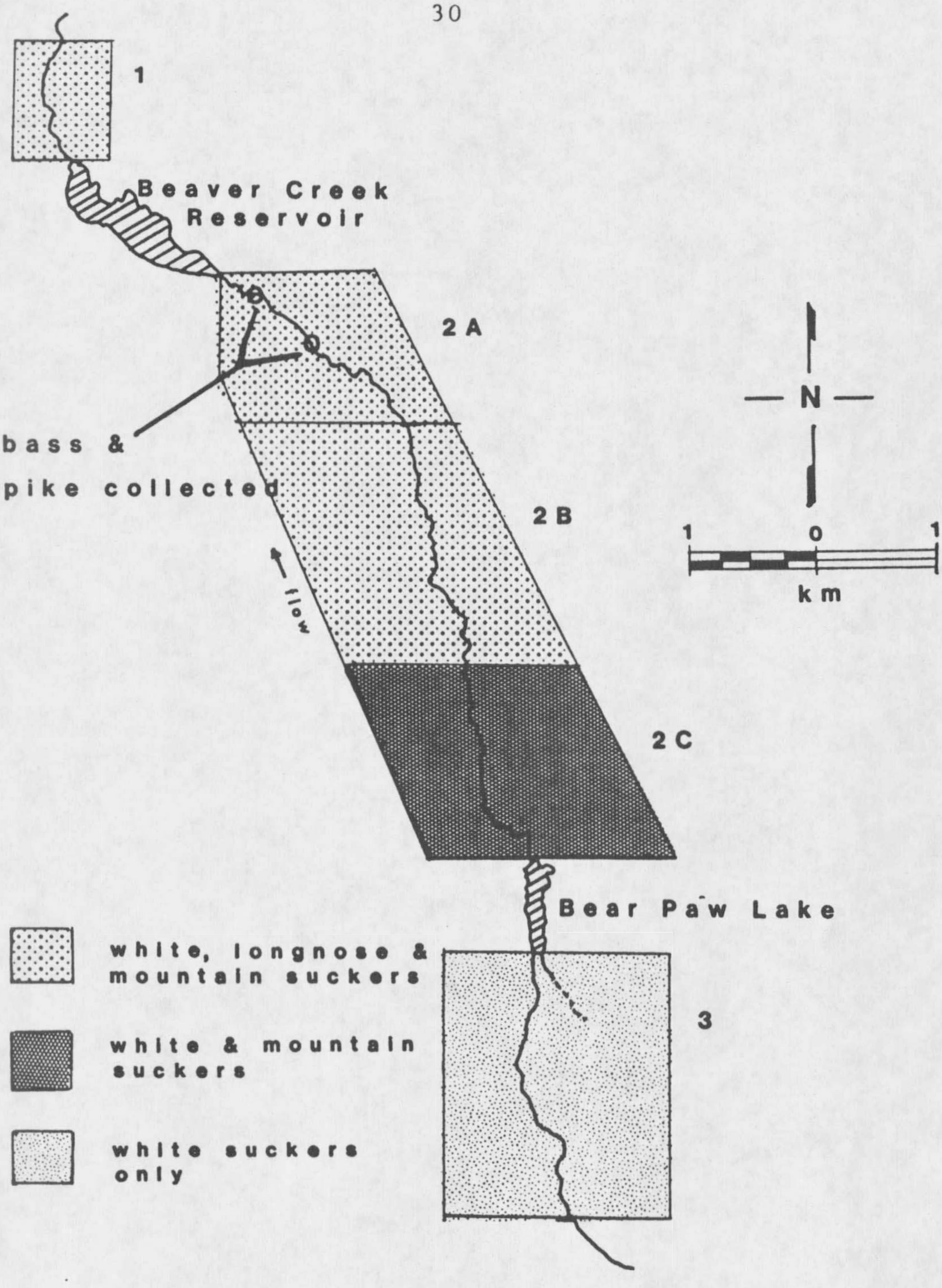

Figure 5. Distribution of white, longnose, and mountain suckers in Beaver Creek. Largemouth bass and northern pike collection sites are also included.

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