F-07-37 #86078 3

PHYSICAL HABITAT, GEOLOGIC BEDROCK TYPES AND TROUT DENSITIES IN TRIBUTARIES OF THE FLATHEAD RIVER DRAINAGE, MONTANA[1]

John J. Fraley and Patrick J. Graham[2]

Abstract.--Stream habitat and trout population densities were compared on 112 tributary reaches of the North and Middle Forks of the Flathead River during 1979 and 1980. The habitat model that best described age I and older westslope cutthroat (*Salmo clarki lewisi*) and juvenile bull trout (*Salvelinus confluentus*) densities contained measurements of trout cover, D-90 (measurement of bed material) and stream order. The correlation (r) between actual trout densities and predicted densities for 23 new reaches surveyed during 1981 was 0.63 with a least squares fit, and 0.84 when fitted with zero Y intercept. Discriminant analysis produced similar results to those of multiple regression. Trout densities and stream habitat parameters differed significantly between geologic types. Results from this study allowed an integration of fisheries information into the land management decision making process in the Flathead National Forest, Montana.

INTRODUCTION

An assessment of trout habitat and associated densities was recently made in tributaries of the North and Middle Forks of the Flathead River (North and Middle Forks, FHR) as part of a baseline environmental study of the Flathead Lake-River ecosystem in northwest Montana (fig. 1). The study assessed the conditions of the aquatic resource to provide information needed to evaluate potential impacts of large-scale coal development in the Flathead drainage in Canada, and oil, gas, and timber developments in both the U.S. and Canadian portions of the drainage (Graham 1980, Graham et al. 1980).

Tributaries to the Flathead River are in fertile, clear mountain streams dominated by a run-riffle channel configuration. Late summer flows in the tributaries ranged from 0.07 to 1.9 m^3 per second. Trout populations consisted mainly of juveniles resulting from westslope cutthroat and bull trout adults migrating from Flathead Lake and Flathead River, and some resident tributary cutthroat. The tributaries serve as the vital rearing areas for the interconnected Flathead Lake River system.

METHODS

Habitat Measurement

Stream habitat was evaluated on a total of 142 North and Middle Fork Flathead River tributary reaches comprising 675 stream kilometers during 1979 and 1980. This total includes all major tributaries south of the Canadian border in the North Fork drainage and approximately two-thirds of the tributaries

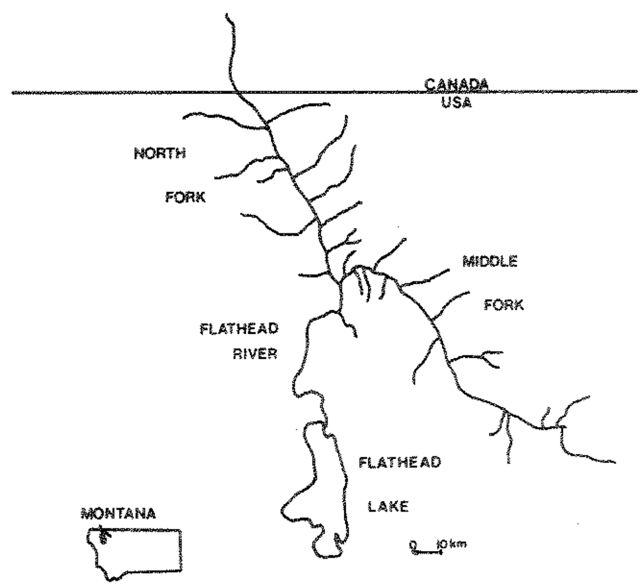

Figure 1. Map of the study area.

---

[1]Paper presented at the symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information (American Fisheries Society, Western Division, Portland, OR, October 28-30, 1981

[2]Montana Department of Fish, Wildlife and arks, P.O. Box 67, Kalispell, MT

in the Middle Fork drainage. Approximately two-thirds of the reaches surveyed are located in wilderness areas or Glacier National Park and have not been impacted by development. One-third of the stream reaches have been impacted to some degree by road building or logging activities.

Stream habitat condition was measured using methods developed by the Aquatic Studies Branch of the British Columbia Ministry of Environment (Chamberlin 1980a, 1980b).

Each study tributary was flown by helicopter and divided into one or more reaches. Reaches were portions of the stream having uniform associations of physical habitat characteristics. Changes in stream gradient resulted in differences in bed material size, stream channel pattern, and channel morphology, and was the major factor used to delineate the reach. Major stream features such as log jams, fish barriers and mass wasted banks were also recorded during helicopter surveys.

Field survey crews measured 30 individual physical habitat parameters for each tributary reach (Chamberlin 1980a, 1980b, Fraley et al. 1981). Major habitat conditions measured were stream hydraulics, channel morphology, bed material, bank material, stream pattern, stream cover, pool class, and pool-riffle-run-pocket water quantities. Log jams, fish barriers, bank and bed stability, and debris were also measured.

Measurements were taken at randomly selected transects in a 0.8 to 2.5 km (0.5-1.5 mi.) portion of each reach, depending on reach length. On a typical 1.6 km (1 mile) section, a total of 40 random transects were selected. At 15 of these transects, measurements were made of bed material compaction, channel particle imbededness, D-90 (substrate size), canopy cover, overhang cover, organic debris, channel width and average stream depth. Stream habitat was classified as to pool, riffle, run or pocket water at all 40 transects and the wetted parameter was measured at 20 of the transects. Bank material, channel substrate and stream channel stability were evaluated for each section (Chamberlin 1980a, 1980b). Instream cover was evaluated for a 150 m (495 feet) section of each reach by snorkeling. Overhang cover was measured for the habitat section and included material such as logs or vegetation extending over the stream at a height of one meter or less. Instream cover was measured in the snorkel section as overhang touching the water surface plus water depth, turbulence, debris and rocks.

Chemical conditions and stream flows were measured once during late summer on the lowermost reach of each major tributary. Alkalinity, conductivity, and flow were measured in the field. The University of Montana Biological Station analyzed nitrate (NO_3^-), total phosphorus (TP), total organic carbon (TOC), calcium (CA^{++}), magnesium (Mg^{++}), potassium (K^+) and sodium (Na^+).

The study area was divided into geologic types based on the nature of the underlying bedrock. Physical and chemical characteristics typical of each bedrock type were determined by soil samples of the unweathered soil horizon (Martinson et al. 1982). Stream reaches were then classified into geologic types on the basis of the dominant underlying bedrock type.

Fish Population Estimates

Population estimates of westslope cutthroat and bull trout were made on randomly chosen 100-150 m long sections of each reach. Observers wore a wet suit, diving mask and snorkel, and estimated the number of fish in each age class based on predetermined length frequencies for pools, runs, riffles and pocket water habitats as they pulled themselves upstream.

Snorkeling was preferrable to electrofishing because of the clarity, low conductivity, and inaccessibility of many waters in the Flathead drainage. In wilderness areas and Glacier National Park where regulations restrict the use of electrofishing equipment, snorkeling was an effective and practical method for obtaining fish population estimates. Comparisons of snorkeling and two pass electrofishing estimates for 13 North and Middle Fork FHR tributary reaches indicated no significant difference between the means of the two methods for age I and older cutthroat and bull trout (Fraley et al. 1981). Snorkeling efficiency was lower for juvenile bull trout and estimates for this species were not considered as reliable as those for cutthroat trout (Fraley et al. 1981, Shepard et al. 1982).

Analysis of Habitat and Fish Population Data

Physical-chemical habitat parameters and fish densities measured for each tributary reach were entered on the standard Montana Interagency Stream Fishery Data forms (Fish, Wildlife and Parks, Helena 1980). Data were entered into the statewide data base administered through the Department of Fish, Wildlife and Parks in Helena (Holton and McFarland, this volume). A "dictionary" defining locations of each habitat and fish population variable in the data base was constructed on the Montana State University CP-6 Interactive Data Base Processing System. The dictionary enabled the user to obtain all information available for each stream reach. This information will also be published by the Montana Fish, Wildlife and Parks as an aid to land managers, and will include tabulated data and physical habitat and fish population maps for each drainage (figs. 2 and 3).

A total of 30 physical habitat parameters were tested for their relationships to fish densities in 112 tributary reaches which contained trout through the use of simple linear correlation. Multiple regression (Snedecor and Cochran 1969) was then utilized to identify the most significant combination of habitat variables which affected population densities of age I and older cutthroat and bull trout. All correlations and regressions were calculated with "Mregress", "Sumstat" and "Biplot" computer programs of the Montana State University Statistical Library (Lund 1979). Discriminant analysis was performed using programs in the Statistical Package for the Social Sciences series (Nie et al. 1975). Trout densities and stream habitat conditions in the different geologic types were also analyzed using discriminant analysis.

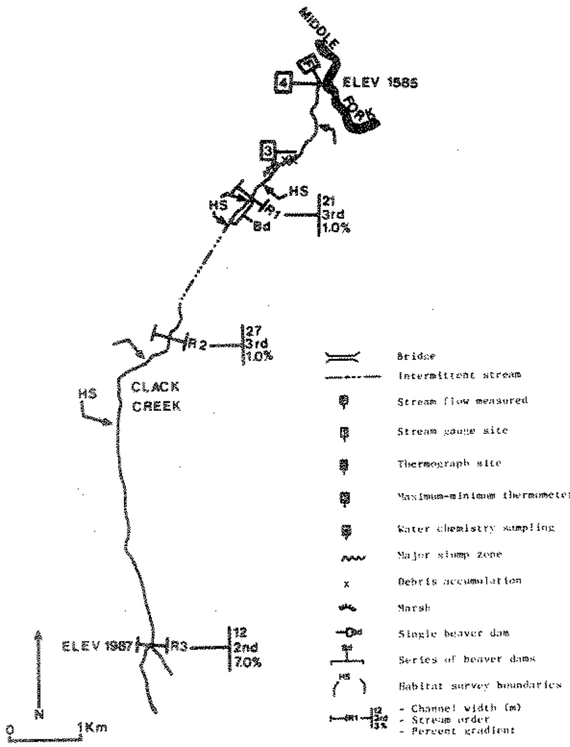

Figure 2. Physical habitat map for Clack Creek (Middle Fork FHR drainage). R indicates a reach break.

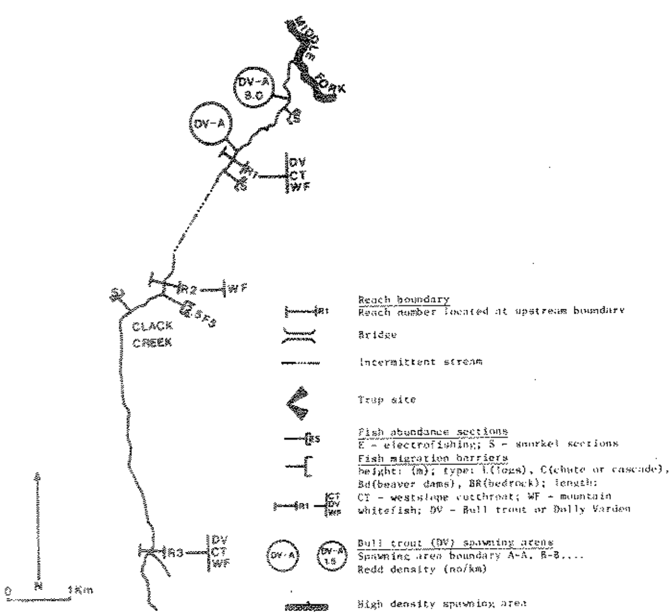

Figure 3. Fish population characteristics map of Clack Creek (Middle Fork FHR drainage).

RESULTS AND DISCUSSION

Habitat-Trout Relationships

Of the 30 physical habitat parameters tested, 10 were found to have significant relationships to trout densities ($p<0.01$). These included six cover variables or variable combinations, substrate size (D-90), wetted perimeter, average depth and stream order.

Variables or variable combinations associated with cover had the highest simple correlation coefficients. All four cover variables tested had significant positive relationships to trout densities. The combination of the variables overhang and instream cover had the best correlation with trout densities ($r=.602$, $p<0.01$). This two variable combination was chosen as best representing trout cover in the tributary reaches. Canopy had the lowest significant correlation of all cover variables tested.

Substrate size (D-90), wetted width, average depth and stream order were all negatively correlated at the 99% level. This indicates that larger measurements of these variables in a reach were associated with lower trout densities. Although water temperature was an important variable affecting trout densities in other studies (Binns and Eiserman 1979), there did not appear to be a strong relationship between measured fish densities and maximum summer water temperatures in North and Middle Fork tributaries in the reaches where temperature data were available.

In the small number of stream reaches where chemical data were available, ion concentrations did not seem to be associated with high fish densities within the range of ion cencentrations sampled. Dissolved ion concentrations were about twice as large in the Middle Fork drainage, but average trout density was only half as large as the density in North Fork tributaries. Nutrient concentrations (phosphorus and nitrate) and total organic carbon were relatively low and varied little in tributaries of both drainages.

Multiple Regression Analysis

Age I and Older Cutthroat and Bull Trout

Trout cover, stream order, and D-90 (substrate size) formed the best variable combination or model ($R=0.64$) describing the relationship between habitat and combined densities of age I and older cutthroat and bull trout (Table 2). Each remaining habitat parameter in the data base was inidividually added and tested, but none increased precision of the model at the 95% level. No multi-collinearity problem existed among the three habitat variables in the model based on tests performed following methods in Cavallaro et al. (1981).

Trout cover had the highest partial correlation coefficient in the model and is probably the single most important habitat variable measured that affected observed variations in trout densities. Binns and Eiserman (1979), Platts (1979b), Harshbarger and Bhattacharyya (1981), Cardinal (1980) and Lewis (1967) reported cover was a critical component of stream habitat affecting trout densities when considered in combination with other habitat variables.

Table 2. Physical habitat variables which formed the best mutual relationship with trout densities (age I and older cutthroat and bull trout) in 134 North and Middle Fork tributary reaches ($R=0.64$, $N=134$).

Variable	R-Partial[a/]	Slope[b/]	P-Value[c/]
Trout cover(X_1)	0.50	0.53	0.001
Stream order(X_2)	-0.19	-2.62	0.040
D-90(X_3)	-0.18	-0.082	0.050

a/ Correlation of habitat variable to fish densities while other habitat variables are held constant.

b/ Slope is a measure of the direction and magnitude of a change in fish numbers with an increase in the measurement of a habitat variable by one unit.

c/ Level of significance of the relationship of a habitat variable to fish densities when considered in combination with the other habitat variables.

Stream order is a classification (Platts 1979a) assigned to a reach based on its position in a stream drainage and is roughly indicative of drainage area, discharge, and wetted width. Streams of lower order were associated with larger trout densities in the model. Platts (1979a) also found a negative correlation of stream order with cutthroat and juvenile bull trout densities.

The D-90, or the substrate size which is larger than 90 percent of the remaining streambed material in a reach, also related negatively to trout density in the model, suggesting larger substrate sizes in association with the other habitat variables in the model are associated with lower fish densities in a reach

Age I and Older Cutthroat Trout

The same habitat conditions describing variations in cutthroat and bull trout densities combined also best described variations in cutthroat densities ($R=0.61$, $p<0.001$). Cutthroat were generally found in much higher densities than bull trout and had dominant influence on the combined species model.

Age I and Older Bull Trout

Juvenile bull trout were closely associated with cover in the North and Middle Fork tributary reaches. Canopy, instream cover and percent of Class 1 pools best explained variations in juvenile bull trout densities ($R=0.472$, $p<0.05$). Bull trout were found in only about half as many reaches as cutthroat and the smaller sample size limited development of a model.

Predicting Fish Densities Based on Habitat Quality

To test the three variable model, trout densities were predicted based on habitat quality for 23 Middle Fork FHR tributary reaches in Glacier National Park which were surveyed in 1981. The equation used to predict the fish densities was:

$$\hat{Y} = 0.533X_1 - 2.57X_2 - 0.082X_3 + 9.30$$

Where,

$\hat{Y}$ = Predicted trout density (age I and older cutthroat and bull trout)

X_1 = Trout cover

X_2 = Stream order

X_3 = D-90

Y intercept - 9.30

Predicted trout densities were much lower than measured densities in several reaches of Ole and Muir creeks (Table 3). This may have been due to underestimation of the instream cover component. Both streams had reaches with very large substrate (D-90) measurements which resulted in a large negative component in the equation for that reach. The instream cover estimates for those reaches did not appear to be as large as expected considering the size of the bed material. A larger measurement for instream cover would have greatly reduced the residual error for those reaches.

Table 3. Measured and predicted trout densities and residual error for 23 tributary reaches surveyed in the Middle Fork FHR drainage, Glacier National Park, during 1981.

Stream	Reach	Measured density Age I+ trout	Predicted density Age I+ trout	Residual error
Park	1	1.5	0.8	-0.7
	2	4.2	7.2	+3.0
	3	5.4	2.8	-2.6
	4	4.3	5.9	+1.6
Coal	1	3.3	1.5	-1.5
	2	7.5	12.6	+5.1
	3	2.7	3.2	+0.2
Ole	1	5.7	1.6	-4.1
	2	6.7	5.0	-1.7
	3	7.8	2.2	-5.6
McDonald	1	0.8	0.1	-0.7
Muir	1	11.7	2.2	-9.5
	2	5.3	6.8	+1.5
	3	19.6	11.4	-8.2
Nyack	1	0.1	1.6	+1.5
	2	0.2	0.1	-0.1
Pinchot	1	5.0	4.8	-0.2
	2	6.1	6.3	+0.2
Walton	1	3.7	8.1	+4.4
	2	14.8	16.1	+1.3
Lincoln	1	1.0	1.0	0
	2	4.7	11.3	+6.6
Harrison	1	0.6	0.1	-0.5

The correlation between predicted and actual fish densities was 0.63 which is significant to the 99.9% level (fig. 4). When fitted with a zero intercept, the correlation coefficient was 0.84. Harshbarger and Bhattacharyya (1981) reported similar correlation coefficient between trout biomass and physical habitat measurements in small North Carolina streams. Binns and Eiserman (1979) obtained a much higher correlation coefficient (0.977) in a model predicting trout densities in Wyoming; however, the model was based on ratings of 11 variables or variable combinations and constructed with only 20 observations. The habitat model developed for the North and Middle Fork FHR tributary reaches consisted of the actual measurements of only three variables which are relatively easy to quantify and was based on 112 observations (reaches). In addition, Binns' model was based on chosen observations from throughout the State of Wyoming, while our model is based on observations from only the Flathead drainage. A much higher correlation coefficient could probably be obtained if streams from other parts of Montana were included in the model, but this would not improve its predictive qualities for the Flathead drainage.

The equation for the final habitat model which includes the 23 Middle Fork reaches surveyed in 1981 was:

$$\hat{Y} = 0.523X_1 - 2.58X_2 - 0.068X_3 + 8.9$$

This model includes all 134 reaches which contained trout in the interconnected North and Middle Fork Flathead River system surveyed from 1979 to 1981.

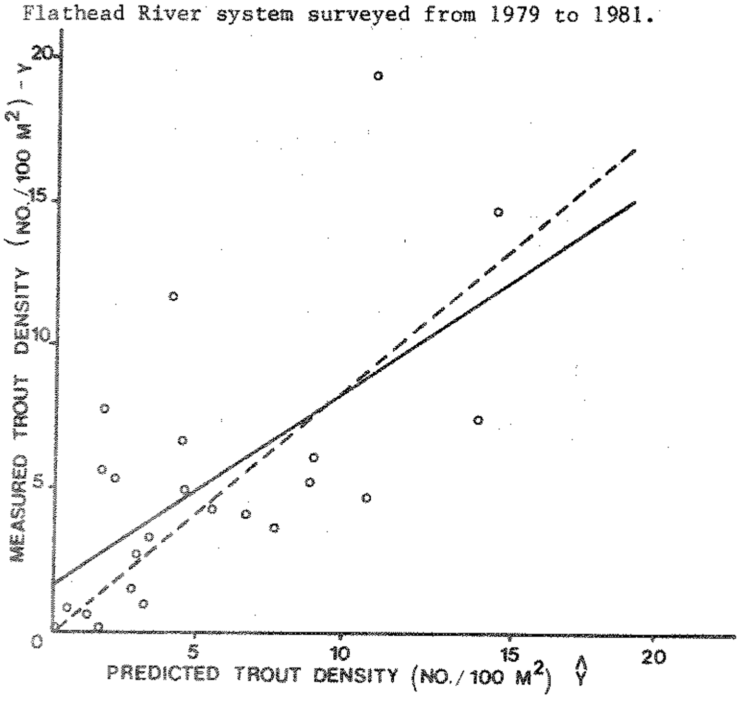

Figure 4. Measured trout densities (Y) and predicted trout densities ($\hat{Y}$) for 23 tributary reaches surveyed in the Middle Fork drainage in 1981. The solid line is the least squares fit ($Y = 1.75 - .67\hat{Y}$, r = .63) and the dotted line is fitted with zero intercept ($Y = 0 + .87\hat{Y}$, r= .84).

Discriminant Analysis

Discriminant analysis was used as a check for the usefulness of habitat variables to classify stream reaches. Groups of reaches with low (0.1 to 1.9), medium (2.0 - 7.9) and high (8.0+ trout/100m^2) trout densities were compared with 10 habitat variables considered important to trout densities (table 4). The 112 stream reaches surveyed in 1979 and 1980 were used in the initial analysis.

Table 4. Means of physical habitat and trout density measurements for reaches grouped in low, medium and high trout density categories.

Parameter	Trout density categories		
	Low	Medium	High
Number of reaches	37	39	36
Trout density	1.0	4.5	17.7
Stream order	3.1	2.9	2.6
D-90 (cm)	45	42	31
Trout cover (% area)	13	16	22
Wet width (m)	7.1	6.7	4.9
Wet cross-sectional area (m^2)	2.1	1.8	1.2
% run	46	41	45
Gradient	2.7	2.9	2.9
% pool	12	13	10
Average depth (cm)	26	25	20
% cobble	23	24	23

To obtain a significant relationship between fish density and habitat variables ($p<0.005$), the discriminant function analysis used seven of the 10 habitat variables. The three variables which formed the best mutual significant combination in multiple regression analysis, trout cover, substrate size (D-90) and stream order, were three of the top four significant variables used to derive the discriminant function. Average depth, wetted cross-sectional area, percent run habitat and wetted width were also significant in the discriminant function. Gradient, percent cobble and percent pool were not significant and did not enter the discriminant function at the specified level of significance.

Results from discriminant analysis of habitat parameters indicated a highly significant difference between reaches in the low and high trout density categories ($F=4.13$, $p<0.0005$), and between reaches in the medium and high trout density categories ($F=3.14$, $p<0.005$). A less significant difference existed between reaches in the low and medium trout density categories ($F=1.62$, $p<0.07$).

The second portion of the discriminant analysis involves classification of the stream reaches into groups based on habitat parameters. This procedure allows a check of the adequacy of the discriminant function by determining the percent of the original reaches correctly classed into groups by the habitat variables. Based on the habitat parameters utilized, 58 percent of the reaches were correctly classified into three groups (table 5).

Table 5. Classification of reaches based on the discriminant function analysis of habitat parameters for three fish density groups.

Fish density group	Number of reaches	Predicted group membership		
		Low	Medium	High
Low	37	22	5	10
Medium	39	11	21	7
High	36	9	6	21

This classification function was also applied to the 23 Middle Fork tributary reaches surveyed in 1981. Based on the discriminant functions derived from the habitat measurements of the 112 reaches in the original analysis, 14 of these new reaches were correctly classified and nine were incorrectly classified. The results from discriminant analysis were similar and supported the multiple regression analysis. Other workers have recently used discriminant analysis in conjunction with regression analysis in studies of wildlife habitat (Capen 1981).

Geologic Bedrock Associations

The tributary reaches of the Middle and North Forks FHR draining areas where the geology has been mapped were classified according to geologic bedrock type (table 6). The classifications were based on geologic maps in a publication by the Flathead National Forest (1977) adapted from earlier geologic mapping (Johns 1970). Of the 89 reaches classified, only two were type B and were not analyzed. Twenty-one reaches had portions of their drainages composed of both A and C geotype (AC) and were classed as a separate group (table 7). The characteristics of the bedrock of these reaches are functionally similar to group B. Reaches in the D and AC geotypes had the highest trout densities (indicating high fisheries rearing potential) while reaches draining the C geotype had the lowest.

Discriminant analysis was used to determine if trout densities and physical habitat parameters differed between geologic types. To derive two significant ($P<0.002$) discriminant functions, the analysis used nine of the 11 variables. Gradient and average depth were not significant and did not enter the analysis of reaches in the five geologic groups. The discriminant analysis indicated highly significant differences (based on physical habitat and trout densities) between reaches in most of the geologic types (table 8). Discriminant classification functions placed 55% of the reaches correctly into the five geologic groups. Geologic type I was quite distinct from other groups as 76% of the reaches in this geotype were predicted correctly. Platts (1974, 1979a, 1979b) also found correlations between fish populations and selected aquatic and terrestrial geomorphic conditions.

Table 6. Geologic bedrock types in the Flathead National Forest. Physical and chemical characteristics are mean values derived from samples of typical unweathered soil materials (Martinson et al. 1982).

Parameter	Geologic bedrock type				
	A	B	C	D	I
Bedrock nature	Limestone	Calcareous Argillite	Argillite & siltite	Quartzite	Shales, Sandstone and Limestones
Permeability rating 1-10 low high	10	6	4	4	(1-9)
pH	7.8	7.0	6.7	5.7	7.8
Base ion exchange (meq/100g soil)	9.2	5.7	9.8	4.5	20
Ca^{++} (meq/100g soil)	6.2	2.2	4.9	2.5	18.0
Mg^{++}	0.9	1.0	1.5	1.1	3.0
P (mg/l)	1.0	2.0	0.4	1.0	3.0
Soil texture	silty	silty	silty	sandy	sand and clay
% Gravel (% total by weight)	46	39	40	60	30

Table 7. Means of physical habitat parameters and trout densities for 89 reaches grouped in the five geologic types.

Parameter	Mean for geologic type				
	A	C	D	I	AC
Number of reaches	22	16	6	24	21
Trout density (no/100m²)	5.9	2.4	18.4	5.1	15.3
Stream order	2.9	2.8	2.7	3.0	2.9
D-90 (cm)	48.9	42.8	24.7	35.7	32.7
Trout cover (% area)	17.0	14.3	15.0	15.3	23.9
Wet width (m)	5.7	6.7	7.0	5.6	4.9
Wet cross sectional area (m²)	1.4	1.7	1.9	1.5	1.3
Gradient	4.3	2.8	2.4	1.8	3.1
% cobble	21.0	23.2	27.8	23.7	19.2
% pool	8.3	9.4	15.2	25.5	7.8
% run	40.0	48.6	42.0	43.6	43.7
Average depth	22.6	23.0	24.7	26.0	20.0

Table 8. Significance of differences between reaches in pairs of geologic groups (from F statistics) based on physical habitat and trout densities.

Group	A	C	D	I
C	.338			
D	.008	.028		
I	.001	.0021	.002	
AC	.146	.003	.023	.0000

Evaluation of Model Performance and Management Implications

Hynes (1972) suggested that the most important environmental factors interacting to affect fish distribution and abundance in streams were temperature, discharge, cover or shelter, and streambed material. He states that these habitat variables are not independent of one another and must be considered in combination.

Platts (1974) has documented multivariate control of fish populations in streams. More recently Binns and Eiserman (1979) developed a model predicting trout densities in Wyoming streams based on 11 stream habitat variables or variable combinations.

Our model is valuable in predicting the existing fisheries potential of a stream reach based on major habitat characteristics. The slope associated with each variable is a measure of the probable increase or decrease in trout densities with a one unit change in the measurement of the habitat variable (assuming a linear relationship). For example, trout cover was associated with a slope of +0.53. This would mean that if trout cover were increased by 10 units in a reach, it should result in an increase in trout density by 5.3 fish per 100 m^2. However, an increase or decrease in trout cover by adding debris to a stream or logging operations in a drainage might also change the bed material size (D-90) by altering the stream hydraulics or channel morphology. Because of this interrelationship of variables, it is difficult to predict the exact nature of the effects of a change in habitat.

Physical habitat components and fish populations are variable and often difficult to measure. It is likely that the precision of our model is limited by the difficulty of obtaining accurate measurements for these variables in a reach of stream. The presence of resident and migratory fish populations in the Flathead drainage create further difficulty in obtaining accurate relationships between trout densities and habitat variables.

It was a basic assumption that the North and Middle Fork FHR tributaries were at carrying capacity for juvenile trout. Burns (1971) reported that juvenile salmonid populations were not always at carrying capacity in small California streams. He suggested carrying capacity of a stream may fluctuate from year to year. Studies conducted by Graham (1977), Sekulich and Bjornn (1981), and Horner (1978) indicated that densities of some age classes of salmonids in several Idaho tributaries may not be at carrying capacity.

Analysis of data from the Flathead drainage demonstrated important relationships among trout populations, physical habitat and geologic bedrock type. Using these relationships, habitat quality in relation to fisheries potential was determined for important rearing areas in the interconnected Flathead Lake-River system. Through cooperation with the Flathead National Forest Office, this information has provided a basis for integrating fisheries into the land management process in the Flathead drainage.

ACKNOWLEDGEMENTS

Funding for the study was provided by the Environmental Protection Agency through the Flathead River Basin Steering Committee. Steve Leathe, Don Read and Brad Shepard were project biologists during portions of the study. Bob McFarland provided guidance in statistical analyses and George Holton, Burwell Gooch and Bob McFarland assisted in data processing. We thank personnel of the U.S. Forest Service (particularly Al Martinson, Phyllis Marsh and Hank Dawson) and the U.S. Park Service for their cooperation. Dr. William Platts, Dr. Robert White and John Mundinger reviewed the manuscript.

LITERATURE CITED

Binns, N.A. and F.E. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Trans. Amer. Fish. Soc. 108(3):215-228.

Burns, J.W. 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game. 57(1):44-57.

Capen, D.E., editor. 1981. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87, U.S. Forest Service Rocky Mtn. Range Exp. Stat., Fort Collins, CO.

Cardinal, P.J. 1980. Habitat and juvenile salmonid populations in streams in logged and unlogged areas of southeastern Alaska. M.S. Thesis Montana State University, Bozeman.

Cavallaro, J.I., J.W. Menke and W.A. Williams. 1981. Use of discriminant analysis and other statistical methods in analyzing microhabitat utilization of dusky footed wood rats. Pages 222-231 in D.E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87, U.S. Forest Service Rocky Mtn. Exp. Sta., Fort Collins, CO

Chamberlin, T.W. 1980a. Aquatic system inventory (biophysical stream surveys) ADP Technical Paper 1. British Columbia, Ministry of the Environment.

Chamberlin, T.W. 1980b. Aquatic survey terminology. ADP Technical Paper 2. British Columbia, Ministry of the Environment.

Flathead National Forest. 1977. Topographic adaption of the geologic map of Flathead County, Montana.

Fraley, J., D. Read and P. Graham. 1981. Flathead River Fishery Study. Mont. Dept. of Fish, Wildl, and Parks, Kalispell, MT

Graham, P.J. 1977. Juvenile steelhead trout densities in the Lochsa and Selway River drainages. M.S. Thesis, University of Idaho, Moscow.

Graham, P.J. 1980. Flathead River Basin environmental impact study - perspectives on the fisheries study. Mont. Dept. Fish, Wildl. and Parks.

Graham, P.J., D. Read, S. Leathe, J. Miller and K. Pratt. 1980. Flathead River Basin fishery study. Mont. Dept. Fish, Wildl. and Parks, Kalispell, MT.

Harshbarger, T.J. and H. Bhattacharyya. 1981. An application of factor analysis in an aquatic habitat study. Page 180-184 in D.E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87, U.S. Forest Service Rocky Mtn. Range Exp. Sta., Fort Collins, CO.

Horner, N.J. 1978. Survival, densities, and behavior of salmonid fry in streams in relation to fish predation. M.S. Thesis, University of Idaho, Moscow.

Hynes, H.B.N. 1972. The ecology of running waters. Univ. of Toronto Press.

Johns, W.M. 1970. Geology and mineral deposits of Lincoln and Flathead Counties, Montana. Mont. Bureau of Mines and Geology, Bulletin 36.

Lewis, S.L. 1967. Physical factors influencing fish populations in pools of a trout stream. M.S. Thesis. Mont. State Univ., Bozeman.

Lund, R.E. 1979. A users guide to MSUSTAT - an interactive statistical analysis package. Technical Report, The Statistical Center, Montana State University, Bozeman.

Martinson, A.H., D.A. Sirucek and W.J. Basko. 1982. Soil Survey of the Flathead National Forest and Stillwater, Coal Creek and Swan State Forest. National Coop. Soils Survey Report. U.S.D.A., Washington, D.C.

Nie, H.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner and D.H. Bent. 1975. SPSS - statistical package for the social sciences (2nd ed.) McGraw Hill, New York.

Platts, W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification. U.S.F.S. surface environment and mining program report, Washington, D.C.

Platts, W.S. 1979a. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries (4)2:5-9.

Platts, W.S. 1979b. Including the fishery system in land planning. U.S.D.A. Forest Service Tech. Rep. INI-60.

Sekulich, P.T. and T.J. Bjornn. 1981. The carrying capacity of streams for rearing salmonids as affected by components of the habitat. Ph.D. Dissertation. Idaho Cooperative Fisheries Research Unit., University of Idaho, Moscow.

Shepard, B.B., J.J. Fraley, T.M. Weaver and P.J. Graham. 1982. Flathead River Fishery Study: May, 1982. MT Dept. Fish, Wildlife and Parks, Kalispell, MT.

Snedecor, G.W. and W.G. Cochran. 1969. Statistical methods. Iowa State Univ. Press.