POTENTIAL IMPACTS OF ALTERING DISCHARGE PATTERN FROM HAUSER DAM, MISSOURI RIVER, ON YOUNG-OF-THE-YEAR BROWN TROUT AND RAINBOW TROUT

by

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APPROVAL

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VITA

Daniel Gregory Carty, son of Robert Elden and Joan Lowry Carty, was born in Muskegon, Michigan, on 12 August 1953. He attended Ridgefield High School, Ridgefield, Connecticut and Boca Raton High School, Boca Raton, Florida, and graduated from the latter school in June 1971. In September 1971 he entered the School of Forest Resources, University of Maine, Orono, Maine, and received a Bachelor of Science degree in Wildlife Management in 1975. He began graduate studies and research toward a Master of Science degree in Fish and Wildlife Management at Montana State University in December 1981.

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ABSTRACT

Daily flow fluctuations would occur in the Missouri River between Hauser Dam and Holter Reservoir if Hauser Dam were converted to a hydroelectric peaking facility. To address potential impacts of fluctuating flows on free-swimming young-of-the-year (YOY) brown trout (Salmo trutta) and rainbow trout (S. gairdneri) emergence, growth, abundance, distribution, movement, and habitat use were investigated. During reduced-flow tests stranding, isolation, displacement, and habitat changes were evaluated. Hydraulic modeling was used to predict changes in the quantity of usable habitat at different discharges. Recruitment from a tributary into the river was also monitored. Field data were collected between April 1982 and November 1983. Young-of-the-year brown trout were first observed in early April while YOY rainbow trout were first found in mid-June. Both species used relatively shallow, low-velocity water near shore where cover was abundant. Reduced-flow tests in August of each year revealed little stranding or isolation, and YOY trout were not permanently displaced from temporarily dewatered habitat. Hydraulic modeling predicted an increase in the quantity of habitat as discharge decreased, but field observations indicated a reduction in habitat quality. The tributary was found to be a relatively important source of recruitment to the river rainbow trout fishery but rather unimportant to the river brown trout fishery.

INTRODUCTION

The flowing portion of the Missouri River between Hauser Dam and Holter Reservoir is a high quality fishing and recreation area. Sportfishing in this reach focuses on brown trout (*Salmo trutta*), rainbow trout (*S. gairdneri*), and mountain whitefish (*Prosopium williamsoni*). Longnose sucker (*Catostomus catostomus*) and white sucker (*C. comersoni*) are commonly caught, but not actively harvested. Walleye (*Stizostedion vitreum*), though rarely taken, are a prized addition to the creel. Brown trout, mountain whitefish, longnose sucker, white sucker, and walleye populations are entirely self-sustaining. The rainbow trout population is augmented by annual stocking of hatchery-reared fish into Canyon Ferry, Hauser, and Holter Reservoirs.

Hauser Dam has been operated by Montana Power Company as a run-of-the-river hydroelectric power plant, i.e. when the reservoir is full, all water which cannot pass through the turbines must be spilled over the dam. Recent engineering studies by Montana Power Company indicated that construction of a new powerhouse, coupled with hydroelectric peaking, would maximize the operational benefit:cost ratio. Hydroelectric peaking would alter discharge patterns that have been in effect since 1954 (when the U.S. Bureau of Reclamation initiated hydroelectric power generation at Canyon Ferry Dam located approximately 24 km upstream) and daily flow fluctuations in the river downstream of the dam would occur during one or more seasons of the year.

This study was part of a larger investigation designed to predict potential impacts of altering discharge patterns from Hauser Dam on fish populations (White et al. 1984). Due to the importance of the brown trout and rainbow trout fisheries, research emphasis was placed on these species. Specifically, my study concerned potential impacts of fluctuating flows associated with hydroelectric peaking on young-of-the-year brown trout and rainbow trout.

Effects of fluctuating flows due to hydroelectric peaking, experimental drawdowns, and dam inspections on juvenile salmonids have been reported since the 1950's. Lindroth (1956) observed lateral displacement of age-0 anadromous brown trout during daily fluctuations below a hydroelectric plant on a large Swedish river. A number of investigators have reported stranding of fry and fingerlings of chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), steelhead trout (*Salmo gairdneri*), and rainbow trout on dewatered substrate (Phillips 1969; Phinney 1974; Witty and Thompson

1974; Bauersfeld 1977,1978; Becker et al. 1981). Others have observed that juvenile fish may become isolated in pools during reduced discharges and exposed to increased water temperatures, decreased dissolved oxygen levels, and increased predation (Bauersfeld 1978; Becker et al. 1981).

I know of no information on potential impacts of fluctuating flows on young-of-the-year brown trout or rainbow trout under flow regimes similar to those tested by Montana Power Company at Hauser Dam. The following objectives were established for investigating potential impacts on young-of-the-year of both species: 1. determine date of earliest emergence; 2. monitor growth, abundance, distribution, and movement; 3. locate and describe habitat used by young-of-the-year trout; 4. evaluate stranding, isolation, and displacement during reduced-flow tests; 5. observe and predict habitat changes at different discharges; and 6. determine the importance of Beaver Creek as a source of recruitment to the river fishery.

Field research for this study was conducted between April 1982 and November 1983.

DESCRIPTION OF STUDY AREAS

Missouri River Below Hauser Dam

Hauser Dam is located on the Missouri River approximately 23 km northeast of Helena, Montana. The dam, in operation since 1911 as a run-of-the-river hydroelectric power generating facility, is a concrete structure with a height of 39.6 m, length of 135.6 m, and a spillway crest elevation of 1,103.7 m above mean sea level. Present intake capacity of the turbines is 121.8 m^3/sec; surplus water exceeding this capacity is spilled (White et al. 1984).

The Missouri River study area extended from Hauser Dam downstream to American Bar Gulch near the head of Holter Reservoir, a river distance of about 6.8 km (Figure 1). From the dam to the mouth of Beaver Creek, the river flows in a confined channel through a high-walled, rugged canyon. It continues through a narrow floodplain bordered by several benches and bars until reaching Upper Holter Reservoir.

A ponderosa pine (*Pinus ponderosa*)-grassland vegetation type is dominant along the banks of the river; patches of red osier dogwood (*Cornus stolonifera*) and willow (*Salix sp.*) are also present (White et al. 1984).

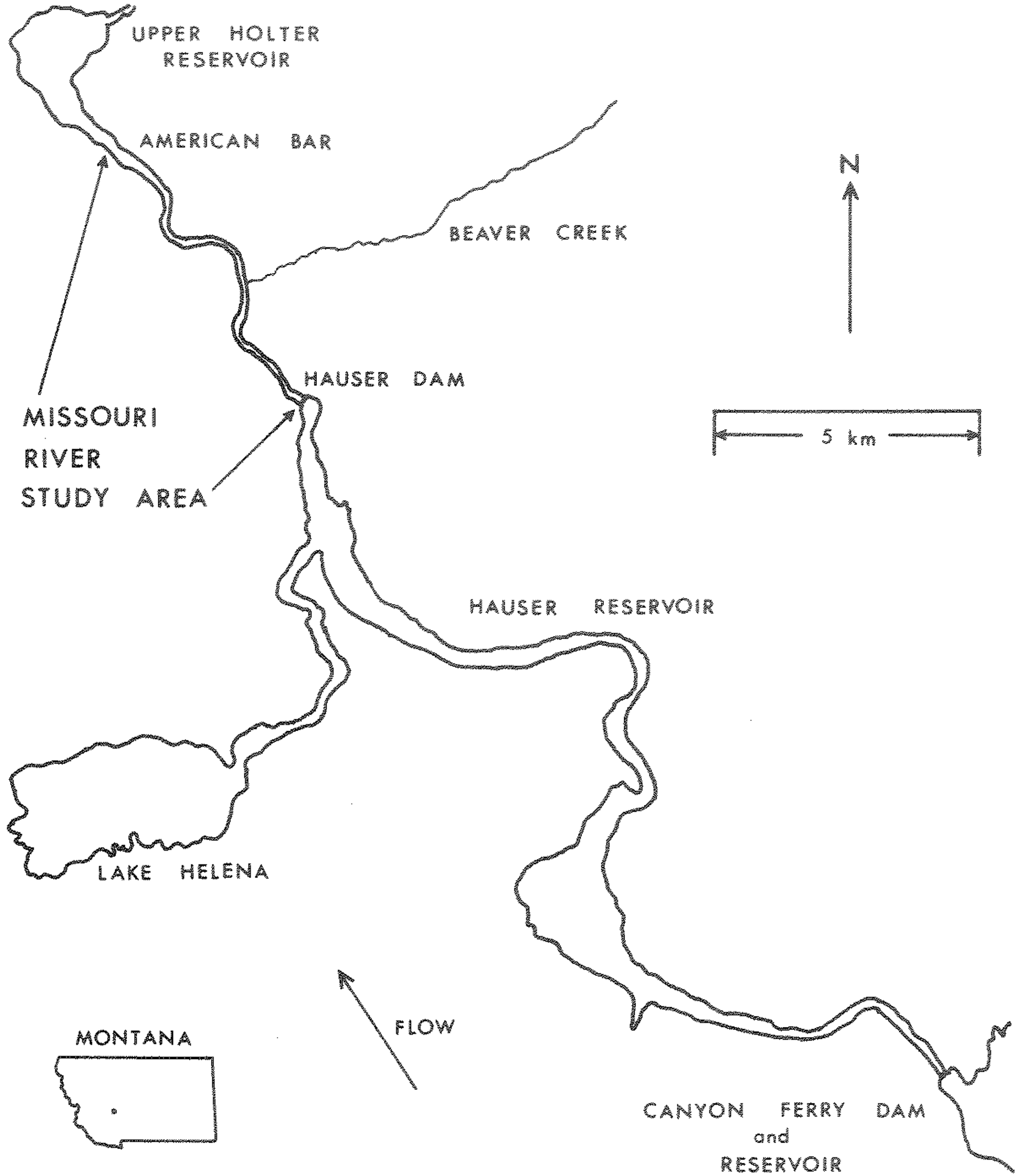

Figure 1. Map of Missouri River showing Hauser Dam and study area.

Talus slopes are common between the dam and the mouth of Beaver Creek. The three major access points are at Hauser Dam, the mouth of Beaver Creek, and the Hilger's Landing-Gates of the Mountains area; access is primarily by boat and foot.

Average monthly discharge at Hauser Dam for the period 1954-1976 was 156 m^3/sec. Peak discharges occurred in June at a mean of 254 m^3/sec while minimum flows occurred in September at an average of 120 m^3/sec. Average monthly discharges during the period 1982-1983 were similar to those from 1954-1976 (Figure 2)(Montana Power Company, unpublished data).

Average monthly water temperatures during the period 1982-1983 ranged from 1.5 C in January to 14.3 C in August (Figure 3). The river is virtually free of ice during winter.

Fifteen fish species representing six families are known to occur in this section of the Missouri River (Table 1). Brown trout, rainbow trout, and mountain whitefish are the most abundant game fishes. Longnose suckers and mottled sculpin (*Cottus bairdi*) are the most numerous non-game species.

Beaver Creek

Beaver Creek is the only perennial tributary within the Missouri River study area (Figure 1). It is

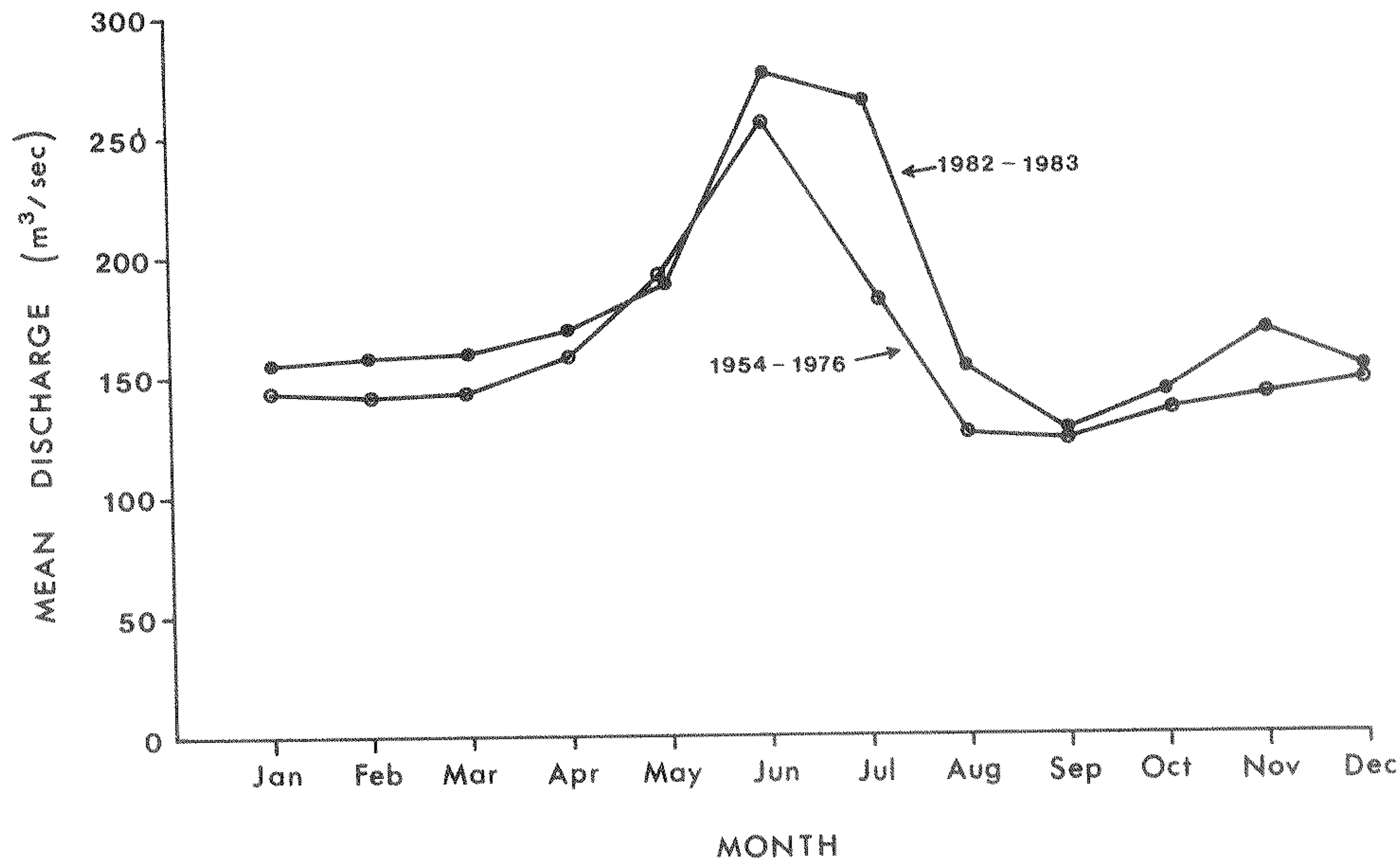

Figure 2. Mean monthly discharge of the Missouri River at Hauser Dam for the periods 1954-1976 and 1982-1983.

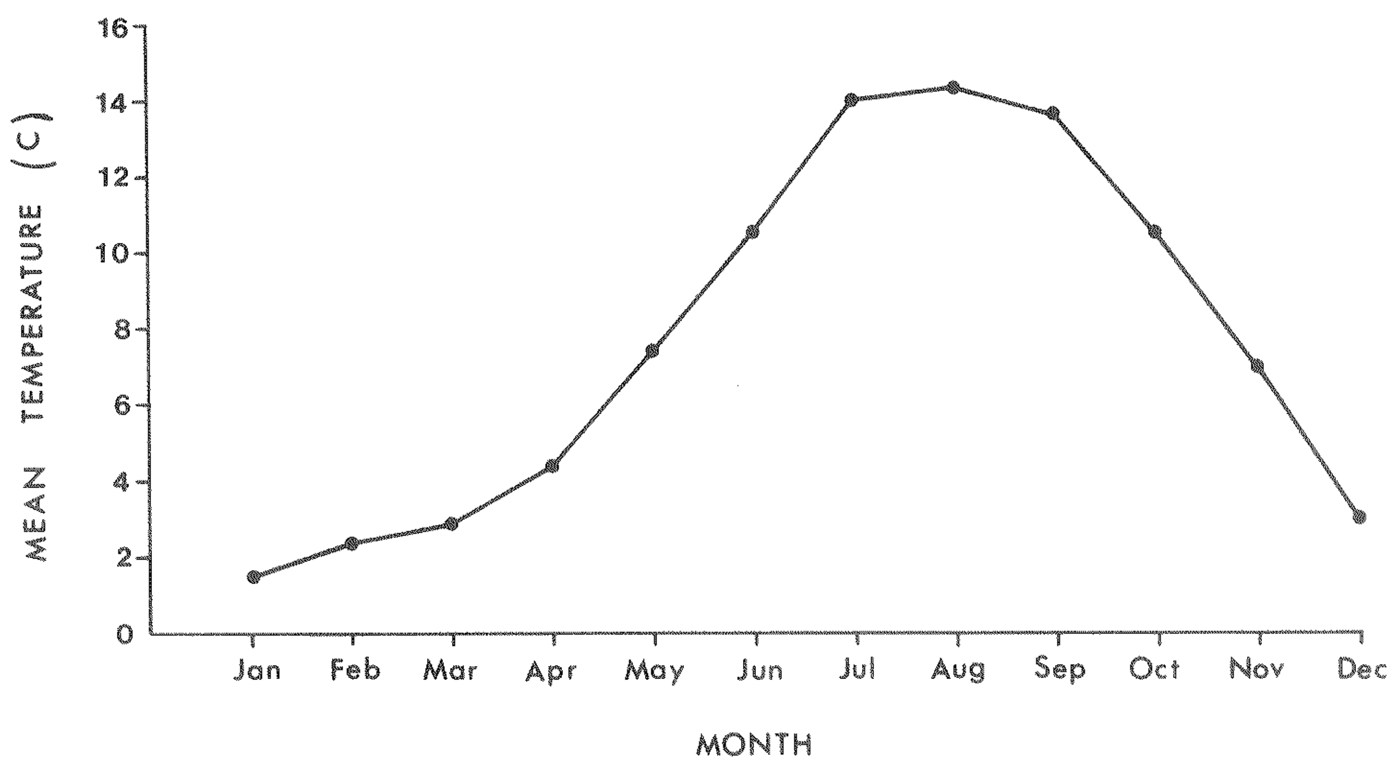

Figure 3. Mean monthly temperature of the Missouri River at Hauser Dam for the period 1982-1983.

Table 1. Fish species known to occur in the Missouri River between Hauser Dam and Holter Reservoir (White et al. 1984).

Family Name Common Name	Scientific Name
Salmonidae	
Kokanee	*Oncorhynchus nerka*
Brown trout	*Salmo trutta*
Rainbow trout	*Salmo gairdneri*
Cutthroat trout	*Salmo clarki*
Brook trout	*Salvelinus fontinalis*
Mountain Whitefish	*Prosopium williamsoni*
Catostomidae	
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Centrarchidae	
Crappie	*Pomoxis sp.*
Cottidae	
Mottled sculpin	*Cottus bairdi*
Cyprinidae	
Common carp	*Cyprinus carpio*
Longnose dace	*Rhinichthys cataractae*
Fathead minnow	*Pimphales promelas*
Percidae	
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*

approximately 27.4 km long and has an average gradient of 1.72%. From its source to the town of Nelson, Montana, Beaver Creek flows through a narrow limestone canyon. Downstream from this point, the creek meanders through a broad floodplain until joining the Missouri River about 2.7 km below Hauser Dam. Numerous beaver dams are found throughout the stream.

Severe habitat degradation has occurred in Beaver Creek from alteration of the stream bed for construction of roads and a pipeline, as well as from channelization and dewatering. Prior to 1974, the lower 3.2 km was under private control and was completely dewatered for several years during the irrigating season. A 1973 survey by the Montana Department of Fish, Wildlife, and Parks found that 24% of a 22.4 km reach had been adversely impacted by human activities (Hill and Wipperman 1976). Currently, most of the land surrounding Beaver Creek is managed by the U.S. Forest Service. Stream access is provided by a USFS road which parallels the creek from the mouth to a point 19 km upstream.

Average monthly discharge from April through November for the period 1982-1983, measured at the USFS Beaver Creek gauging station, was 0.62 m^3/sec. Flows were lowest in October and November and highest in May and June (Figure 4). The gauging station was not operated from December through March.

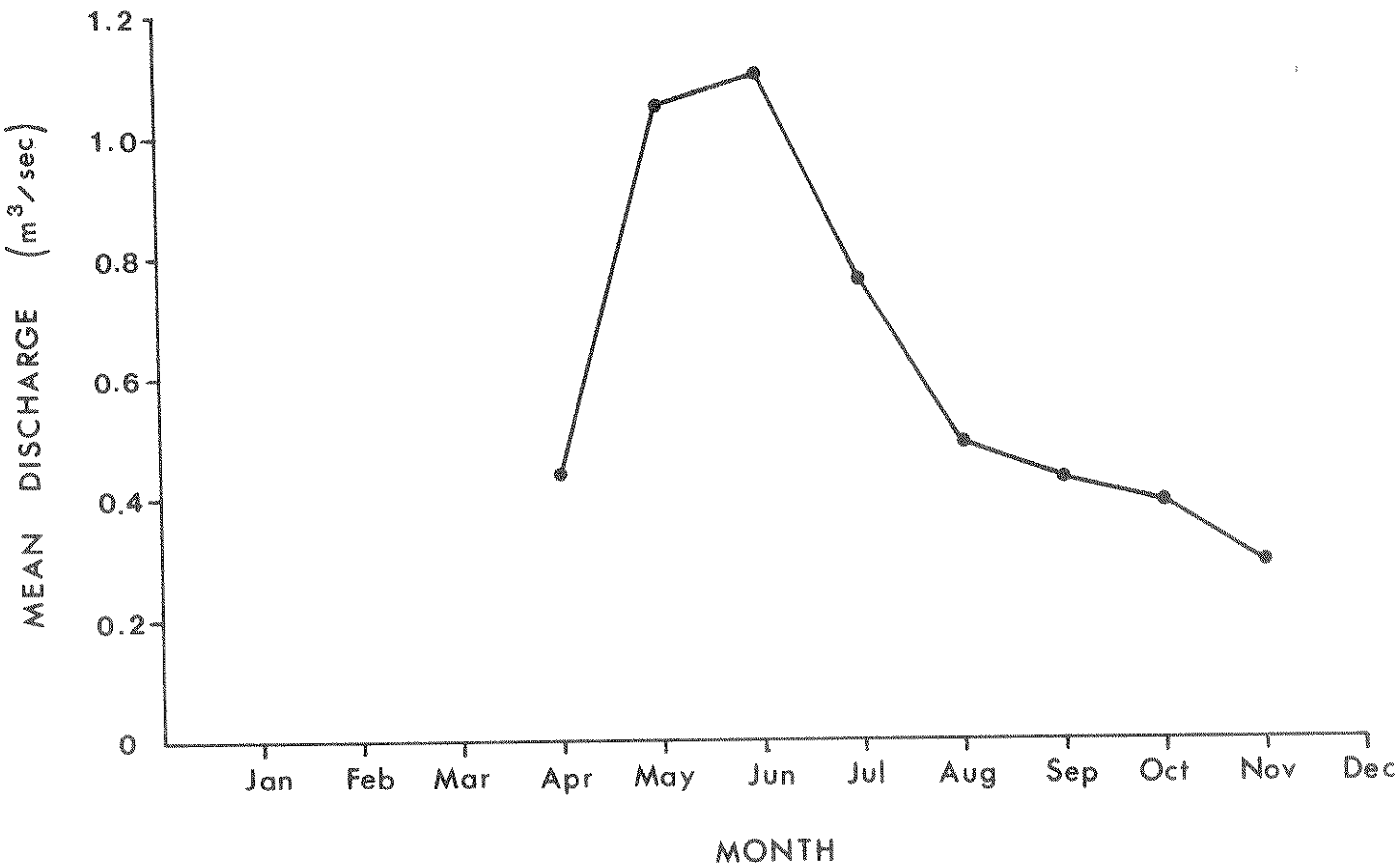

Figure 4. Mean monthly discharge of Beaver Creek, April -November, for the period 1982-1983.

Average monthly water temperatures for the same period ranged from 0.7 C in January to 14.0 C in August (Figure 5). No temperature data were available for February of either year due to thermograph malfunction. Surface ice and snow covered most of the creek during winter.

Five fish species representing two families are resident in Beaver Creek (Table 2). Brown trout, rainbow trout, cutthroat trout (*Salmo clarki*), and rainbow trout x cutthroat trout hybrids were the most numerous game fishes. Rainbow trout from the Missouri River used the creek extensively for spawning from late March through early June. Brown trout of river origin rarely used the creek for spawning due to low discharges in the creek during fall (White et al. 1984).

Table 2. Fish species known to be resident in Beaver Creek.

Family Name Common Name	Scientific Name
Salmonidae	
Brown trout	*Salmo trutta*
Rainbow trout	*Salmo gairdneri*
Cutthroat trout	*Salmo clarki*
Brook trout	*Salvelinus fontinalis*
Rainbow trout x cutthroat trout hybrids	
Cottidae	
Mottled sculpin	*Cottus bairdi*

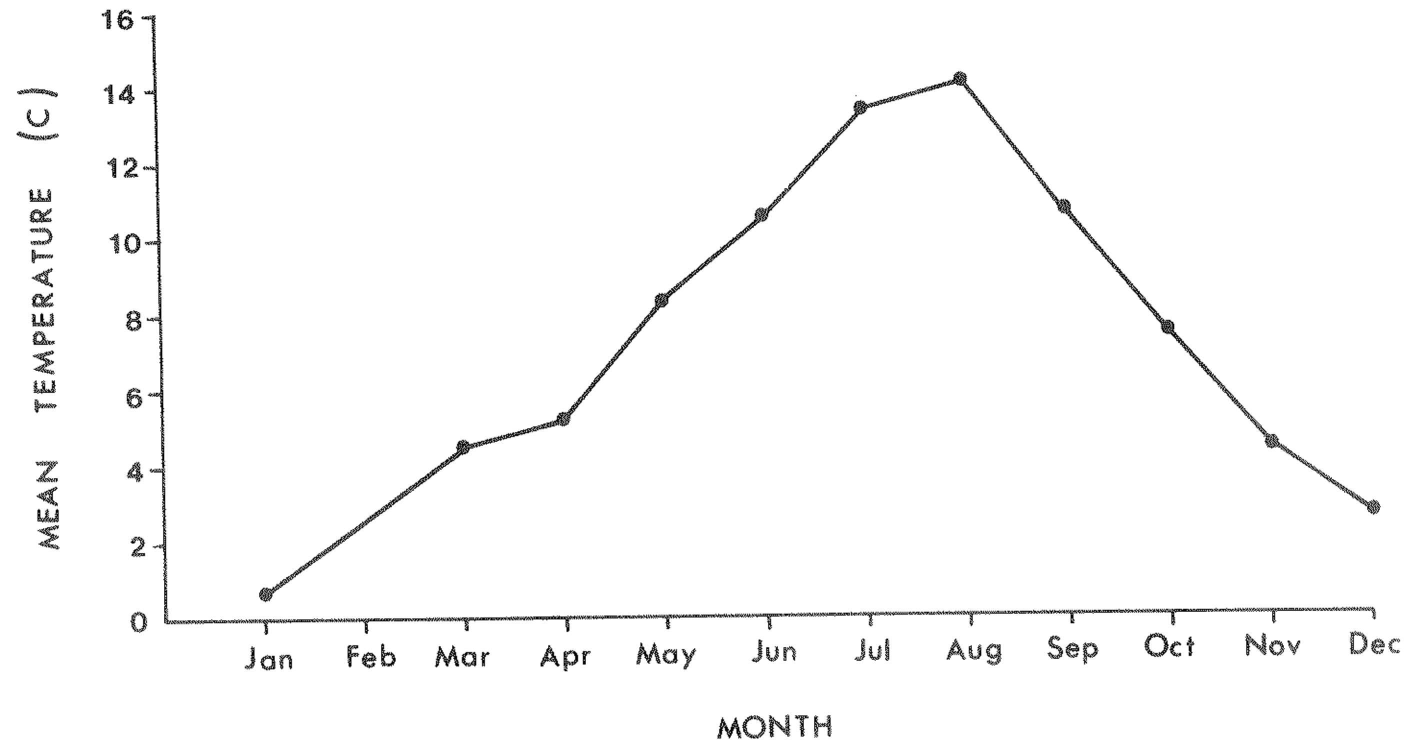

Figure 5. Mean monthly temperature of Beaver Creek for the period 1982-1983 (no data for February).

METHODS

Missouri River Fish and Habitat Sampling

Young-of-the-year (YOY) brown trout and rainbow trout were sampled in the Missouri River study area between 25 April and 31 October 1982 and 10 April and 13 November 1983. Sampling was centered in relatively shallow, low-velocity waters near shore where YOY fish concentrate and where impacts of fluctuating flows would be greatest. In 1982, the entire length of both shorelines was sampled from the dam downstream to the head of the island between Cochran and Foster Gulches, a river distance of approximately 4.5 km (Figure 6). In 1983, 14 sampling stations, each 100 m long, were established between the dam and American Bar Gulch (Figure 6); all 1983 data were collected from within sampling station boundaries.

In both years, most YOY trout were captured by electrofishing; a few were caught by dipnetting. When trout were less than 35 mm total length (TL), a backpack electrofishing system was used. This system was powered by a 12 volt DC battery. Smith-Root Type V or VII rectifying units were used to output pulsating direct current.

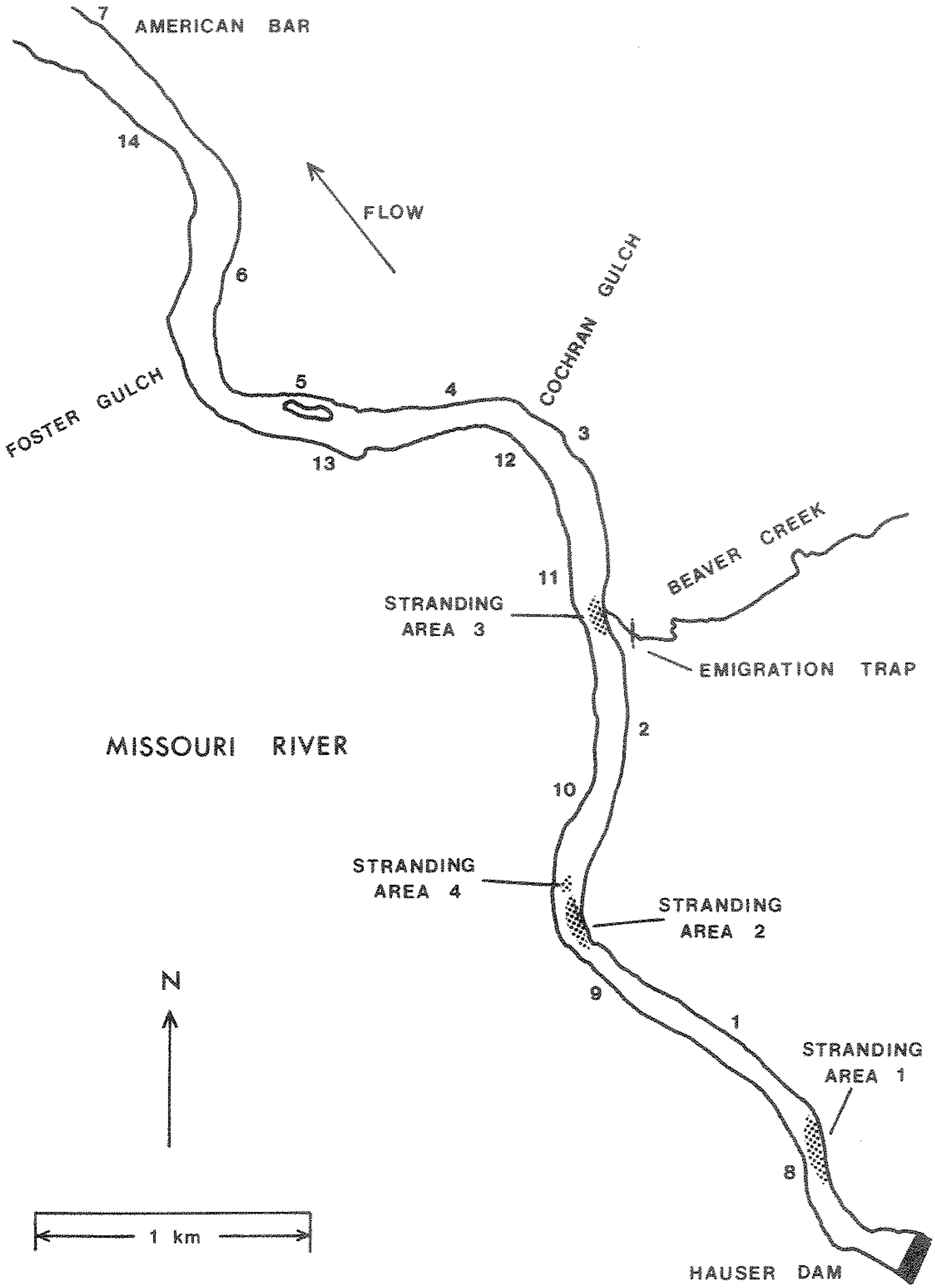

Figure 6. Map of study area showing YOY trout electrofishing stations (1-14), stranding sampling areas (1-4), and Beaver Creek emigration trap.

A more powerful electrofishing system was used when most YOY trout had reached 35 mm TL: a Honda 1500-watt, 115-volt AC generator mounted in an aluminum canoe. In 1982, a Coffelt Model VVP-2C rectifying unit was used to convert alternating current to pulsed direct current (60 pulses/sec). In 1983, a Fisher Model 1010 "Fish Shocker" was used to convert alternating current to non-pulsed direct current; this type of current appeared to be more efficient in capturing small fish. Electrofishing was conducted by walking upstream in shallow, near-shore waters. One person operated the positive electrode while the other netted stunned fish as they drifted downstream.

Date of Earliest Emergence, 1982 and 1983

Beginning in late March of each year, weekly visual searches were made in near-shore areas of the Missouri River. A few YOY trout were captured with a hand-held dip net to allow for positive identification. Electrofishing sampling began 1 week after the first YOY brown trout were captured by dipnetting.

Growth, Abundance, Distribution, and Movement, 1983

Monitoring of growth, abundance, distribution, and movement began on 16 April 1983 and continued bi-weekly, with one exception, to 13 November (Appendix Table 1). Within each sampling period and station, captured YOY trout were identified to species and measured to the nearest 1 mm TL. The number of each species observed (but not captured) was also recorded. Captured fish were released in shallow, low-velocity water near the upstream boundary of the sampling station.

To monitor movement of YOY trout, the Missouri River study area was divided into three sections. The Upper Section included all sampling stations from the dam downstream to just below the mouth of Beaver Creek (Sampling Stations 1, 2, 8, 9, 10, and 11). The Middle Section included all sampling stations from just below the mouth of Beaver Creek downstream to the head of the island between Cochran and Foster Gulches (Sampling Stations 3, 4, and 12). The Lower Section included all sampling stations from the head of the island between Cochran and Foster Gulches downstream to American Bar Gulch (Sampling Stations 5, 6, 7, 13, and 14) (Figure 6).

Beginning with the 12-14 June sampling period, YOY trout greater than 35 mm TL were marked with a caudal fin punch. Captured fish in the Upper Section received an upper caudal fin punch while those in the Middle Section received a lower caudal fin punch. Young-of-the-year trout captured in the Lower Section received no mark; sampling stations in this section were used for recapturing downstream migrants. Primary interest lay in detecting movement by recapturing fish outside the area in which they were originally marked, but recaptures within sections were also recorded.

This mark-recapture technique was useful only for detecting movement between the Upper and Middle Sections, from the Upper to Lower Section and from the Middle to Lower Section. Movement between sampling stations or movement outside effective electrofishing range could not be detected.

Habitat, 1982 and 1983

In 1982, habitat used by YOY brown trout and rainbow trout was located and described (Appendix Table 2). Young-of-the-year trout were captured by electrofishing and capture locations were marked with a small float. Captured YOY trout were identified to species and measured to the nearest 1 mm TL before release.

Physical parameters measured at the point of capture included water depth and distance to shore; both measurements were made with a meter stick to the nearest 1 cm. Mean water velocity was determined to the nearest 1.5 cm/sec with a Marsh-McBirney electronic current meter. Dominant substrate type and the presence of cover components were visually estimated within a 0.5 m radius around the point of capture. Substrates were classified using a modified version of the Wentworth particle size scale (Welch 1948) (Table 3). Cover components were uniquely defined for this study (Table 4).

Table 3. Classification of substrates used in the study of YOY brown trout and rainbow trout habitat in the Missouri River between Hauser Dam and Holter Reservoir, 1982-1983.

Substrate Type	Particle Size (mm)
Fines	< 2
Gravel	2-64
Cobble	65-256
Boulder	> 256

In 1983, during three time periods (Table 5), habitat within the 14 electrofishing stations was measured to evaluate habitat changes at various discharges. On these same occasions, habitat-use data were collected in the manner described previously to determine whether YOY trout selected similar habitat at different discharges. The period 29 June-4 July was chosen because it represented conditions existing during spring runoff. The other periods, 26-30 July and 23-26 August, were selected as representative of average summer discharges.

To measure habitat changes at various discharges, five permanent cross-sectional transects were established in each of the 14 sampling stations. Within each sampling station, beginning at the upstream boundary and extending to the downstream boundary, transects were spaced 25 m

Table 4. Classification of cover components used in the study of YOY brown trout and rainbow trout habitat in the Missouri River between Hauser Dam Holter Reservoir, 1982-1983.

Cover Component	Description
Submerged Vegetation (SV)	Aquatic, emergent, or terrestrial vegetation partially or wholly submerged
Rock Cover (RC)	River substrate large enough to be used by YOY trout as cover (Relative to size of fish)
Woody Organic Debris (OD)	Dead woody vegetation wholly or partially submerged or living or dead woody vegetation extending into the water from the bank
Undercut Bank (UB)	River bank undercut by erosion
Overhanging Vegetation (OHV)	Living or dead vegetation extending out over the water's surface and within 30 cm of the surface

Table 5. Discharge and YOY brown trout and rainbow trout habitat sampling schedule in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Periods	Mean Discharge for Period (m^3/sec)
June 29-July 4	295 ± 19
July 26-30	149 ± 6
August 23-26	157 ± 8

apart and were oriented perpendicular to the thalweg. Measurements of water depth and mean water velocity, and visual estimates of dominant substrate type and cover components were made at 0.5 m intervals. The greatest distance from shore at which measurements were taken depended on wadability, usually a minimum of 3 m and never greater than 6 m.

Reduced-Flow Test, 1982

A reduced-flow test was conducted on 16-17 August 1982. The purpose was to provide information for evaluating potential impacts of periodic flow reductions on trout spawning, trout rearing, and fish-food organisms (White et al. 1984). The time required to reduce flow from a maximum of 269 m^3/sec to a minimum of 39 m^3/sec was approximately 18 hours and occurred in three steps (Table 6). The largest decrease occurred over a period

Table 6. Flow schedule for the reduced-flow test, Missouri River at Hauser Dam, 16-17 August 1982.

Date	Time of Day (h)	Approximate Discharge (m^3/sec)	Elapsed Time (hrs)
August 16	1100 to 1700	269	6.0
	1700 to 1800	269 - 232	1.0
	1800 to 2400	232	6.0
August 17	0000 to 0700	232	7.0
	0700 to 0800	232 - 176	1.0
	0800 to 1000	176	2.0
	1000 to 1100	176 - 39	1.0
	1100 to 1900	39	8.0
	1900 to 2000	39 - 167	1.0
	2000 to 2400	167	4.0

of 30-40 minutes on 17 August between 1000 and 1100 hours when discharge was reduced from approximately 176 m^3/sec to 39 m^3/sec; flow remained at this minimum level for about 8 hours.

Stranding of YOY trout and other fish on dewatered substrate and the isolation of fish in pools were evaluated during the period of minimum flow. Sampling was restricted to four areas previously found to contain relatively large concentrations of YOY trout or where they were most likely to be affected by dewatering (Figure 6). Twelve transects were established over the four areas (three transects in Area 1, six in Area 2, one in Area 3, and two in Area 4) to evaluate stranding. Numbers and sizes of all species of fish found stranded along transects were recorded. The location and size of pools isolated from the main river channel at minimum flow and the species and size of fish captured in these pools were also recorded.

Reduced-Flow Test, 1983

On 4 August 1983 a reduced-flow test was conducted to evaluate the accuracy of hydraulic modeling (see following section), determine if YOY trout were displaced from habitat, and measure changes in habitat (White et al. 1984). Displacement from habitat and changes in habitat were evaluated at three flows (Table 7). Sampling was restricted to 1983 electrofishing stations 1, 2, 4, and 10 (Figure 6). Station 1 was sampled at 81 m^3/sec, Stations 2 and 10 at 67 m^3/sec, and Station 4 at 55 m^3/sec.

Young-of-the-year trout were captured by electrofishing. At each station, the number of each species captured added to the number of each species observed (but not captured) was recorded. Captured trout were measured to the nearest 1 mm TL before release. Techniques described previously were used to evaluate

Table 7. Flow schedule for the reduced-flow test, Missouri River at Hauser Dam, 4 August 1983.

Time of Day (h)	Approximate Discharge (m^3/sec)	Elapsed Time (hrs)
0800 to 0900	165 - 81	1.0
0900 to 1130	81	2.5
1130 to 1200	81 - 67	0.5
1200 to 1345	67	1.75
1345 to 1415	67 - 55	0.5
1415 to 1600	55	1.75
1600 to 1700	55 - 143	1.0

habitat changes and habitat use.

Physical Habitat Simulation, 1982

Predictions of habitat alterations associated with fluctuating flows were made using the Water Surface Profile (WSP) option of the U.S. Fish and Wildlife Service Physical Habitat Simulation System (PHABSIM) (Milhous et al. 1981; Bovee 1982). This model is a multiple-transect approach which uses data collected at a minimum of one discharge to calculate a weighted suitability index called Weighted Usable Area (WUA). This index is expressed as the percentage of gross surface area in a given stream segment which contains suitable combinations of habitat variables for each species and life stage of interest at simulated discharges.

During the 3-day period in which data were collected, Montana Power Company regulated river discharge at 147 m^3/sec. Survey data were obtained from four transects in each of three sections of the river. These sections corresponded to brown trout and rainbow trout spawning areas, but were deemed adequate for examining the influences of flow on YOY trout rearing habitat. Data collected along transects included distance between high water marks and water's edge, substrate, and bank and aquatic vegetation. For a detailed description of field techniques see Graham et al. (1979).

Computer-generated habitat-preference curves (derived from empirical habitat-use data) were used in conjunction with simulated physical and hydraulic conditions in the surveyed areas to predict the percent of habitat suitable for rearing at as many as 36 flows ranging from 36-269 m^3/sec (Table 8).

Beaver Creek Fish Sampling

Emigration of YOY brown trout and rainbow trout from Beaver Creek into the Missouri River was monitored from 19 June-27 August 1983. A hoop net (13 mm down to 6 mm bar mesh) and four modified insect drift nets were used to trap downstream migrants. Each net was equipped with a

Table 8. Example of the Physical Habitat Simulation System (PHABSIM) output from one transect location on the Missouri River between Hauser Dam and Holter Reservoir, 1982.

Simulated Discharge (m^3/sec)	Gross Surface Area (ha)	Weighted Usable Area by Life Stage (% of Gross Surface Area)		
		Fry	Spawning	Adult
77	3.17	0.93	13.10	30.93
79	3.22	0.87	12.25	30.22
82	3.27	0.86	11.45	29.60
85	3.32	0.87	10.71	28.84
99	3.42	0.54	8.27	26.65
113	3.45	0.23	7.28	26.95
127	3.48	0.12	7.52	26.94
142	3.51	0.09	7.87	25.28
147	3.52	0.07	7.91	24.70
156	3.53	0.05	7.78	23.68
170	3.54	0.07	7.13	21.59
184	3.55	0.07	6.14	19.82
198	3.56	0.07	5.14	17.55
212	3.57	0.07	4.15	15.31
227	3.58	0.07	3.24	13.11
241	3.59	0.06	2.37	11.16
255	3.60	0.06	1.71	9.37
269	3.61	0.04	1.18	7.88

"live box" attached to its downstream end to hold migrating fish between net checks. The hoop net was installed approximately 100 m upstream of the confluence of Beaver Creek and the Missouri River and the drift nets were placed about 50 m downstream of the hoop net. The hoop net was size-selective for fish greater than 40 mm TL while fish as small as 23 mm TL could be caught in the drift nets.

Nets were checked each morning and evening from 19 June-27 August, except for the period 11-15 July. High water due to heavy rains necessitated removal of the nets during this time. The number of each species of trout captured was recorded at each net check and body lengths of a subsample were measured to the nearest 1 mm TL each day. All captured fish were released just downstream from the drift nets.

Discharge and Temperature Monitoring

Discharge information for the Missouri River study area for the period 1982-1983 was obtained from Montana Power Company's gauging station located just downstream of Hauser Dam. The stage-discharge relationship developed by the company in 1982 was

$$Q=477.2H^{1.52},$$

where Q=discharge in cubic feet per second and H=gauge height reading in feet. All discharge information reported here, other than that for reduced-flow tests, was based on gauge readings taken by the dam operators at 1600 hours each day. Discharge information for Beaver Creek was obtained from the U.S. Forest Service gauging station located 2.4 km upstream of the creek mouth.

Water temperatures in the river and creek were recorded continuously with submersible Ryan Model J, 90-day thermographs that were installed in October 1981. The range of water temperatures measureable by these thermographs was -5 to 25 C. They were accurate to within 0.6 C and 3 minutes/day. The Missouri River thermograph was located 0.4 km downstream of Hauser Dam while the Beaver Creek thermograph was located near the USFS gauging station.

RESULTS

Missouri River

Date of Earliest Emergence, 1982 and 1983

In 1982, YOY brown trout were first found on 25 April in waters along the east bank of the river between Cochran Gulch and the side channel approximately 0.4 km downstream. Initial observations of YOY rainbow trout were made on 22 June in the same section of river (Figure 6).

Earliest observations of YOY brown trout in 1983 were on 10 April in waters along the east bank of the river between the mouth of Beaver Creek and the side channel 1.6 km downstream. Young-of-the-year rainbow trout were first located on 13 June in waters along both shorelines from the dam downstream to American Bar Gulch (Figure 6).

Growth, 1983

Young-of-the-year brown trout and rainbow trout were about 25 mm TL when newly emerged from the gravel. The yolk sac was completely resorbed in nearly all captured trout of this length. Brown trout growth was greatest from late June through mid-September while growth for rainbow trout was greatest from early July through mid-

September (Figure 7)(Appendix Tables 3 and 4). Mean total length of captured fish increased an average of 20 mm each 30 days during these periods. Mean total length of YOY brown trout was 122 mm in mid-November and that of YOY rainbow trout was 79 mm. Young-of-the-year brown trout averaged 15-43 mm longer than YOY rainbow trout on comparable sampling dates due to their earlier hatching and emergence period.

Abundance and Distribution, 1983

Young-of-the-year brown trout were observed during all 15 bi-weekly sampling periods between 16 April and 13 November 1983, and YOY rainbow trout were found during the 11 bi-weekly sampling periods between 12 June and 13 November 1983. Young-of-the-year brown trout reached greatest abundance during the 12-14 June sampling period when 328 were captured (Figure 8). Abundance of YOY rainbow trout peaked during the 25-27 June sampling period when 673 were captured. Numbers of both species declined from respective maximums until late July. Thereafter, numbers of captured YOY brown trout remained between 9 and 17% of their highest level while YOY rainbow trout numbers fluctuated between 22 and 52% of their greatest level.

Approximately 80% of 1,480 YOY brown trout and 61% of 2,879 YOY rainbow trout were captured in the seven sampling stations along the east bank of the Missouri

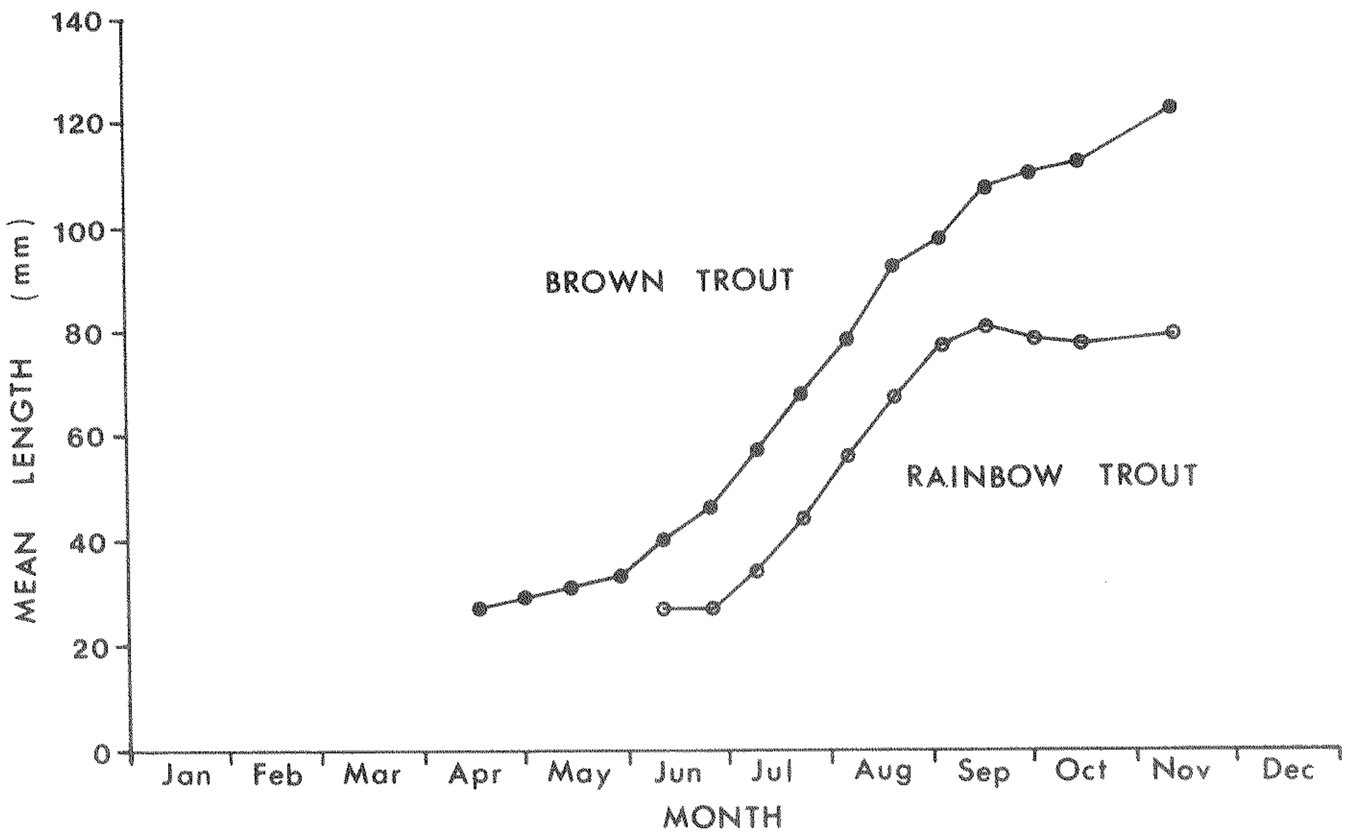

Figure 7. Mean lengths of YOY brown trout and rainbow trout captured by electrofishing on selected sampling dates in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

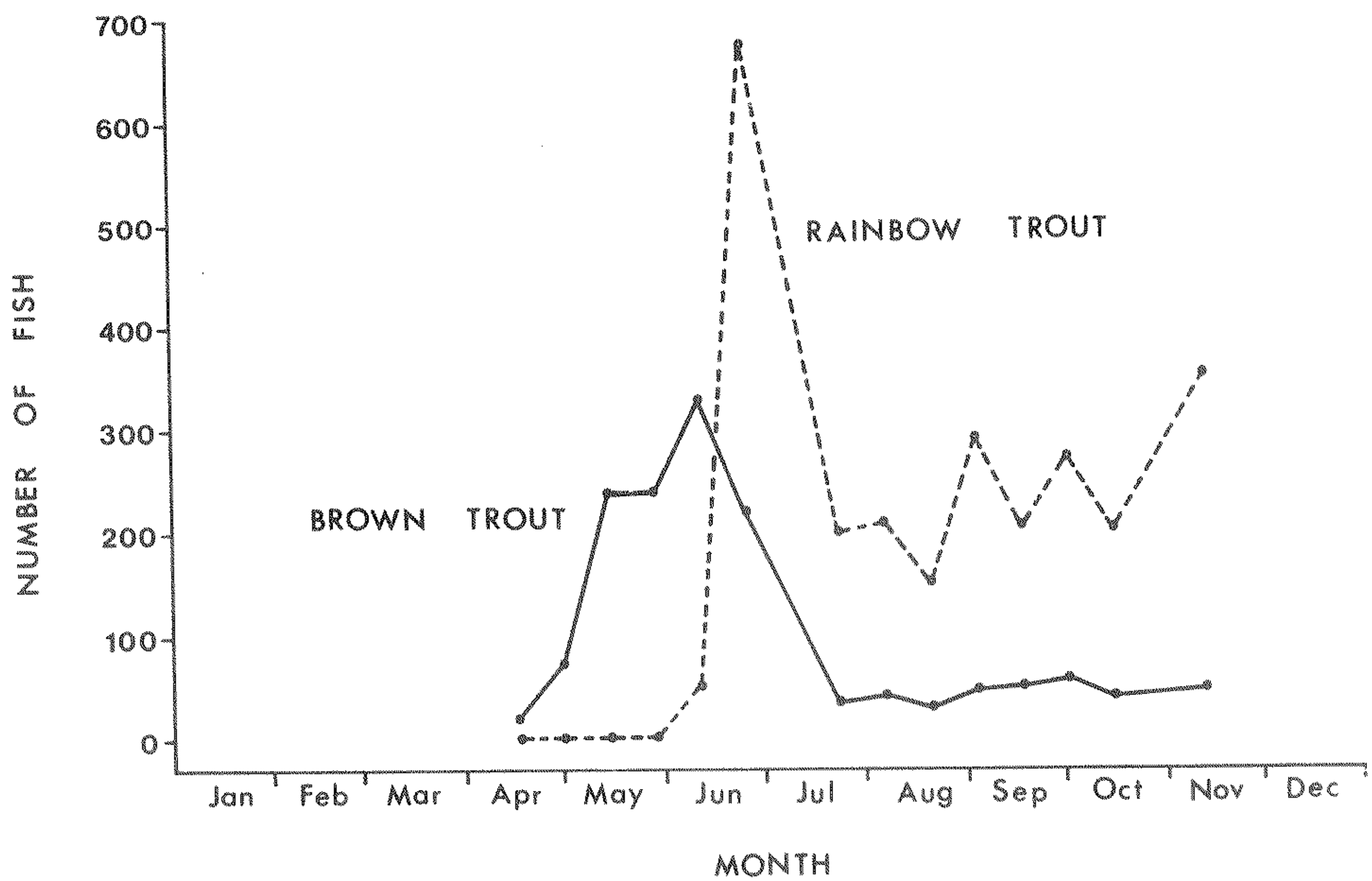

Figure 8. Numbers of YOY brown trout and rainbow trout captured by electrofishing during 14 sampling periods in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

River. Spoon (1985) observed that in 1982 and 1983 most brown trout and rainbow trout spawning activity in the Missouri River between Hauser Dam and Holter Reservoir occurred in four areas along the east side of the river. Numbers of YOY brown trout captured in the seven east-bank sampling stations were significantly greater than numbers captured in the seven west-bank sampling stations from April through June and also in late August (Table 9). Numbers of YOY rainbow trout captured in the seven east-bank sampling stations were significantly greater than numbers captured in the seven west-bank sampling stations from June through early October (Table 10).

Movement, 1983

Between 12 June and 13 November 1983, 436 YOY brown trout were marked (243 in the Upper Section and 193 in the Middle Section). Between 25 June and 13 November, 1,226 YOY rainbow trout were marked (932 in the Upper Section and 294 in the Middle Section).

Recaptures of marked fish outside of original marking sections were too few to draw any conclusions about upstream or downstream movements (Table 11). Only six marked YOY brown trout were recaptured downstream and two were recaptured upstream from original marking sections. One marked YOY rainbow trout was recaptured downstream and none were recaptured upstream. Recaptures of marked YOY

Table 9. Distribution of YOY brown trout captured by electrofishing in shallow-water areas along the banks of the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Period	Number Captured	Distribution (%) East	Distribution (%) West
April 16-17[a]	20	100*	0
April 30 - May 1	73	96*	4
May 14-15	238	88*	12
May 28-29	239	90*	10
June 12-14	328	85*	15
June 25-27	219	84*	16
July 9-12[b]	20	55	45
July 23-24	34	62	38
August 6-7	41	51	49
August 20-21	29	83*	17
September 3-4	46	61	39
September 17-18	50	60	40
October 1-2	57	58	42
October 15-16	39	49	51
November 12-13	47	49	51

[a]Stations 7 and 14 were not sampled as they were not yet established

[b]Stations 1, 4, 8, and 11 were not sampled due to high water

*Indicates a significant difference (Chi-square @ .05)

Table 10. Distribution of YOY rainbow trout captured by electrofishing in shallow-water areas along the banks of the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Period	Number Captured	Distribution (%) East	Distribution (%) West
June 12-14	50	76*	24
June 25-27	673	68*	32
July 9-12[a]	279	62*	38
July 23-24	199	64*	36
August 6-7	209	57*	43
August 20-21	150	61*	39
September 3-4	290	63*	37
September 17-18	205	66*	34
October 1-2	271	58*	42
October 15-16	202	56	44
November 12-13	351	45	55

[a]Stations 1, 4, 8, and 11 were not sampled due to high water

*Indicates a significant difference (Chi-square @ .05)

Table 11. Movement of marked YOY brown trout and rainbow trout in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

	Upper Section[a]			Middle Section[b]			Lower Section[c]		
		Recaptures From:			Recaptures From:			Recaptures From:	
Species	Number Marked	Upper Section	Middle Section	Number Marked	Upper Section	Middle Section	Number Captured	Upper Section	Middle Section
Brown Trout	243	49	2	193	2	31	194	3	1
Rainbow Trout	932	195	0	294	0	61	381	0	1

[a]Sampling Stations 1, 2, 8, 9, 10, 11

[b]Sampling Stations 3, 4, 12, 13

[c]Sampling Stations 5, 6, 7, 14

brown trout within original marking sections were 20 and 16% of those marked in the Upper and Middle Sections, respectively (Table 11). Comparable figures for YOY rainbow trout are 21 and 21% in the Upper and Middle Sections, respectively (Table 11).

Habitat, 1982

From April through October 1982, 387 YOY brown trout and 1,460 YOY rainbow trout were captured (Figure 9). Physical habitat measurements and visual estimates of dominant substrate type and cover components recorded at capture sites were grouped by species for the entire sampling period. Grouping the data allowed for a general comparison of habitat used by each species and appeared to be an appropriate way to relate the data to potential impacts of hydroelectric peaking.

Young-of-the-year brown trout and rainbow trout occupied similar habitat in the Missouri River study area. For each species, about 80% were captured in water depths less than 50 cm and where mean water velocities were less than 10 cm/sec (Figure 10). Approximately 88 and 80% of YOY brown trout and rainbow trout, respectively, were caught within 2 m of shore (Figure 11). Seventy and 53% of YOY brown trout and rainbow trout, respectively, were captured over substrate dominated by fines or boulders (Figure 11); these areas almost always coincided with

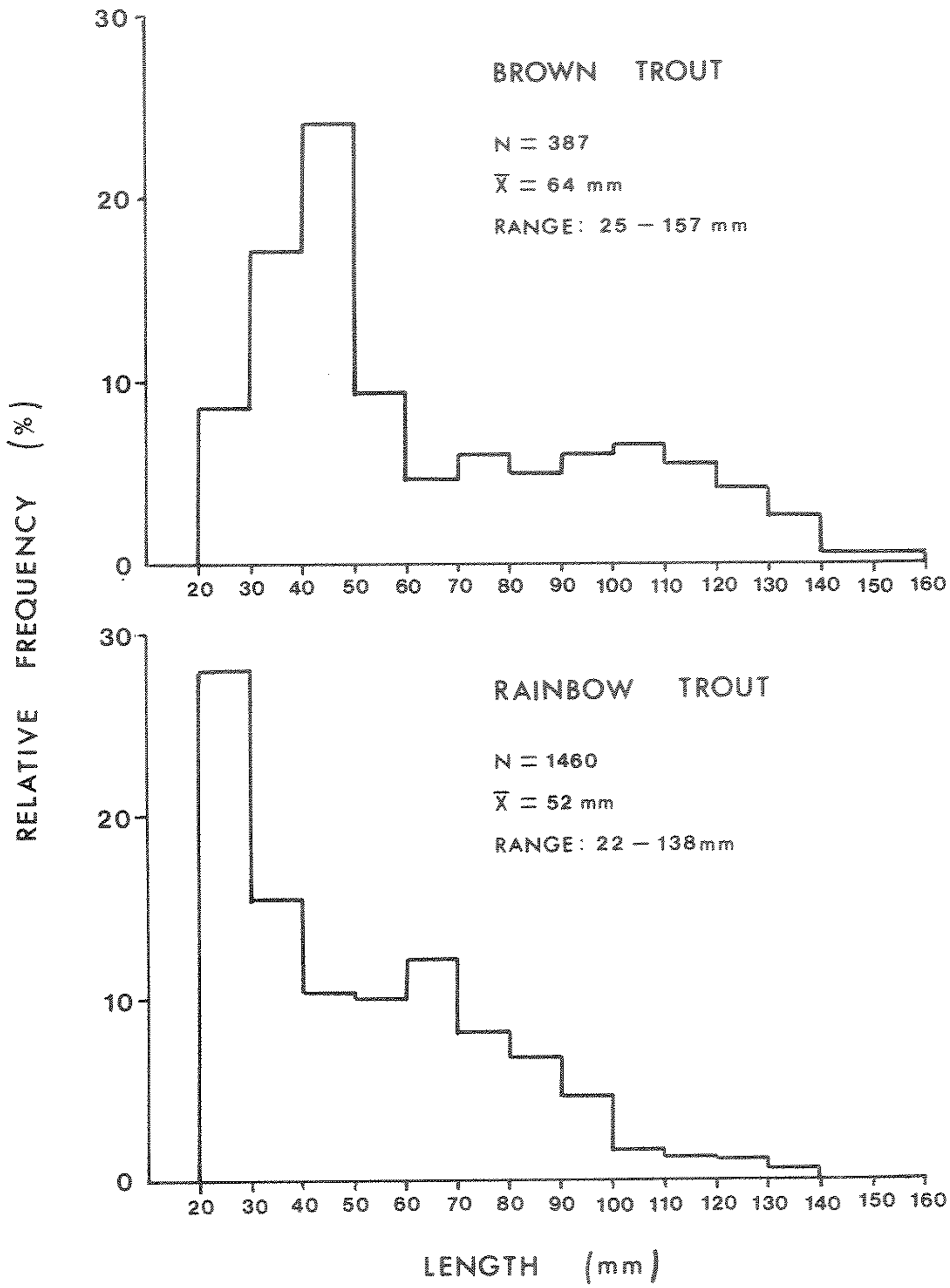

Figure 9. Length frequencies of YOY brown trout and rainbow trout captured by electrofishing in the Missouri River between Hauser Dam and Holter Reservoir, April-October, 1982.

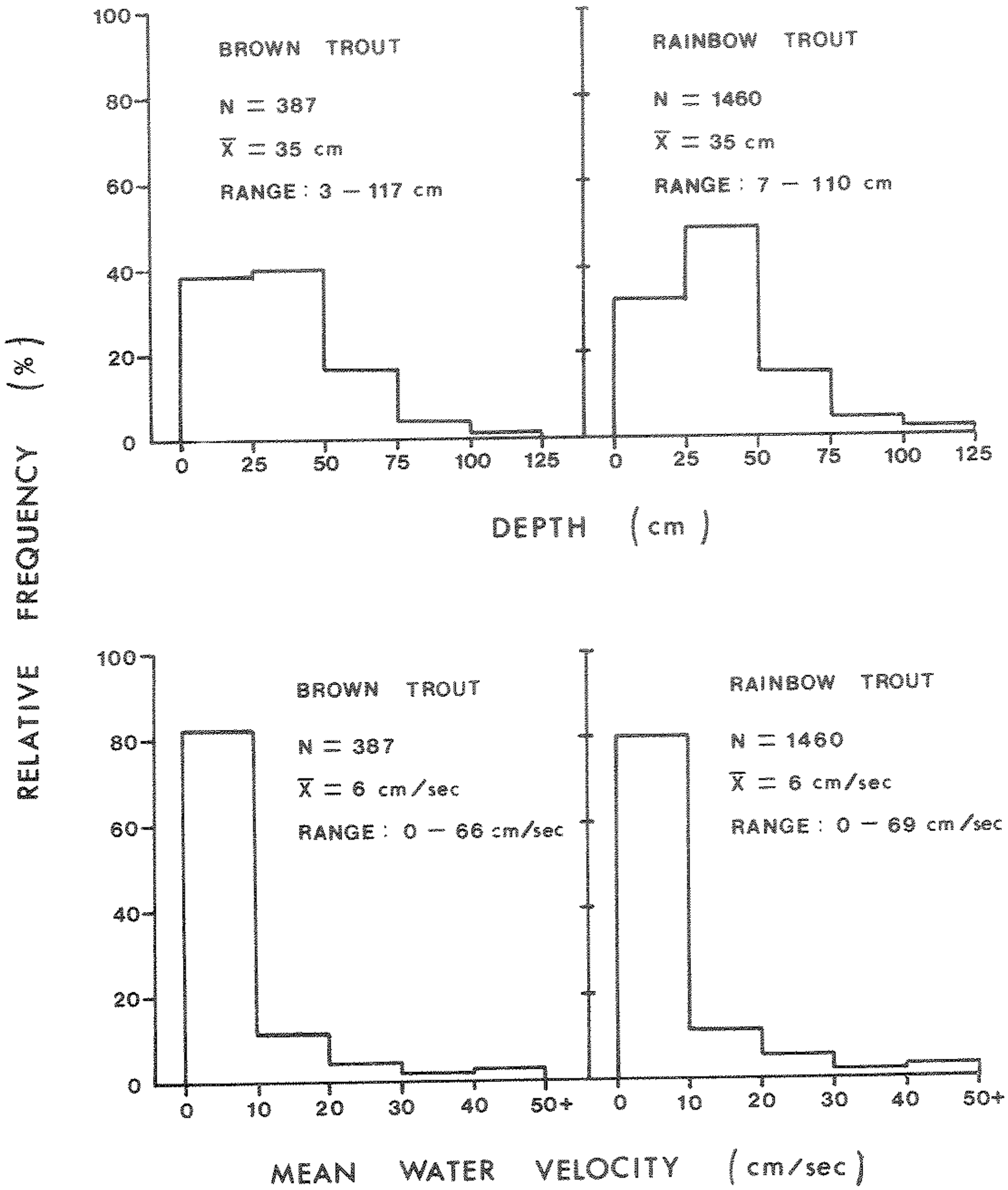

Figure 10. Distribution, by depth and mean water velocity, of YOY brown trout and rainbow trout captured by electrofishing in the Missouri River between Hauser Dam and Holter Reservoir, April-October, 1982.

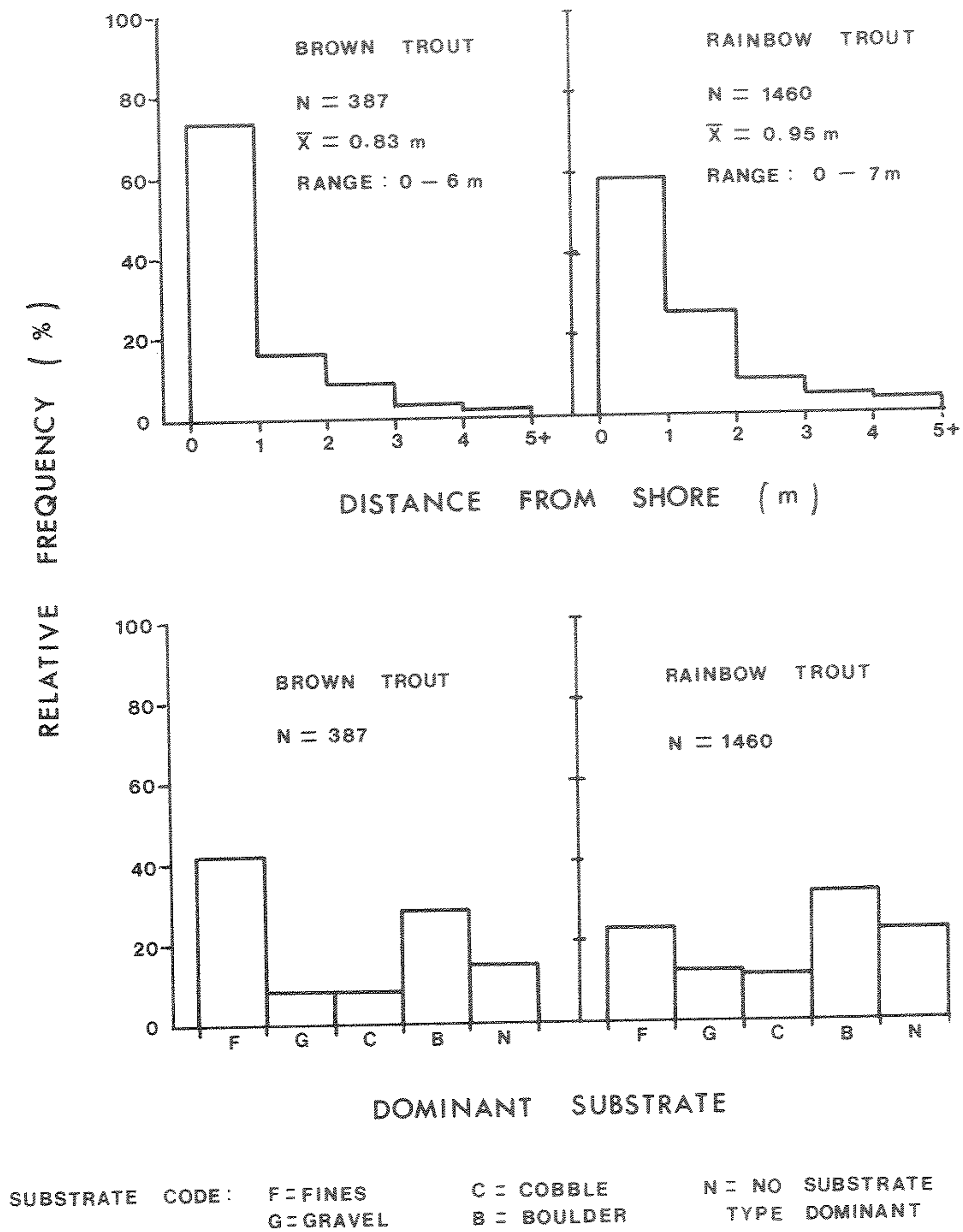

Figure 11. Distribution, by distance to shore and dominant substrate type, of YOY brown trout rainbow trout captured by electrofishing in the Missouri River between Hauser Dam and Holter Reservoir, April-October, 1982.

areas of low mean water velocity. Groups of boulders also appeared to serve as cover.

One or more cover components such as rock cover, submerged vegetation, woody organic debris, undercut bank, or overhanging vegetation were present at 99% of YOY brown trout and rainbow trout capture sites. For each species, 35-40% were captured at sites with one cover component. Approximately 25% were captured at sites with two cover components and at sites with three cover components. Four cover components were observed at 9-12% of capture sites while five cover components were found at less than 4% of these sites (lower portions of Figures 12 and 13). Rock cover, submerged vegetation, and overhanging vegetation entirely or partially comprised those cover types most frequently observed at all capture sites, regardless of the number of cover components present (upper portions of Figures 12 and 13).

Reduced-Flow Test, 17 August 1982

Data collected from 12, 1-m wide transects established over the four areas sampled (Figure 6) showed no stranding of YOY trout on dewatered substrate (Table 12). Although a few YOY trout were observed stranded in areas outside transect boundaries, the extent of fish dewatering appeared to be insignificant. Electrofishing about 1 week prior to the reduced-flow test

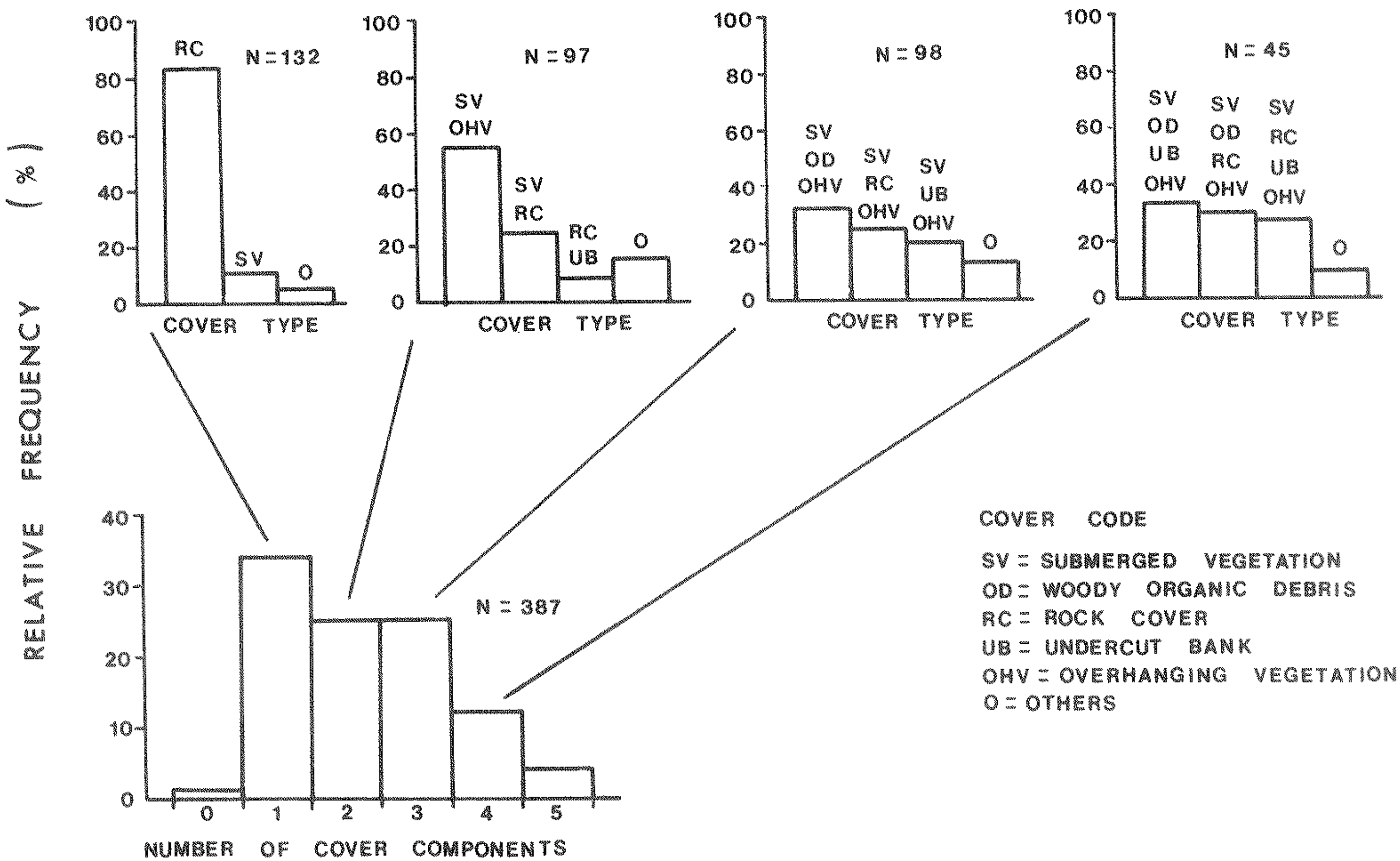

Figure 12. Distribution, by number of cover components and cover type, of YOY brown trout captured by electrofishing in the Missouri River between Hauser Dam and Holter Reservoir, April-October, 1982.

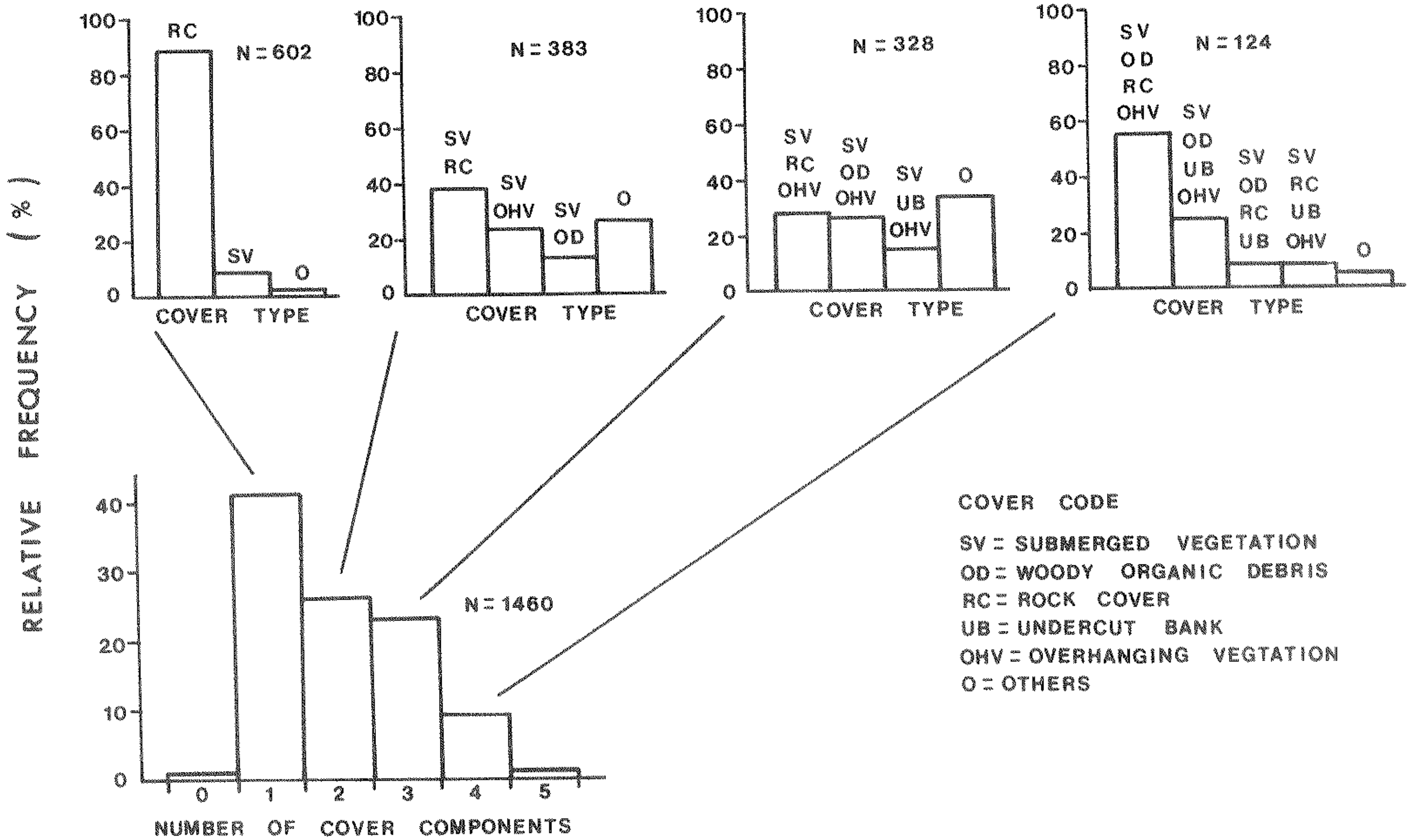

Figure 13. Distribution, by number of cover components and cover type, of YOY rainbow trout captured by electrofishing in the Missouri River between Hauser Dam and Holter Reservoir, April-October, 1982.

Table 12. Number of fish observed stranded, by area and species, during the 17 August 1982 reduced-flow test on the Missouri River between Hauser Dam and Holter Reservoir.

Area No. (Area Dewatered)	Transect	Area of Transect (m^2)	Number Stranded		
			Trout	Sculpin	Sucker
1	A	26	0	15	2
	B	13	0	3	0
(0.60 ha)	C	22	0	13	0
2	D	19	0	0	0
	E	25	0	0	0
	F	32	0	3	0
(0.31 ha)	G	10	0	3	0
	H	20	0	0	0
	I	13	0	0	0
3 (0.72 ha)	J	25	0	3	0
4	K	35	0	8	0
(0.24 ha)	L	40	0	3	0

revealed mean total lengths of YOY brown trout and rainbow trout to be 76 (n=100) and 56 mm (n=490), respectively.

Mottled sculpin were stranded in relatively large numbers, particularly in Area 1 where beds of aquatic vegetation were extensively dewatered (Table 12). Expanding the number of sculpin stranded to the total area dewatered provides an estimate of the magnitude of possible mortality. The estimated loss of sculpin in sampling areas 1 through 4, respectively , was 3,050, 157, 862, and 346.

Two pools were isolated from the main river channel at minimum flow. Pool A was located in Area 1 and Pool B in Area 2. Examination of these pools revealed that they contained live trout, sculpin, and suckers (Table 13). The number of isloated fish observed is conservative due to difficulties in the capturing process, but it did not appear to be extensive.

Reduced-Flow Test, 4 August 1983

The displacement of YOY brown trout and rainbow trout from occupied habitat was evaluated by comparing the number found in Sampling Stations 1, 2, 4, and 10 (Figure 6) during three sampling periods with differing discharges (Table 14). The first sampling period, 23-24 July, occurred prior to flow reduction and the second, on 4 August, occurred during flow reduction. The third

Table 13. Number of fish observed isolated in pools, by area and species, during the 17 August 1982 reduced-flow test on the Missouri River between Hauser Dam and Holter Reservoir.

Area No.	Pool	Surface Area of Pool (m^2)	Number Isolated		
			Trout	Sculpin	Sucker
1	A	135	2	Numerous	3
2	B	5	3	14	0

Table 14. Number of YOY trout (brown trout and rainbow trout combined) observed at four sampling stations during three sampling periods in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Period	Mean Discharge (m^3/sec)	Number of YOY Trout Observed at Station				
		1	2	4	10	Total
July 23 to 24	142	28	35	54	44	161
August 4[a]		9	1	29	7	46
August 6 to 7	153	20	39	69	33	161

[a]Reduced Flow Test: Station 1 sampled at 81 m^3/sec
Stations 2, 10 sampled at 67 m^3/sec
Station 4 sampled at 55 m^3/sec

sampling period, 6-7 August, took place after flow was returned to pre-reduction levels. Species responses were similar so species were combined to provide a larger sample size.

The number of trout observed at each station at reduced discharges on 4 August declined from the number found at 142 m^3/sec on 23-24 July. Decreases ranged from 46% (54 to 29) at Station 4 to 97% (35 to 1) at Station 2. Abundance dropped 71% (161 to 46) when data from all four stations were combined.

On 6-7 August, when discharge was approximately 153 m^3/sec, the number of YOY trout captured at each station was similar to pre-flow reduction levels. Abundance over all four stations was identical to that observed on 23-24 July (161 and 161), suggesting that YOY trout were not permanently displaced from temporarily dewatered habitat. Their true distribution at reduced discharges is unknown.

Changes in habitat were examined by comparing habitat data collected in Stations 1, 2, 4, and 10 for the period 29 June-2 July to data obtained from these areas on 4 August (Table 15). The first sampling period took place before flow reduction while the second period occurred during flow reduction. At each station, area dewatered was determined and mean water depth and mean water velocity profiles were obtained. Also, differences in visual

Table 15. Discharge, change in discharge, and area dewatered for four sampling stations during two sampling periods (29 June-2 July *vs.* 4 August) in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Station	Sampling Date	Discharge (m^3/sec)	Change in Discharge (high-low)	Area Dewatered (m^2)
1[a]	June 29	268	187	499
	August 4	81		
2[b]	July 1	300	233	402
	August 4	67		
4[c]	July 2	300	244	142
	August 4	55		
10[d]	June 30	277	211	956
	August 4	67		

[a]Station 1 was located along the east bank of the river and was 1.1 km downstream of the dam.

[b]Station 2 was located along the east bank of the river and was 2.6 km downstream of the dam.

[c]Station 4 was located along the east bank of the river and was 4.0 km downstream of the dam.

[d]Station 10 was located along the west bank of the river and was 2.4 km downstream of the dam.

estimates of substrate and cover were recorded.

Area dewatered decreased as downstream distance from the dam increased, probably due to the moderating influence of Holter Reservoir (Table 15). Stations 1, 2, and 4, located on the east bank of the river, were 1.1, 2.6, and 4.0 km downstream from the dam, respectively, and had similar channel morphology. Area dewatered was least at Station 4, though the difference between high and low discharge was greatest. Likewise, discharge difference was greater at Station 2 than 1, but the area dewatered was less.

When downstream distance from the dam was about equal, area dewatered was most affected by channel morphology (Table 15). Stations 2 and 10 were, respectively, 2.6 and 2.4 km downstream of the dam, but located on opposite banks of the river. Greater area was dewatered in Station 10 due to its gradually descending bottom contour even though the difference between high and low discharge was less.

Mean water depth decreased at each station when flows were reduced (Figure 14). Declines were greatest in Station 4 and least in Station 2, dropping an average of 33 and 3 cm, respectively, at each 0.5 m interval into the channel. Average decrease at Station 1 at each interval was 30 cm while at Station 10 it was 10 cm.

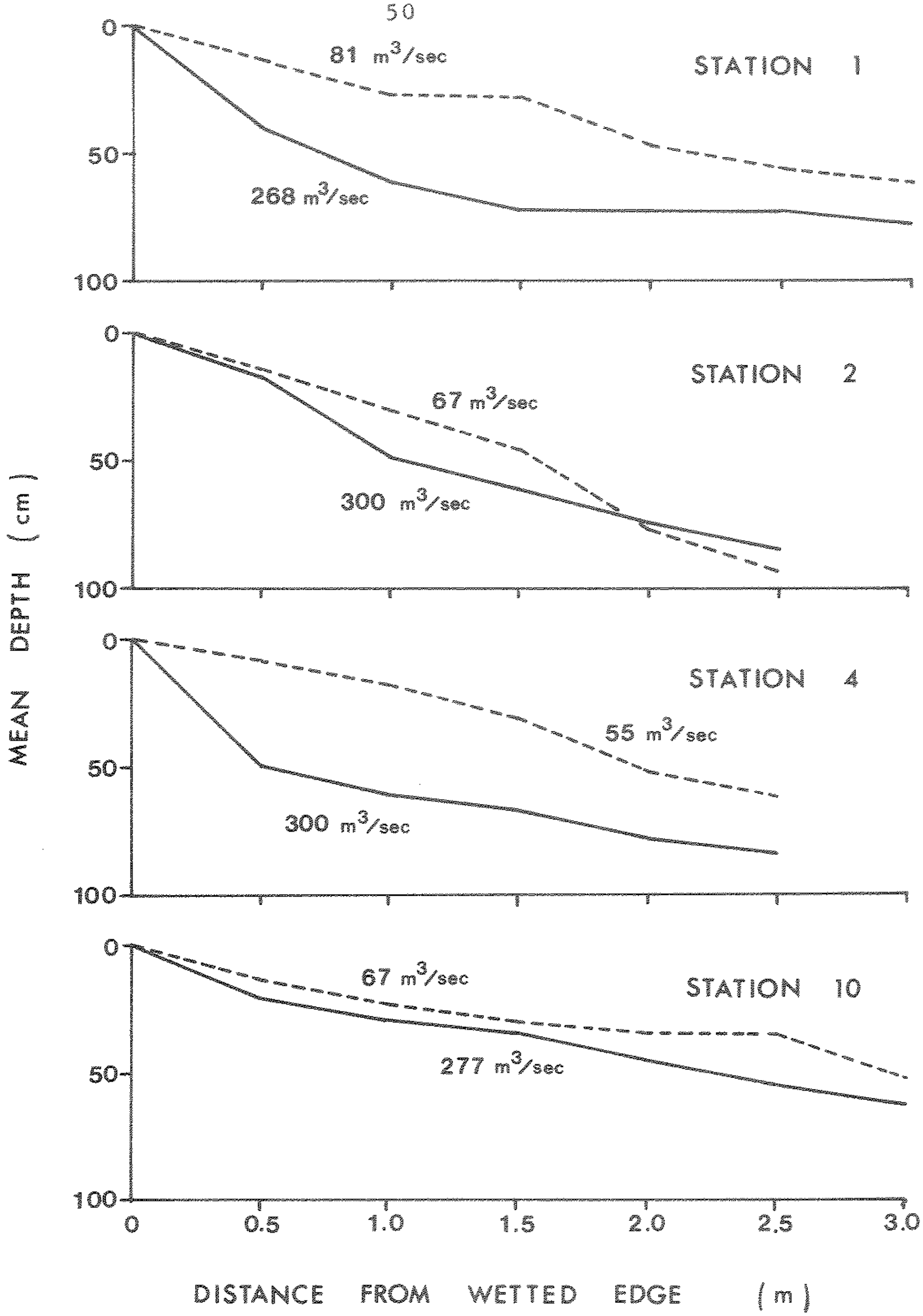

Figure 14. Water depth profiles of four sampling stations at different discharges in the Missouri River between Hauser Dam and Holter Reservoir, 29 June-2 July vs. 4 August 1983.

Mean water velocity declined in three stations but increased in the fourth at low discharges (Figure 15). Decreases averaged 24, 11, and 7 cm/sec at each 0.5 m interval into the channel at Stations 1, 4, and 2, respectively. At Station 10, mean water velocity rose an average of 2 cm/sec at each interval.

Cover differences were notable between high and low discharges. At high discharges, submerged vegetation, rock cover, and overhanging vegetation were observed at each station; undercut bank was also found at Station 4. At low discharges, rock cover was the only cover component remaining.

Substrate differences were minor at high and low discharges. At high discharge, substrate at Stations 1 and 4 was dominated by fines and boulder, at Station 2 by fines and cobble, and at Station 10 by boulder. At low discharges, boulder was the dominant substrate at Stations 1, 2, and 4 while boulder and cobble dominated at Station 10.

Habitat use by YOY brown trout and rainbow trout was evaluated by comparing habitat parameters measured or estimated at capture sites in Sampling Stations 1, 2, 4, and 10 during selected periods of normal seasonal flows (29 June-2 July, 26-29 July, and 23-25 August) to habitat-use data collected in these areas during reduced flows on 4 August. Discharge during the former three periods

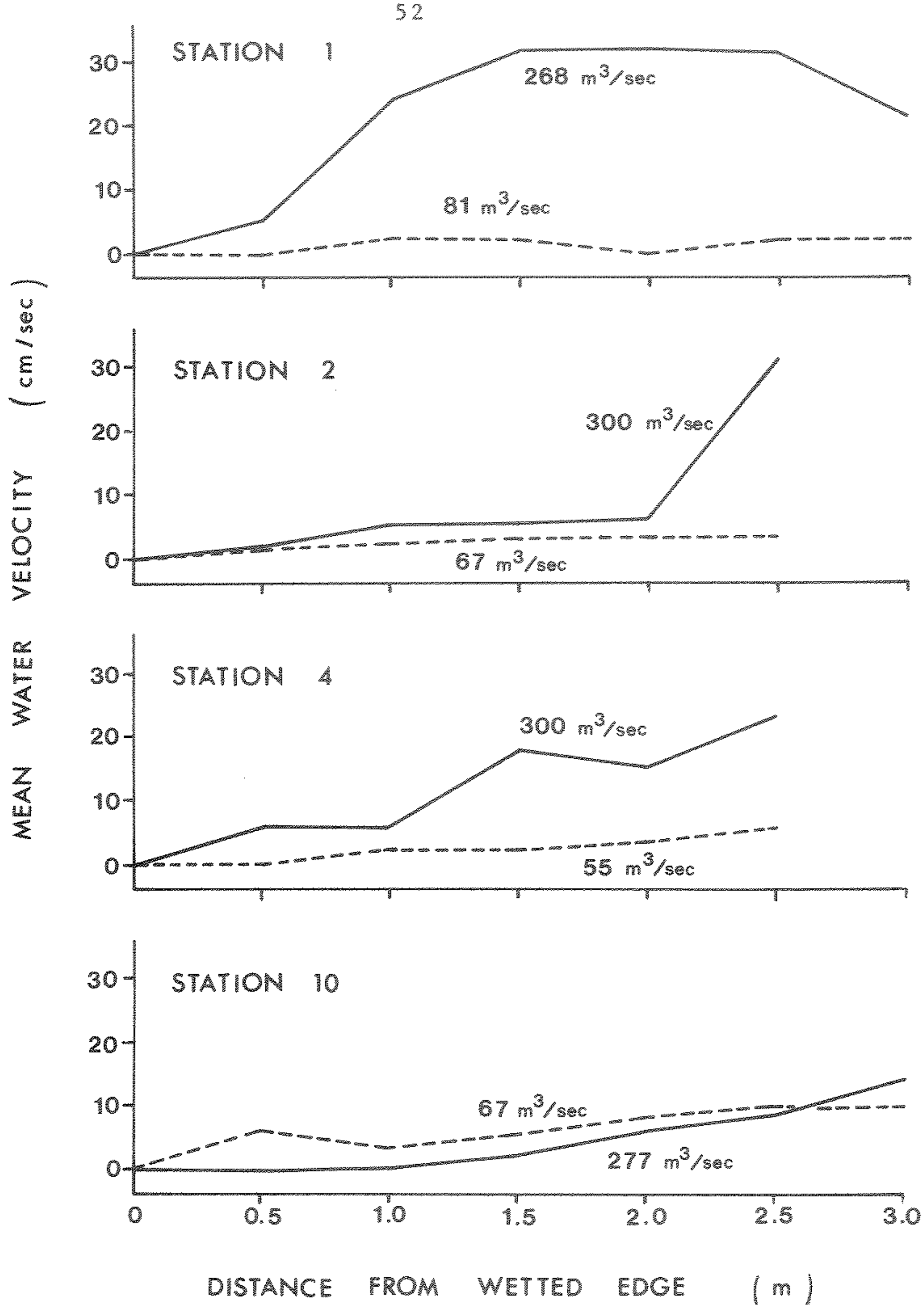

Figure 15. Mean water velocity profiles of four sampling stations at different discharges in the Missouri River between Hauser Dam and Holter Reservoir, 29 June-2 July vs. 4 August 1983.

averaged 196 m^3/sec and ranged from 142-300 m^3/sec. Discharge on 4 August averaged 67 m^3/sec and ranged from 55-81 m^3/sec. Biases inherent in this comparison are nonrepresentative sampling of YOY trout habitat at reduced discharges on 4 August as well as small sample sizes.

For each species, means and ranges of water depth, mean water velocity, and distance to shore measurements obtained at capture sites were similar between normal seasonal and reduced discharges (Tables 16 and 17). At normal seasonal discharges, YOY brown trout and rainbow trout were most often associated with cover components such as rock cover, submerged vegetation, and overhanging vegetation (either singly or in combination) and were found most frequently over substrate dominated by fines, cobble or boulder. During reduced discharges on 4 August, each species was most frequently associated with rock cover and most often captured over substrate dominated by boulder.

Physical Habitat Simulation, 1982

Probability-of-use curves (Figure 16) were developed from depth and velocity measurements made at YOY brown trout and rainbow trout capture sites. According to the fitted curves, optimum depths and velocity for YOY brown trout were 27-34 cm and 0.0 cm/sec, respectively. Similarly, optimum depths and velocity for YOY rainbow

Table 16. Means and ranges of fish length and habitat parameters for YOY brown trout captured by electrofishing during selected periods of normal seasonal discharges (29 June-2 July, 26-29 July and 23-25 August) and reduced discharges (4 August) in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

	Normal Seasonal Discharges[a] (N = 43)		Reduced Discharges[b] (N = 13)	
Parameter	Mean	Range	Mean	Range
Fish Length (mm)	71	46 - 114	81	69 - 94
Water Depth (cm)	43	18 - 64	37	15 - 52
Mean Water Velocity (cm/sec)	8	0 - 34	3	0 - 8
Distance to Shore (m)	1.07	.06 - 3.69	1.16	.46 - 1.92

[a]Mean discharge = 196 m^3/sec
Range = 142 to 300 m^3/sec

[b]Mean discharge = 67 m^3/sec
Range = 55 to 81 m^3/sec

Table 17. Means and ranges of fish length and habitat parameters for YOY rainbow trout captured by electrofishing during selected periods of normal seasonal discharges (29 June-2 July, 26-29 July and 23-25 August) and reduced discharges (4 August) in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

	Normal Seasonal Discharges[a] (N = 95)		Reduced Discharges[b] (N = 16)	
Parameter	Mean	Range	Mean	Range
Fish Length (mm)	48	23 - 91	61	46 - 71
Water Depth (cm)	31	9 - 64	31	9 - 76
Mean Water Velocity (cm/sec)	5	0 - 46	6	0 - 37
Distance to Shore (m)	.96	0[c] - 4.21	1.19	.24 - 4.4

[a]Mean discharge = 196 m^3/sec
Range = 142 to 300 m^3/sec

[b]Mean discharge = 67 m^3/sec
Range = 55 to 81 m^3/sec

[c]Captured under an undercut bank

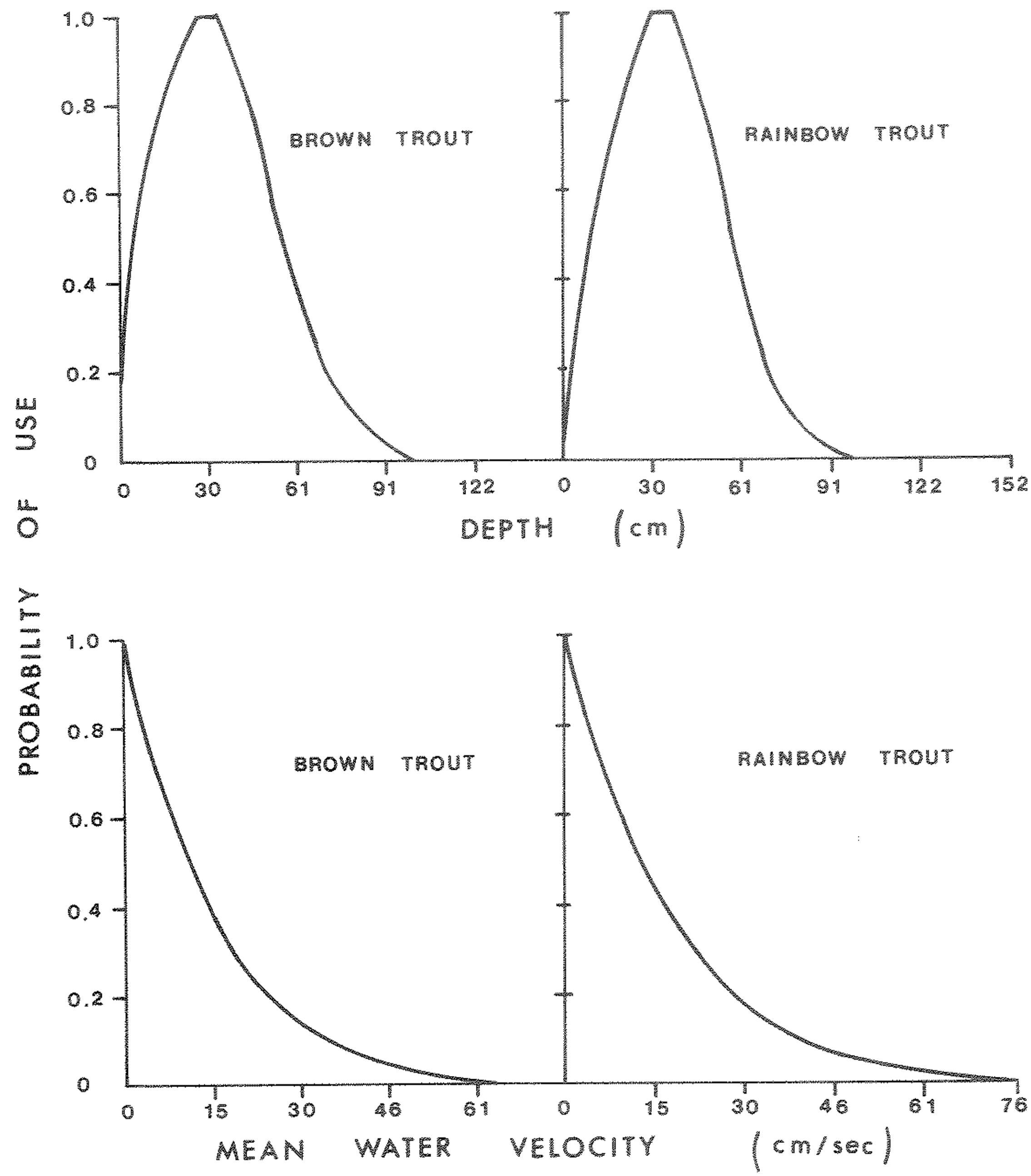

Figure 16. Probability-of-use curves for YOY brown trout and rainbow trout in the Missouri River between Hauser Dam and Holter Reservoir, 1982.

trout were, respectively, 31-37 cm and 0.0 cm/sec. The probability-of-use curves were used in the PHABSIM model to predict the quantity of usable rearing habitat at various discharges.

At Transect Set 1 the PHABSIM model predicted decreasing YOY trout habitat as discharge increased from 28 to 269 m^3/sec (Figure 17). Maximum habitat for YOY brown trout was predicted to occur at 37 m^3/sec and at 28 m^3/sec for YOY rainbow trout. According to the model, habitat became virtually unavailable at discharges between 227 and 255 m^3/sec.

At Transect Set 2 the model predicted, in general, a decrease in YOY trout habitat as discharge increased from 28 to 269 m^3/sec (Figure 18). Maximum habitat for YOY trout of both species was at 28 m^3/sec with secondary peaks at 68 m^3/sec. Within the range of flows predicted, habitat reached a minimum at about 269 m^3/sec for both species.

The secondary peak in habitat generated by the model for Transect Set 2 is related to a cobble-boulder bar located near midstream in this section of river. At discharges at or below 43 m^3/sec, this bar is dewatered and unusable as fish habitat. However, at discharges between 43 and 68 m^3/sec, the cobble-boulder bar becomes partially to wholly submerged and, according to the model, becomes usable as habitat. At discharges greater than

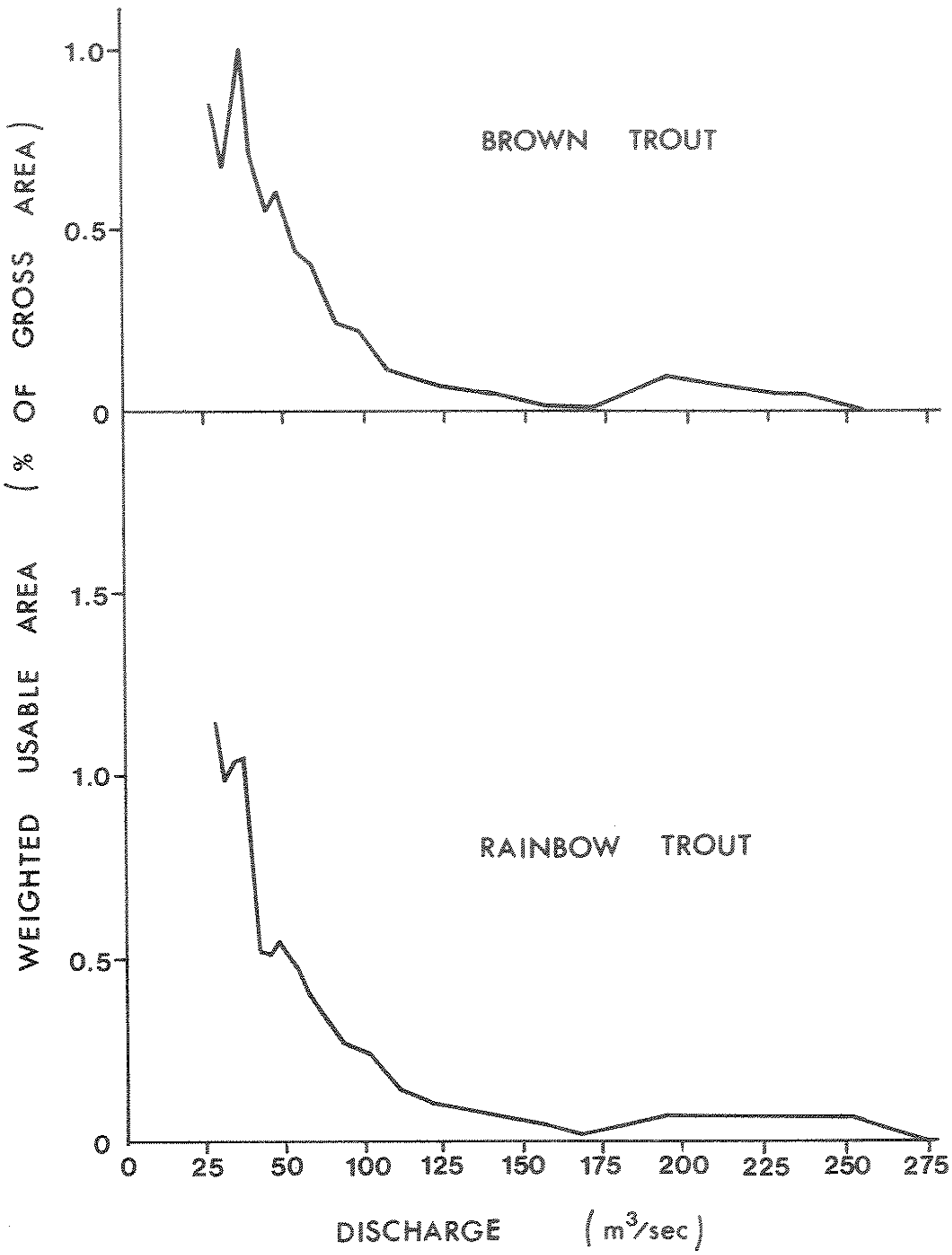

Figure 17. Young-of-the-year brown trout and rainbow trout habitat at different discharges as predicted by the PHABSIM model, Transect Set No. 1, in the Missouri River between Hauser Dam and Holter Reservoir, 1982.

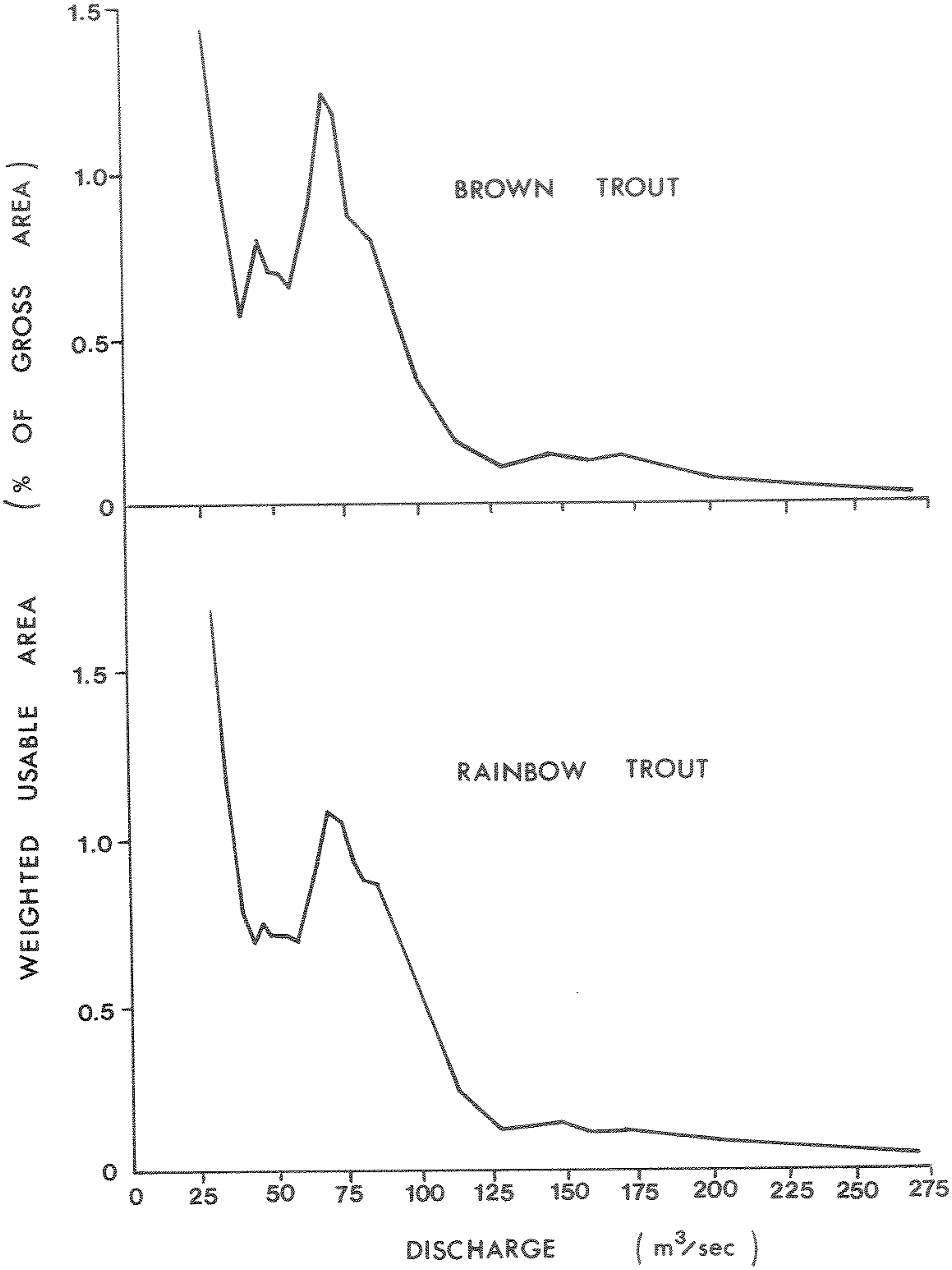

Figure 18. Young-of-the-year brown trout and rainbow trout habitat at different discharges as predicted by the PHABSIM model, Transect Set No. 2, in the Missouri River between Hauser Dam and Holter Reservoir, 1982.

68 m^3/sec, depths and velocities apparently exceed the limits tolerated by YOY trout and habitat declines.

Beaver Creek

Trout captured in the hoop and drift nets between 19 June and 27 August 1983 were assumed to be migrating from Beaver Creek into the Missouri River. Ninety nine percent of 6,742 trout captured were rainbow trout while the remainder was comprised of cutthroat trout, brown trout, and brook trout. Of 6,693 rainbow trout captured, 93% were classified in the field by length at date of capture as young-of-the-year and 7% as age I and older (Table 18).

Mean total lengths of respective rainbow trout age groups, based on a subsample of 2,130 fish, were 31 mm for YOY fish and 91 mm for age I and older. Mean total lengths of captured brown trout and cutthroat trout were, respectively, 61 and 163 mm. The brook trout was 134 mm TL.

Age I and older rainbow trout were emigrating when the nets were installed on 19 June and virtually ceased emigrating by the end of July. Young-of-the-year rainbow trout were first captured on 30 June. Downstream migration of YOY rainbow trout appeared to be nearing completion when the nets were removed on 27 August (Figure 19).

Table 18. Catch statistics for trout emigrating from Beaver Creek into the Missouri River between Hauser Dam and Holter Reservoir, 1983.

	Number of Each Age Group Captured	
Species	YOY	Age I and Older
Rainbow Trout	6,254	439
Brown Trout	14	1
Cutthroat Trout	0	33
Brook Trout	0	1

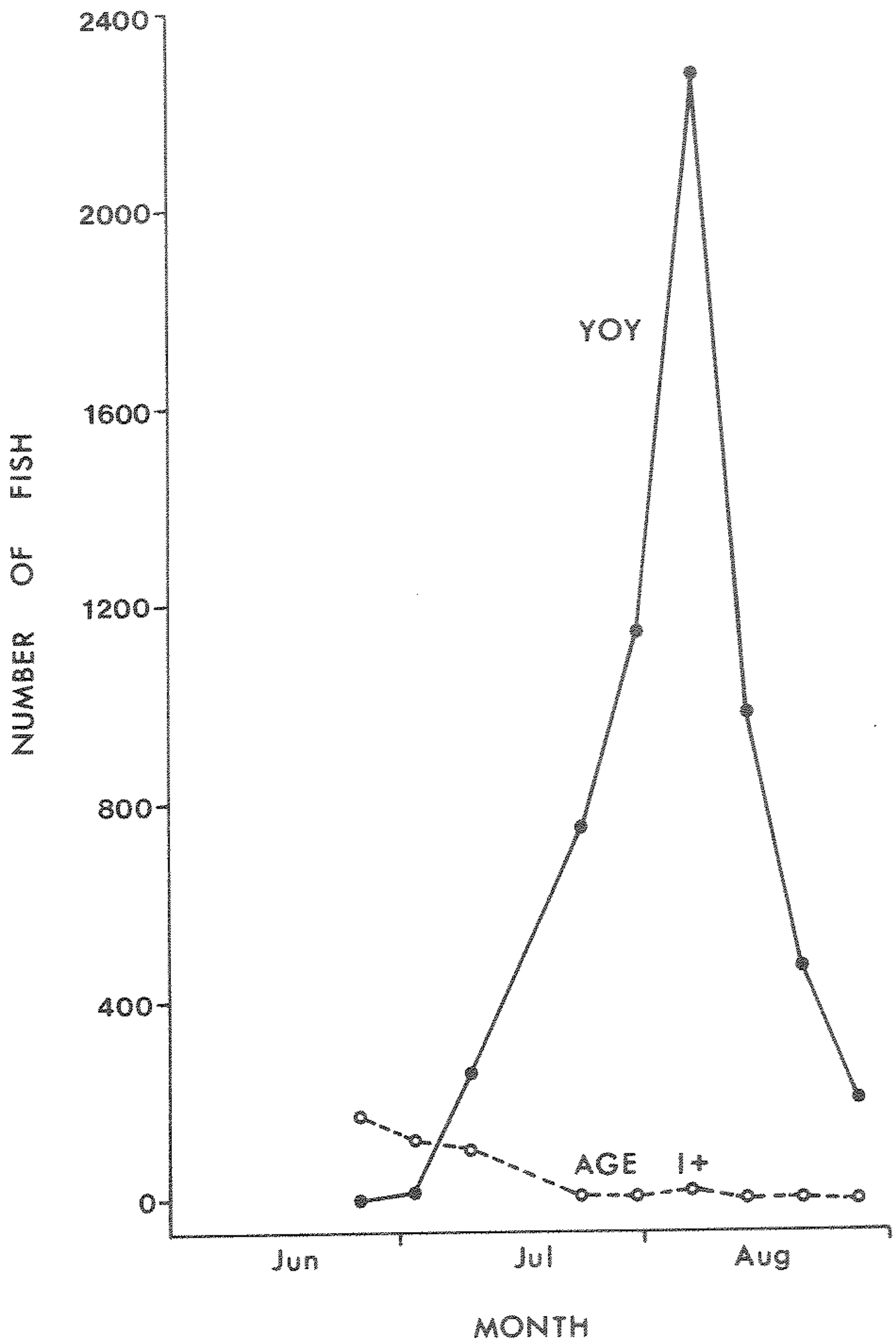

Figure 19. Weekly counts of rainbow trout emigrants from Beaver Creek into the Missouri River, June-August, 1983.

DISCUSSION

Potential impacts of fluctuating flows due to hydroelectric power peaking on YOY brown trout and rainbow trout in the Missouri River between Hauser Dam and Holter Reservoir include stranding on dewatered substrate, isolation in pools, displacement from occupied habitat, interference with the establishment and maintenance of territories, reduced growth rates due to increased energy expenditure and possible reduction of the food supply, and increased exposure to predation. These impacts may be influenced by stage of development, daily and seasonal abundance and distribution, quantity and quality of habitat, magnitude and rate of flow change, and number and time of daily fluctuation. The portion of each year class of each species which migrates downstream to rear in Holter Reservoir or is recruited from an unimpacted area, e.g. a tributary, may also affect the overall impact of a fluctuating flow regime on the adult population.

Stranding of YOY trout on dewatered substrate may represent a serious negative impact, since these fish occupy areas which would be periodically dewatered by fluctuating flows. In 1982 and 1983 both species selected relatively shallow, low water velocity areas near shore with abundant cover and substrate dominated by fines or boulders (Figures 10, 11, 12, and 13)(Tables 16 and 17). Although sampling the entire width of the river channel was not possible, a high degree of use of shoreline areas by YOY brown trout and rainbow trout has been reported in this and other relatively large rivers (Lindroth 1956; Gosse and Helm 1979; Berg 1981; Sando 1981).

Young-of-the-year trout may be most vulnerable to stranding during the first few weeks of post-emergent life, primarily due to their small size. Hamilton and Buell (1976) stated that stranding could be particularly critical during the first 3 months following emergence. Observed dates of emergence in the Missouri River study area indicated that this would encompass April through June for YOY brown trout and June through August for YOY rainbow trout. Mean total lengths of brown trout ranged from 26-46 mm during the former period and those for YOY rainbow trout ranged from 27-67 mm during the latter.

Aside from my observations during reduced-flow tests in the Missouri River below Hauser Dam in August of 1982 (Table 12) and 1983, I know of no available data to test Hamilton and Buell's (1976) contention with regard to YOY brown trout and rainbow trout under flow regimes similar to those tested at Hauser Dam. However, stranding of recently emerged anadromous salmonids during hydroelectric peaking (Bauersfeld 1977) and experimental flow reductions

(Phinney 1974; Bauersfeld 1978) is well documented.

Stranding losses of newly emerged YOY trout could be reduced if emergence and/or periods of greatest abundance occurred during the period of spring runoff. Bauersfeld (1977) reported that flow fluctuations due to hydroelectric peaking were uncommon below Dalles and Bonneville Dams during spring runoff and areas susceptible to dewatering were often flooded when chinook salmon fry were present. In the Missouri River at Hauser Dam, spring runoff usually commences in early June and continues through July. Though YOY brown trout began emergence in April, they did not reach greatest abundance in sampling areas until mid-June (Figure 8). Emergence of YOY rainbow trout began in early June and greatest numbers were observed late the same month (Figure 8). It is not known how spring runoff would affect peaking operations at Hauser Dam, but stranding mortality should be reduced if fluctuating flows did not occur during this time.

Stranding losses following spring runoff may be reduced by an apparent increase in the ability of YOY trout to adjust to receding water levels. Virtually no stranding of YOY trout occurred during the 17 August 1982 reduced-flow test (Table 12). Mean total lengths of YOY brown trout and rainbow trout 1 week prior to the test were 76 and 56 mm, respectively. Under test conditions, trout of this size were successful in making the necessary adjustments to avoid being stranded; however, the effects of greater magnitudes and/or rates of flow decrease are not known.

Comparable information comes primarily from stranding studies of juvenile anadromous salmonids. Bauersfeld (1978) recorded extensive mortality of chinook salmon fry below Mayfield Dam on the Cowlitz River, Washington during two experimental flow reductions. Discharge intially dropped from 266 to 157 m^3/sec between 1800 and 2200 hours at successive hourly rates of 58, 30, 15, and 6 m^3/sec on 29 April 1976. A second reduction occurred on 1 May between 1900 and 2400 hours when discharge decreased from 156 to 65 m^3/sec at successive hourly rates of 28, 24, 24, 9, and 6 m^3/sec. Phinney (1974) also observed stranding of chinook salmon fry when discharge was experimentally lowered at Gorge Dam on the Skagit River, Washington. Flow declined from 156 to 65 m^3/sec between 2300 and 0040 hours on 16-17 March and from 143 to 31 m^3/sec between 2315 and 0200 hours on 17-18 March 1973. In contrast, virtually no stranding of chinook fingerlings, steelhead smolts, or "resident" rainbow trout occurred during inspection of Minto Dam on the North Santiam River, Oregon when discharge decreased from 28 to 2 m^3/sec on 2 May 1972 (Herb 1972).

Stranding losses following spring runoff may also be reduced by lower numbers of YOY trout rearing in the study area. From late July through mid-November 1983, YOY brown trout and rainbow trout numbers fluctuated between 9 and 17% and 22 and 52% of highest levels, respectively (Figure 8). Downstream movement into Holter Reservoir, natural mortality, and utilization of habitat outside effective electrofishing range probably account for observed declines in abundance.

Vulnerability of YOY trout to stranding may be high in winter when cold water temperatures are the norm. On 14 December 1983 at Hauser Dam discharge was reduced from about 170 to 43 m^3/sec to look for deep-water redds (White et al. 1984); water temperature was 4 C. Though not quantitatively evaluated, there appeared to be considerably more stranding of YOY trout than was observed during the 17 August 1982 reduced-flow test. Juvenile salmonids show a strong association with the bottom when water temperatures drop below 5 C (Hartman 1963; Chapman and Bjornn 1969) which apparently offers protection from predators and helps prevent downstream displacement at a time when metabolic rates are low (Gibson 1978). This strong association may hamper the ability of fish to adjust to periodic flow reductions.

Isolation of YOY brown trout and rainbow trout in pools separated from the main river channel at low flows was minimal in the Missouri River study area (Table 13). Only two small pools formed when discharge was experimentally reduced on 17 August 1982. Fish trapped in these pools would probably survive daily fluctuating flows, since the pools held water until discharge returned to normal seasonal levels later that day. Isolated fish, though, may be subject to stress from increased water temperatures in summer (Bauersfeld 1978; Becker et al. 1981) and would be quite vulnerable to avian and terrestrial predators (Erman and Leidy 1974; Bauersfeld 1977).

How time of day of flow reduction affects stranding and isolation of YOY trout is a complex issue. Close association with the substrate at night may increase overall stranding losses if flows are reduced at this time. In studies cited previously (Phinney 1974; Bauersfeld 1977, 1978), extensive mortality of chinook salmon fry occurred when flows were lowered during periods of darkness. Lindroth (1956) noted that age-0 anadromous brown trout rested on and possibly in the substrate at night while ranging away from the substrate to feed and defend territories during daylight. Becker et al. (1981) speculated that fish could escape more readily if rapid flow reductions occurred in daylight.

Young-of-the-year trout actively migrating downstream, however, may be more vulnerable during daytime flow reductions. Stober (University of Washington, personal communication, March 1983) found that actively migrating juvenile chinook and chum salmon were often stranded during daytime flow reductions while little stranding occurred at night, primarily because these fish occupied gravel intersticies during the day and moved downstream at night. Migration of YOY rainbow trout from Beaver Creek into the Missouri River took place almost exclusively at night and occasional trapping in the Missouri River in May 1983 captured a few YOY brown trout in overnight trap sets only. Nighttime downstream migration of YOY brown trout and rainbow trout has also been reported by other investigators (Elliot 1966; Northcote 1969; Stauffer 1972; Alexander and MacCrimmon 1974; Carl 1982), suggesting similar behavior to migrating juvenile chinook and chum salmon.

Young-of-the-year brown trout and rainbow trout were not permanently displaced from habitat temporarily dewatered during experimentally reduced discharges on 4 August 1983; they recolonized these areas when flows were returned to normal seasonal levels (Table 14). Frequent temporary displacements, though, would be common under a fluctuating flow regime. Lindroth (1956) observed daily lateral displacements of up to 10 m for age-0 anadromous brown trout trout in the River Indalsalven, Sweden below a hydroelectric plant.

Frequent lateral movements required to adjust to changing water levels may interfere with territorial behavior and growth in YOY trout. Juvenile salmonids are territorial (Kalleberg 1958) and securing food resources is thought to be a primary function of this behavior (Keenleyside 1979). Lindroth (1956) observed that age-0 anadromous brown trout were forced to leave their territories and establish new ones each time discharge increased or decreased. Greater energy expenditure would be required to adjust to changing water levels and to occupy and hold "new" territories. If food resources were diminished as a result of flow fluctuations, growth rates of YOY trout could be negatively affected.

An aspect of displacement not investigated in this study is the potential downstream displacement of YOY trout due to sudden increases in water velocity which may accompany sudden rises in discharge. Ottaway and Clarke (1981) and Ottaway and Forrest (1983), working with hatchery brown trout fry in experimental stream channels, found that vulnerability to downstream displacement during increasing water velocity was highly dependent on stage of development. Fry with little or no yolk sac which had just begun exogenous feeding were vulnerable when they rose off the bottom to feed. Yolk sac fry, in contrast, were not displaced because they remained in niches on or in the bottom and were relatively inactive.

Habitat data collected in 1982 and 1983, coupled with generalized predictions of the PHABSIM model, provide insight into effects on YOY trout of changes in the quantity and quality of habitat occurring under a fluctuating flow regime. The model predicted that less than 2% of the total wetted surface area was usable by YOY trout at discharges between 269 and 43 m^3/sec (Figures 17 and 18). This seems consistent with the fact that YOY trout were rarely captured more than 4.8 m from shore (Figure 11). Also, the model predicted that the quantity of habitat rose as discharge declined, due to an increase in low water velocity areas. This, too, appears correct since declines in mean water velocity were observed in three of four sampling stations during the 4 August 1983 reduced flow test (Figure 15). The model's prediction that YOY trout habitat is virtually lost at discharges greater than about 255 m^3/sec may be incorrect, as these fish were found in nearly all near-shore areas sampled in 1982 at discharges between 255 and 473 m^3/sec. This discrepancy is a result of the model being incapable of taking into account that usable habitat is provided by physical structures such as larger substrate, submerged and overhanging vegetation, undercut banks, and woody debris.

Although the PHABSIM model predicted an increase in the quantity of YOY trout habitat at relatively lower flows, field observations during the 4 August 1983 low-flow test suggest habitat quality may be reduced. In areas sampled, habitat occupied by YOY trout at normal seasonal discharges was extensively dewaterd at reduced discharges of 81, 67, and 55 m^3/sec (Table 15). Also, of those cover components most frequently available and used at relatively higher discharges, namely rock cover, submerged vegetation, and overhanging vegetation, only rock cover was observed at reduced discharges. A review of the PHABSIM model by Annear and Conder (1984) stated that while weighted usable area (WUA) may increase with decreasing discharge, relatively low flows may result in a reduction of cover, lower water quality, and/or elevated water temperatures.

A reduction in habitat quality at relatively low discharges may be especially detrimental in those areas which contain relatively high numbers of YOY trout during one or more seasons of the year. Dewatering of preferred trout fry habitat forces fry into other areas and may result in reduced growth rates or increased mortality unless suitable replacement habitat is availble (Gosse and Helm 1979). Unfortunately, no attempt was made in this study to evaluate whether larger substrate, such as cobble and boulder, might provide adequate replacement habitat and compensate for reductions in submerged and overhanging vegetation.

Another issue not addressed in this study was the potential for greater exposure of YOY trout to predation at reduced flows. At normal seasonal discharges, larger juvenile or adult trout were infrequently captured in areas where YOY trout were common. Separation of age groups has been reported for stream dwelling brown trout (Jones 1975; Kennedy and Strange 1982) and for age-0 anadromous brown trout in a freshwater stream (Bohlin 1977). Apparently, YOY trout require isolation from larger, potentially piscivorous trout (Gosse and Helm 1979). The PHABSIM model predicted increased habitat for both YOY and adult trout in the Missouri River as discharge declined, suggesting that YOY trout may be more likely to encounter larger, predatory trout at reduced flows.

Detrimental impacts of a fluctuating flow regime on brown trout and rainbow trout populations may be lessened if a large portion of each year class of each species migrates downstream to rear in Holter Reservoir. Although there are "patterns" in the lakeward migratory behavior of young trout from streams (Northcote 1969) that may be genetically induced and environmentally modified (Raleigh 1971), there is little information with which to address this issue in the Missouri River study area. Downstream movement of a few marked YOY brown trout and rainbow trout was detected between June and November 1983 (Table 11). Also, the substantial decline in numbers of both species observed following spring runoff (Figure 8) suggests downstream movement out of the study area, though natural mortality undoubtedly accounts for some of the decline. This circumstantial evidence, however, gives no real clue to the percentage of each year class of each species migrating downstream to rear in Holter Reservoir.

Detrimental population impacts may also by reduced if a portion of each year class is recruited from an unimpacted area, e.g. a tributary. Beaver Creek appears to be a relatively important source of recruitment to the river rainbow trout fishery but unimportant to the river brown trout fishery (Table 18). As intensive trapping operations of downstream migrants in Beaver Creek did not begin until mid-June 1983, migration of YOY brown trout may have been missed; however, little use of the creek by brown trout spawners of river origin (White et al. 1984) suggests little recruitment would occur. Impacts on rainbow trout should be lessened each year recruitment from Beaver Creek is high.

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APPENDIX

Appendix Table 1. Schedule for monitoring growth, abundance, distribution, and movement of YOY brown trout and rainbow trout in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Month	Number of Sampling Periods	Dates of Sampling Periods
April	2	4/16 - 17[a] 4/30 - 5/01[a]
May	2	5/14 - 15 5/28 - 29
June	2	6/12 - 14 6/25 - 27
July	2	7/09 - 12[b] 7/23 - 24
August	2	8/06 - 07 8/20 - 21
September	2	9/03 - 04 9/17 - 18
October	2	10/01 - 02 10/15 - 16
November	1	11/12 - 13

[a]Stations 7, 14 not sampled (not established)

[b]Stations 1, 4, 8, 11 not sampled (high water)

Appendix Table 2. Schedule for sampling habitat used by YOY brown trout and rainbow trout in the Missouri River between Hauser Dam and Holter Reservoir, 1982.

Month	Number of Sampling Periods	Dates of Sampling Periods
April	1	4/25
May	2	5/20 - 21 5/31
June	2	6/22 - 24 6/25 - 7/02
July	3	7/06 - 09 7/14 - 16 7/23 - 24
August	3	7/30 - 8/05 8/11 - 12 8/24 - 27
September	1	9/18 - 20
October	1	10/28 - 31

Appendix Table 3. Mean lengths and length ranges of YOY brown trout captured by electrofishing on selected sampling dates in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Period	Number Measured	Mean Length (mm)	Standard Deviation (mm)	Length Range (mm)
April 16-17	10	27	±1	26-29
April 30-May 1	11	29	±2	24-32
May 14-15	49	31	±3	26-37
May 28-29	74	33	±4	23-42
June 12-14	291	40	±6	26-53
June 25-27	201	46	±6	28-64
July 9-12	20	57	±7	47-69
July 23-24	32	68	±8	50-82
August 6-7	41	78	±8	61-96
August 20-21	29	92	±12	61-112
September 3-4	46	97	±12	67-122
September 17-18	48	107	±13	71-134
October 1-2	57	110	±16	78-143
October 15-16	38	112	±17	76-149
November 12-13	46	122	±19	75-154

Appendix Table 4. Mean lengths and length ranges of YOY rainbow trout captured by electrofishing on selected sampling dates in the Missouri River between Hauser Dam and Holter Reservoir, 1983.

Sampling Period	Number Measured	Mean Length (mm)	Standard Deviation (mm)	Length Range (mm)
June 12-14	47	27	± 2	23-32
June 25-27	614	27	± 3	23-37
July 9-12	215	34	± 5	25-47
July 23-24	164	44	± 8	26-62
August 6-7	189	56	± 9	31-76
August 20-21	140	67	± 12	36-101
September 3-4	278	77	± 16	40-116
September 17-18	198	81	± 20	47-133
October 1-2	262	78	± 18	50-137
October 15-16	193	77	± 18	50-129
November 12-13	336	79	± 18	46-129