Trout mortality, movements, and habitat selection during winter in South Willow Creek, Montana
by William Cecil Schrader

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

Abstract:
Few studies have assessed impacts of small hydropower development or provided information to recommend winter minimum instream flows. I examined trout populations, movements, and habitats selected during winter in three South Willow Creek study sections before small hydropower development. Streamflows were lowest during winter (November-March) both years of the study (1984-86). Overwinter decreases in rainbow trout (>75 mm) densities averaged 32% (range 18 to 45%) over both years and all sections; standing crops decreased 30,% (range 11 to 36%) . Changes in brook trout populations were less. During winter 1985-86, net distances moved by radio-tagged rainbow trout (>225 mm) ranged from 3 to 261 m. They selected high-quality pools with overhead cover, especially overhanging rock and surface turbulence, and avoided areas without cover. Selected depths were >45 cm and selected velocities were <30 cm/s; they avoided depths <15 cm and velocities >45 cm/s. Substrate selection was variable, but large substrate (>256 mm) was used for cover. Instream flows that provide maximum quantities of these selected habitats are recommended to sustain rainbow trout populations during winter.

TROUT MORTALITY, MOVEMENTS, AND HABITAT SELECTION DURING WINTER IN SOUTH WILLOW CREEK, MONTANA

by

William Cecil Schrader

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

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 1989

APPROVAL

of a thesis submitted by

William Cecil Schrader

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

July 24, 1989 — Robert G. White
Date — Chairperson, Graduate Committee

Approved for the Major Department

24 July 1989 — Robert E. Moore
Date — Head, Major Department

Approved for the College of Graduate Studies

August 11, 1989 — Henry L. Parsons
Date — Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Dean of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature William C. Schrader

Date July 20, 1989

ACKNOWLEDGMENTS

My sincere thanks to those who assisted in all phases of this study. Dr. Robert White directed the study and assisted in preparation of the manuscript. Drs. Ray White and Lynn Irby critically reviewed the manuscript. I also wish to thank the other members of my graduate committee, Drs. Calvin Kaya and Alfred Cunningham, for their assistance in completing this thesis. A number of Montana State University undergraduate and graduate students helped with field operations. Dr. Dalton Burkhalter provided assistance with computer programming, and Dan Gustafson helped with data analysis. Charlie Smith and Pat Dwyer provided technical advice. Special thanks are extended to Pete Gross for providing housing and help at the study site.

Lastly, I especially appreciate the encouragement and help my wife, Lynn, has given throughout my graduate school career. Her support, confidence, and patience were a continual source of inspiration.

This study was funded by the United States Fish and Wildlife Service through the Montana Cooperative Fishery Research Unit, Montana State University, Bozeman, Montana.

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF TABLES - Continued

LIST OF FIGURES

LIST OF FIGURES - Continued

LIST OF FIGURES - Continued

LIST OF FIGURES - Continued

ABSTRACT

Few studies have assessed impacts of small hydropower development or provided information to recommend winter minimum instream flows. I examined trout populations, movements, and habitats selected during winter in three South Willow Creek study sections before small hydropower development. Streamflows were lowest during winter (November-March) both years of the study (1984-86). Overwinter decreases in rainbow trout (>75 mm) densities averaged 32% (range 18 to 45%) over both years and all sections; standing crops decreased 30% (range 11 to 36%). Changes in brook trout populations were less. During winter 1985-86, net distances moved by radio-tagged rainbow trout (>225 mm) ranged from 3 to 261 m. They selected high-quality pools with overhead cover, especially overhanging rock and surface turbulence, and avoided areas without cover. Selected depths were >45 cm and selected velocities were <30 cm/s; they avoided depths <15 cm and velocities >45 cm/s. Substrate selection was variable, but large substrate (>256 mm) was used for cover. Instream flows that provide maximum quantities of these selected habitats are recommended to sustain rainbow trout populations during winter.

INTRODUCTION

Recent federal and state economic incentives have stimulated development of renewable electrical energy and have led to increased interest in small hydropower (less than 5 megawatts) production. For example, since passage of the Public Utility Regulatory Policies Act in 1978 and the National Energy Security Act in 1980, the Federal Energy Regulatory Commission (FERC) has received over 6,100 hydropower applications; less than 3,000 applications had been submitted in the preceding 60 years (O'Connor 1985). In Montana, nearly 90 applications for small hydropower were filed with FERC in 1981 and 1982 (Leathe and Enk 1985). Although most of this interest has proved to be speculative, several projects in Montana have been licensed or exempted from licensing and are now operational.

Small hydropower development in Montana and elsewhere has resource management agencies, developers, and the public concerned about potential impacts to stream fisheries. This concern led to a symposium on small hydropower and fisheries in Colorado in 1985 (Olson et al. 1985). Graham (1985) noted that the potential for adverse impacts is partly dependent on the type of project, its mode of operation, and the status of the stream fishery.

Projects of primary concern in the Rocky Mountains are high-head diversions on small, high-gradient streams inhabited by salmonids (Graham 1985). This kind of project would impound and then divert water around a section of stream (often a kilometer or more) to create hydraulic head and run electrical turbines. Although streamflows in the section would be reduced throughout the year, relatively severe dewatering could occur during winter when power demand is largest and streamflows are smallest. Salmonid abundance may decrease with winter dewatering if winter habitat is limiting or if fish are already stressed by snow and ice, low water temperatures, or other harsh conditions.

Besides reduced streamflows, other potential impacts include (Rochester et al. 1984; Graham 1985; Leathe and Enk 1985):

1. Direct mortality from turbines.
2. Barriers to migration.
3. Increased fine sediment deposition.
4. Altered flow and temperature regimes.
5. Excessive streambed scouring by ice.
6. Gas supersaturation.

These concerns are compounded by lack of information (Sale 1985). Little research has been published describing the individual or cumulative impacts of small hydropower development. This is especially true with regard to winter dewatering. Resource agencies are responsible for recommending minimum instream flows to protect stream fisheries, and they often rely on information about habitats selected by fish (e.g., Instream Flow Incremental Methodology-Bovee and Cochnauer 1977; Bovee and Milhous 1978; Bovee 1982, 1986). Yet habitat selection information for salmonids, though generally known for summer and fall (Bovee 1978; Raleigh et al. 1984), is lacking for winter (Wesche and Rechard 1980). This lack of information may be particularly significant if salmonid habitat requirements change seasonally (Campbell and Neuner 1985; Cunjak and Power 1986).

Lotic ecosystem response to modified flow regimes is complex and not well understood for any season (Sale 1985). Flow alterations can result in changes not only in physical habitat availability but also in water chemistry and temperatures, nutrient cycling, biomass and energy relationships, and fish population and community dynamics.

This study was conducted at South Willow Creek, Montana, during 1984-86. My objectives were to (1) provide baseline information on stream physical conditions and trout population parameters, especially winter mortality and movements, before small hydropower development; and (2) quantify winter habitats selected by adult rainbow trout. "Winter" is defined as that period when water temperatures were less than 4C (November through March).

STUDY AREA

The study area was in South Willow Creek, Montana (Figure 1), at and around a site where a small hydropower project began operating in 1986. Starting at a diversion dam immediately below the confluence of Potosi Creek (Figure 2), water from the mainstem is piped 700 m downstream, run through a turbine, and returned to the stream channel. Montana Department of Fish, Wildlife, and Parks (MDFWP) recommends that a minimum flow of 0.28 m^3/s remain in the bypassed channel throughout the year (Fred Nelson, MDFWP, personal communication).

South Willow Creek is a drainage of the Tobacco Root Mountains in southwestern Montana (Figure 1). The stream originates at the confluence of its north headwater fork, which flows from Granite Lake (elevation 2719 m), with its south fork, which flows from Bell Lake (2682 m). From its headwaters, South Willow Creek flows 22 km northeast, joins North Willow Creek, and forms a braided inlet to Harrison (Willow Creek) Reservoir. Willow Creek drains into the Jefferson River at the town of Willow Creek, Gallatin County, Montana.

The South Willow Creek drainage basin is about 90 km^2 and ranges in elevation from 1609 to 3228 m. Average stream

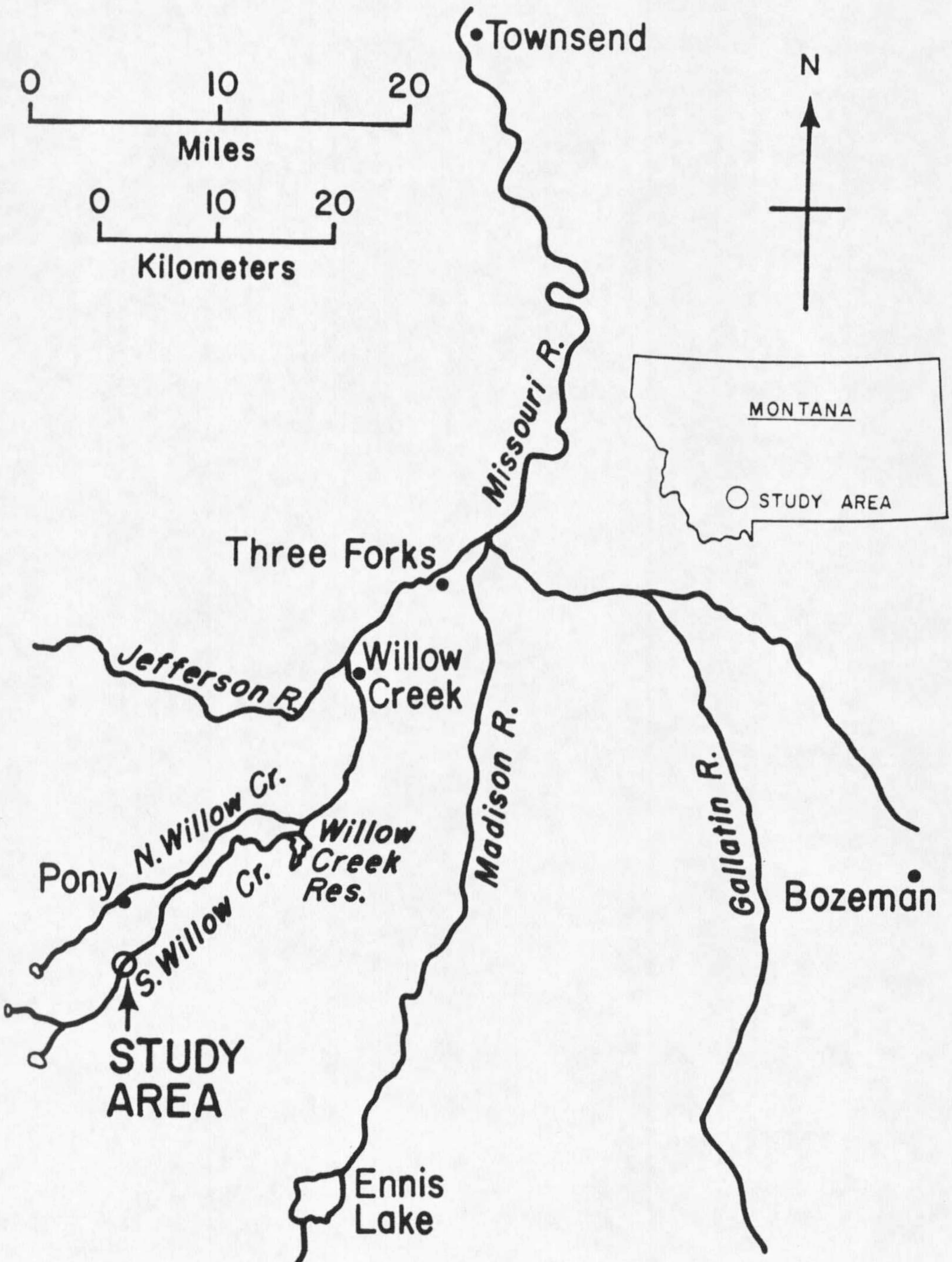

Figure 1. Location of the study area, South Willow Creek, Montana.

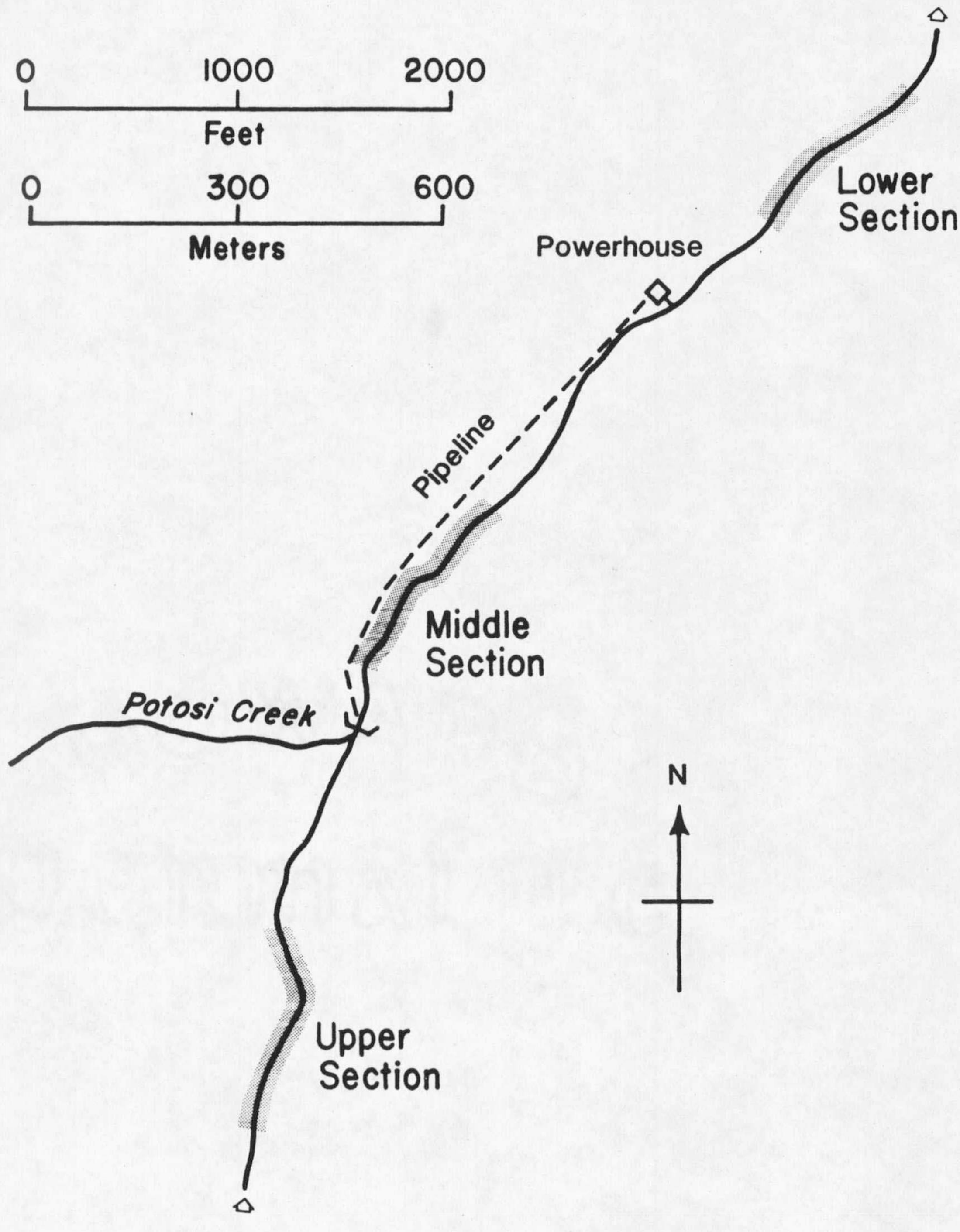

Figure 2. Location of the study sections in relation to the small hydropower project, South Willow Creek, Montana.

gradient above the study area is about 4%. Major tributaries to the mainstem are Rock, Camp, and Potosi Creeks; the last is influenced by thermal hot springs. No flow or temperature records exist for the mainstem or any of its tributaries. Some manipulation of flows for irrigation occurs at the Bell Lake outlet during summer.

The study area is about 14 km downstream from the headwater lakes (7 km below the joining of the forks) and 6 km south of Pony, Madison County, Montana, in Section 6, T3S, R2W (Figure 1). At 1829 m elevation, South Willow Creek is a third order stream at the site. MDFWP considers the study area to be representative of small, high-gradient mountain streams being developed for small hydropower production in Montana.

Three study sections (Figure 2) were chosen in fall, 1984, and surveyed and mapped in spring, 1985. The upper and lower sections are controls and are upstream and downstream of the partially dewatered middle section. Sections were chosen based on within-section habitat diversity, between-section habitat similarity, and ease of accessibility.

The lower and middle sections have similar habitats and represent typical high-gradient areas (>4%) chosen for small hydropower development (Table 1). These sections are characterized by rapids and cascades with backwater and pocketwater pools. In contrast, the upper section is of

Table 1. General characteristics of the three study sections, South Willow Creek, Montana. Measurements were made shortly after ice-out, April 13 and 14, 1985, following procedures of Orth (1983).

	Upper	Middle	Lower
Slope (%)	1.2	4.3	4.0
Channel center length (m)	294	307	300
Mean wetted width (m)	6.9	6.6	6.9
Surface area (ha)[a]	0.204	0.203	0.206
Mean water depth (cm)	19	29	22
Mean water velocity (cm/s)[b]	37	51	45
Streamflow (m^3/s)	0.680	0.850	0.708

[a]Product of channel center length and mean wetted width.
[b]Taken at 0.6 depth.

lower gradient (1.2%) and mostly riffle with some pools. Streambed substrate is primarily boulders (>256 mm) in the lower and middle sections and cobble (65 to 256 mm) in the upper section. Riparian vegetation bordering all sections is predominately willow (*Salix* spp.) and alder (*Alnus* spp.) associated with lodgepole pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*). Riparian areas were not grazed by livestock during the study.

Logging, mining, livestock grazing, and recreation are the primary land uses above the study area. Camping and fishing are the major recreational activities. The Beaverhead National Forest maintains a campground 3 km upstream from the study area, and fishing pressure there in 1975-76 was estimated to be 55 angler-days per 10 km annually (George Holton, MDFWP, personal communication). Though the upper 60% of the stream lies within the National Forest, much of the adjacent riparian land (including the upper and middle study sections) is privately owned. Few fishermen were observed in the study area during summer, and the stream was closed to fishing from November to May.

South Willow Creek has been managed for wild trout since 1973 when the last hatchery plant occurred; catchable rainbow trout (*Oncorhynchus mykiss*, formerly *Salmo gairdneri*) were stocked in the lower part of the stream in the summer of that year (George Holton, MDFWP, personal communication). Fingerling brook trout (*Salvelinus fontinalis*) were last planted at unknown locations on the stream in 1951, and cutthroat trout (*Oncorhynchus clarki*, formerly *Salmo clarki*) were last planted in 1936. In addition to these species, brown trout (*Salmo trutta*) and mottled sculpins (*Cottus bairdi*) are present. Hybrid rainbow x cutthroat trout are common, so much so that the likely hybrid is referred to as "rainbow trout" in this writing and cutthroat trout are ignored.

METHODS

Stream Physical Conditions

Stream discharge and temperature were monitored at the study area before small hydropower development. General ice conditions were noted and photographed but were not measured.

Discharge was monitored using a staff gage placed immediately above the middle section but below the confluence of thermally-influenced Potosi Creek. I placed the gage below the confluence to reduce the probability of icing during cold weather; ice dislodged gages that had been installed in the other sections. Water stage was recorded about once each week beginning in December, 1984. To calibrate the gage, a range of streamflows was measured using standard United States Geological Survey techniques (Buchanan and Sommers 1969; Platts et al. 1983) and then regressed against water stage using a logarithmic least-squares procedure (Nelson 1984; Herschey 1985). I estimated discharge from weekly stage readings using the fitted regression equation (Figure 3).

Water temperature was monitored in the upper section and immediately above the middle section using submersed continuous-recording Peabody Ryan thermographs, accurate to

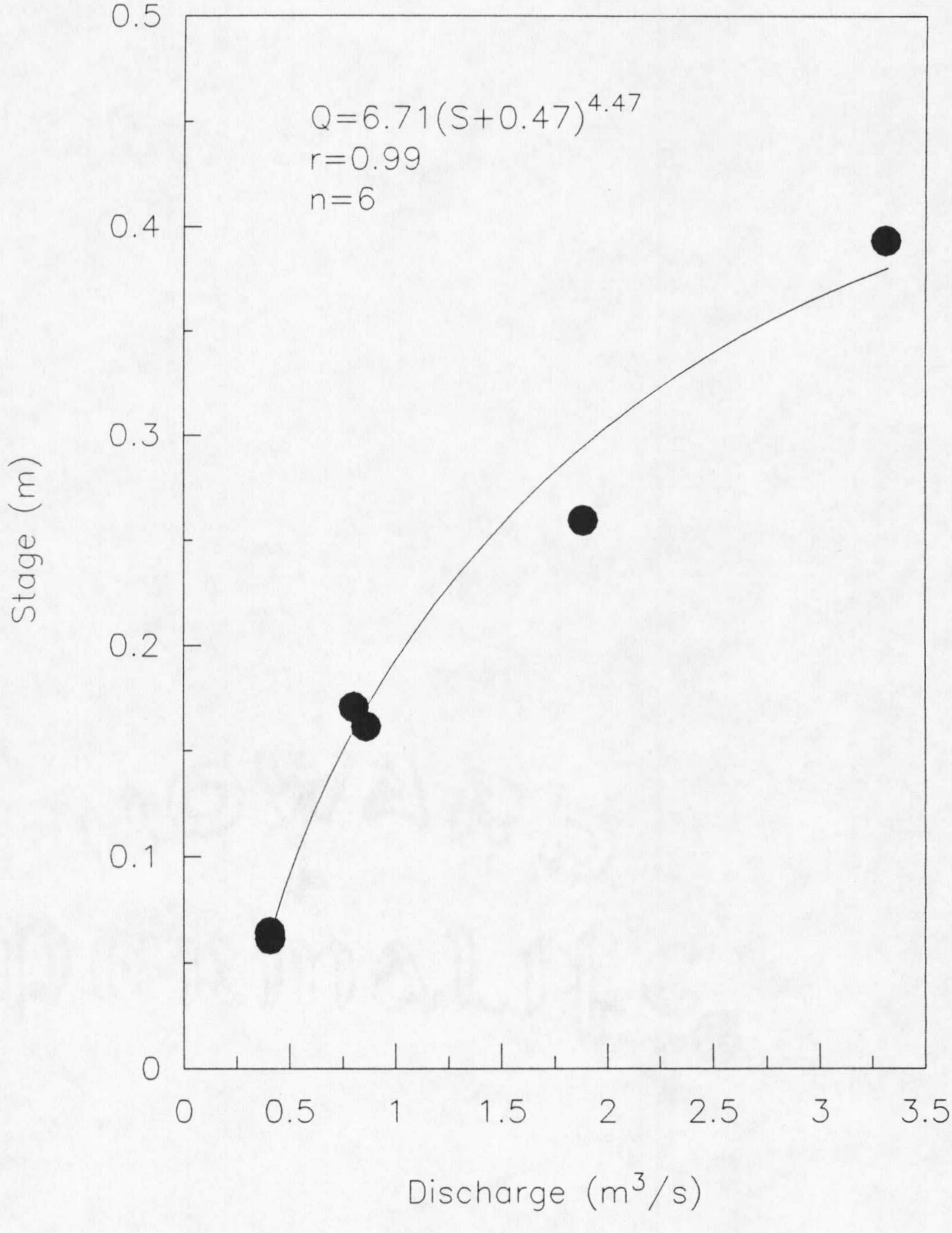

Figure 3. Stage-discharge rating curve for the staff gage near the middle section, South Willow Creek, Montana. Q = predicted discharge and S = stage in the fitted regression equation.

± 0.6 C and 3 min/d. Thermographs were calibrated and installed in September, 1984, and were frequently checked for accuracy using a hand-held thermometer. I did not place a thermograph in the lower section due to the probability of icing. Air temperature data were obtained from the national weather station at nearby Pony, Montana (elevation 1700 m).

Trout Populations

I collected baseline information on trout populations by electrofishing each study section during early October, 1984, late April and late September, 1985, and late March, 1986. Fish were captured using streambank direct-current electrofishing equipment. Though sections were not blocked at each end, I assumed fish would not move beyond natural habitat boundaries. I allowed 7 d or more for fish to redistribute themselves between marking and recapture runs.

After capture, trout were anesthetized with tricaine methane-sulfonate (MS-222), identified, weighed to the nearest 5 g, and measured to the nearest millimeter (total length). Rainbow and brook trout were fin-clipped for population estimates. Color-coded, numbered Floy fingerling tags were attached to the anterior base of the dorsal fin of rainbow and brook trout >100 mm during spring and fall, 1985, to evaluate movement.

Several parameters were used to describe trout populations over time and space. As unbiased population estimates could not always be made for brook and brown trout, I estimated relative abundance of each trout species using proportions of all trout captured. Size structures were estimated using length frequency distributions of unmarked trout captured. Chapman's modification of Peterson's mark-recapture formula was used to estimate abundance (Ricker 1975):

$$N = \left[\frac{(M + 1)(C + 1)}{(R + 1)} \right] - 1$$

where N = estimated number; M = number of fish marked on the first run; C = total number of fish captured on the second run; and R = number of marked fish recaptured on the second run. Seber's formula was used to estimate the variance (Seber 1973):

$$s^2 = \frac{(M + 1)\ (C + 1)\ (M - R)\ (C - R)}{(R + 1)^2\ (R + 2)}$$

where s^2 = estimated variance, and other variables are as above. A Fulton-type condition factor was calculated for individual fish using the formula (Anderson and Gutreuter 1983):

$$K = \frac{W}{L^3} \times 10^5$$

where K = condition factor; W = weight in g; and L = total length in mm. Condition factors of fish >125 mm were then averaged.

I assumed that fish in each study section were a distinct population, and that each population during each sampling period was geographically and demographically closed (Otis et al. 1978; White et al. 1982). I further assumed that no marks were lost during the sampling period, that all marks were recognized and recorded correctly, and that marked and unmarked fish mixed at random.

Estimates of abundance, biomass, and average condition factor were calculated using a computer program described by Vincent (1971, 1974). Estimates of density were derived from abundance estimates, as was standing crop from biomass estimates, using water surface areas of each section.

Winter Movements and Habitat Selection

Radiotelemetry

During winter, 1985-86, I used radiotelemetry to monitor adult rainbow trout movements and their use of habitats. Fish >225 mm were collected in each study section with a Coffelt BP-2 backpack electrofishing unit, anesthetized in a 0.004% MS-222 solution, weighed, and measured. The radio transmitter was surgically implanted using standard procedures reported for fish of similar size (Hart and Summerfelt 1975; Wichers 1978; Winter 1983;

Chisholm 1985). I practiced my techniques using cutthroat trout at the U.S. Fish and Wildlife Service Fish Technology Center, Bozeman, Montana.

The procedure involved inverting fish in a V-shaped trough with the head and gills submerged in anesthetic. A 30 mm incision was made through the ventral abdominal wall immediately anterior to the pelvic girdle. After inserting the transmitter into the body cavity, the incision was closed with four or five stitches using a 1/2-curved cutting needle and non-absorbable chromic 4-0 collagen suture. Water was kept out of the incision, and instruments were kept clean but not sterile. Antiseptic was not used. Time in surgery was generally less than 10 min. Opercular movement was monitored and anesthetic strength adjusted accordingly.

Immediately after surgery, radio-tagged trout were fin-clipped, placed in holding cages in the stream, and given 24 h for recovery. All fish regained their equilibrium within 15 min and appeared active when released a day later.

Sixteen adult rainbow trout (6 males and 10 females) were radio-tagged on November 16 and 17, 1985. Five trout were released in the upper section, five in the middle section, and six in the lower section. One fish released in the lower section had originally been captured in the upper section.

Radiotelemetry equipment was manufactured by Custom Telemetry and Consulting, Athens, Georgia. The beeswax-coated transmitters had an expected life of 90 d, magnetic on-off reed switches, and enclosed loop antennas. Individual frequencies were unique and ranged from 30.046 to 30.246 MHz; pulse rates ranged from 26 to 40 pulses per min (Table 2). The transmitters were capsule-shaped and approximately 26 mm long by 15 mm in diameter. Weights in air ranged from 4.57 to 4.94 g and from 1.6 to 3.3% of the fish's body weight.

The receiver operated on the 30 MHz band with 12 operating channels and a frequency range of 30.000 to 30.250 MHz. A hand-held bi-directional loop antenna (19.0 by 19.7 cm) was connected to the receiver with 4.88 m of coaxial cable. Headphones were used with the receiver when tracking fish.

All equipment was checked and calibrated before being used for data collection. Accuracy and precision of transmitter locations were determined for a single transmitter located on the ground and in water with and without ice cover. Transmitters had an effective detection range of about 100 m and appeared unaffected by snow and ice. All transmitters were operated for 48 h before being implanted.

Table 2. Characteristics of radio transmitters used to evaluate adult rainbow trout winter habitat use in South Willow Creek, Montana.

Number	Frequency (MHz)	Pulse rate (ppm)	Length (mm)	Diameter (mm)	Weight (g)	Percent fish weight	Operating time (d)
1	30.046	27	25	14	4.90	2.6	--[a]
2	30.059	36	27	15	4.73	2.3	58
3	30.067	36	25	15	4.72	3.1	87
4	30.169	40	25	15	4.67	2.1	100
5	30.171	37	26	15	4.73	2.9	86
6	30.179	37	27	16	4.88	2.0	64
7	30.189	36	27	14	4.60	2.6	78
8	30.196	34	26	13	4.73	2.6	87
9	30.209	39	27	15	4.94	3.3	65
10	30.216	35	28	14	4.81	2.3	85
11	30.218	40	27	14	4.57	2.0	100
12	30.227	26	26	15	4.76	3.1	87
13	30.230	39	26	15	4.75	2.5	100
14	30.238	34	26	15	4.72	1.6	80
15	30.239	36	26	15	4.83	3.2	80
16	30.246	26	26	14	4.59	2.6	106

[a] Transmitter frequency dropped below range of receiver detection.

Movements and Habitat Use

I attempted to locate all radio-tagged trout at least once a week after releasing them. About half of the locations were made during the day (1000 to 1430 h); the other half were made during evening (1430 to 2400 h). I held the antenna over the surface of the ice or water and used the point of maximum signal strength to define a fish's location. To minimize frightening the fish, I attached the antenna to the end of a 4 m pole and searched areas while wading upstream. I often saw the fish whose signal was being received.

Fish locations were marked with a weighted buoy and later plotted on a detailed map of each study section. Maps were constructed using on-shore baselines parallel to the stream channel. In addition, 30 transects, 10 per study section, were established 27.4 m apart and perpendicular to the channel. After surveying baselines and transects, general habitat features were used to help construct the maps.

Habitat variables were measured within 24 h after marking fish locations and included:

(1) Primary habitat type within a 30 cm radius of the fish's location. Five categories were used (Bisson et al. 1981): rapid, riffle, glide, pocket water, and pool. Pools were rated according to Platts et al. (1983) and ranged from one (low quality) to five (high quality).

(2) Total depth of the water column. Depths were measured to the nearest 3 cm with a top-setting rod and grouped into 15 cm categories. Herein, "depth" refers to total depth.

(3) Average water velocity (at 0.6 depth). They were measured to the nearest 3 cm/s with a Marsh/McBirney current meter and grouped into 15 cm/s categories. Herein, "velocity" refers to average water velocity.

(4) Major overhead cover type within a 30 cm radius of the fish's location. Seven categories were used (Bisson et

al. 1981): organic debris (rootwads and small and large debris); overhanging vegetation (live or dead plant material within 1 m of the water surface); undercut bank; moss (<u>Fontinalis</u> spp.); turbulence (assigned if the bottom of the top-setting rod could not be seen due to the presence of air bubbles in the water column); overhanging rock; and no cover. In cases where two or more cover types were present, I chose the one I thought to be most important to the fish.

(5) Predominant substrate type within a 30 cm radius of the fish's location. Four categories were used (Platts et al. 1983; Bovee 1986): sand/silt (< 2 mm); gravel (2 to 64 mm); cobble (65 to 256 mm); and boulder (> 256 mm).

<u>Habitat Availability</u>

Habitat availability was estimated in each section during late winter, 1986-87, immediately after ice-out. Streamflows were lowest of the year and were similar to those during which habitat use data were collected. I assumed structural and hydraulic characteristics of the stream channel had not changed between years.

To quantify available habitat, I used a random-point, non-mapping technique described by Marcum and Loftsgaarden (1980). Stream areas used by radio-tagged fish were divided into a grid with points one pace apart (about 60 cm). A separate grid encompassed each study section. Points within each grid were then randomly sampled to evaluate habitat variables (as described above).

Although this technique is useful in evaluating highly complex areas where habitat variables are difficult or impossible to map (e.g. depth and velocity), it does not provide absolute measurements for those variables. Thus, point estimates and their simultaneous confidence intervals were made according to Neu et al. (1974) as modified by Byers et al. (1984). Habitat use data were analyzed similarly. I concluded fish were selecting or avoiding certain habitats when the two intervals did not overlap. Other statistical analyses were performed according to Zar (1974) using MSUSTAT (Lund 1985).

RESULTS

Stream Physical Conditions

Discharge

Estimated discharge in the middle section (Figure 4) was lowest during November to March and highest during May and June. After peak snowmelt and rainfall in the spring, flows gradually declined through late summer and fall. Flows ranged from 0.37 to 4.43 m^3/s in 1985 and from 0.37 to 10.68 m^3/s in 1986.

Measured discharge was similar in the three sections (within 0.20 m^3/s) during winter, early spring, and late summer (Table 3). Discharge was always greatest, however, in the middle section, followed by the lower and upper sections. Flows in Potosi Creek were estimated to be from 0.03 to 0.20 m^3/s during winter, early spring, and late summer and provided the added discharge to the middle and lower sections.

Temperature

Average monthly maximum and minimum water temperatures in the upper and middle sections (Figure 5) were lowest during November to March and highest during July and August. Average maximum temperatures ranged from 2 C in December to

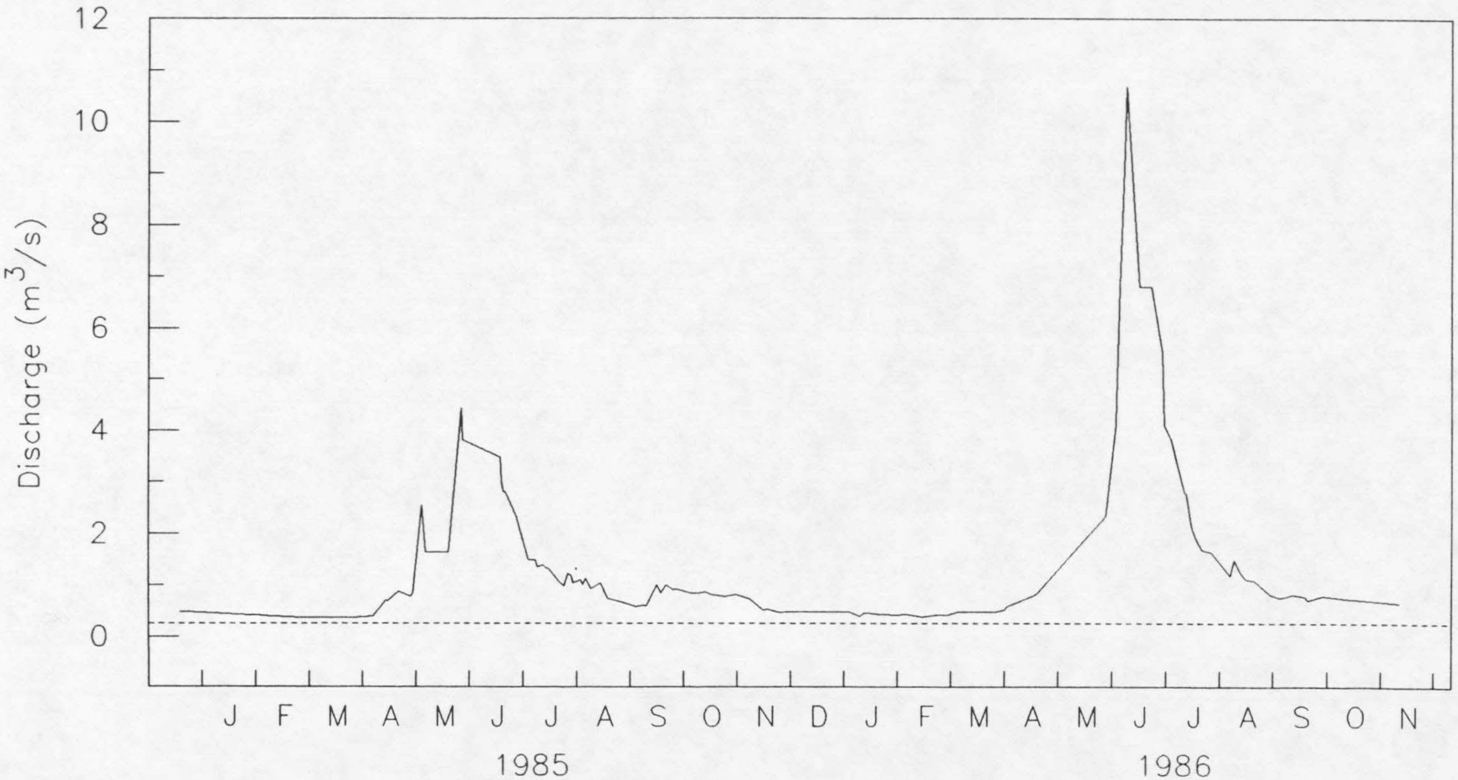

Figure 4. Point estimates of discharge and interpolations over time in the middle section, South Willow Creek, Montana (n=118). Dashed line is MDFWP's minimum flow recommendation (0.28 m^3/s) as determined by the wetted perimeter method.

Table 3. Measured discharge (m^3/s) in the three study sections, South Willow Creek, Montana.

Date	Upper	Middle	Lower
1/27/85	0.35	0.40	----
2/2/85	----	0.41	----
4/14/85	0.66	0.86	0.68
5/18/85	1.46	1.88	----
6/16/85	2.92	3.31	----
8/6/85	0.66	0.80	0.71

13 C in August. Average minimum temperatures ranged from 1 C in December to 8 C in August.

Average monthly water temperatures and seasonal temperature patterns were similar between the upper and middle sections (Figure 5). Small differences between the two sections were attributed to sampling error; point temperatures measured with a hand-held thermometer did not differ between any section (including the lower one) on any day sampled.

Although water temperatures were similar in all three sections, ice conditions were different. Anchor ice was common during very cold weather (<-18 C) in the upper and lower sections, but was never observed in the middle section. Surface ice did form in the middle section, however, and was common in all sections from October to

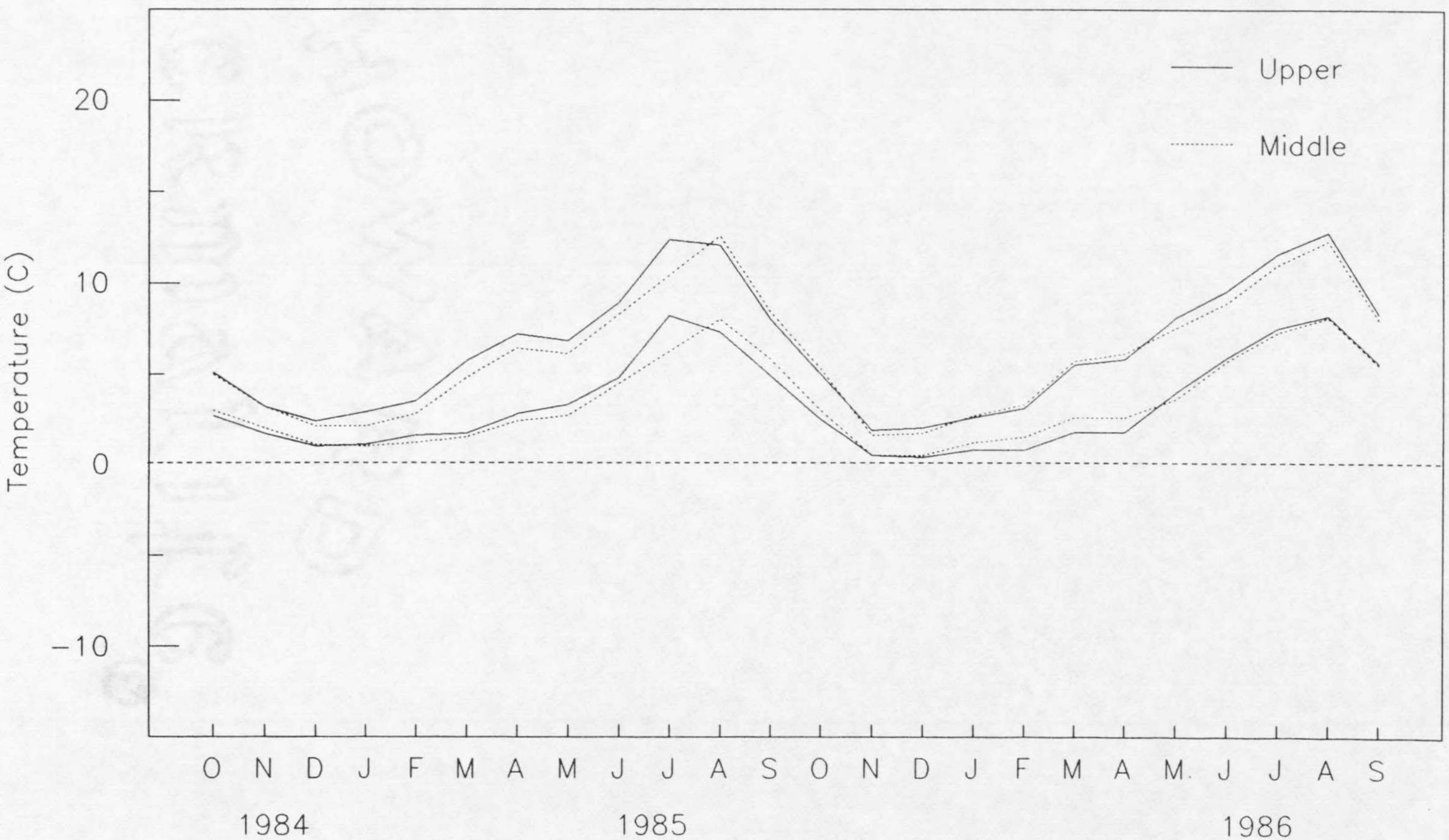

Figure 5. Average monthly maximum and minimum water temperatures and interpolations over time in the upper and middle sections, South Willow Creek, Montana.

April.

Patterns of average monthly maximum and minimum air temperatures were similar but more extreme than water temperatures (Figure 6). Air temperatures were lowest during November to March and highest during June to August. With the exception of an unusually cold November, temperatures during the winter of 1985-86 were warmer than the winter of 1984-85. Average minimum air temperatures <0 C occurred during 7 months of each year.

Trout Populations

Species Composition and Relative Abundance

Rainbow trout were the predominant species in the study area, followed by brook and brown trout (Figure 7). Overall, about 70% of the trout captured were rainbow, 27% were brook, and 3% were brown. There was no significant difference in these proportions over the study period ($p>0.5$, chi-square 4x3 contingency table).

Relative abundance of trout species differed between sections but, for any given section, remained similar throughout the study period (Figure 7). Proportions of rainbow to brook to brown trout captured were roughly 50:45:5 in the upper section, 75:23:2 in the middle section, and 85:13:2 in the lower section. Differences in relative abundance between sections were highly significant for any given season of sampling ($p<0.0001$, chi-square 3x3

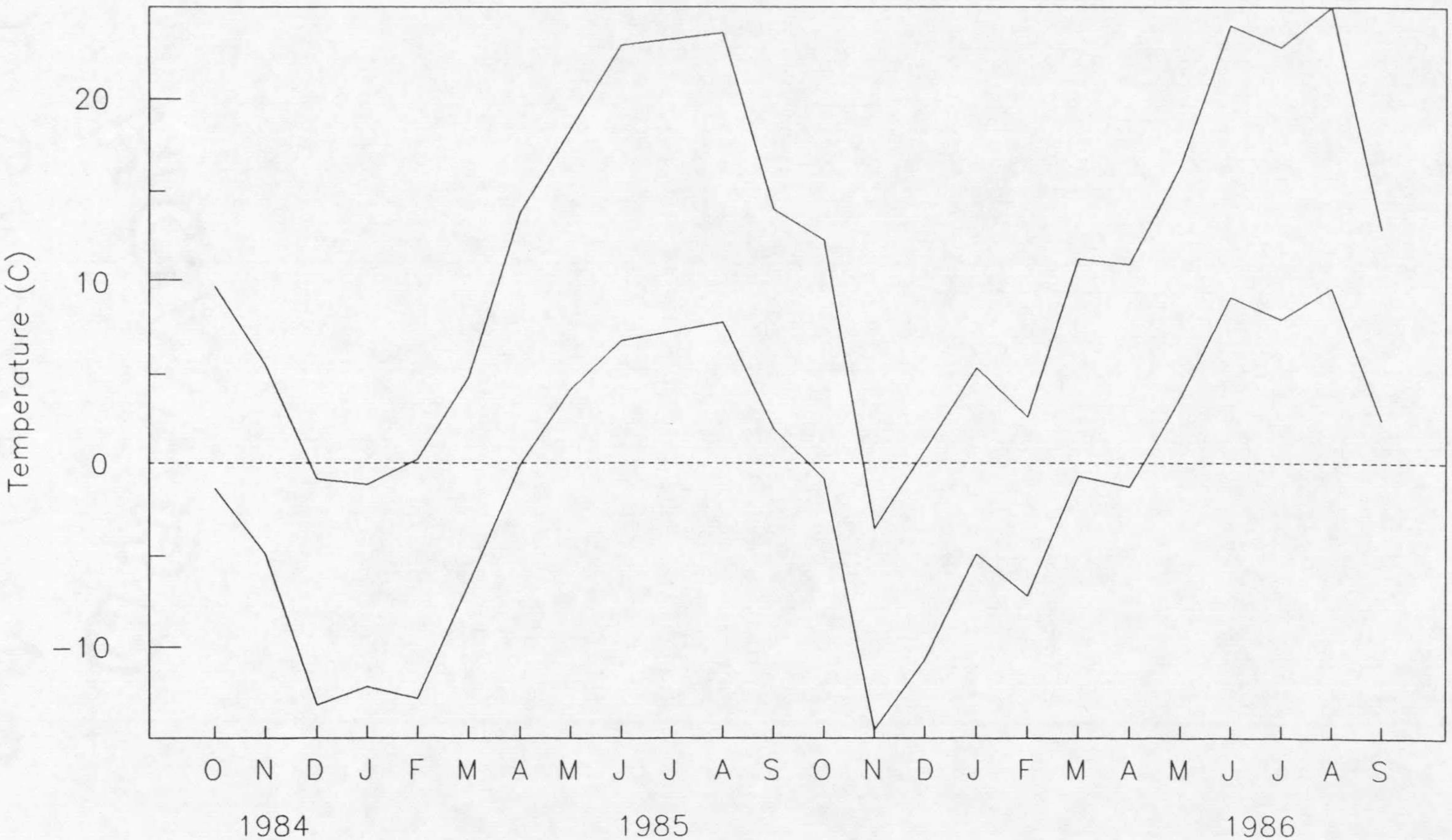

Figure 6. Average monthly maximum and minimum air temperatures and interpolations over time at Pony, Montana (NOAA, 1984-86).

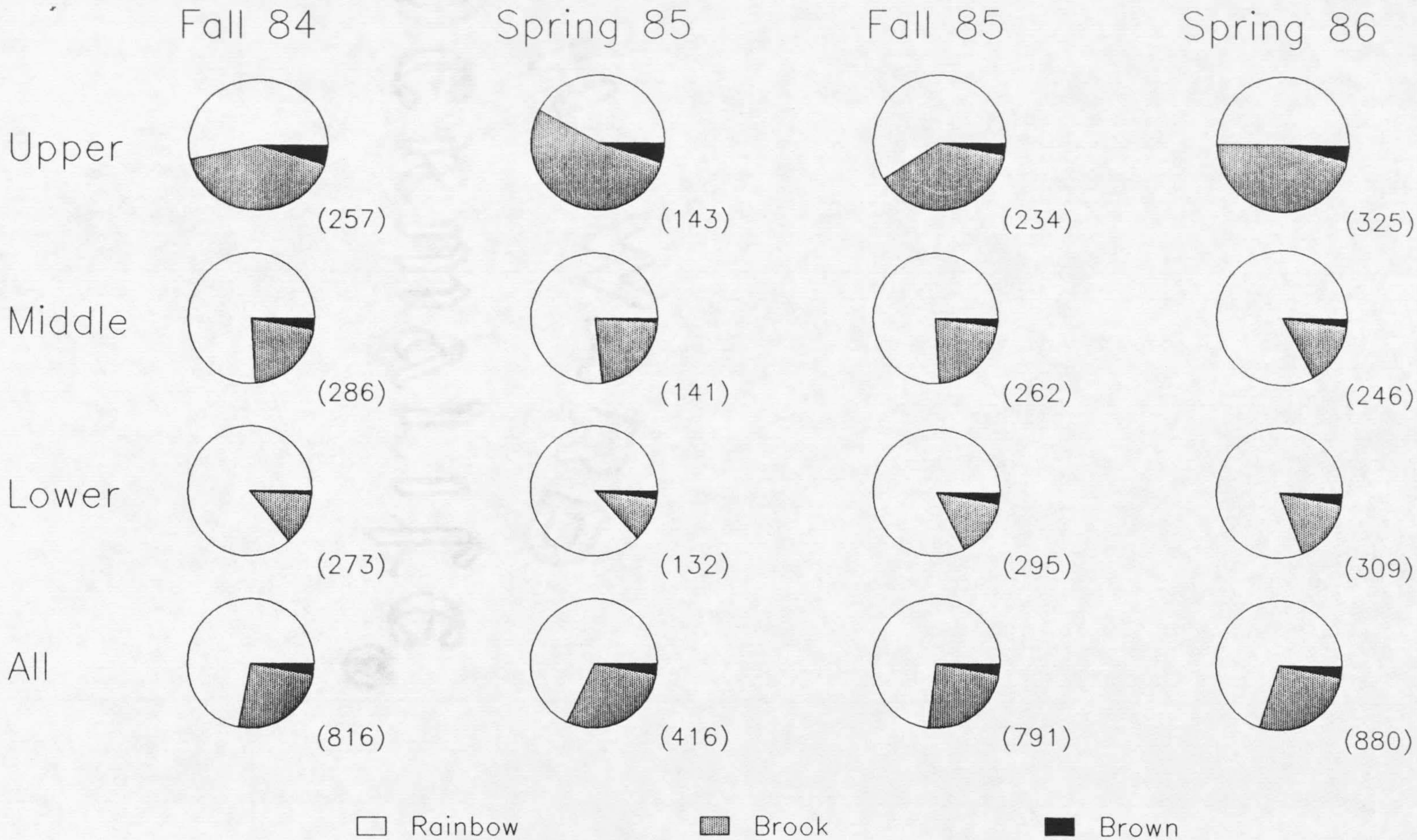

Figure 7. Relative abundance of trout species captured in the three study sections and all sections combined, South Willow Creek, Montana. Sample sizes are in parentheses.

contingency tables). For any given section, however, there was no significant difference over the study period ($p>0.05$, chi-square 4x3 contingency tables).

Size Structure

Because water temperatures were similar (Figure 5), and because rainbow trout lengths were distributed similarly between sections (Figures 20-22, Appendix A), all sections were combined to generate composite length frequency distributions by sampling period (Figure 8). Brook trout were also combined (Figure 9).

Although I did not age fish, modal peaks in these composite distributions may indicate average sizes-at-age. For rainbow trout captured in the fall, modal peaks of 55 mm might represent young-of-the-year (YOY) fish, 105 mm likely indicate age I fish, and 145 to 155 mm probably represent those age II and older (Figure 8). Modal peaks of 65, 115, and 165 mm in the spring might indicate average overwinter growth of these cohorts.

For brook trout captured in the fall, modal peaks of 65 mm might represent YOY fish, 115 mm likely indicate age I fish, and 145 to 155 mm probably represent those age II and older (Figure 9). Modal peaks of 75, 125 to 135, and 165 to 175 mm in the spring might indicate their average overwinter growth.

Captured rainbow trout ranged in size from 40 to >300

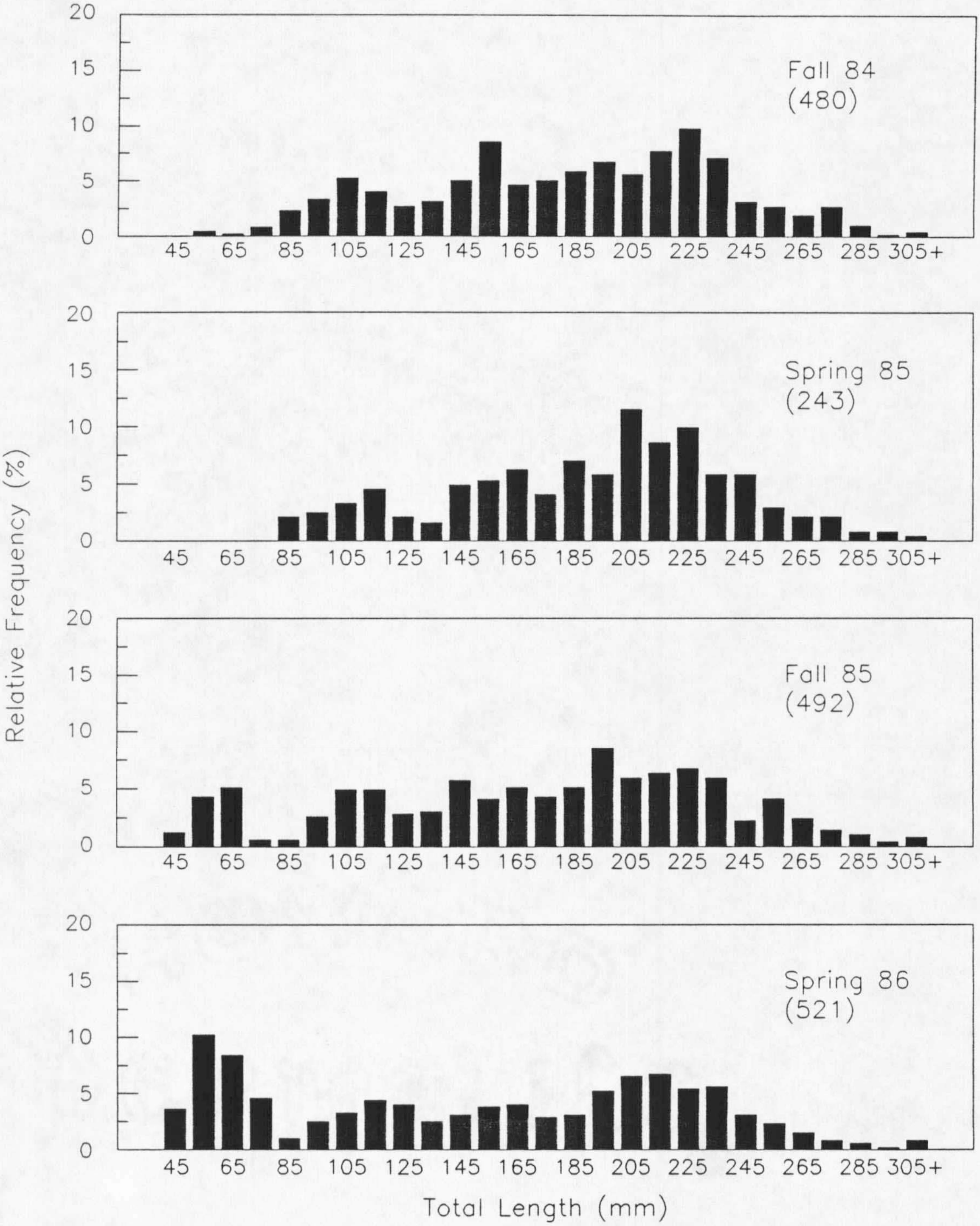

Figure 8. Length frequency distributions of rainbow trout captured in all sections combined, South Willow Creek, Montana. Sample sizes are in parentheses.