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THE SPAWNING AND REARING HABITATS OF RAINBOW TROUT AND BROWN TROUT IN TWO RIVERS IN MONTANA

by

Steven Kent Sando

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

of

MASTER OF SCIENCE

in

Fish and Wildlife Management

Approved:

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Chairperson, Graduate Committee

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Head, Major Department

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Graduate Dean

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VITA

Steven Kent Sando was born on 30 August, 1956 in Alexandria, Virginia to Mr. and Mrs. William Sando. He attended T. C. Williams High School in Alexandria, Virginia and was graduated in June 1974. In September 1974 he enrolled at Virginia Polytechnic Institute and State University at Blacksburg and received a Bachelor of Science degree in Fish and Wildlife Management in June 1978. In September 1978 he began work toward a Master of Science degree in Fish and Wildlife Management at Montana State University. On 29 June 1980 he married Nancilee Massie, the daughter of Mr. and Mrs. Walter Massie.

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Thanks are extended to my wife, Lee, for her love and encouragement. Appreciation is offered to my family for their moral support.

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ABSTRACT

The habitats of rainbow trout and brown trout redds and fry in the Beaverhead and Yellowstone rivers were studied from April-November, 1979 and March-May, 1980. The middle 90% of 67 rainbow trout redds on the Beaverhead River were found at depths of 23.0-43.0 cm, in current velocities of 0.40-0.83 m/sec and composed of substrates of at least 50% pebble and less than 1.6% silt. On the Yellowstone River, the middle 90% of nine rainbow trout redds were found at depths of 24.0-34.0 cm, in current velocities of 0.42-0.65 m/sec and composed of substrates of at least 50% pebble and less than 0.6% silt. The middle 90% of 77 brown trout redds on the Beaverhead River were found at depths of 18.0-46.0 cm, in current velocities of 0.35-0.95 m/sec and composed of substrates of at least 33% pebble and less than 3.0% silt. On the Yellowstone River, the middle 90% of 25 brown trout redds were found in depths of 17.0-34.0 cm, in current velocities of 0.28-0.63 m/sec and composed of substrates containing at least 60% pebble and less than 0.1% silt. A total of 102 fry of both species averaging 3.3 cm in length were found in the Beaverhead River at a mean depth of 14.9 cm, in an average current velocity of 0.05 m/sec over a substrate composition averaging about 80% fines and 20% gravel. A total of 31 rainbow trout and 114 brown trout fry averaging 6.8 and 7.7 cm in length respectively were found on the Beaverhead River in waters with a mean depth of 22.5 cm, an average current velocity of 0.12 m/sec over a substrate composition of about 70% fines and 30% gravel. Fry were always found within 1 m of cover and shifted from use of largely semi-aquatic vegetation to largely submerged organic debris as they increased in length.

INTRODUCTION

The withdrawal of water from streams in the western United States by agricultural, municipal and industrial interests has increased substantially in recent years and is continuing. Withdrawals reduce instream flows and decreases the water depth, cover, current velocity and the availability of suitable substrates (Giger 1973, Bayha 1974, Wesche 1976, White 1976) which result in a lowered carrying capcity for fish (Nelson 1978).

Conservation agencies are becoming increasingly concerned about providing sufficient instream flows to maintain quality habitat for fishery resources. The Montana Department of Fish, Wildlife and Parks is attempting to protect some fisheries habitat by legally establishing minimum instream flows. The department has obtained water rights on 12 streams and has also established flow reservations on the Yellowstone River drainage. It is preparing to file for flow reservations on streams in two more major drainages within 3 to 5 years.

The instream flow reservations obtained by the department on Montana streams are subject to challenge every 5 years. Retention of the reservations is dependent upon showing a biological need for them. As a result, studies are needed to establish the relationship between flows and fish populations. The purpose of this investigation was to measure selected characteristics of the spawning and rearing habitats of rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) in the Beaverhead and Yellowstone rivers so that these necessary habitats in streams can be protected by minimum instream flows. Field research for the investigation was conducted between April, 1978 and June, 1980.

DESCRIPTION OF STUDY AREAS

Beaverhead River

The Beaverhead River is located in Beaverhead County in southwestern Montana. The waters forming it arise in the Centennial and Tendoy mountains and flow into Clark Canyon Reservoir. The Beaverhead River is formed below Clark Canyon Reservoir and flows for about 100 km to join the Ruby and Big Hole rivers near Twin Bridges, Montana.

Flows in the Beaverhead River are controlled by releases from Clark Canyon Reservoir which is managed primarily for flood control and irrigation. The flows released into the river are relatively low from October through March when water is stored in the reservoir and are relatively high from April through September when water is released for irrigation (Nelson 1978).

The study section was located directly below the Clark Canyon Dam and extended from the U.S.G.S. gaging station at Grant, 0.4 km below the dam, to just below Pipeorgan Bridge about 12 km downstream (Figure 1). The elevation of the river at the gage station is about 1659 m above mean sea level. Gradients and other physical characteristics of the Beaverhead River measured near Grant and about 4 km downstream in the Hildreth Section are given in Table 1.

The chemical characteristics of the Beaverhead River at two sties within the study area are presented in Table 2. The measured parameters varied little between sampling stations. Flows recorded at

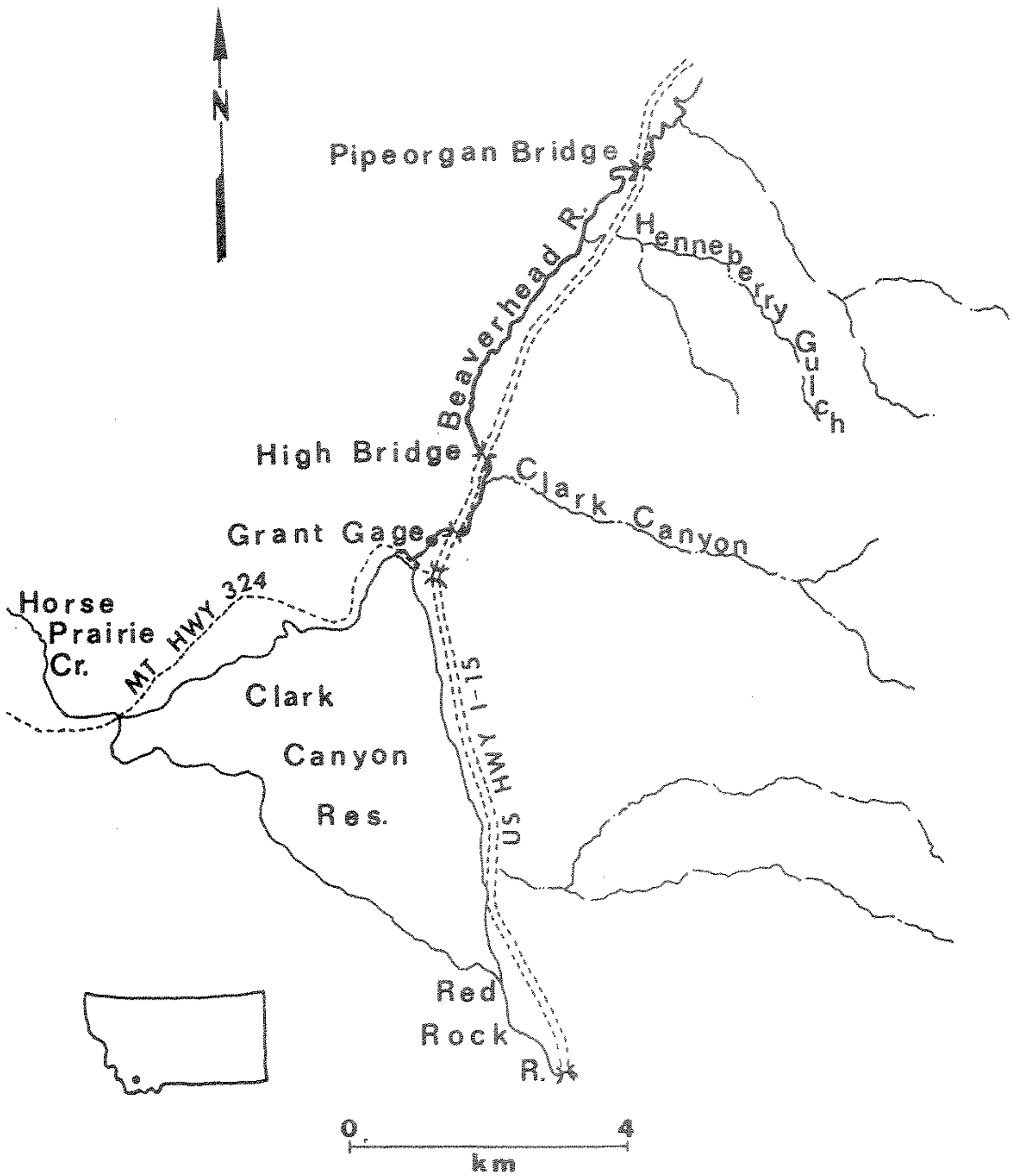


Figure 1. Map showing the location of the study area on the Beaverhead River.

Table 1. Selected characteristics of the channel of the Beaverhead River at two sections within the study area. Data from Nelson (1978).

Section	Sinuosity	Gradient (%)[1/]	Riprap (%)[2/]	Willow bank cover (%)[3/]
Grant	1.19	0.21	14.6	
Hildreth	1.32	0.33	1.2	67

1/ $\% = \frac{\text{Rise}}{\text{Run}} \times 100$

2/ $\% = \frac{\text{Total length of riprap on both banks}}{2 \times \text{section length}} \times 100$

3/ $\% = \frac{\text{Total length of willow cover on both banks}}{2 \times \text{section length}} \times 100$

Table 2. Selected chemical characteristics of the Beaverhead River at sites within the study area, measured in the summer of 1972. Data from Smith (1973).

Parameter	Distance (km) below Clark Canyon Dam	
	0.4	9.7
Turbidity (JTU)	4	4
Conductivity (μmhos @ 25° C)	565	572
pH	8.1	8.2
Dissolved oxygen (ppm)	9.6	9.7
Total alkalinity (ppm $CaCO_3$)	198	199
Total hardness (ppm $CaCO_3$)	220	230
Ammonia (ppm NH_3-N)	0.14	0.08
Nitrate (ppm NO_3^--N)	0.057	0.110
Nitrite (ppm NO_2^--N)	0.015	0.018
Orthophosphate (ppm PO_4^{-3}	0.11	0.10

the Grant gaging station for the study period are presented in Figure 2. These flows were slightly below the average discharge for the record period of 1962-1979 (U.S.G.S. 1979).

Water temperatures for 1972 taken near the Grant gaging station are presented in Figure 3. The reservoir, which was constructed in 1964, has caused reduced fluctuations in water temperatures in the upper reaches of the river and altered the natural temperature regime by inducing a general trend of lower water temperatures in the early spring and higher temperatures in the fall (Smith 1973).

Rainbow trout, brown trout, mountain whitefish (*Prosopium williamsoni*), burbot (*Lota lota*), white sucker (*Catostomus commersoni*), mottled sculpin (*Cottus bairdi*) and longnose dace (*Rhinichthys cataractae*) have been reported in the study area (Nelson 1978).

Yellowstone River

The Yellowstone River flows from its headwaters in Yellowstone National Park in northwestern Wyoming in a northeasterly direction through southeastern Montana for 1091 km to its confluence with the Missouri River near Cartwright, North Dakota. Approximately 70% of the annual flow of the river comes from mountain snowpack which causes high flows in the spring and low flows through fall and winter (Peterman 1979). The upper Yellowstone River from Gardiner to Big

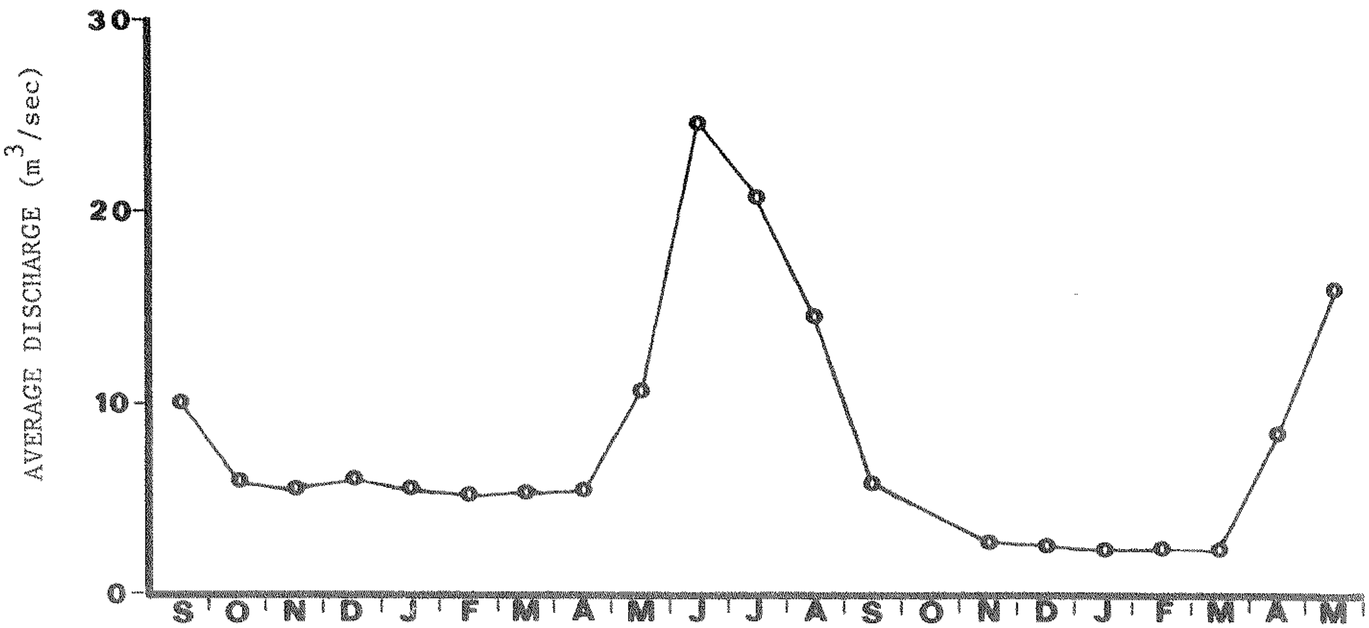


Figure 2. Average monthly discharge of the Beaverhead River at U.S.G.S. gage at Grant Station from September, 1978 through May, 1980 (U.S.G.S. 1979 and unpublished data).

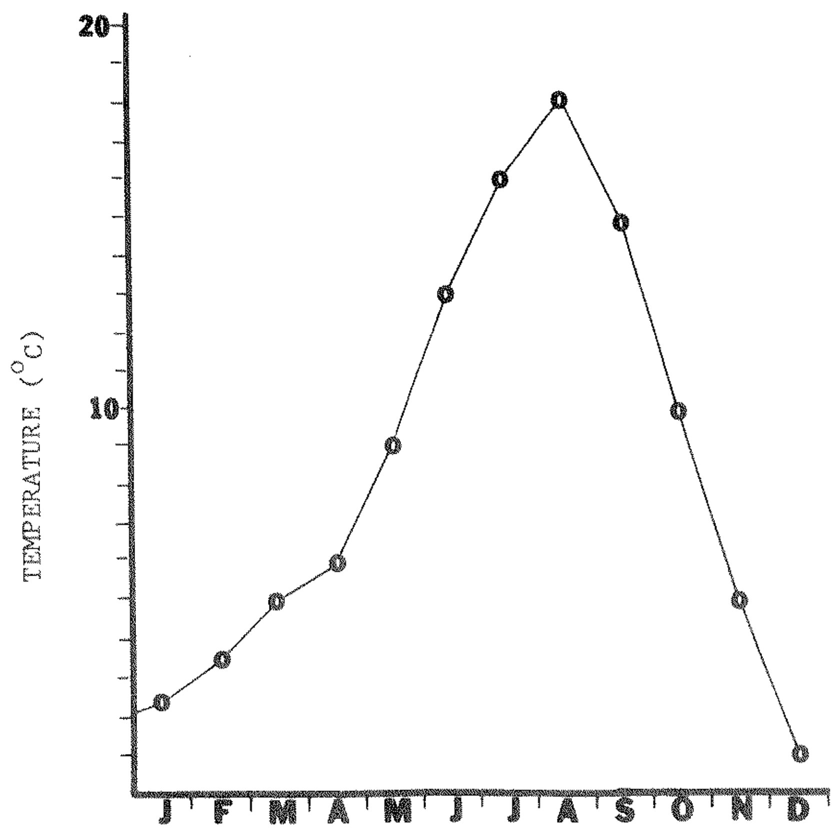


Figure 3. Average water temperatures of the Beaverhead River at U.S.G.S. gage at Grant Station for 1972. Data from Smith (1973).

Timber, Montana is classified as a Blue Ribbon trout stream by the Montana Department of Fish, Wildlife and Parks (Brown 1965).

The study area on the upper Yellowstone River was situated from just above the Pine Creek Bridge downstream to the Route 10 Bridge in Livingston, Montana (Figure 4). The elevation of the river at the U.S.G.S. gaging station, located approximately 6.4 km south of Livingston, is 1384 m above mean sea level. During the study period, flows (Figure 5) at this station were slightly below the average discharge for the 53 year period of record sited in U.S.G.S. (1979), whereas selected chemical and physical characteristics (Table 3) and temperatures (Figure 6) were within the normal range (U.S.G.S. 1979).

Eleven species of fish in five families have been reported from the upper Yellowstone River (Graham et al. 1979). Cutthroat trout (*Salmo clarki*), rainbow trout and brown trout are the main sport species. Mountain whitefish, longnose sucker (*Catostomus catostomus*) and mottled sculpin were also present.

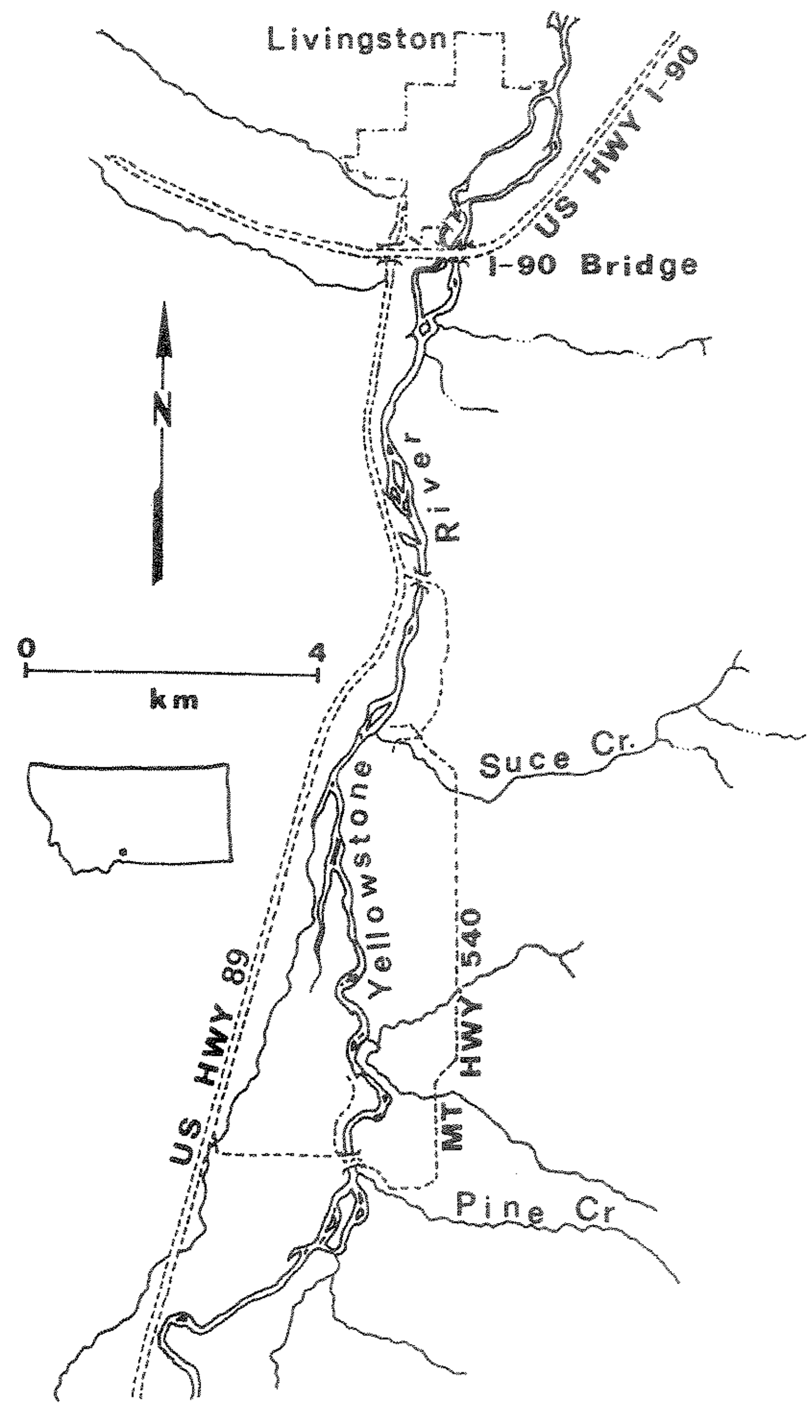


Figure 4. Map showing the location of the study area on the Yellowstone River.

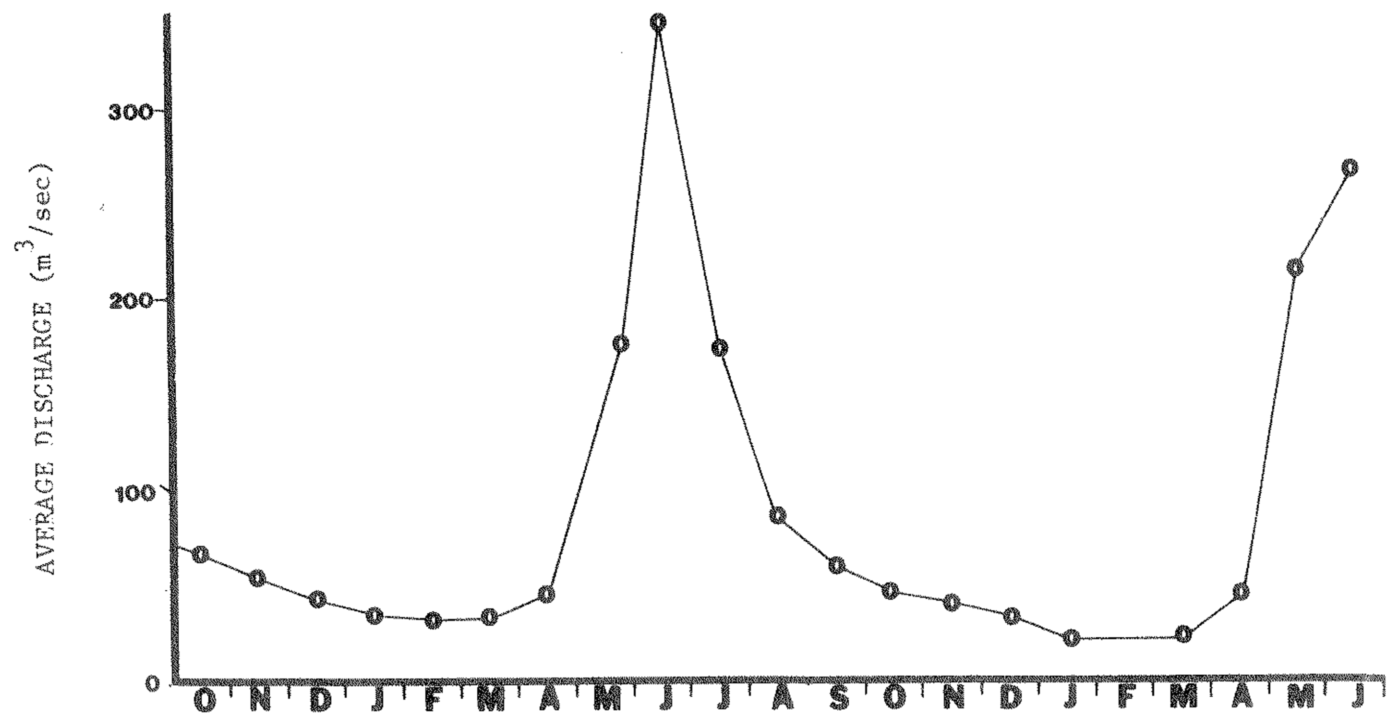


Figure 5. Average monthly discharge for the Yellowstone River at the U.S.G.S. gage 6.4 km south of Livingston, Montana from October, 1978 through June, 1980 (U.S.G.S 1979 and unpublished).

Table 3. Selected chemical-physical characteristics of the Yellowstone River at the U.S.G.S. gage 6.4 km south of Livingston, Montana from October, 1978 through June, 1980 (U.S.G.S. unpublished data).

Parameter	1978 O	N	D	1979 J	F	M	A	M	J	J
Turbidity (NTU)						4.3	3.3	4.9	6.7	10.0
Conductivity (μmhos)	268	278	289	331	335	334	299	254	108	103
pH	8.4	7.8	8.9	8.1	8.1	7.9	8.1	7.9	7.5	8.0
Dissolved oxygen (mg/l)						11.2	11.9	10.4	ND	8.8
Total alkalinity (mg/l $CaCO_3$)	80	82	82	91	95	94	85	69	31	28
Total hardness (mg/l $CaCO_3$)	79	85	42	110	110	110	97	80	64	52
Total nitrogen (mg/l $NO_2^- + NO_3^-$)	0.06	0.24	0.53	0.36	0.37	0.35	0.22	0.08	0.06	0.04
Total phosphorus (mg/l P)						0.04	0.02	0.02	0.05	0.07

Table 3. (cont.)

Parameter	A	S	O	N	D	1980 J	F	M	A	M	J
Turbidity (NTU)	2.0	1.4		1.1	1.7	0.60	1.0	3.2	2.3	14.0	8.2
Conductivity	190	231		285	322	357	371	293	301	157	132
pH	8.1	8.3		7.9	7.6	8.1	8.2	7.6	8.1	7.6	7.3
Dissolved oxygen (mg/l)	8.7	10.2		11.8	12.1	11.4	9.2		10.6	11.8	9.6
Total alkalinity (mg/l $CaCO_3$)	56	72		83	100	110	110	86	84	41	45
Total hardness (mg/l $CaCO_3$)	60	80		88	110	110	130	84	91	47	42
Total nitrogen (mg/l $NO_2^- + NO_3^-$)	0.02	0.02		1.3	0.34	0.45	0.40	0.37	0.09	0.12	0.06
Total phosphorus (mg/l P)	0.00	0.02		0.01	0.03	0.03	0.01	0.06	0.05	0.11	0.01

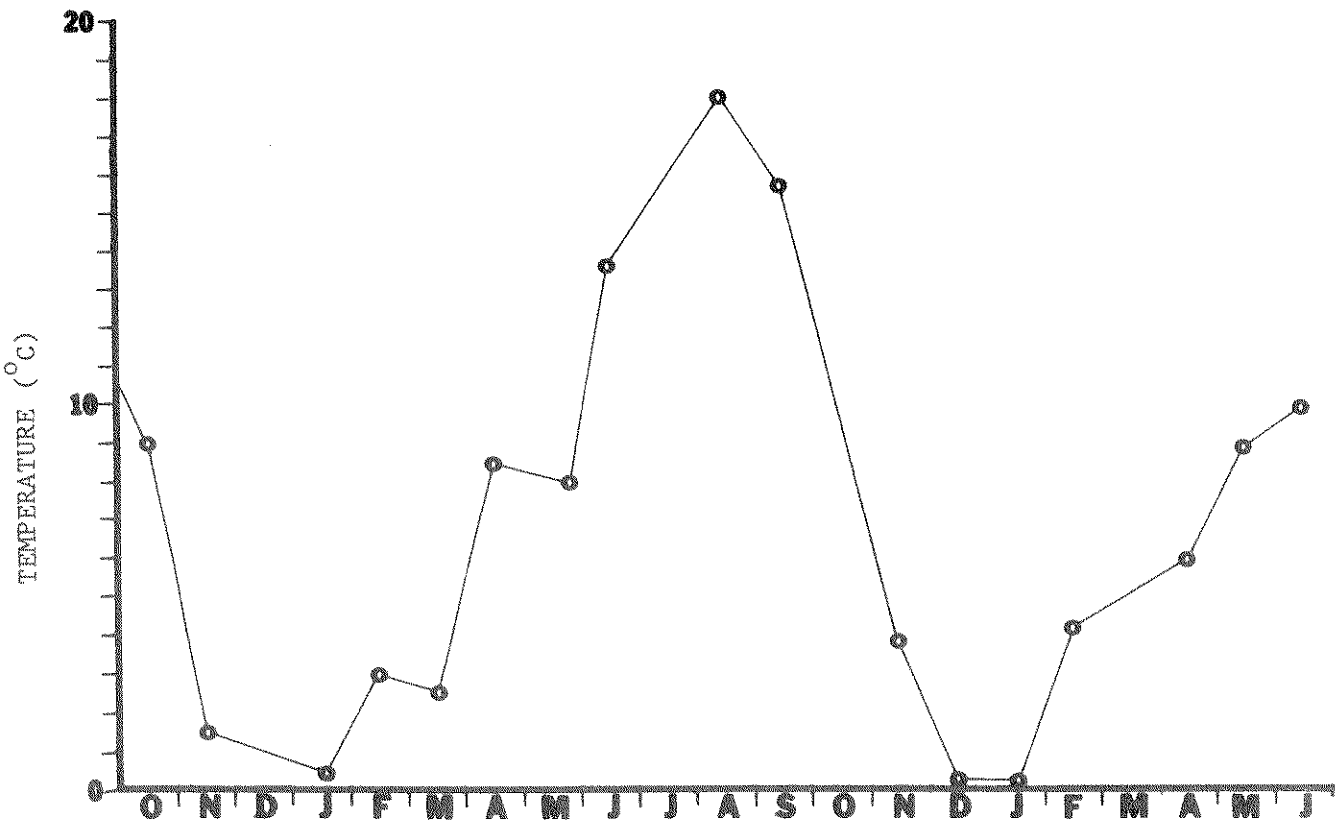


Figure 6. Water temperatures of the Yellowstone River at U.S.G.S. gage 6.4 km south of Livingston, Montana from October, 1978 through June, 1980 (U.S.G.S. 1979 and unpublished data).

METHODS

Study of Redds

Concentrations of trout redds were located by inspection. Ten to twenty redds in each concentration were selected for study and marked with a series of numbered rocks. The current velocity of the water directly in front of each redd was measured at 0.6 of the depth from the water's surface and at the level of the substrate. All current velocities were measured with a Gurley Model AA current meter.

The depth of the water directly in front of each redd was measured. The distances from each pit to the nearest point of land and the nearest significant holding cover were registered. The distance from the pit of each brown trout redd on the Beaverhead River to the nearest riffle also was recorded.

The substrates in selected redds were sampled to determine the size of materials used by spawning trout. Samples were taken from the front edge of the mound with a metal cylinder 15 cm in diameter driven to a depth of approximately 15 cm. Care was taken to retain the smaller particle sizes in the samples. Each sample was air dried and then sorted through a series of U.S. Standard sieves. Initially each sample was sorted through the 63.5, 31.5 and 16.0 mm sieves by hand shaking for about 30 sec. The materials in each of the three size groups in each sample were weighed to the nearest 0.1 gm. The particles of less than 16.0 mm in the sample were then sorted through 8.0, 4.0 and 2.0 mm sieves by a powered sieve shaker operated for approximately 2 min. Those particles retained by each of these sieves were weighed. The amounts of materials in size classes less than 2.0 mm in each sample were determined by (1) the hydrometer method (Black 1965) if there were 45 gm or more or (2) further sorting through the 1.0, 0.5, 0.25, 0.125 and 0.0625 mm sieves with the shaker operated for approximately 2 min if there were less than 45 gm. No analysis of materials that passed through the 2.0 mm sieve was made when they composed less than 0.1% of the total substrate sample by weight. The terminology for substrate classes (Table 4) was modified after the Wentworth classification that appeared in Welch (1948).

Table 4. Classification of substrate materials in redds as modified after the Wentworth classification in Welch (1948).

Substrate class	Particle size range (mm)
Cobble	64-256
Pebble	16-64
Gravel	2-16
Sand	0.0625-2
Silt	<0.0625

Habitat of Trout Fry

Rainbow trout and brown trout fry were collected with a Smith-Root Type VII Electrofisher and dipnet. The collection site of each captured fry was marked. The total length (to nearest mm) and, when practical, the species of each fish were determined. To avoid making multiple measurements on the same fry, each captured fish from an area was retained in a holding container until sampling in the area was completed, and no area was sampled more than once. The current velocity at each collection site was measured with a Gurley Pygmy current meter. The relative abundance of stream substrate classes within a radius of 1 m of each collection location were visually estimated using the classification given in Table 5. The surface area of aquatic vegetation, undercut bank, rock, semi-aquatic vegetation and submerged organic debris, which could serve as cover, within the 1 m radius was measured with a meter stick. The depth of the water at each capture site and the distance to the nearest bank also were measured.

Table 5. Classification of substrate materials used in the study of fry as modified after the Wentworth classification in Welch (1948).

Substrate class	Particle size range (mm)
Cobble	64-256
Gravel	2-64
Fines	<2

Statistical Analyses

Probability-of-use curves for the selected spawning and rearing habitat factors were derived using the Frequency Analysis technique described by Bovee and Cochnauer (1977). The Statistical Package for the Social Sciences (SPSS) was used for stepwise multiple regression analysis of the data on the habitat of fry and the analysis of variance on the data of the habitat of redds. The analyses were performed on the Sigma 7 computer at Montana State University.

RESULTS

Spawning Habitat

Fifteen redds of rainbow trout from one concentration of nests on the Beaverhead River were examined in April, 1979 (Appendix Table 14). The means and ranges of values of selected habitat factors associated with the redds are presented in Table 6. Ninety percent of the redds were in water 23.1-43.2 cm deep, with current velocities of 0.66-0.91 m/sec at their fronts and were situated in substrates of at least 30% pebble and 3.0% or less silt.

Table 6. Means and ranges for selected characteristics of 15 redds of rainbow trout on the Beaverhead River in 1979.

Parameter	Mean (Range)
Current velocity at front of redd at 0.6 of depth from Water's surface	0.75 (0.52-0.91)
Current velocity at front of redd near substrate	0.52 (0.36-0.62)
Depth at front of redd	32.3 (18.7-45.9)
Percent weight of cobble in substrate	19.3 (0.0-37.3)
Percent weight of pebble in substrate	55.5 (31.3-72.1)
Percent weight of gravel in substrate	19.5 (15.2-27.5)
Percent weight of sand in substrate	4.0 (0.5-9.2)
Percent weight of silt in substrate	1.6 (0.0-3.3)

In March and April, 1980 a total of 67 rainbow trout redds were examined. Of these, 58 were in three concentrations on the Beaverhead River (Appendix Table 15) and nine were in one concentration on the Yellowstone River (Appendix Table 16). The means and ranges for the measured characteristics of the redds on the Beaverhead River are presented in Table 7. Analysis of variance indicated that there were significant differences at the 90% level (F=2.48) between the concentrations in depth of water (F=38.4), distance to cover (F=15.4), distance to shore (F=38.5), percent pebble in the substrate (F=5.9), percent gravel in the substrate (F=15.9) and percent silt in the substrate (F=2.65). These differences indicate rainbow trout spawn in several fairly diverse areas on the Beaverhead River.

Ninety percent of the redds of rainbow trout on the Beaverhead River in 1980 were found at depths of 23.0-43.0 cm of water with velocities of 0.40-0.83 m/sec, in substrates composed of at least 50% pebble and less than 1.6% silt. The probability-of-use curves for rainbow trout spawning on the Beaverhead River in 1979 and 1980 are given in Figure 7. The optimum spawning habitat values calculated for rainbow trout were in water with 20.0-21.0 cm of depth, 0.73-0.74 m/sec of current velocity, with a substrate composed of 80% pebble and 20% gravel. Bovee (1978) reported optimum values of 18.3-24.4 cm of depth, 0.45-0.58 m/sec of current velocity and a substrate composed of 100% gravel. Although the current velocities measured in this study were

Table 7. Means and ranges of selected characteristics of 58 redds of rainbow trout on the Beaverhead River in 1980.

Parameter	Redd concentration number		
	1	2	3
Current velocity at front of redd at 0.6 of depth from water's surface (m/sec)	0.62 (0.40-0.91)	0.67 (0.36-1.21)	0.54 (0.22-0.77)
Current velocity at front of redd at substrate (m/sec)	0.39 (0.23-0.68)	0.49 (0.18-0.76)	0.43 (0.31-0.58)
Depth of front of redd (cm)	29.2 (19.0-42.0)	28.5 (4.4-53.0)	17.33 (10.0-27.0)
Percent of redds within 5 m of cover	9.9	85.0	13.0
Distance to shore (cm)	685.2 (200.0-1300.0)	677.5 (70-500)	430.8 (125.0-780.0)
Percent weight of cobble in substrate	4.32 (0.0-21.6)	3.52 (0.0-17.6)	6.6 (0.0-40.0)
Percent weight of pebble in substrate	63.4 (48.8-79.4)	45.6 (39.9-55.0)	69.0 (43.2-84.0)
Percent weight of gravel in substrate	26.6 (18.3-36.8)	44.5 (34.2-54.4)	22.1 (4.3-32.2)
Percent weight of sand in substrate	4.5 (1.1-11.9)	4.9 (1.9-10.2)	1.95 (0.4-6.6)
Percent weight of silt in substrate	1.2 (0.0-2.9)	1.4 (0.6-3.0)	0.47 (0.0-1.4)

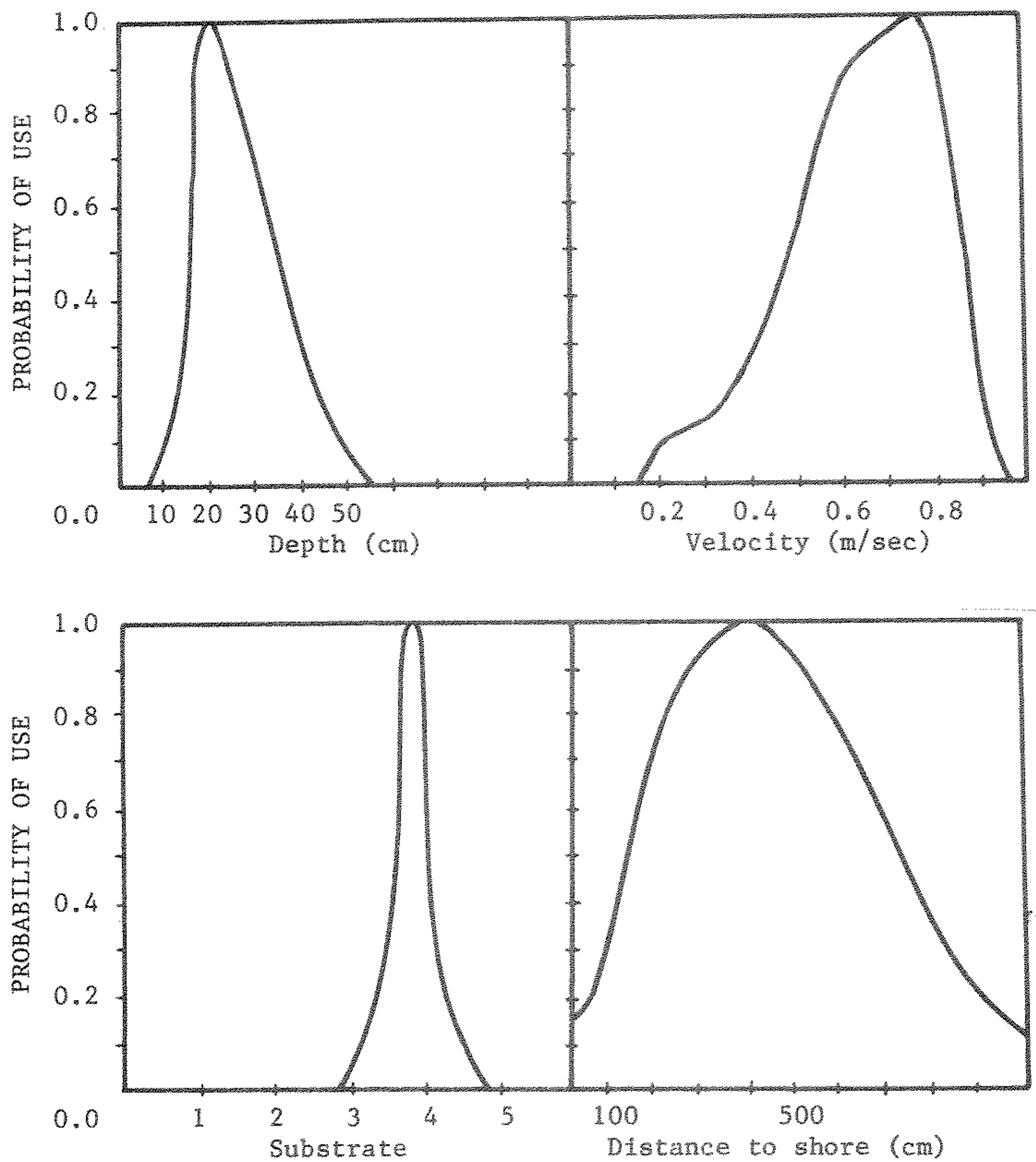


Figure 7. Probability-of-use curves for selected characteristics of rainbow trout redds on the Beaverhead River during 1979 and 1980. Substrate code: 1=silt, 2=sand, 3=gravel, 4=pebble and 5=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

greater than he reported, the optimum values for depth and substrate were roughly comparable.

The means and ranges for measurements made on the nine rainbow trout redds on the Yellowstone River are given in Table 8. Ninety percent of the redds were found at depths of 24.0-34.0 cm, in current velocities of 0.42-0.65 m/sec and composed of substrates of at least 50% pebble and less than 0.6% silt. Probability-of-use curves for the habitat factors associated with these redds are presented in Figure 8. The optimum spawning habitat values for rainbow trout on the Yellowstone River were 22.0-26.0 cm of water depth, 0.48-0.51 m/sec of current velocity, with a substrate composed of 80% pebble and 20% gravel. The results of this study generally agree with those of Bovee (1978) who reported optima of 18.3-24.4 cm of depth, 0.45-0.58 m/sec of current velocity and a substrate composed of 100% gravel.

A total of 102 brown trout redds were examined in October and November, 1979. Of these, 77 were in four concentrations on the Beaverhead River (Appendix Table 17) and 25 were in two concentrations on the Yellowstone River (Appendix Table 18). The means and ranges for the measured characteristics of the redds on the Beaverhead River are given in Table 9. An analysis of variance indicated there were significant differences at the 90% level ($F=2.37$) among the concentrations in current velocity at 0.6 of the depth from the water's surface ($F=3.51$), current velocity at the substrate ($F=3.52$), depth ($F=6.24$),

Table 8. Means and ranges of selected characteristics of nine redds of rainbow trout on the Yellowstone River in 1980.

Parameter	Mean (Range)
Current velocity at front of redd at 0.6 of depth from water's surface (m/sec)	0.52 (0.41-0.65)
Current velocity at front of redd at substrate (m/sec)	0.35 (0.22-0.54)
Depth at front of redd (cm)	28.6 (22.0-34.0)
Percent of redds within 5 m of cover	0.0
Distance to shore (cm)	894 (100-1450)
Percent weight of cobble in substrate	15.3 (0.0-32.9)
Percent weight of pebble in substrate	62.6 (45.7-78.7)
Percent weight of gravel in substrate	19.3 (14.7-23.8)
Percent weight of sand in substrate	2.4 (1.3-3.5)
Percent weight of silt in substrate	0.5 (0.0-0.8)

percent of redds within 5 m of cover (F=7.93), distance of redds to cover (F=2.62), distance of redds to shore (F=22.9) and percent sand in the substrate (F=2.52). These differences showed brown trout spawned in several types of areas with different combinations of characteristics on the Beaverhead River.

Eighty-seven percent of the 77 redds of brown trout on the Beaverhead River were located within riffles. Those redds not located in a riffle were within an average of 4.2 m (range of 0.6-7.2 m) of a

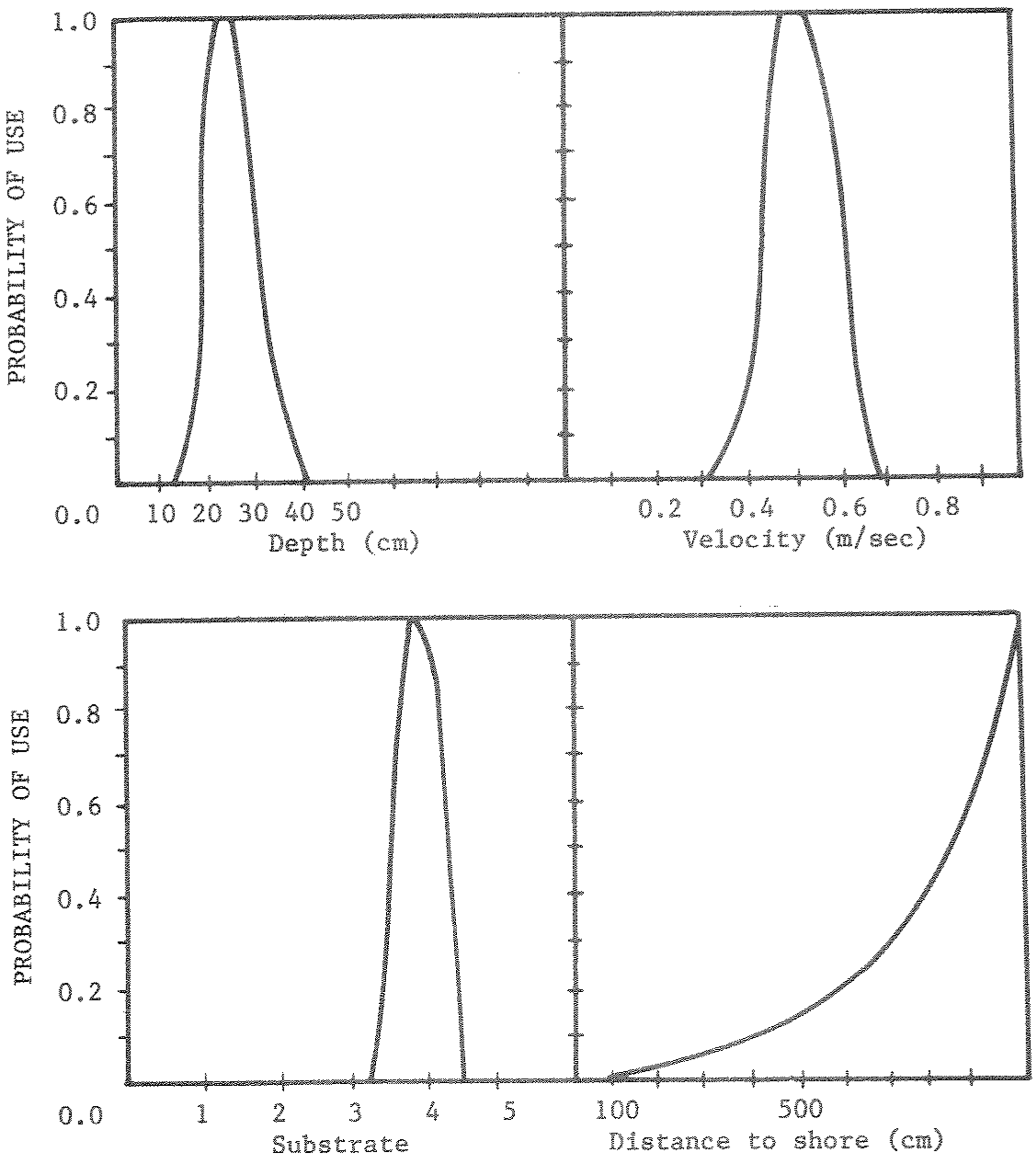


Figure 8. Probability-of-use curves for selected characteristcs of nine rainbow trout redds on the Yellowstone River during 1980. Substrate code: 1=silt, 2=sand, 3=gravel, 4=pebble and 5=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

Table 9. Means and ranges for selected characteristics of 77 redds of brown trout on the Beaverhead River in 1979.

Parameter	Redd concentration number			
	1	2	3	4
Current velocity at front of redd at 0.6 of depth from water's surface (m/sec)	0.63 (0.30-0.95)	0.78 (0.34-1.17)	0.79 (0.35-0.95)	0.70 (0.45-0.93)
Current velocity at front of redd at substrate (m/sec)	0.44 (0.23-0.64)	0.53 (0.25-0.78)	0.54 (0.26-0.64)	0.48 (0.32-0.63)
Depth at front of redd (cm)	38.3 (18.0-59.0)	35.0 (15.0-50.0)	29.3 (15.0-40.0)	26.8 (18.0-35.0)
Percent of redds within 5 m of cover	94.7	100.0	72.2	50.0
Distance to shore (cm)	213 (77-405)	213 (62-400)	887(0-2118)	778 (245-1310)
Percent weight of cobble in substrate	0.0	0.2 (0.0-0.8)	6.7 (0.0-22.7)	4.9 (0.0-29.6)
Percent weight of pebble in substrate	80.9 (62.7-91.8)	49.3 (7.1-78.7)	64.1 (55.6-80.8)	62.3 (40.7-87.8)
Percent weight of gravel in substrate	18.1 (7.2-36.4)	42.7 (18.9-76.0)	26.2 (18.8-33.9)	25.9 (10.5-34.7)
Percent weight of sand in substrate	0.8 (0.2-2.0)	6.7 (1.5-15.0)	2.3 (0.2-3.7)	5.2 (1.3-10.3)
Percent weight of silt in substrate	0.1 (0.0-0.6)	0.9 (0.0-2.6)	0.6 (0.0-1.1)	1.5 (0.0-3.5)

riffle. Spence (1975) found 81% of the redds of brown trout in a 1 mile section of the Blackfoot River, Montana were in riffles or the tails of pools. What Spence (1975) called "tails of pools" were considered to be riffles in the present study.

Brown trout redds on the Beaverhead River were closely associated with escape cover. All of the concentrations had 50% or more of their redds within 5 m of escape cover. Spence (1975) found that brown trout redds on the Blackfoot River, Montana were usually closely associated with escape cover, and that areas which appeared to be suitable for spawning but without nearby escape cover were not utilized.

Probability-of-use curves were developed for selected characteristics of redds of brown trout from the Beaverhead River (Figure 9). Ninety percent of the redds were found in depths of 18.0-46.0 cm with current velocities of 0.35-0.95 m/sec with substrates containing at least 33% pebble and less than 3% silt. The optimum spawning habitat values calculated for brown trout were 27.0-29.0 cm in depth, 0.70-0.73 m/sec of current velocity and a substrate composition of 60% pebble and 40% gravel. Bovee (1978) reported the optimum spawning values for brown trout were 15.2-21.3 cm in depth, 0.48-0.61 m/sec in current velocity and substrates with a composition of 100% gravel. The values obtained in this study tended to show higher optima for both depth and current velocity as well as larger substrate materials

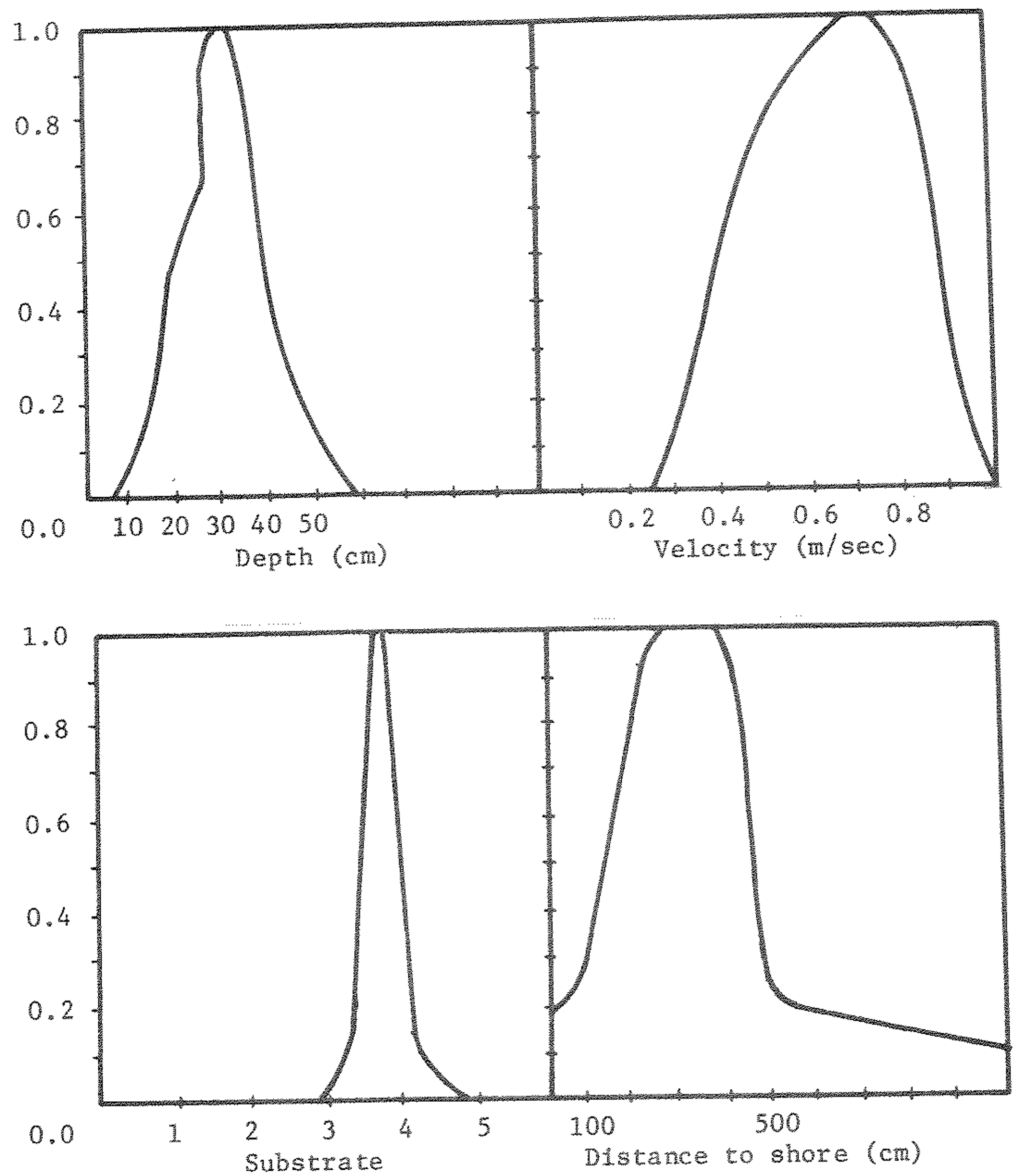


Figure 9. Probability-of-use curves for selected characteristics of 77 brown trout redds on the Beaverhead River during 1979. Substrate code: 1=silt, 2=sand, 3=gravel, 4=pebble and 5=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

than those Bovee (1978) reported. However, there was considerable overlap in the figures obtained in the two studies.

The means and ranges for measurements made on the redds in the Yellowstone River are given by concentration of redds in Table 10. An analysis of variance showed no statistically significant differences between the averages of the parameters for the redds of the two concentrations. Ninety percent of the redds were found in water 17.0-34.0 cm deep with current velocities of 0.28-0.63 m/sec in substrates composed of at least 60% pebble and less than 0.1% silt.

The values of depth, current velocity and distance to shore obtained in this study for brown trout redds on the Yellowstone River tended to be less than the comparable values obtained by Berg (unpublished data) and Workman (unpublished data) (Table 11). The differences may have resulted from examining redds located in smaller side channels in this study, whereas they studied redds in the main and larger side channels. However, the results of this study showed the highest percentage of substrate particles in the redds to be in the 16-32 mm size range which roughly compares with Workman's (unpublished data) report that most redds were in substrates composed largely of particles in the 12.7-25.4 mm size range. Also, the results of this study on the Yellowstone River showed no association of brown trout redds with cover. This was similar to Berg's (unpublished data) results on two spawning areas in the Yellowstone River downstream from

Table 10. Means and ranges for selected characteristics of 25 redds of brown trout on the Yellowstone River in 1979.

Parameter	Redd concentration number	
	1	2
Current velocity at front of redd at 0.6 of depth from water's surface (m/sec)	0.41 (0.28-0.51)	0.45 (0.18-0.74)
Current velocity at front of redd at substrate (m/sec)	0.30 (0.22-0.36)	0.32 (0.15-0.51)
Depth at front of redd (cm)	21.8 (17.0-26.0)	24.7 (10.0-37.0)
Percent of redds within 5 m of cover	0.0	0.0
Percent weight of cobble in substrate	7.1 (0.0-35.3)	13.8 (0.0-25.8)
Percent weight of pebble in substrate	86.9 (63.2-95.0)	76.1 (60.7-90.2)
Percent weight of gravel in substrate	5.9 (1.6-8.6)	9.8 (1.3-16.9)
Percent weight of sand in substrate	0.1 (0.0-0.3)	0.3 (0.0-0.7)
Percent weight of silt in substrate	0.0	0.0

Table 11. Means and ranges for selected redd characteristics for brown trout on the Yellowstone River in 1974. Data from Berg (unpublished data) and Workman (unpublished data).

Location	# of redds	Mean (range) Depth (cm)	Current velocity (m/sec)	Dist. to shore (cm)
33.8 km downstream from Livingston	75	30.8 (15.2-82.3)	0.54 (0.23-0.93)	568.4 (152.4-1524.0)
29.0 km downstream from Livingston	12	28.3 (18.3-51.8)	0.52 (0.40-0.66)	441.5 (61.0-914.4)
24.1 km downstream from Livingston	7	50.0 (21.3-88.4)	0.54 (0.34-0.71)	234.9 (61.0-396.2)
Town of Livingston*	97	57.6 (12.2-131.1)	0.59 (0.10-1.23)	
17.8 km upstream from Livingston	8	60.4 (39.6-67.1)	0.76 (0.60-0.94)	1016.3 (335.3-1249.7)
45.2 km upstream from Livingston	47	34.7 (18.3-76.2)	0.54 (0.37-0.99)	737.9 (182.9-1493.5)
59.6 km upstream* from Livingston	28	39.0 (18.3-73.2)	0.49 (0.20-0.85)	

* From Workman (unpublished data).

Livingston. However, Workman (unpublished data) did note a close association of the brown trout redds with willow cover and undercut bank. Apparently brown trout will use a variety of spawning habitats.

Probability-of-use curves for important brown trout spawning habitat factors were developed for the upper Yellowstone River using the data of this study as well as those from Workman (unpublished data) and Berg (unpublished data). These curves are presented in Figure 10. The optimum spawning habitat values calculated for brown trout on the Yellowstone River were 23.0-24.0 cm in depth, 0.46-0.51 m/sec in current velocity, in substrates with a composition of 90% pebble and 10% gravel. These results are comparable to those of Bovee (1978) which gave optimum values of 15.2-21.3 cm in depth, 0.48-0.61 m/sec in current velocity and substrates with a composition of 100% gravel.

Habitat of Fry

A total of 145 fry were captured on the Beaverhead River from July 9-August 29, 1979. Of these, 31 were rainbow trout (Appendix Table 19) and 114 were brown trout (Appendix Table 20). Specimens ranged from 4.2-11.1 cm in total length.

Probability-of-use curves for the habitat variables measured at capture points of rainbow trout fry are presented in Figure 11. Ninety percent of the rainbow trout were taken in water depths of

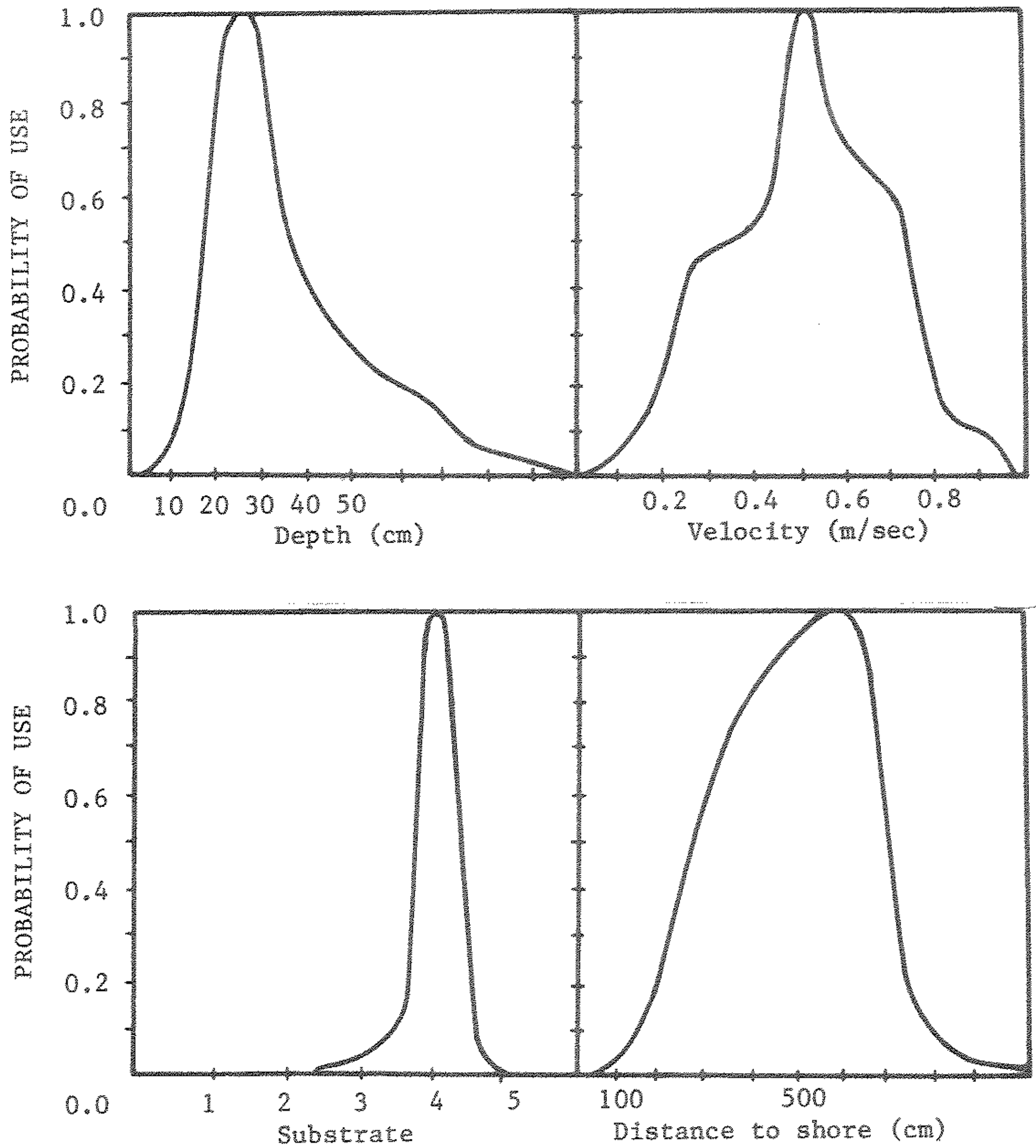


Figure 10. Probability-of-use curves for selected characteristics of brown trout redds on the Yellowstone River during 1974 and 1979. Substrate code: 1=silt, 2=sand, 3=gravel, 4=pebble and 5=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

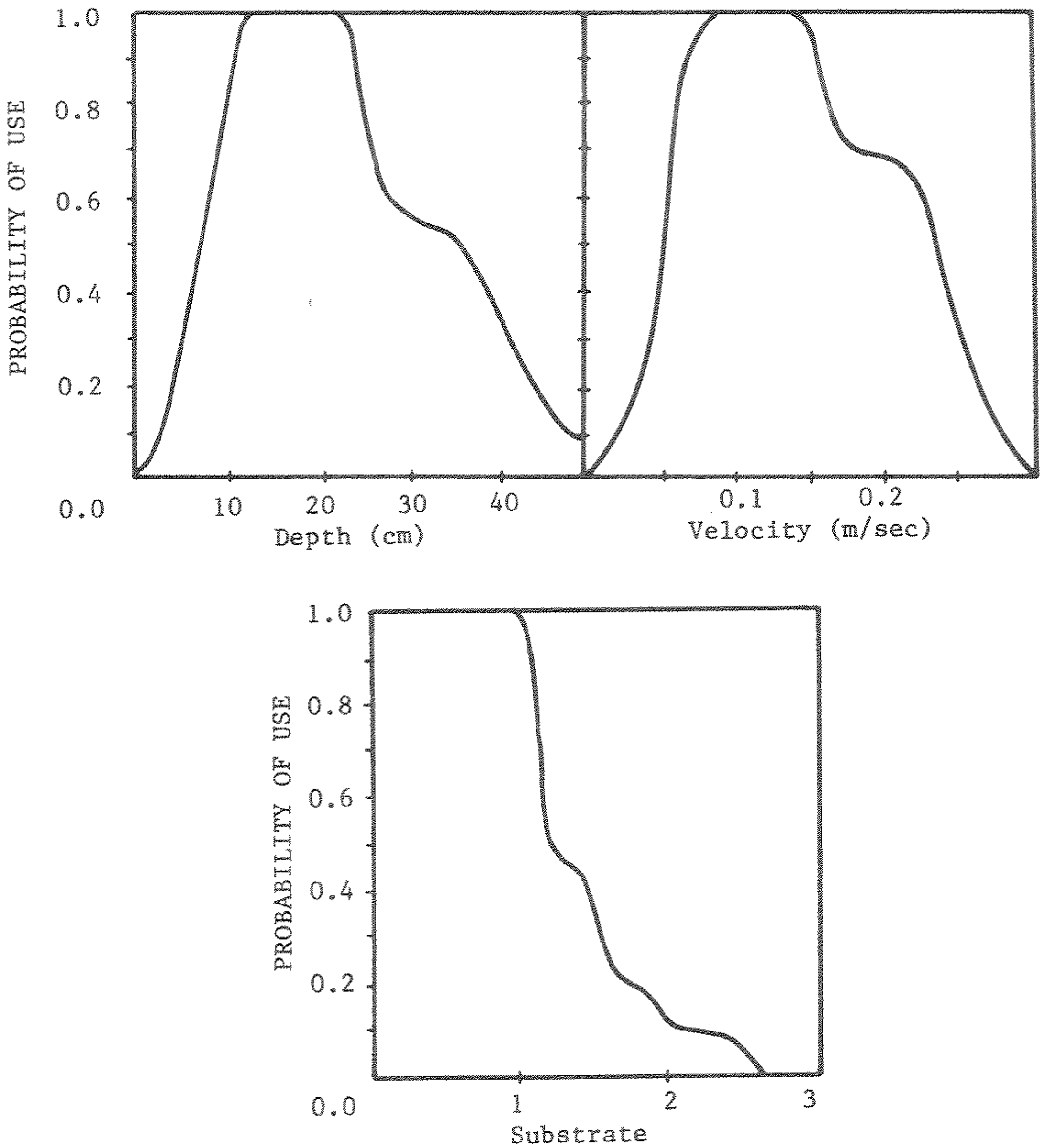
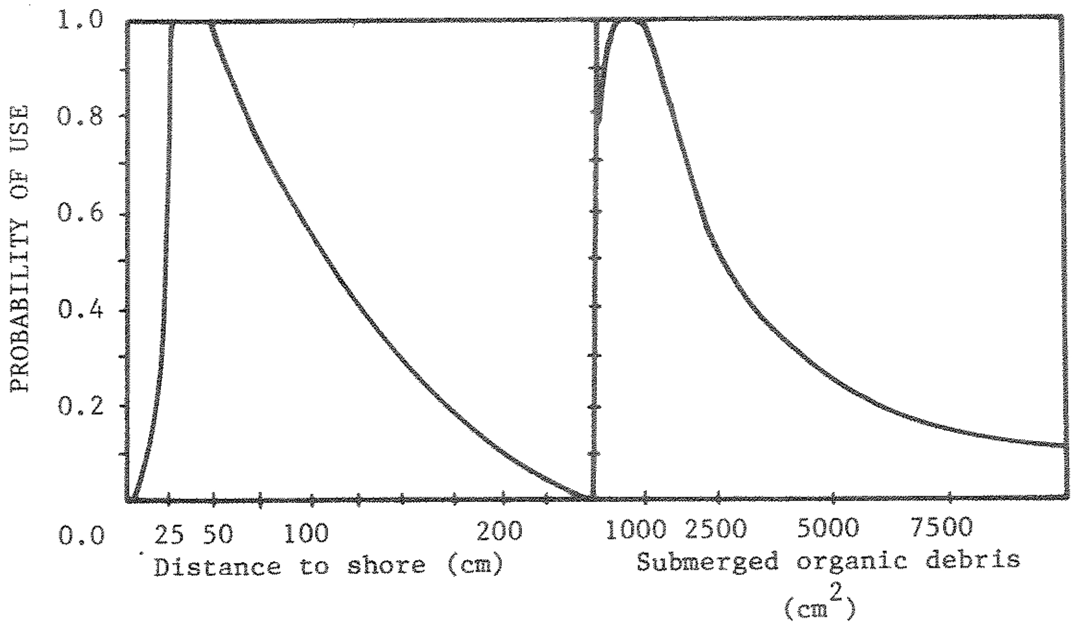


Figure 11. Probability-of-use curves for 31 rainbow trout 4.2-10.3 cm in total length taken from the Beaverhead River during 1979. Substrate code: 1=fines, 2=gravel and 3=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).



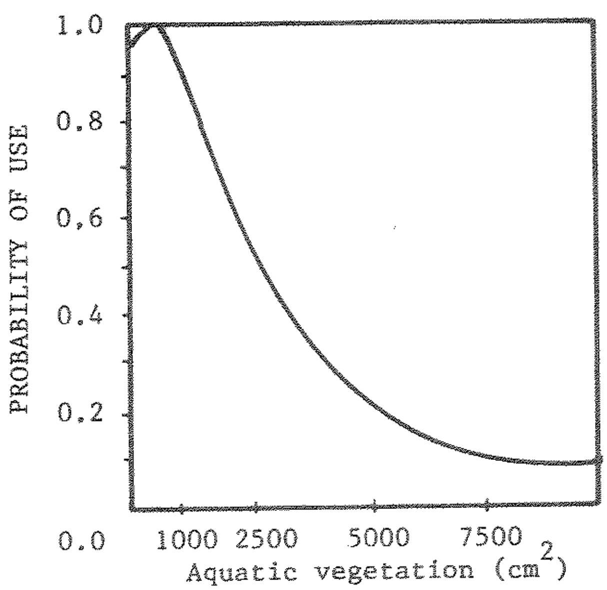


Figure 11. (cont.)

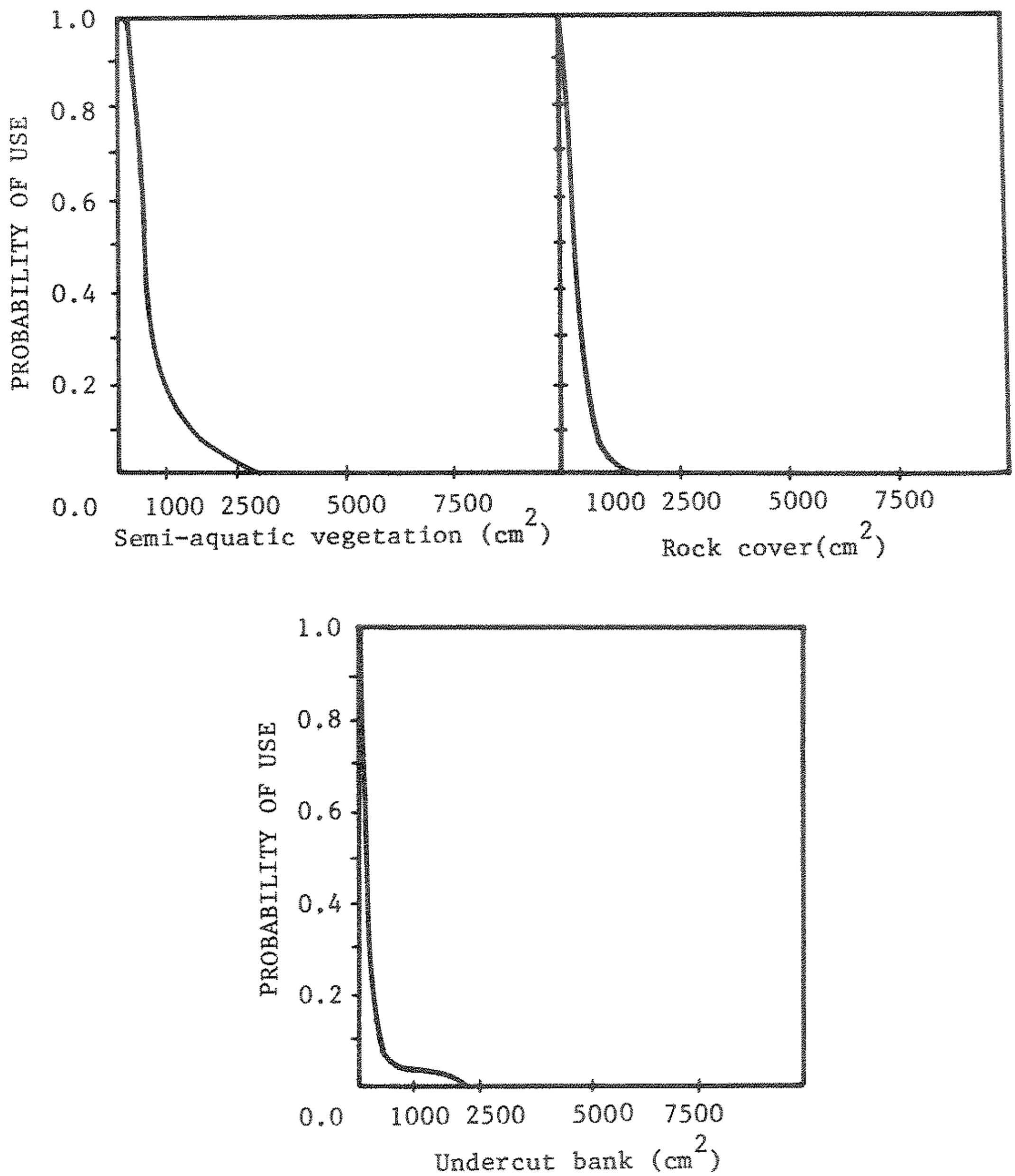
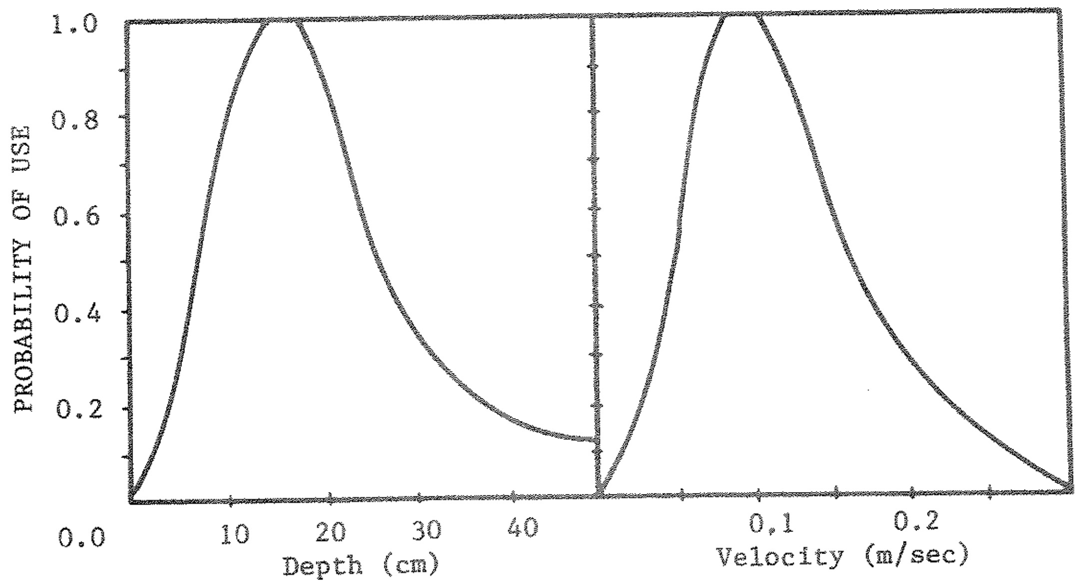


Figure 11. (cont.)

9.0-37.0 cm with current velocities of 0.01-0.17 m/sec over substrates composed of at least 30% of particles 2 mm in diameter or less. The optimum habitat values were 12.0-20.0 cm in depth, 0.09-0.14 m/sec of current velocity and the substrate composed of 100% fines. Bovee (1978) reported greater optimum values for rainbow trout fry of 18.0-27.0 cm in depth, current velocity of 0.12-0.18 m/sec and substrate composed of 100% gravel, but he may have worked with larger fish.

Probability-of-use curves for the habitat variables measured at capture points of brown trout fry are presented in Figure 12. Ninety percent of the specimens were taken at depths of 7.0-31.0 cm and current velocities of 0.03-0.19 m/sec over substrates having at least 60% of their particles 6.4 cm in diameter or smaller. The optimum habitat values calculated for brown trout fry were 14.5-17.5 cm in depth, 0.08-0.11 m/sec of current velocity and a substrate composition of 85% or more fines. Bovee (1978) reported the optimum values for brown trout fry were 24.4-58.6 cm in depth, 0.00-0.37 m/sec in current velocities and substrates with a composition of at least 30% gravel and the remainder sand. However, these larger values Bovee (1978) reported were obtained with "fairly large young-of-the-year brown trout" which were probably larger than the fish examined in this study.

A regression analysis was utilized to complete a discriminant analysis for determining the differences in levels of the measured variables associated with rainbow trout and brown trout fry (Appendix



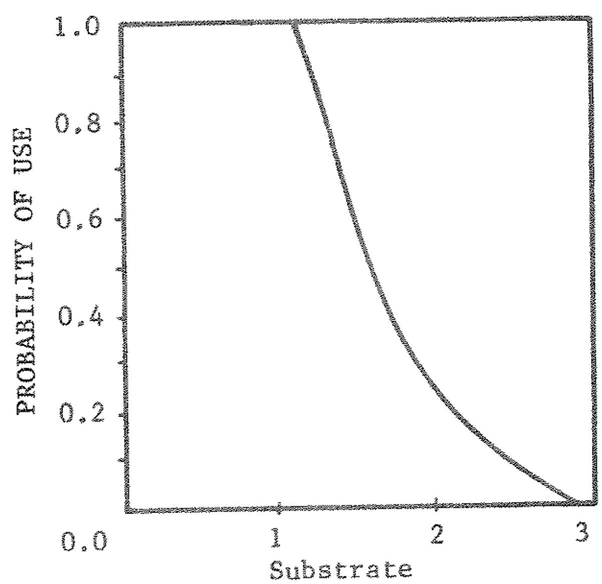


Figure 12. Probability-of-use curves for 114 brown trout 4.2-11.1 cm in total length taken from the Beaverhead River during 1979. Substrate code: 1=fines, 2=gravel and 3=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

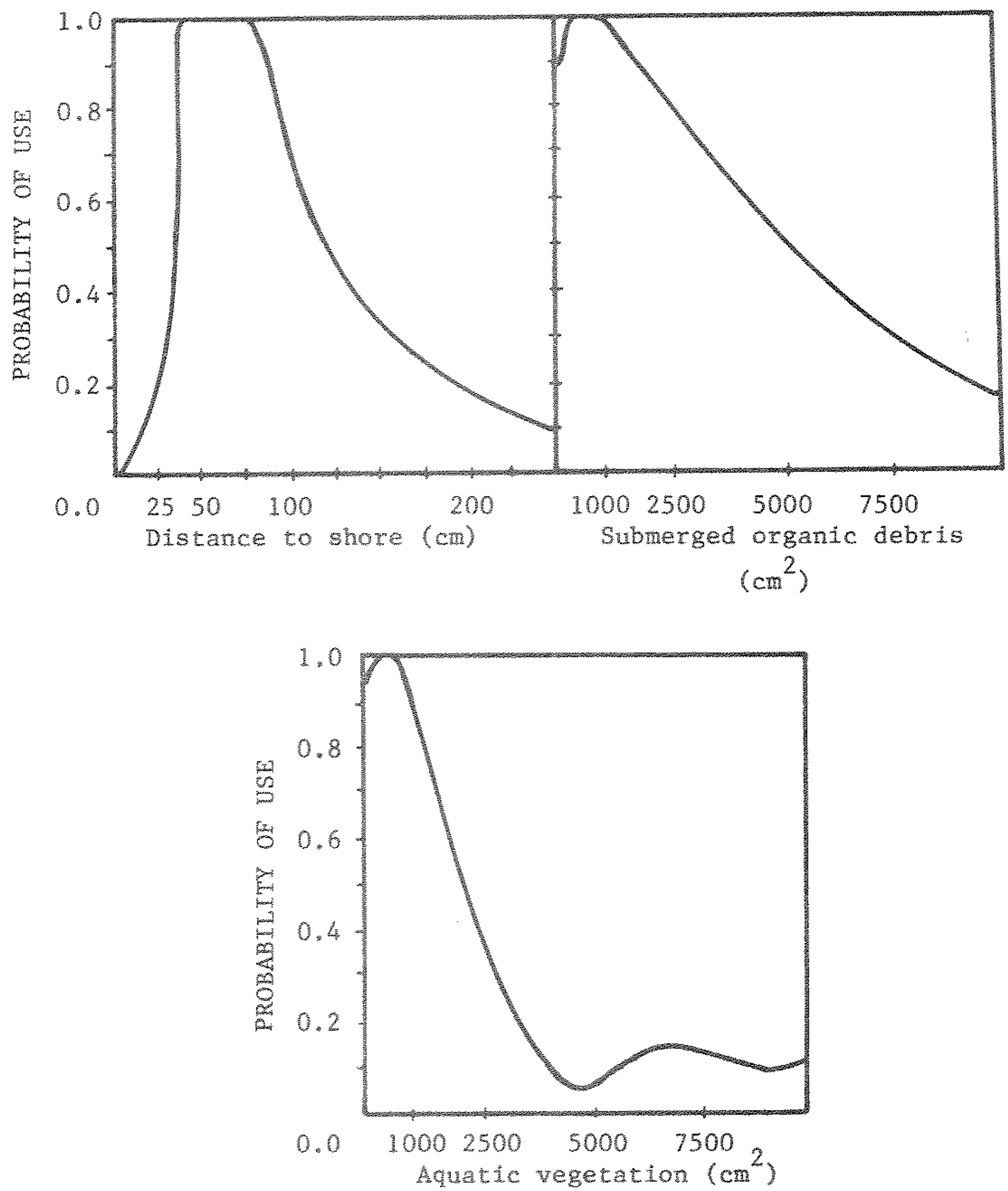


Figure 12. (cont.)

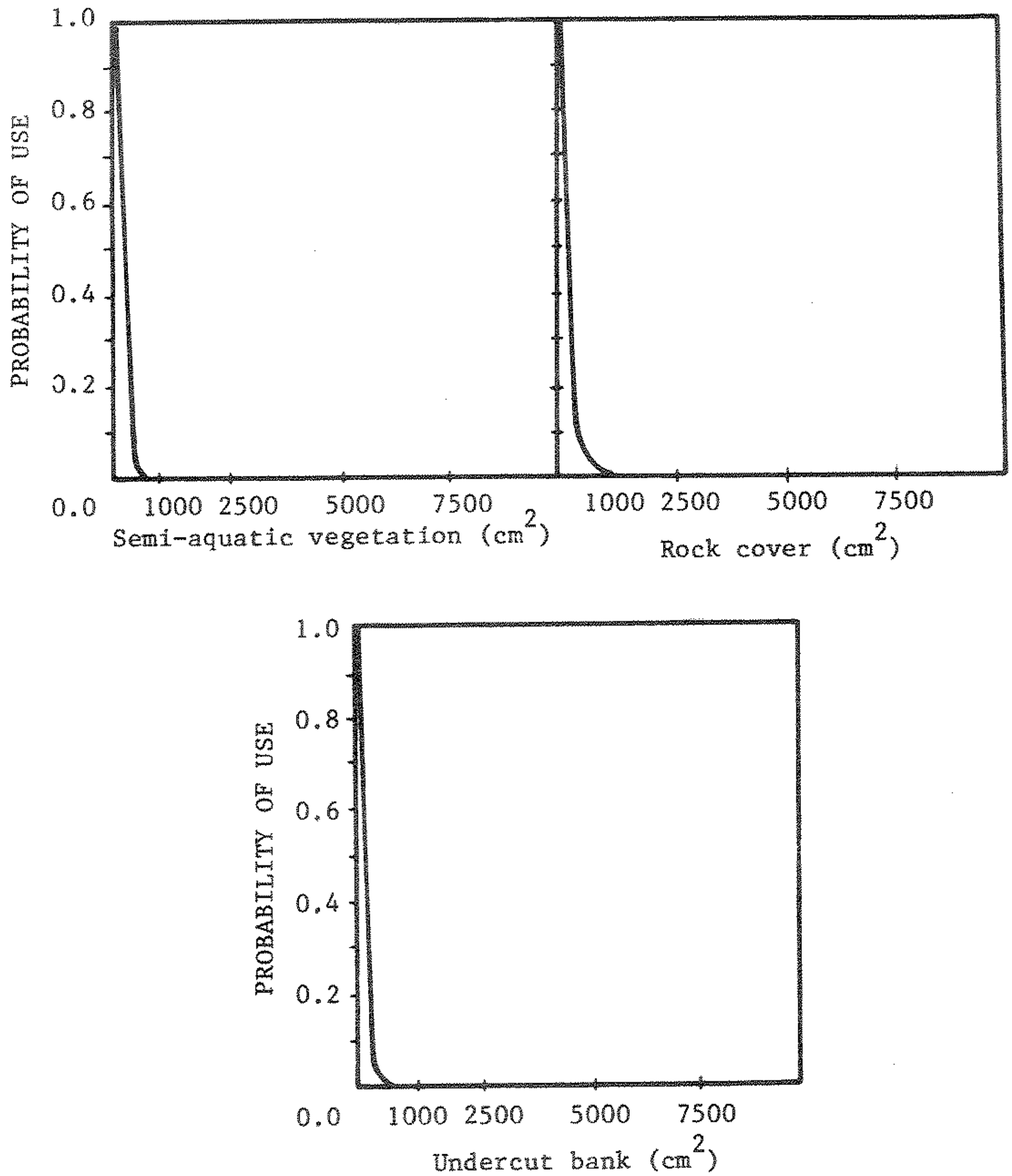


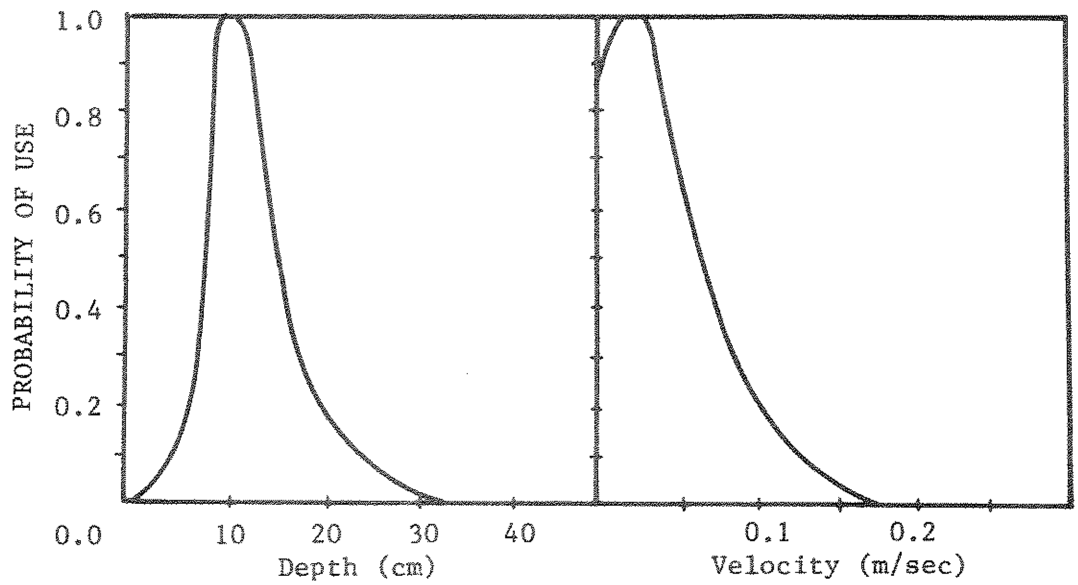
Figure 12. (cont.)

Table 21). The result of the analysis showed that rainbow trout fry were smaller than brown trout fry, utilized deeper water and were found closer to shore than brown trout fry.

A series of regressions were used in the form of another discriminant analysis on data obtained in 1979 to test for statistical differences in the habitats utilized by the rainbow trout and brown trout fry as their length increased (Appendix Table 22). The analysis showed that rainbow trout apparently tended to select deeper and faster water as they grew, while brown trout fry focused more on the presence of certain cover types, especially submerged organic debris. These tendencies also have been noted in the adults of the two species (Lewis 1969).

A total of 102 fry were captured on the Beaverhead River from April 24-May 5, 1980 (Appendix Table 23). The small size of the fish made field identification impractical, although most of the fry were believed to be brown trout.

Probability-of-use curves for the habitat variables measured at capture points of the fry are presented in Figure 13. The middle ninety percent of the specimens were taken at depths of 6.0-27.0 cm and in current velocities of 0.00-0.09 m/sec over substrates having at least 60% of their particles 2 mm in diameter or smaller. The optimum habitat values calculated for these fry were 10.0 cm in depth, 0.00-0.02 m/sec of current velocity and a substrate composition of



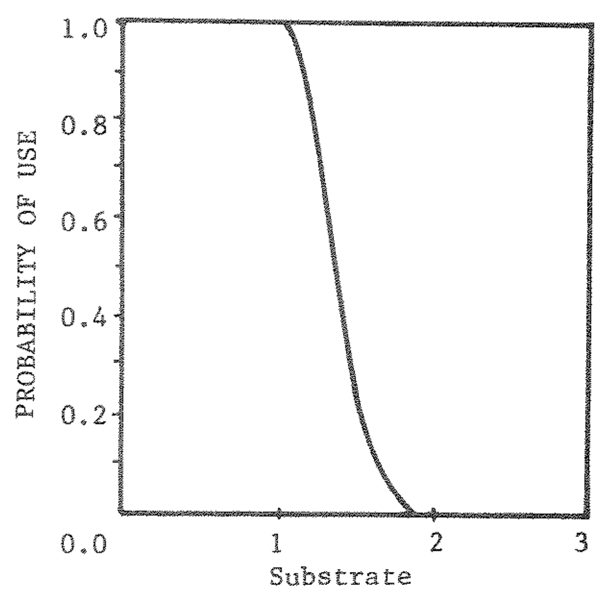


Figure 13. Probability-of-use curves for 102 brown trout and rainbow trout 2.5-4.7 cm in total length taken from the Beaverhead River during 1980. Substrate code: 1=fines, 2=gravel and 3=cobble. Gradations between code numbers refer to rough proportions between one substrate type and another (Bovee and Cochnauer 1977).

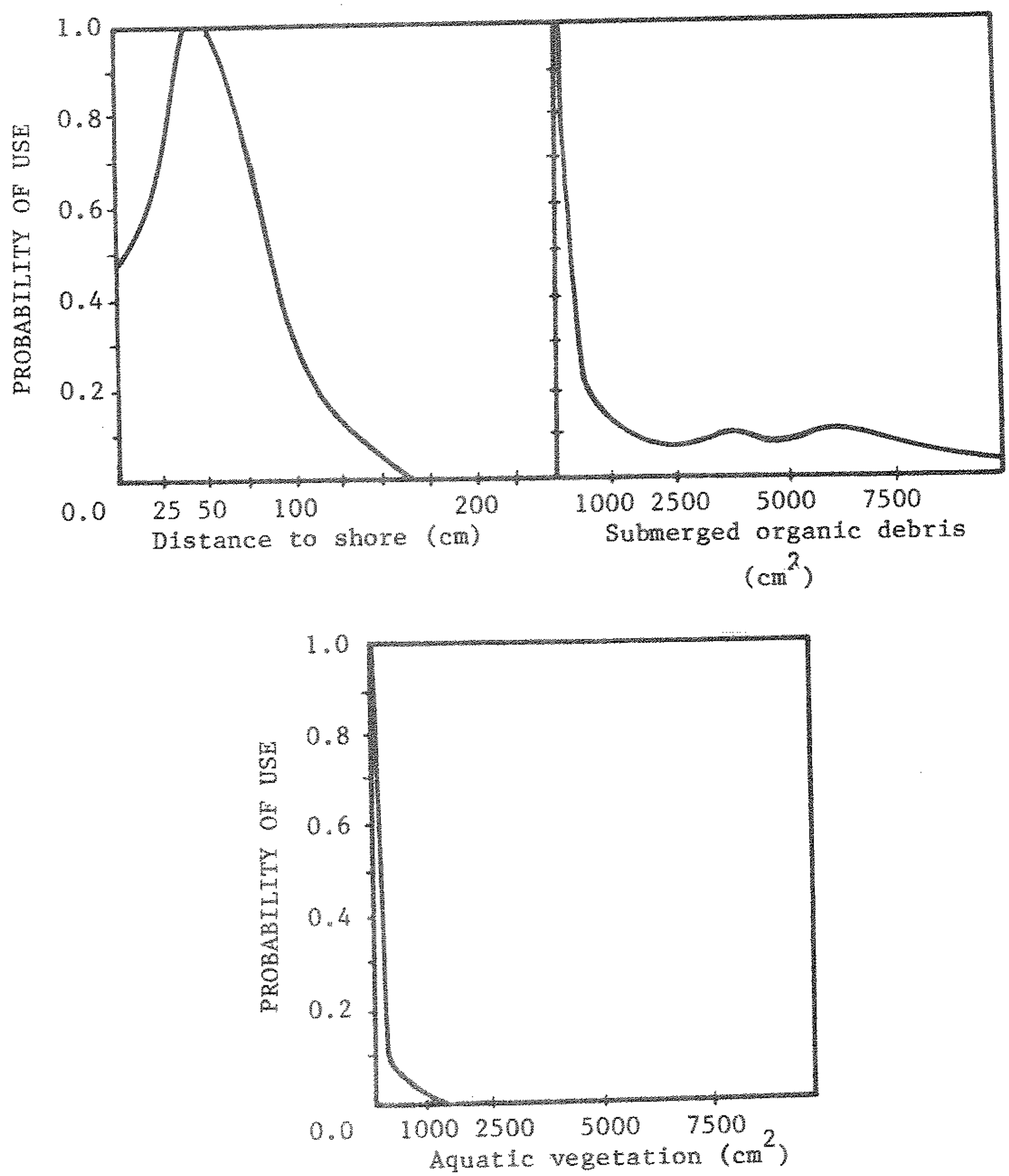


Figure 13. (cont.)

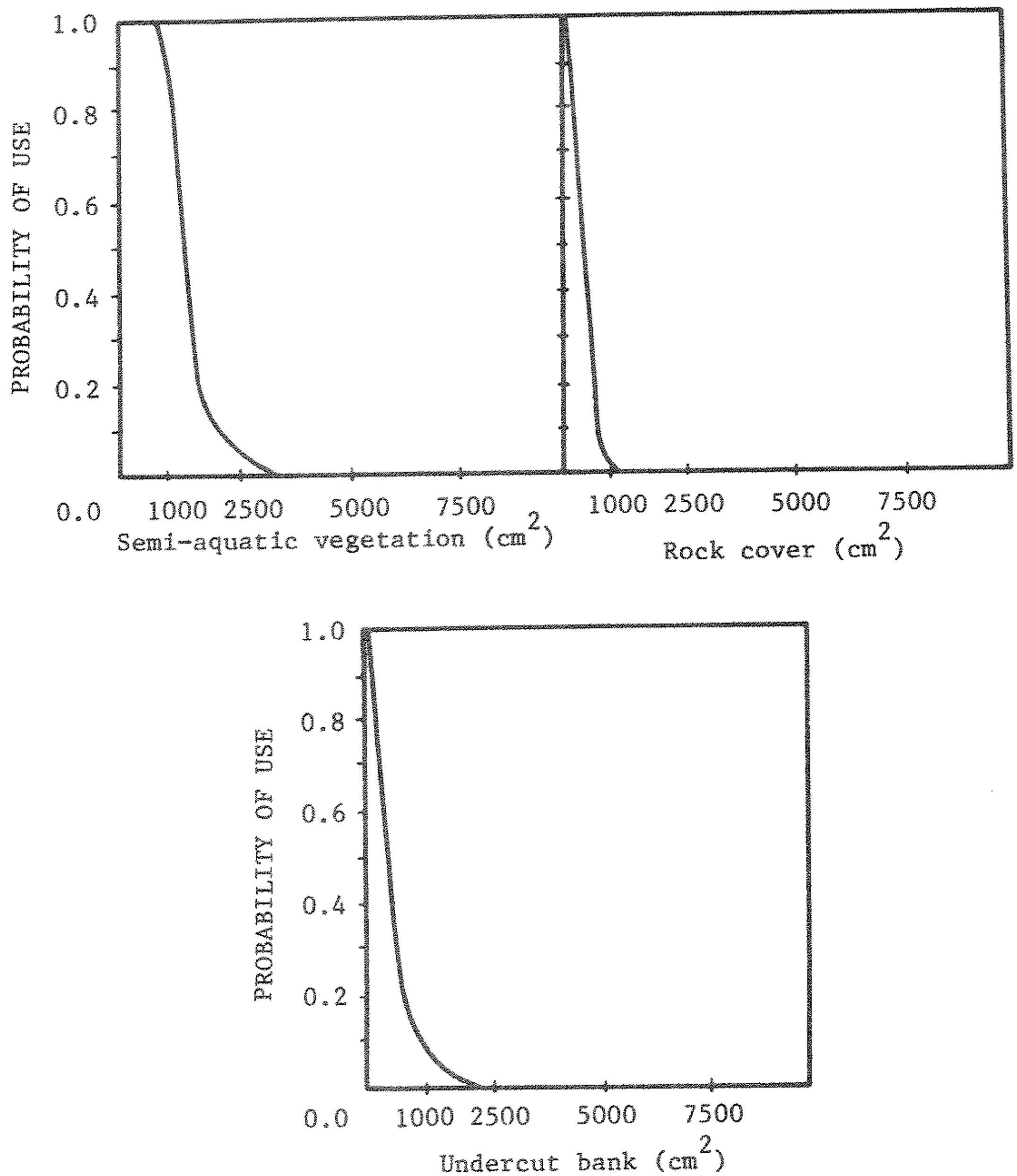


Figure 13. (cont.)

100% fines. These values were considerably lower than optima for rainbow trout and brown trout fry examined in 1979. However, the fry collected in 1980 were smaller than those taken in 1979, indicating they use different habitats as they grow in length.

SUMMARY AND DISCUSSION

Rainbow trout in general selected sites for spawning with definite characteristics of depth, current velocity and substrates. The middle 90% of the rainbow trout redds on the Beaverhead River were located at depths of 23.1-43.2 cm, in current velocities of 0.40-0.83 m/sec in substrates composed of at least 50% pebble and less than 1.6% silt. The middle 90% of the rainbow trout redds on the Yellowstone River were located at depths of 24.0-34.0 cm, in current velocities of 0.42-0.65 m/sec in substrates composed of at least 50% pebble and less than 0.6% silt. These values may approximate the general requirements for spawning since the optimum and mean depths, current velocities and substrate sizes associated with the rainbow trout redds in this study compare favorably with those reported in other studies (Table 12).

Rainbow trout also select spawning sites located in areas with accelerating current velocities (Tautz and Groot 1975). Although the presence of accelerating current at redd sites was not measured in this study, it was noted that rainbow trout redds were most often found (1) alongside or downstream of large rocks, (2) in areas with undulations in the bottom or (3) in areas where the water flowed into a narrower channel, where accelerating currents would be expected.

The middle 90% of the redds of brown trout in the Beaverhead River were found at depths of 18.0-46.0 cm in current velocities of 0.35-0.95 m/sec and in substrates containing at least 33% pebble and

Table 12. Depths, current velocities and substrate sizes associated with spawning sites of rainbow trout.

Parameter	Value	Source
Depth (cm)	27.0-29.0*(26.3)**	Present study (Beaverhead R.)
	28.5**	Present study (Yellowstone R.)
	34.2**	Smith (1973)
	18.5-24.4*	Bovee (1978)
Current velocity (m/sec)	0.70-0.73*(0.62)**	Present study (Beaverhead R.)
	0.52**	Present study (Yellowstone R.)
	0.70**	Smith (1973)
	0.45-0.58*	Bovee (1978)
Substrate size (mm)	8.0-64.0*	Present study (Beaverhead R.)
	8.0-64.0*	Present study (Yellowstone R.)
	8.0-16.0*	Bovee (1978)

* expressed as optimum as defined by Bovee and Cochnauer (1977).
** expressed as mean.

less than 3% silt. The middle 90% of the brown trout on Yellowstone River were found at depths of 17.0-34.0 cm in current velocities of 0.28-0.63 m/sec in substrates composed of at least 60% pebble and less than 0.1% silt. These values are similar to values obtained in other studies (Table 13).

Brown trout select areas for spawning which have currents that penetrate into the substrate (Stuart 1953). The currents provide the eggs with oxygen and remove the metabolic waste products (Wesche 1976). Areas with percolation often are located between the lower ends of pools and the following riffle (Stuart 1953). It is likely that the combinations of depths, current velocities and substrate

Table 13. Depth, current velocity and substrate criteria of spawning areas of brown trout. All references other than present study from Reiser and Wesche (1977).

Parameter	Value	Source
Depth (cm)	18.0 minimum*	Present study (Beaverhead R.)
	17.0 minimum*	Present study (Yellowstone R.)
	24.4 minimum	Thompson (1972)
	24.4 minimum	Smith (1973)
	15.2 minimum	Bovee (1975)
Current velocity (m/sec)	0.35-0.95**	Present study (Beaverhead R.)
	0.28-0.63**	Present study (Yellowstone R.)
	0.21-0.64	Thompson (1972)
	0.30-0.91	Hooper (1973)
	0.20-0.68	Smith (1973)
	0.30-0.76	California (in Hunter, 1973)
	0.43-0.82	Bovee (1975)
Substrate size (mm)	16.0-64.0***	Present study (Beaverhead R.)
	16.0-64.0***	Present study (Yellowstone R.)
	6.4-63.5	Percival (1932)
	up to 63.5	Hobbs (1948)
	6.4-38.1	Hooper (1973)
	6.4-76.2	Hunter (1973)

* lower value of the middle 90%.
** middle 90%.
*** size interval with 70% or more of all particles in the substrate.

sizes repoorted in this and previous studies produced percolations. However, attempts to measure percolations in this study failed. Eighty-seven percent of the brown trout redds studied in the Beaverhead River were within either the upper end of a riffle or the pool-riffle interchange. Stuart (1953) obtained similar results.

Spawning sties are not necessarily located near cover. About 79% of the measured redds of brown trout on the Beaverhead River were within 5 m of cover and all concentrations had 50% or more of their redds within this distance. However, all of the measured redds of this species on the Yellowstone River were further than 5 m from cover. Reiser and Wesche (1977) also reported the association between brown trout redds and cover varied.

The fry of both species averaging 3.3 cm in total length utilized water with a mean depth of 14.9 cm, and average current velocity of 0.05 m/sec over a substrate composition averaging about 80% fines and 20% gravel. Rainbow trout and brown trout fry averaging 6.8 and 7.7 cm in total length, respectively, were found in waters with a mean depth of 22.5 cm, an average current velocity of 0.12 m/sec and a substrate composition averaging about 70% fines and 30% gravel which showed a movement to faster and deeper water with increase in length of the fry. Stuart (1953) has reported that brown trout fry move from the redds into pools containing mud, silt and large stones. Calhoun (1966) and Sundeen (1968) have reported that rainbow trout move to shallow water areas of low current velocity. As they grow, the fry of both species tend to move to faster and deeper water where they encounter a greater stream of food per unit time (Chapman and Bjornn 1969).

All of the areas fry use appear to have a component of cover. About 56% of the fry averaging 3.3 cm in length were found in areas with semi-aquatic vegetation, while 43% and 10% of fry of this size were within 1 m of submerged organic debris and aquatic vegetation respectively. Eighty-three percent of the rainbow trout and brown trout fry having mean lengths of 6.8 and 7.7 cm, respectively, were found within 1 m of submerged organic debris and 75.5% were found within 1 m of aquatic vegetation. The association of fish 6.8 cm and larger with semi-aquatic vegetation dropped to 2.7%, reflecting the movement of larger fry into deeper water.

Reduced flows have been correlated with decreases in reproductive success (Farnes and Bulkley 1964) and in standing crops of trout populations (Nelson 1978, Vincent and Nelson 1978). Riffles are critical areas for spawning sites of brown trout and shallow inshore areas are required for rearing the fry of rainbow trout and brown trout. Since these areas are among the first habitats to be affected by flow reductions (Kraft 1968, Nelson 1978, Sundeen 1968), they should receive the highest priority for protection from dewatering.

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APPENDIX

Table 14. Date, location and number of redds for one concentration of rainbow trout redds on the Beaverhead River in 1979.

Date	Distance downstream from Clark Canyon Dam (km)	Number of redds
Apr. 14	1.7	15

Table 15. Date, location and number of redds per concentration for rainbow trout studied on the Beaverhead River in 1980.

Concentration #	Date	Distance downstream from Clark Canyon Dam (km)	Number of redds
1	Apr. 14	1.7	20
2	Apr. 15	4.7	20
3	Apr. 15	7.9	15

Table 16. Date, location and number of redds for one concentration of rainbow trout redds on Yellowstone River in 1980.

Date	Location	Number of redds
Apr. 18	12.9 km upstream of Livingston, MT	9

Table 17. Date, location and number of redds per concentration for brown trout studied on the Beaverhead River in 1979.

Concentration #	Date	Distance downstream from Clark Canyon Dam (km)	Number of redds
1	Nov. 2	1.7	19
2	Nov. 16	4.7	20
3	Nov. 13	7.9	18
4	Nov. 9	12.1	20

Table 18. Date, location and number of redds per concentration for brown trout studied on the Yellowstone River in 1979.

Concentration #	Date	Location	Number of redds
1	Nov. 6	17.8 km upstream of Livingston, MT	10
2	Nov. 17	Town of Livingston, MT	15

Table 19. Selected habitat parameters of rainbow trout fry on the Beaverhead River in 1979.

Date	Number of fry	Depth (cm)	Velocity (m/sec)	Mean percentages Fines	Gravel	Cobble	Dominant cover type
July 9	6	16.0-17.5	0.09-0.23	100	0	0	Submerged organic debris
July 26	6	19.5-88.5	0.05-0.15	73.3	26.7	0	Aquatic vegetation
Aug. 1	2	9.4-24.2	0.05-0.17	50	37.5	12.5	Submerged organic debris
Aug. 3	1	15.5	0.09	100	0	0	Submerged organic debris
Aug. 6	3	27.5-30.5	0.09-0.13	91.7	8.3	0	S.O.D./AQ. VEG.
Aug. 21	3	14.0-27.0	0.01-0.08	88.3	1.7	10.0	Submerged organic debris
Aug. 22	2	26.0-30.0	0.05-0.10	62.5	37.5	0	Submerged organic debris
Aug. 23	5	13.0-31.0	0.09-0.19	59.0	35.0	6.0	S.O.D./AQ. VEG.
Aug. 29	2	20.0-26.5	0.14-0.23	25.0	45.0	30.0	Submerged organic debris

Table 20. Selected habitat parameters of brown trout fry on the Beaverhead River in 1979.

Date	Number of fry	Depth (cm)	Velocity (m/sec)	Mean percentages Fines	Gravel	Cobble	Dominant cover type
July 9	1	26.0	0.06	100	0	0	Submerged organic debris
July 26	5	18.0-88.5	0.05-0.15	100	0	0	Submerged organic debris
Aug. 1	26	9.4-56.7	0.02-0.21	81.3	16.2	2.5	S.O.D./AQ. VEG.
Aug. 3	8	14.5-20.5	0.10-0.16	71.3	28.8	0	Submerged organic debris
Aug. 6	21	11.0-34.0	0.07-0.19	81.9	18.1	0	S.O.D./AQ. VEG.
Aug. 21	8	6.0-30.0	0.17-0.30	68.1	28.1	3.8	Submerged organic debris
Aug. 22	11	11.5-48.0	0.05-0.16	61.8	31.8	6.4	Submerged organic debris
Aug. 23	12	7.0-31.0	0.05-0.19	42.5	42.5	15.0	S.O.D./AQ. VEG.
Aug. 28	14	8.5-18.0	0.02-0.18	44.3	51.9	3.8	Submerged organic debris
Aug. 29	10	9.0-31.0	0.07-0.14	57.0	34.0	9.0	Submerged organic debris

Table 21. Regression analysis to test for differences between the measured variables associated with rainbow trout and brown trout fry. Variables showing significance at the 90% level (F=2.71) have F-values in parentheses.

$$Y = 0.1762 + 0.0056\ (LT) - 0.0003\ (UCB) - 0.0084\ (D) - 0.0002\ (SAV) + 0.0010\ (DTS) + 0.0031\ (\%F) + 0.0050\ (DE) + 0.00001\ (AV) + 0.0003\ (RC) + 0.1415\ (CV) + 0.0047\ (\%G) - 0.0023\ (\%C) - 0.0046\ (SOD)$$

where Y=species, LT=total length in mm (F=4.35), UCB=undercut bank in cm^2, D=depth in cm (F=6.08), SAV=semi-aquatic vegetation in cm^2, DTS=distance to shore in cm (F=3.44), F=fines, DE=date, AV=aquatic vegetation in cm^2, RC=rock cover in cm^2, CV=current velocity in m/sec, G=gravel, C=cobble, and SOD=submerged organic debris in cm^2.

The multiple correlation coefficient of the regression was R=0.41.

Table 22. Regression analysis of relationship between increase in fish length and change in habitat parameters.

$$Y = -12.89 + 0.436\ (DE) + 3.17\ (SOD) + 5.47\ (SP) + 0.170\ (D) + 24.73\ (CV) - 0.439\ (\%C) - 0.276\ (\%F) - 3.18\ (SAV) - 0.200\ (\%G) - 0.00007\ (AV) - 0.002\ (DTS) - 0.0013\ (RC) + 0.0044\ (UCB)$$

[Equation 1]

where Y=total length for both rainbow trout and brown trout fry, DE=date, SOD=submerged organic debris in sq. cm, SP=species rating, D=depth in cm, CV=current velocity in m/sec, C=cobble, F=fines, SAV=semi-aquatic vegetation in sq. cm, G=gravel, AV=aquatic vegetation in sq. cm, DTS=distance to shore in cm, RC=rock cover in sq. cm and UCB=undercut bank in sq. cm.

The multiple correlation coefficient of the regression was R=0.56.

The variables that were significant or those that approached significance from Equation 1 were then used in the following three regressions to perform an F-test with the sums of squares of the three regressions.

$$Y = -55.30 + 0.552\ (DE) + 0.0003\ (SOD) - 0.136\ (\%C) + 31.332\ (CV) + 0.136\ (D)$$

[Equation 2]

where Y=total length of both species and all other variables were as defined in Equation 1.

Variables significant at the 90% level (F=2.71) were DE (F=45.9) and CV (F=2.82).

The multiple correlation coefficient of the regression was R=0.52. The sums of squares value for the equation was SS_{res}=20753.8.

Table 22. (Cont.)

$$Y = -66.99 + 0.405\ (D) + 0.527\ (DE) + 124.48\ (CV) - 0.467\ (\%C) - 0.0006\ (SOD) \qquad \text{[Equation 3]}$$

where Y=total length for rainbow trout fry and all other variables were as defined in Equation 1.

Variables significant at the 90% level (F=2.92) were DE (F=9.17), CV (F=5.25) and D (F=4.53).

The multiple correlation coefficient of the regression was R=0.56. The sums of squares value for the equations was SS_{res}=5547.6.

$$Y = -51.36 + 0.556\ (DE) + 0.0006\ (SOD) - 0.074\ (\%C) + 0.035\ (D) + 5.38\ (CV) \qquad \text{[Equation 4]}$$

where Y=total length for brown trout fry and all other variables were as defined in Equation 1.

Variables significant at the 90% level (F=2.76) were DE (F=36.03) and SOD (F=9.19).

The multiple correlation coefficient of the regression was R=0.56. The sums of squares value of the equation was SS_{res}=11174.5.

An F-test was derived from the sums of squares of equations 2, 3 and 4 by the following equation:

$$F = \frac{(SS_{res}(\text{Eq. }3) + SS_{res}(\text{Eq. }4)) - SS_{res}(\text{Eq. }2)/df}{(SS_{res}(\text{Eq. }3) + SS_{res}(\text{Eq. }4)/df}$$

The analysis yielded an F-value of 4.39 which was significant at the 99.5% level (F=3.09), showing a significant difference in the

Table 22. (Cont.)

relationship of these variables to the increase in length between species.

The habitat factors for each species with significance at the 90% level were selected from equations 3 and 4 and used in a model for each species. The model for rainbow trout was:

$$Y = 48.26 + 0.440 (D) + 75.230 (CV) \qquad \text{[Equation 5]}$$

where Y=total length for rainbow trout and the other variables were as defined in Equation 1.

The multiple correlation coefficient of the regression was R=0.43.

The model for brown trout was:

$$Y = 74.99 + 5.82 (SOD) \qquad \text{[Equation 6]}$$

where Y=total length for brown trout and the other variable was as defined in Equation 1.

The multiple correlation coefficient of the regression was R=0.24.

Table 23. Selected habitat parameters of trout fry on the Beaverhead River in 1980.

Date	Number of fry	Depth (cm)	Velocity (m/sec)	Mean percentages Fines	Gravel	Cobble	Dominant cover type
Apr. 24	28	3.0-13.0	0.01-0.15	82.3	17.7	0	Semi-aquatic vegetation
May 5	8	10.0-25.0	0.02-0.10	90.0	10.0	0	Semi-aquatic vegetation
May 6	28	6.0-23.0	0.00-0.14	75.4	21.4	3.2	Semi-aquatic vegetation
May 8	8	15.0-35.0	0.01-0.12	92.5	6.9	0.6	Submerged organic debris
May 9	22	9.0-31.0	0.00-0.17	82.3	15.9	1.8	Submerged organic debris