The effects of metals on trout populations in the Upper Boulder River, Montana
by Frederick Allen Nelson

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:
The effects of metals on the trout populations in the upper Boulder River were studied during 1975 and 1976. The water quality, shoreline cover, and trout populations were measured in Section A, located above Basin, Montana, and in Sections B and C, located between Basin and Boulder. The chemical and physical characteristics of the water in the study sections were similar, except for levels of metals. The median concentrations of total recoverable metals in Sections A, B, and C, respectively, were 0.02, 0.13, and 0.24 mg/l for zinc and <0.01, 0.02, and 0.04 mg/l for copper. The frequency of detectable levels of total recoverable lead progressively increased from Section A to C. Total cover in Section B was judged far superior to that in Sections A and C. Total cover in Section A was judged slightly superior to that in Section C. The estimated numbers of I+ and older trout in Sections A, B, and C were 650, 245, and 70/ha, respectively. The estimated standing crops of I+ and older trout in Sections A, B, and C were 37.7, 22.4, and 5.7 kg/ha, respectively. Zinc, copper, and lead were the measured metals probably depressing trout populations between Basin and Boulder.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature Frederick Allen Nelson

Date 12/17/76

THE EFFECTS OF METALS ON TROUT POPULATIONS IN THE UPPER BOULDER RIVER, MONTANA

by

FREDERICK ALLEN NELSON

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

of

MASTER OF SCIENCE

in

Fish and Wildlife Management

Approved:

William R. Gould
Chairperson, Graduate Committee

James M. Pickett
Head, Major Department

Henry L. Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

December, 1976

ACKNOWLEDGMENT

The author expresses his appreciation to those who assisted in the study. Dr. William R. Gould directed the study and assisted in field work and preparation of the manuscript. Drs. Robert L. Eng and Calvin M. Kaya critically reviewed the manuscript. Dr. John C. Wright provided field and laboratory equipment for chemical analyses. Personnel at the Water Quality Laboratory, Department of Health and Environmental Sciences, Helena, Montana performed metal analyses. Robert Piper of the Bozeman Fish Cultural Development Center and Wesley Orr of the Ennis National Fish Hatchery provided bioassay test specimens. William Gardner and other graduate students aided in the field work. Dalton Burkhalter assisted with the selection of computer programs. The Montana Department of Fish and Game loaned equipment.

The study was financed by the Montana Cooperative Fisheries Research Unit and a training grant from the Environmental Protection Agency to Dr. John C. Wright (EPA Training Grant T-900058).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

ABSTRACT

The effects of metals on the trout populations in the upper Boulder River were studied during 1975 and 1976. The water quality, shoreline cover, and trout populations were measured in Section A, located above Basin, Montana, and in Sections B and C, located between Basin and Boulder. The chemical and physical characteristics of the water in the study sections were similar, except for levels of metals. The median concentrations of total recoverable metals in Sections A, B, and C, respectively, were 0.02, 0.13, and 0.24 mg/l for zinc and <0.01, 0.02, and 0.04 mg/l for copper. The frequency of detectable levels of total recoverable lead progressively increased from Section A to C. Total cover in Section B was judged far superior to that in Sections A and C. Total cover in Section A was judged slightly superior to that in Section C. The estimated numbers of I+ and older trout in Sections A, B, and C were 650, 245, and 70/ha, respectively. The estimated standing crops of I+ and older trout in Sections A, B, and C were 37.7, 22.4, and 5.7 kg/ha, respectively. Zinc, copper, and lead were the measured metals probably depressing trout populations between Basin and Boulder.

INTRODUCTION

The mining and processing of gold, silver, lead, copper, and zinc within the Boulder River drainage between the towns of Basin and Boulder has been extensive. Since 1870 at least 51 ore producing mines and 11 mills have been located in this area (Roby *et al.*, 1960). In 1976 only one mine in this area produced ore in commercial quantities.

Metals from acid mine drainage and the leaching and erosion of old mill tailings and exposed overburden are impairing water quality in the Boulder River below Basin. Fragmentary water quality data presented by Braico and Botz (1974) showed concentrations of metals were lowest above Basin, increased substantially between Basin and Boulder, and persisted at relatively high levels to the river's mouth.

The depressed populations of trout found in a 36 km section of the Boulder River below Boulder were partially attributed to periodic metals pollution (Vincent, 1975). However, the effects of metals alone could not be assessed since the depressed populations also reflected the adverse effects of excessive sedimentation, severe dewatering, and the removal of streambank cover.

The primary purpose of this study was to measure the effects of metals on the fish populations in sections of the Boulder River between Basin and Boulder. In this area metals were the only major potential depressant. Information from this study will be useful in determining if the influx of metals must be reduced to enhance the fish populations in the area. If control measures are adopted, this study also will provide data for evaluating improvements in water quality and fish populations. Field research was conducted from April, 1975 through August, 1976.

DESCRIPTION OF STUDY AREA

The Boulder River is located in southwestern Montana in Jefferson County. It originates in the Boulder Mountains near the continental divide at an approximate elevation of 2219 m and flows in a southeasterly direction for approximately 111 km to its confluence with the Jefferson River near Cardwell, Montana. Its drainage basin encompasses 1974 km^2. Approximately 14.4% of the natural channel has been altered by man (Bishop and Peck, 1962).

The study area was located on the Boulder River between the confluence of Red Rock Creek and the town of Boulder. In this area the river lies in a narrow, rocky canyon within the Boulder Mountains. Alder (*Alnus* spp.) and willow (*Salix* spp.) were dominant on the river banks, and conifers on the canyon slopes. Exposed strata were primarily quartz monzonite of the Boulder batholith (Roby *et al.*, 1960). Important tributaries in the study area were Basin, Cataract, and High Ore Creeks.

Mean, minimum, and maximum discharges of the Boulder River near Boulder for a 41 year period of record ending in 1972 were 206, 0, and 5933 m^3/min, respectively (U.S.G.S., 1972). During this study, discharges were abnormally high. Minimum and maximum discharges near Boulder for the period April 26, 1975 through April 9, 1976 were 90 and 5972 m^3/min, respectively (U. S. Soil Conservation Service, 1976).

Three study sections were established in the study area (Fig. 1). They were selected primarily on the basis of differences in their concentrations of metals as determined by preliminary sampling. Section A was established above the town of Basin. It began approximately 1.0 river km below the confluence of Red Rock Creek and extended 884 m downstream. Its approximate elevation was 1658 m. Construction of a now abandoned railway bed more than 50 years ago resulted in the straightening of 58% of the present channel. The minimum discharge measured was 60 m^3/min. This section served as the control. Its waters contained low levels of metals.

Sections B and C were established between the towns of Basin and Boulder. Section B began approximately 0.9 river km below the confluence of Cataract Creek and extended 847 m downstream. Its approximate elevation was 1597 m. The lower boundary of Section B was approximately 7.7 river km below the upper boundary of Section A. The water in this section contained intermediate levels of metals.

Section C began approximately 2.3 river km below the confluence of High Ore Creek and extended 1029 m downstream. Its approximate elevation was 1536 m. The minimum discharge measured was 72 m^3/min. The lower boundary of Section C was approximately 13.6 river km below the upper boundary of Section A and 6.7 river km below the upper boundary of Section B. The water in this section contained high levels of metals.

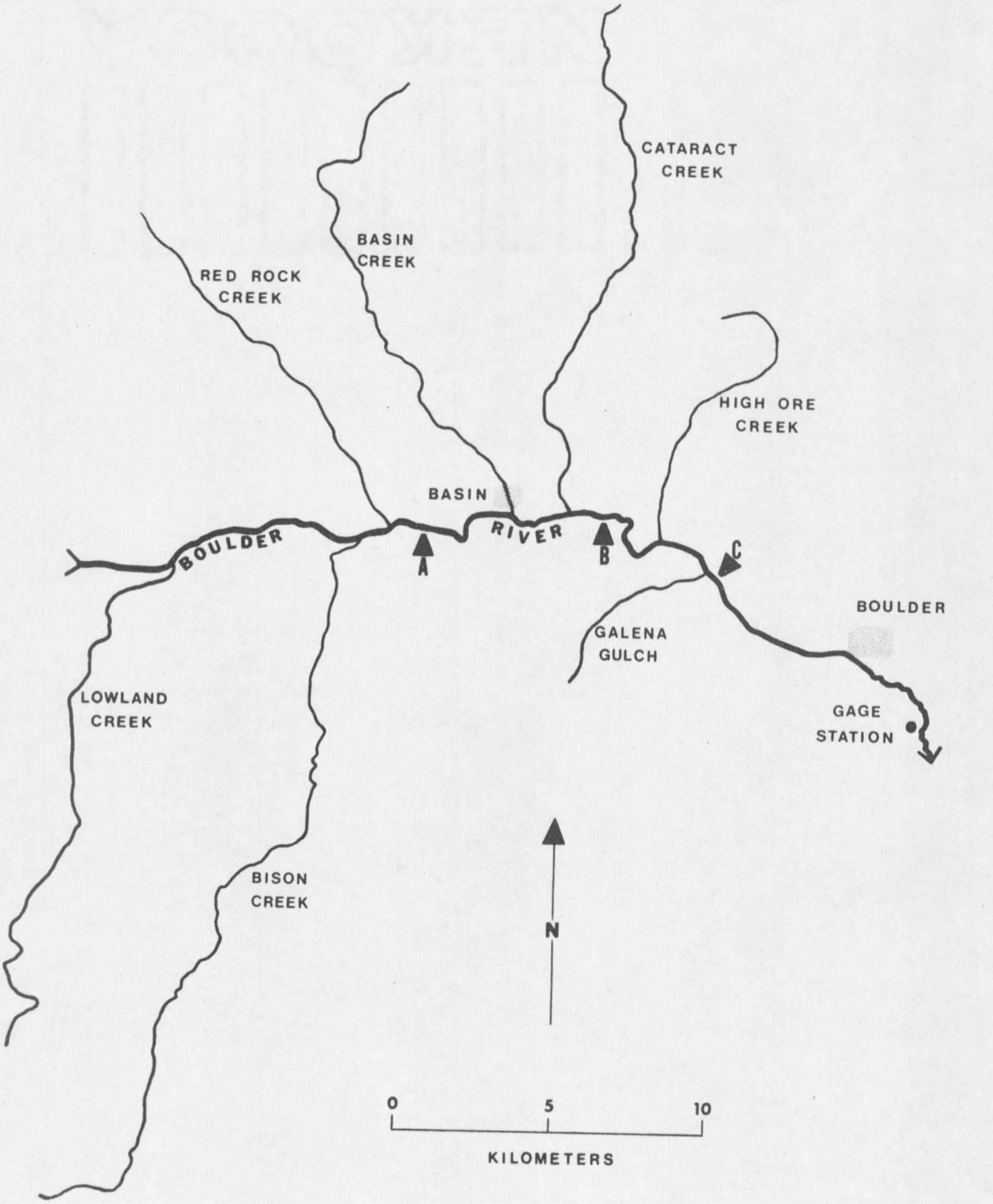

Figure 1. Map of the study area showing the location of the study sections. Arrows indicate the direction of flow.

In all three study sections the Boulder River lies in a single, stable channel. The substrate in the sections was primarily gravel, rubble, and boulders.

Rainbow trout *(Salmo gairdneri)*, brook trout *(Salvelinus fontinalis)*, mountain whitefish *(Prosopium williamsoni)*, longnose sucker *(Catostomus catostomus)*, white sucker *(Catostomus commersoni)*, longnose dace *(Rhinicthys cataractae)*, and mottled sculpin *(Cottus bairdi)* were found in the study sections. Brown trout *(Salmo trutta)*, found by Vincent (1975) in the river below Boulder, were not taken in my study sections. No hatchery fish have been stocked in the study area since 1973.

METHODS

Water samples were collected at or near the lower end of each study section. Most chemical and physical characteristics were measured monthly.

Grab samples for metal analyses were collected in one liter polyethylene bottles, immediately acidified with 5 ml of distilled, concentrated nitric acid, and analyzed within the 6 month storage period recommended by EPA. Metal analyses were performed primarily by personnel at the Water Quality Laboratory, Department of Health and Environmental Sciences, Helena, Montana using flame atomic absorption spectrophotometry (AAS). Some iron, zinc, and copper analyses were performed by the investigator. The lower detection limits for iron, zinc, copper and cadmium were 0.05, 0.01, 0.01, and 0.001 mg/l, respectively. During the study, the lower detection limit for lead was increased from 0.02 to 0.05 mg/l. Concentrations of metals are reported as the total recoverable metal, and are a measure of both the toxic and non-toxic species of a metal.

Dissolved oxygen was measured by a modified azide-Winkler method using Hach Chemical Company reagents. Other chemical and physical analyses were performed according to Standard Methods (A.P.H.A., 1971). The pH was measured with a Beckman Expandomatic pH meter. Calcium and magnesium concentrations were measured by flame AAS, and sodium and potassium concentrations by flame emission. Hardness was computed from calcium and magnesium concentrations. Sulfate, ammonia, nitrate, and orthophosphate concentrations were measured using filtered water samples by the turbidimetric, phenolhypochlorite, Mullin and Riley reduction, and single reagent methods, respectively. Chloride concentrations were measured by the nitrate method. Turbidity was measured with a Hach 2100 turbidometer. Nonfiltrable residue was determined by passing a 125 ml water sample through a predried Gelman glass fiber type A filter, then drying at 105 C for one hour.

Water temperatures were monitored using Taylor maximum-minimum thermometers. Discharges were calculated using velocity measurements made with a Gurley type AA current meter at 0.6 of the depth below the surface. Elevations and distances were obtained from U.S.G.S. maps.

The channel morphology and shoreline cover in each study section were measured. Section length was measured down the center of the channel. Transects were established 10 m apart at Section A and 15 m apart at Sections B and C. River width was measured to the nearest 0.1 m along each transect. Water depth was measured to the nearest 0.1 ft (3.0 cm) at 0.5 m intervals along each transect. A mean depth was computed for each transect. These values were averaged to obtain the mean section depth. Aerial photographs were used to measure sinuosity and evaluate channel stability. Gradient was measured with a level and stadia rod. The surface area of shoreline cover 1.5 m on each side of the transects was measured to the nearest 0.1 m^2. Cover was defined as brush (overhanging, rooted, woody vegetation), debris (unrooted driftwood, logs, and snags), and undercuts (overhanging shelf of soil or grassy vegetation) having a mean water depth $\geq$ 0.3 m under or surrounding it. Only brush and debris in the water or $\leq$ 1.0 m above the surface were considered cover. The length of each pool was measured. Pools were distinct units having smooth surfaces, low water velocities, and maximum depths $\geq$ 0.8 m.

Fish populations in the study sections were sampled by electrofishing. The weight and total length (TL) of each captured fish were measured to the nearest gram and 0.1 in (2.54 mm), respectively. Scales of rainbow trout were taken from the area between the dorsal fin and lateral line. Fish were marked with a fin clip and released for mark-recapture population estimates. Impressions of the scales were made on cellulose acetate slides and examined on a scale projector at 66X. Trout numbers were estimated using Chapman's modification of the Petersen formula. Standing crops, age structures, and appropriate 95% confidence limits were computed using methods summarized by Vincent (1971).

The regressions of total length on anterior scale radius of rainbow trout in the study sections were linear (r=.870 to .915), permitting the back calculation of total length at annulus formation (age) with the direct-proportionality formula (Tesch, 1971):

$$l_n - C = \frac{S_n}{S}(l - C)$$

where ln = total length of fish at time of annulus "n" formation,

l = total length of fish at time scale was taken,

Sn = radius of annulus "n",

S = total anterior scale radius, and

C = Y-axis intercept of total length: scale radius regression.

The length: weight relationship of rainbow trout $\geq$ 125 mm in TL was derived using the formula (Ricker, 1975):

$$\log W = \log a + b (\log L),$$

where W is the weight (g) and L is the total length (mm). This relationship and the grand mean total length at age were used to calculate the weight of rainbow trout at age. The slope (b) from the length: weight relationship was used in computing the mean instantaneous annual rates of increase in weight ($\overline{G}$), derived according to the method on page 219 of Ricker (1975).

The condition factor (K) was calculated using the formula (Rounsefell and Everhart, 1953):

$$K = \frac{W\,(10^5)}{L^3},$$

where W is the weight (g) and L is the total length (mm).

Three bioassays were conducted at the lower end of each study section. Two were conducted with the fingerlings and one with the eyed eggs of hatchery rainbow trout. Trout cages and cylindrical egg sacs were constructed from fiberglass screening.

Statistical tests were made using methods in Dixon and Massey (1969). The term significant refers to statistical significance at the $p<.05$ level. Linear regressions were derived using the method of least squares.

RESULTS

Chemical and Physical Characteristics of Water Samples

The chemical and physical characteristics of water samples measured on each sampling period are presented in Appendix Tables 1 through 15. The median and range of the total recoverable metals in each study section are presented in Table 16. Median concentrations

TABLE 16. MEDIAN AND RANGE (IN PARENTHESIS) OF TOTAL RECOVERABLE METAL (TRM) CONCENTRATIONS (mg/1) FOR 14, 12, AND 14 WATER SAMPLES COLLECTED AT OR NEAR SECTIONS A, B, AND C, RESPECTIVELY, FROM APRIL 26, 1975 THROUGH APRIL 9, 1976.

	Section		
TRM	A	B	C
Fe	.49 (.22-1.8)	.66 (.18-2.0)	.73 (.21-2.6)
Zn	.02 (<.01-.05)	.13 (.09-.25)	.24 (.07-.53)
Cu	<.01 (<.01-.02)	.02 (<.01-.09)	.04 (.01-.10)
Cd	<.001 (<.001-<.001)	<.001 (<.001-.001)	<.001 (<.001-.001)
Pb	<.05 (<.02-<.05)	<.05 (<.02-<.05)	<.05 (<.02-.10)

of iron, zinc, and copper progressively increased from Section A through C. Median cadmium and lead concentrations were lower than the detection limit of the procedure used. However, the maximum concentration of cadmium was highest in Sections B and C and the maximum concentration of lead was highest in Section C. The frequency of detectable levels of cadmium and lead also progressively increased from Section A through C (Table 17), indicating concentrations during

TABLE 17. PERCENT OF 14, 12, AND 14 WATER SAMPLES COLLECTED AT OR NEAR SECTIONS A, B, AND C, RESPECTIVELY, HAVING TOTAL RECOVERABLE METAL (TRM) CONCENTRATIONS ≥ THE LOWER DETECTION LIMIT OF AAS.

TRM	Lower Detection Limit (mg/l)	Section A	Section B	Section C
Fe	.05	100	100	100
Zn	.01	71	100	100
Cu	.01	43	92	100
Cd	.001	0	25	43
Pb	.02 or .05	0	8	43

the study were probably lowest in Section A, intermediate in B, and highest in C. Supplementary sampling (Appendix Tables 18 and 19) implicated the extensive tailings deposits on the south bank at the town of Basin and Basin, Cataract, and particularly High Ore Creeks as major contributors of metals to the Boulder River above the town of Boulder.

The median and range of the other chemical and physical characteristics measured in each study section are presented in Table 20. The medians for each characteristic were similar at all study sections. The ranges for each characteristic, except turbidity and nonfiltrable residue, were also similar. The maximum turbidity at Section B was

TABLE 20. MEDIAN AND RANGE (IN PARENTHESIS) OF CHEMICAL AND PHYSICAL CHARACTERISTICS FOR WATER SAMPLES COLLECTED IN THE BOULDER RIVER AT OR NEAR THE STUDY SECTIONS FROM APRIL 26, 1975 THROUGH APRIL 9, 1976.

Characteristic	Section A	Section B	Section C
pH	7.5	7.5	7.6
	(7.2-8.0)	(7.1-8.0)	(7.2-8.0)
Conductivity	140	142	152
(μmhos/cm at 25 C)	(87-174)	(77-160)	(80-172)
Alkalinity	43.5	41.0	42.3
(mg/1 $CaCO_3$)	(17.5-55.0)	(16.5-50.5)	(16.0-52.0)
Hardness	43.4	47.6	51.3
(mg/1 $CaCO_3$)	(28.5-64.2)	(25.7-61.8)	(27.1-74.3)
Calcium	12.8	14.2	14.9
(mg/1)	(8.6-19.1)	(7.8-18.3)	(8.2-23.8)
Magnesium	2.9	3.0	3.5
(mg/1)	(1.7-4.0)	(1.5-3.9)	(1.6-4.2)
Turbidity	5.0	7.0	10.0
(JTU)	(1.5-17.0)	(1.1-82.0)	(0.9-24.0)
Nonfiltrable ? Residue	17	8	21
(mg/1)	(0-189)	(0-256)	(0-116)
Sodium	7.6	6.3	6.4
(mg/1)	(7.5-7.7)	(6.2-6.4)	(6.2-6.5)
Potassium	1.4	1.4	1.6
(mg/1)	(1.2-1.5)	(1.2-1.5)	(1.2-2.0)
Chloride	1.5	1.4	1.4
(mg/1)	(1.4-1.6)	(1.3-1.5)	(1.3-1.4)
Sulfate	14.4	18.5	19.9
(mg/1)	(10.5-18.3)	(14.5-22.5)	(16.0-23.7)
PO_4^{-3}-P	.026	.021	.022
(mg/1)	(.024-.028)	(.020-.021)	(.019-.025)
NH_3-N	0	0	0
(mg/1)			
NO_3^--N	.040	.038	.046
(mg/1)	(.033-.047)		(.038-.053)

considerably greater than those at Sections A and C, which were similar. The maximum nonfiltrable residue was highest at Section B, intermediate at A, and lowest at C.

Water temperatures, monitored from July 22 through September 22, 1975 at two sites bracketing the study sections, ranged from 3.5 - 21 and 4 - 22 C near Sections A and C, respectively. Within a recording period, maximum and minimum temperatures near Section A were from 0 - 1 C lower than those near Section C.

Dissolved oxygen was measured frequently throughout the study at irregular intervals. The minimum dissolved oxygen concentration measured for each study section was 10 mg/l.

Channel Morphology and Cover

Channel morphology and shoreline cover were measured in the study sections between October 18 and November 2, 1975 when discharges were 123, 159, and 213 m^3/min at Sections A, B, and C, respectively. These discharges were abnormally high for this time of year.

The morphological characteristics are presented in Table 21. The mean depth, mean thalweg depth, and sinuosity were similar in all sections. The mean width of Section A was approximately 67% of the mean width of Sections B and C, which were similar. The gradient at Section C was approximately 69% of the gradient at Sections A and B, which were similar.

TABLE 21. MORPHOLOGICAL CHARACTERISTICS OF THE STUDY SECTIONS IN THE BOULDER RIVER MEASURED BETWEEN OCTOBER 18 AND NOVEMBER 2, 1975. STANDARD DEVIATION IN PARENTHESIS.

Section	Mean Width (m)	Mean Depth (cm)	Mean Thalweg Depth (cm)	Sinuosity	Gradient (m/km)
A	10.8 (±2.2)	33 (±6)	56 (±12)	1.07	9.6
B	16.1 (±3.5)	32 (±9)	61 (±16)	1.04	9.9
C	16.2 (±2.7)	37 (±6)	63 (±10)	1.07	6.7

The surface area of shoreline cover in each study section is presented on a comparable basis in Table 22. The total shoreline

TABLE 22. SURFACE AREA (m^2/500m) OF SHORELINE COVER IN THE STUDY SECTIONS OF THE BOULDER RIVER MEASURED BETWEEN OCTOBER 18 AND NOVEMBER 2, 1975.

Section	Cover Type			Total
	Brush	Undercut	Debris	
A	109.5	10.4	17.7	137.6
B	22.6	3.0	17.8	43.4
C	77.8	14.8	0	92.6

cover per 500 m in Section A was 217 and 49% greater than that in Sections B and C, respectively. Brush primarily accounted for the greater total shoreline cover in Section A.

Boulders and pools also provided cover in the study sections. Large boulders littered the channel in Section B, but were considerably less abundant in Sections A and C. Pools were also more prevalent in Section B. They comprised 8, 18, and 5% of the lengths of Sections

A, B, and C, respectively.

Considering all the types of cover available to fish, cover in Section B was judged to be far superior to that in Sections A and C. Cover in Section C was judged to be slightly inferior to that in Section A.

Fish Populations

The populations of rainbow trout, brook trout, mountain whitefish, white suckers, and longnose suckers were sampled from August 26 through September 11, September 9 through September 17, and August 27 through September 3, 1975 in Sections A, B, and C, respectively. Catch statistics for the five species collected are presented in Appendix Table 23. Rainbow trout was the dominant species in all study sections, comprising 55, 60, and 74% of the total fish collected in Sections A, B, and C, respectively.

Population estimates were made for rainbow trout in Sections A, B, and C and brook trout in Section A (Appendix Table 23). The small numbers of brook trout in Sections B and C, mountain whitefish in Section C, white suckers in all sections, and longnose suckers in Sections A and C captured during the electrofishing runs indicate populations were too sparse to estimate. Relatively large numbers of longnose suckers in Section B and mountain whitefish in Sections A and B were captured during the electrofishing runs. However, numbers of longnose suckers in Section B could not be estimated because insufficient recaptures were obtained. The numbers of mountain whitefish in Sections A and B could not be estimated because adult whitefish were suspected of entering the study sections subsequent to the marking run, thereby violating a condition necessary for valid mark-recapture estimates. Because whitefish may have moved between areas having different concentrations of metals, comparisons of lengths and weights at age, $\overline{G}$, and condition factors for those captured at Sections A and B were not made.

Estimates of Numbers, Standing Crops, and Age Structures

Estimates of the numbers and standing crops of I+ and older rainbow trout and brook trout in the study sections are presented on comparable bases in Table 24. Total trout numbers per 500 m in Sections B and C were 56 and 16%, respectively, and total trout standing crops were 88 and 23%, respectively, of those in Section A. Differences were more pronounced per hectare. Total trout numbers in Sections B and C were 38 and 11%, respectively, and total trout standing crops were 59 and 15%, respectively, of those in Section A. Estimates were considered significantly different if 95% confidence limits did not overlap. Of these estimates, all but the standing crops per 500 m in Sections A and B were significantly different.

TABLE 24. ESTIMATES OF NUMBERS ($\bar{N}$), STANDING CROPS, AND AGE STRUCTURES OF TROUT IN THE STUDY SECTIONS OF THE BOULDER RIVER. 95% CONFIDENCE LIMITS IN PARENTHESIS.

			Per 500 m		Per ha	
Section	Species	Age-Group	$\bar{N}$	Standing Crop (kg)	$\bar{N}$	Standing Crop (kg)
A	Rainbow Trout	I+	178	4.0	329	7.3
		II+	88	6.8	162	12.6
		III+ & Older	37	6.1	68	11.3
			303	16.9	559	31.2
			(225-381)	(13.4-20.4)	(416-702)	(24.7-37.7)
	Brook Trout	I+ & Older	49	3.5	91	6.5
			(34-64)	(2.4-4.6)	(64-118)	(4.5-8.5)
	Total Trout	I+ & Older	352	20.4	650	37.7
			(273-431)	(16.7-24.1)	(504-796)	(30.9-44.5)
B	Rainbow Trout	I+	91	2.8	113	3.5
		II+	42	3.6	53	4.5
		III+ & Older	63	11.5	79	14.4
			196	17.9	245	22.4
			(171-221)	(15.4-20.4)	(214-276)	(19.2-25.6)
C	Rainbow Trout	I+ & Older	57	4.6	70	5.7
			(32-82)	(2.6-6.6)	(39-101)	(3.2-8.2)

Most estimates for rainbow trout progressively declined between Sections A and C. Rainbow trout numbers per 500 m in Sections B and C were 65 and 19%, respectively, and rainbow trout standing crops were 106 and 27%, respectively, of those in Section A. Again, differences were more pronounced per hectare. Rainbow trout numbers in Sections B and C were 44 and 13%, respectively, and rainbow trout standing crops were 72 and 18%, respectively, of those in Section A. Of these estimates, all but the standing crops per 500 m and hectare in Sections A and B were significantly different.

Sufficient numbers of rainbow trout were sampled in Sections A and B to estimate the age structures and to partition standing crop estimates by age-groups (Table 24). Age-groups I+, II+, and III+ and older comprised 59, 29, and 12%, respectively, of the estimated numbers of rainbow trout in Section A, and 24, 40, and 36%, respectively, of the estimated standing crop. At Section B, the age structure was "top-heavy" compared to Section A. Age-groups I+, II+, and III+ and older comprised 46, 21, and 32%, respectively, of the estimated number of rainbow trout in Section B, and 16, 20, and 64%, respectively, of the estimated standing crop. The estimated numbers and standing crops of rainbow trout in age-groups I+ and II+ were higher in Section A than in Section B. However, the estimated numbers and standing crops of III+ and older rainbow trout were highest in Section B. This caused the estimates of the standing crops of rainbow trout in these sections to be more similar than were the estimates of numbers.

Calculated Lengths and Weights at Age

The total length: scale radius regressions and the length: weight regressions used in the back calculations of lengths and weights, respectively, at age for rainbow trout in the study sections are given in Appendix Table 25. Calculated lengths and weights of rainbow trout at age are given in Table 26.

The grand mean lengths of fish at ages I and II in Section B were significantly greater than those in Sections A and C, which were not significantly different. Grand mean lengths of fish at age III in all sections were not significantly different, although fish in Section C were shortest.

Rainbow trout in Section B were heavier at ages I, II, and III than those in Sections A and C (Fig. 2). The calculated weights of fish at ages I and II in Section C were greater than those in Section A. The calculated weight at age III in Section C was the lowest among the study sections.

Mean Instantaneous Annual Rates of Increase in Weight

Mean instantaneous annual rates of increase in weight $(\overline{G})$ during the second and third years of life for rainbow trout in Sections A and B were compared in relation to the weight at the beginning of the year of life in Figure 3. Rates $(\overline{G})$ at Section B were less than those at