A comparative growth rate of trout in relation to elevation and temperature
by Charles A Purkett Jr

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
A study of 758 trout from the West Gallatin River, in-dicated that growth in length was greater at lower elevations where the water was warmer. Rainbow trout from the upper and lower sections of the West Callatin River showed the following differences inlength at the end of each year: 0.3inche the first year,1.3 inch the second year, 2.1 inches the third year 2.5 inches the fourth year, and 4.0 inches the fifth year, The growth rate of cutthroat and hybrid trout showed a similar trend. The average summer difference in water temperature (early morning), between the upper and lower stations of the West Gallatin River, was 9.6°F. K factors did not show significant variations between sections.

A total of 184 trout from Bridger-Spring Greek did not show significant differences in growth rate. However, water temperatures in the stream did not vary greatly.

A COMPARATIVE GROWTH RATE OF TROUT IN RELATION TO ELEVATION AND TEMPERATURE

by

CHARLES A. PURKETT, JR.

A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the degree of

Master of Science in Fish and Wildlife Management

at

Montana State College

Approved:

Head, Major Department

Chairman, Examining Committee

Dean, Graduate Division

Bozeman, Montana
June, 1950

TABLE OF CONTENTS

ABSTRACT

A study of 758 trout from the West Gallatin River, indicated that growth in length was greater at lower elevations where the water was warmer. Rainbow trout from the upper and lower sections of the West Gallatin River showed the following differences in length at the end of each year: 0.3 inch the first year, 1.3 inch the second year, 2.1 inches the third year, 2.5 inches the fourth year, and 4.0 inches the fifth year. The growth rate of cutthroat and hybrid trout showed a similar trend. The average summer difference in water temperature (early morning), between the upper and lower stations of the West Gallatin River, was 9.6° F. K factors did not show significant variations between sections.

A total of 184 trout from Bridger-Spring Creek did not show significant differences in growth rate. However, water temperatures in the stream did not vary greatly.

A COMPARATIVE GROWTH RATE OF TROUT IN RELATION TO ELEVATION AND TEMPERATURE

INTRODUCTION

A marked difference in the average size of trout from the upper canyon and the lower valley portions of certain mountain streams has been observed by fisheries workers, but little information has been published on this subject. The difference in the size of fish observed could possibly result from a variable rate of growth or from the movement of the larger fishes down stream. If the difference is due to variable growth rates, it is most likely correlated with differences in water temperature. Several workers have shown that temperature influences growth rate. Hazzard (1932), found growth rate of Eastern brook trout (Salvelinus fontinalis) to be slower in cold headwater streams than in lowland streams where temperatures were higher and growing season longer. McHugh (1942), correlated growth rate of whitefish (Prosopium williamsoni) with temperature and altitude. The present study was designed to measure differences in growth rate of trout throughout a river system in relation to existing temperatures.

Description of Streams Studied

The West Gallatin River and Bridger Creek (with its tributary, Spring Creek) were selected for this study because of their accessibility and range in elevation. All are in the headwater drainage of the Missouri River system.

West Gallatin River

The West Gallatin heads in the northwest corner of Yellowstone National Park, in the Madison and Gallatin Ranges of the Rocky Mountains. It runs generally northwest, traversing the central part of Gallatin County, Montana. The upper 25 mile portion, nearly all within the Park, is a meandering mountain meadow stream. This section contains relatively few pools, and little bank cover. A short distance north of the Park, the river begins its descent through Gallatin Canyon. For a distance of about 35 miles, it has a straighter course, and is characterized by rapids and swift water, with some pools and shelter. The gradient of this section is about 43 feet per mile. From the mouth of Gallatin Canyon, to its confluence with the East Gallatin River, it has considerably less gradient (approximately 34 feet per mile). Pools are more abundant in this portion, although riffle areas are predominant. The stream divides to two or more channels in many places, even at low water levels.

It is approximately 90 miles in length and varies in

width from 40 to 150 feet. West and Stubblefield (1948), listed 26 tributaries for this Stream. The most important of these are Fan Creek, Specimen Creek, Sage Creek, Taylor's Fork, West Fork, Squaw Creek, and Spanish Creek. (Fig. 1) In the summer, a large share of the water in the river below Spanish Creek is diverted for irrigation purposes. There are no large dams or other major obstructions. The West Gallatin joins the East Gallatin to form the Gallatin River. This latter stream is one of three tributaries which make up the Missouri River, at Trident, Montana.

For purposes of this study, the river was divided into three sections, on the basis of approximately 1000 foot elevations. Section I (Fig. 1) was that part of the river from the mouth of the East Gallatin (elev. 4155) to the confluence of Spanish Creek (elev. 5190); a distance of approximately 30 miles. Section II lies between the mouth of Spanish Creek and the confluence of West Fork (elev. 6000); about 21 miles. Section III included that portion between the mouth of West Fork to three miles above the mouth of Fan Creek (elev. 7100); approximately 30 miles.

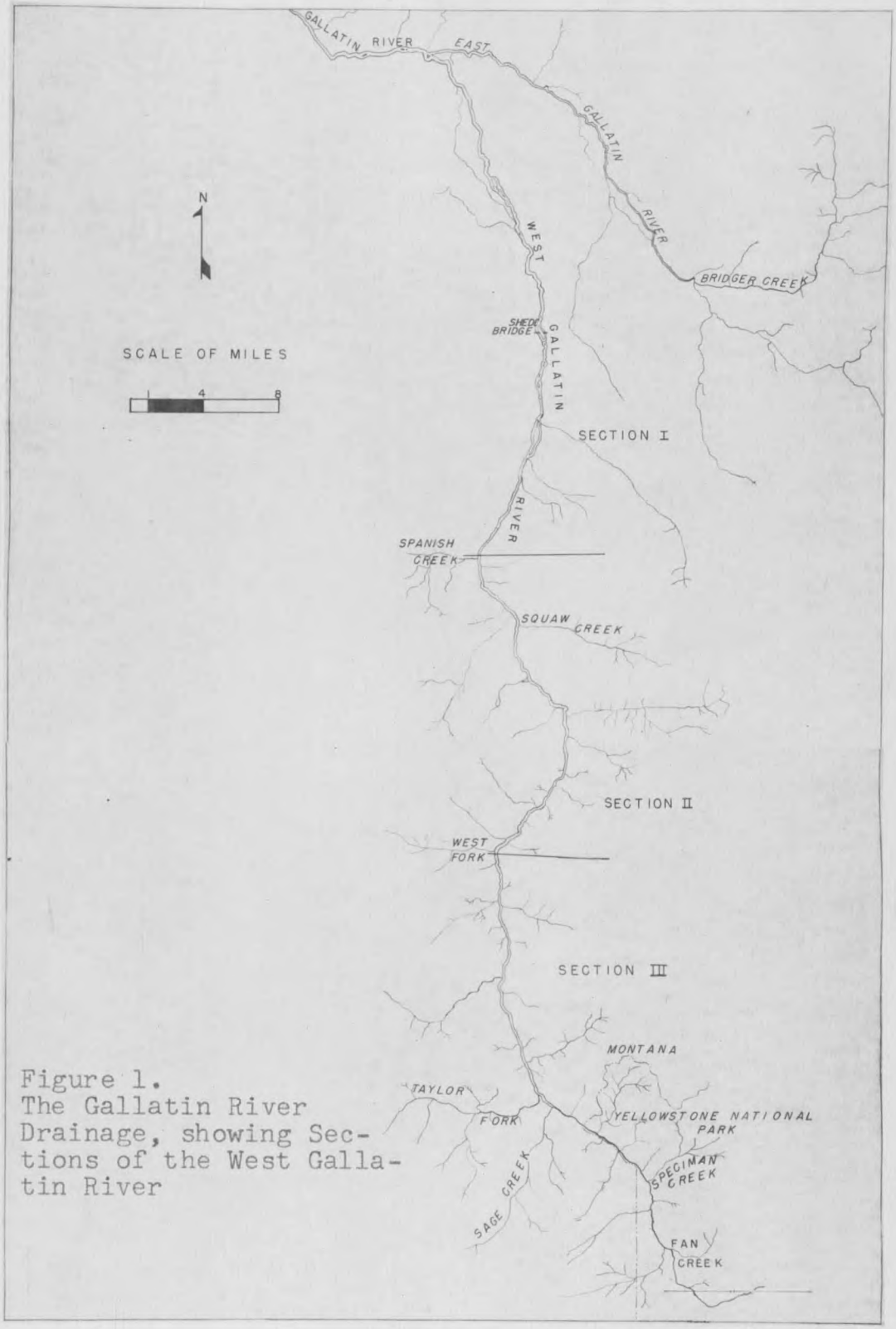

Figure 1.
The Gallatin River Drainage, showing Sections of the West Gallatin River

Bridger Creek and Spring Creek

Bridger Creek and Spring Creek head in the Bridger Range and flow southwest into the East Gallatin River. Spring Creek is a small, rather swift meandering stream, with heavy brush cover. It has an average width of about six feet and a length of seven miles. Bridger Creek is a meandering meadow stream with an abundance of pools and cover. Widths vary from 10 to 30 feet. It has a total length of eighteen miles; nine miles above the mouth of the Spring Creek tributary, and nine miles below. There are 16 other tributaries to this stream. (Fig. 2)

Spring Creek and that portion of Bridger Creek below the confluence of the Spring Creek tributary were considered as a stream unit in this study. This was divided into five sections on the basis of 500 foot contours (Fig. 2) as follows: Section I, Bridger Creek below the 5000 foot contour; Section II, Bridger and Spring Creeks between the 5000 and 5500 foot contours; Section III, Spring Creek between the 5500 and 6000 foot contours; Section IV, Spring Creek between the 6000 and 6500 foot contours; Section V, Spring Creek above the 6500 foot contour.

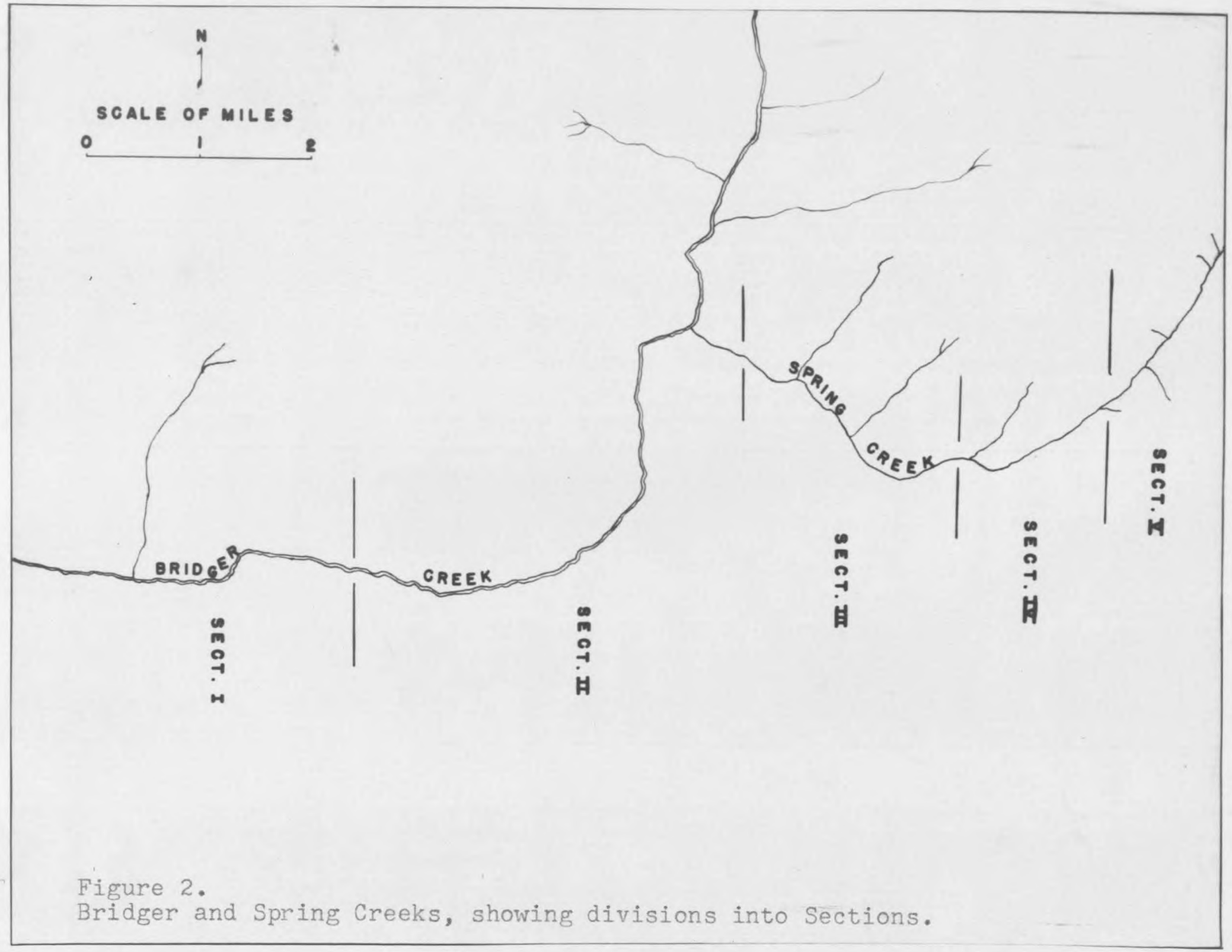

Figure 2.
Bridger and Spring Creeks, showing divisions into Sections.

Species Studied

All species of trout known to be present in the West Gallatin River were considered in this study. The species taken, in descending order of abundance, are as follows: rainbow trout (*Salmo gairdneri*), rainbow-cutthroat hybrids, cutthroat trout (*Salmo clarkii*), brown trout (*Salmo trutta*), and Eastern brook trout (*Salvelinus fontinalis*). Since the rainbow-cutthroat hybrids could not always be recognized, some may have been included as rainbow or cutthroat. Eastern brook trout and brown trout were taken only in the lower thirty miles, although some are reported by fishermen to be present in other parts of the river.

Rainbow trout and Eastern Brook trout were the predominant species in Bridger and Spring Creeks. Cutthroat trout were found at the upper end of Spring Creek and brown trout were present in the lower portion of Bridger Creek.

Other fish present in both systems were: mountain whitefish (*Prosopium williamsoni*), white sucker (*Catostomus commersonnii*), longnose sucker (*Catostomus catostomus*), freshwater sculpin (*Cottus sp.*), longnose dace (*Rhinichthys cataractae*), and burbot (*Lota lota maculosa*).

Methods

Scale samples were secured largely from fish taken by angling. The greatest number of these were collected by the Missouri River Basin Studies of the U. S. Fish and Wildlife Service, who conducted creel census on the lower part of the river during the summer of 1949. Approximately 100 scale samples were taken by a fisheries survey party of the Montana State Fish and Game Department in August of 1948. These were supplemented by other samples taken by angling and electrical shocking in parts of the river not adaquately covered by the above-named agencies.

Scale samples were taken from the left side of the fish between the dorsal fin and the lateral line. Total lengths were secured in tenths of inches and weights in tenths of pounds.

Scales, after being cleaned and mounted, were studied by projection on a machine designed for this purpose. Scale measurements were made from the center of the focus along the median-anterior radius to the edge. The positions of the annuli were marked on strips of manila paper. Calculated growth increments were determined by means of a nomograph.

Coefficients of condition (K) were calculated for each fish using the following formula:

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

where W = weight in pounds, and L = total length in inches.

Each week, during the summer of 1949, a series of water temperature determinations was made on the West Gallatin River. These were taken at designated locations within each Section, beginning at Shedd's Bridge (Fig. 1) and continuing upstream. All minimum readings were taken between 6:30 and 9:00 A. M. The greatest time lapse between first and last readings was two hours. Maximum temperatures were secured by taking afternnon readings in July and August, between 2 and 5 P. M.

Water temperature readings were made at designated stations, on Bridger and Spring Creeks at two weeks intervals, during the summer of 1948.

Temperature recording stations were selected within each Section so as to be in an area representative of the Section. Springs or areas below the mouths of tributaries were avoided. Temperatures were measured with a Taylor pocket thermometer calibrated at 2° F intervals. This was checked against a certified chemical thermometer. All temperature readings were made in the shade and those in the water were taken in the current.

Chemical analysis of the water followed the methods presented in "Standard Methods for the Examination of Water and Sewage", by the American Public Health Association (1946). Tests were made for dissolved oxygen, (Winkler Method), phenolphthalein alkalinity, and methyl orange alkalinity. The pH was determined with a Hellige pocket comparator, using appropriate indicators.

ACKNOWLEDGMENTS

The writer is indebted to several individuals and agencies who assisted in this study. Dr. C. J. D. Brown suggested and directed the problem and offered many suggestions during the preparation of the manuscript. About one-half of the West Gallatin trout scale samples were collected and made available by the Missouri River Basin Studies of the U. S. Fish and Wildlife Service. The Montana Fish and Game Department granted permission to make collections, furnished 100 trout scale samples, and assisted in the preparation of scale mouts. R. A. Hays, of that Department, assisted in collecting and checked scale readings. Several of the students and faculty of Montana State College also assisted in various ways.

West Gallatin River

Comparative Growth Rates

The growth rates of trout within any stream or portion of stream, must certainly depend upon such factors as temperature, food, etc. The trout from any sizable portion of the West Gallatin should reflect, by their growth, the conditions of that particular portion, inasmuch as observations of a general nature indicated no mass movement, even during the spawning season. This conclusion is supported by the work of others. Watts, et al, (1942) demonstrated that there was no extensive movement of brook trout in Kettle Creek. Hazzard and Shetter (1938) reported that most planted rainbow and brook trout were caught within one to three miles of the point of release.

Differences in growth rates between the various parts of a stream system have been observed by fisheries workers, but there is little published information on the subject. The present study attempts a comparison of the growth rates of trout from three main sections of the West Gallatin River, with approximate lengths as follows: Section I - 30 miles, Section II - 21 miles, Section III - 30 miles.

Rainbow Trout. Growth rate of rainbow trout (351) was most rapid in Section I, and decreased progressively in each upstream section (Table I). A differential of 0.3 inch was found at annulus 1, 1.3 inch at annulus 2, 2.1 inches at annulus 3, 2.5 inches at annulus 4, and 4.0 inches at annulus

Table I.

Average calculated total length at annulus of rainbow trout from three sections of the West Gallatin River

Annulus	1		2		3		4		5	
	length inches	No.	length inches	No.	length inches	No.	length inches	No.	length inches	No.
Section I	3.4	142	7.4	126	11.5	81	14.5	34	17.2	6
Section II	3.2	76	6.5	70	8.9	30	12.1	4	15.6	2
Section III	3.1	133	6.1	83	9.4	29	12.0	6	13.2	2

Table II.

Average calculated total length at annulus of rainbow-cutthroat hybrid trout from three sections of the West Gallatin River

Annulus	1		2		3		4		5	
	length inches	No.	length inches	No.	length inches	No.	length inches	No.	length inches	No.
Section I	3.5	71	7.4	69	11.5	50	15.1	16	16.7	6
Section II	3.9	29	7.3	25	10.6	15	14.5	6		
Section III	3.5	21	6.9	18	11.0	6				

5, between the upper and lower sections. The differential also increased with the age of the fish. By the application of the t test (Pearson and Bennett, 1942), it was found that in each year of life the variation between Section I and Section III was statistically significant. At annulus 1, there was a variation significant to the 5% level, between Sections I and III. The variations at this annulus between Sections I and II and between Sections II and III were not significant. At annulus 2 there was a variation, in all cases, significant at the 1% level. Variations at annulus 3 between Sections I and III were significant to the 1% leve, but the growth rate in Section III for this group exceeded that in Section II. This variation was not significant, however. Annulus 4 showed a variation significant to the 1% level between Sections I and II and between Sections I and III. The variation between Sections II and III at this annulus was not significant. Differences at annulus 5 were not tested because of the small numbers involved.

Hybrids-Rainbow cutthroat. In the 121 hybrid (rainbow-cutthroat) trout (Table II), the trend of slower growth in the upper sections was also characteristic, but was not as marked as in the rainbow. This may be due to the small number of samples taken in Sections II and III.

Cutthroat Trout. The 113 cutthroat trout (Table III) likewise show slower growth rate in the upstream sections. However, these differences may not be significant because of the

Table III.

Average calculated total length at annulus of cutthroat trout from three sections of the West Gallatin River

Annulus	1		2		3		4	
	length inches	No.	length inches	No.	length inches	No.	length inches	No.
Section I	4.1	15	7.3	14	12.2	2		
Section II	4.7	7	7.3	5	10.8	1		
Section III	4.1	91	6.9	66	10.1	11	10.8	1

Table IV.

Average calculated total length at annulus of trout from Section I of the West Gallatin River

Annulus	1		2		3		4		5	
SPECIES	Length inches	No.	length inches	No.	length inches	No.	length inches	No.	length inches	No.
Brown Trout	3.7	102	8.8	97	13.2	71	15.9	28	19.2	1
Brook Trout	4.7	71	8.5	63	11.8	13				
Cutthroat Trout	4.1	15	7.3	14	12.2	2				
Rainbow Trout	3.4	142	7.4	126	11.5	81	14.5	34	17.2	6
Rainbow-Cutthroat Hybrid	3.5	71	7.4	69	11.5	50	15.1	16	16.7	6

small size of the smaples taken in Sections I and II.

Brown Trout and Brook Trout. These trout were taken only in Section I, and consequently no comparative growth rates between Sections were possible for these two species. Their average calculated lengths at annulus are, however, presented in Table IV, along with growth rates of the other species in Section II, to illustrate the variations in growth rate between all the species of one Section. These averages show a higher rate of growth for the brown and brook trout taken from this Section than for the cutthroat, rainbow, and rainbow-cutthroat hybrid trout. The brown trout, after the first year, exceed all other species in yearly increment.

Condition Factors

The effects of the environment may be reflected not only in the length, but in the condition of a trout. Coefficients of condition were calculated for each age group in each Section (Table V). There was no correlation between the condition of trout and the Section from which they were taken. Average condition factors were no less in the upper Sections than in the lower.

Table V.

Coefficients of condition for trout from the West Gallatin River

Species	Section	Age Group I		II		III		IV		V	
		K	No.	K	No.	K	No.	K	No.	K	No.
Rainbow	I	33.0	16	36.1	44	37.2	45	36.2	28	35.2	6
	II	29.0	5	37.7	40	35.5	27	34.6	3		
	III	41.0	49	39.1	54	37.2	23	34.7	4	38.1	2
Rb x Ct	I	29.6	2	36.3	19	35.3	34	36.5	10	34.1	5
	II	35.2	4	34.5	10	38.0	9	34.8	3	41.7	2
	III	37.8	3	35.2	10	35.5	5	40.5	1		
Cutthroat	I	26.4	1	33.5	12	31.6	2				
	II	37.3	2	37.8	3	34.7	1				
	III	36.7	25	35.8	55	37.3	10				
Brown	I	40.1	5	36.8	26	35.9	43	34.0	27	37.0	1
Brook	I	45.7	8	39.3	50	36.8	13				

Water Temperatures

Water temperature recordings were made weekly in all Sections to determine whether significant variations did exist between them. The monthly averages of morning water temperatures for each, (Table VI) show a definite lower minimum temperature at each higher elevation. Morning temperatures show a difference of 9.6° F, while afternoon temperatures exhibit only 5° F difference between the upper and lower stations (Table VII). The optimum water temperatures, for trout, of 55-60° F (Davis 1946) are reached in all parts of the river, during the afternoons of the warmer months. However, length of time these temperatures exist during the day, and during the year, is much less at high elevations. Daily and seasonal temperature fluctuations are also more extreme at the higher elevations.

Table VI.

Average morning water temperatures by months

DATE 1949	Section I Temp. ° F	Section II Temp. ° F	Section III Temp. ° F
May 29		45.0	39.0
June	48.0	44.5	40.0
July	55.0	52.5	45.0
August	53.0	52.0	45.0
September	50.0	47.5	40.0
October 2	50.0	49.0	40.0
November 12	36.5	35.0	33.0

Table VII.

Afternnon water temperatures

DATE 1949	Section I Temp. ° F	Section II Temp. ° F	Section III Temp. ° F
July 11	62.0	60.0	58.0
August 14	62.0	59.0	57.0

Chemical Analysis

Limited chemical analysis of the water was made in each Section to determine differences which might influence growth. The results of these tests are listed in Table VIII. No appreciable differences existed between the various Sections. In all cases, dissolved oxygen was near the saturation point, and completely adequate. Methyl orange alkalinity tests indicated moderately hard water at all stations, and hydrogen-ion concentration was in the alkaline range.

Table VIII

Chemical Analysis of the water of the West Gallatin River, September 19, 1949

STATION	D.O. ppm.	Phalth. alk. ppm.	M. O. alk ppm.	pH	H_2O Temp. °F
Shedd Br.	8.2	0	114	8.1	48°
Above Deer Cr.	9.3	9	118	8.2	
Above Sage Cr.	9.4	11	117	8.2	49.5°

Bridger Creek and Spring Creek

Comparative Growth Rates

An attempt was made to correlate the growth rate of 98 rainbow and 86 eastern brook trout from five Sections of Bridger and Spring Creek, with their distribution and the water temperature. The sample size was considerably smaller than in the West Gallatin River and the part of the stream system studied was not as long as any one Section of the West Gallatin. No consistent differences in annual length increments could be shown, even between more distant Sections (Table IX).

Table IX

Average calculated total length at annulus of rainbow and Eastern brook trout from the Bridger-Spring Creek system

Annulus		1		2		3		4	
SPECIES	SECTION	Length inches	No.	Length inches	No.	Length Inches	No.	Length inches	No.
Rainbow	I	3.3	25	6.3	23	8.7	12	11.4	2
	II	3.9	54	6.7	42	8.4	10	10.9	1
	III	4.1	15	6.7	10				
	IV	4.3	4	6.5	2				
Brook	I	4.9	3	7.7	1				
	II	4.4	23	6.7	11	11.0	2		
	III	3.8	17	6.5	15				
	IV	3.9	26	6.4	14				
	V	4.2	17	6.9	12	10.7	1		

Condition Factors

Condition factors for rainbow and Eastern brook trout (Table X) show no correlation between their condition and the Section from which they were taken. As in the West Gallatin, K values and length were not correlated.

Table X.

Coefficients of condition for rainbow and Eastern brook trout from the Bridger-Spring Creek system

Species	Section	Age Group I		II		III		IV	
		K	No.	K	No.	K	No.	K	No.
Rainbow	I	32.9	2	35.7	10	35.2	10	32.2	1
	II	36.0	12	32.8	32	35.3	10		
	III	38.7	5	38.3	9	34.0	1		
	IV	33.9	2	30.6	2				
Brook	I	34.0	2	32.8	1				
	II	33.0	10	36.2	8	37.2	2		
	III	37.1	2	35.6	15				
	IV	34.1	12	38.3	14				
	V	41.9	5	37.1	11	39.9	1		

Water Temperature

Temperature readings were also made in Bridger Creek, to determine variations of water temperature. No great differences in water temperatures were observed between the upper and lower Sections (Table XI). The greatest difference observed was 7° F, and the least difference was 2° F. However, temperatures were not taken at times comparable or frequent enough to give conclusive evidence on this point.

Table XI.

Bridger and Spring Creek water temperatures

Date	July 5, 1948		July 19, 1948		August 3, 1948	
SECTION	Water Temp °F	Time	Water Temp °F	Time	Water Temp °F	Time
Sec. I	62.0	3:30 PM	55.0	8:15 AM	51.0	6:00 AM
Sec. II	60.0	3:00 PM	53.0	11:00 AM	47.0	6:20 AM
Sec. III	56.5	1:00 PM	53.0	11:25 AM	47.0	6:45 AM
Sec. IV	54.0	12:00 PM			47.0	7:30 AM
Sec. V	49.5	10:45 AM	50.0	6:00 PM	46.0	9:00 AM

Date	August 17, 1948		Sept. 1, 1948		Oct. 2, 1948		April 4, 1949	
SECTION	Water Temp °F	Time	Water Temp °F	Time	Water Temp °F	Time	Water Temp °F	Time
Sec. I	55.0	9:45 AM	53.0	6:00 AM	50.0	1:00 AM	44.0	1:00 PM
Sec. II	53.0	10:00 AM	47.0	6:20 AM	49.0	1:30 PM	44.0	1:20 PM
Sec. III	50.0	10:30 AM	47.0	6:35 AM	48.0	2:00 PM	43.0	2:00 PM
Sec. IV	53.0	11:00 AM	46.0	7:00 AM	48.0	2:30 PM	40.0	2:30 PM
Sec. V	52.0	11:30 AM						

Chemical analysis

Limited chemical analysis of the water of the Bridger-Spring Creek system was made to determine whether any chemical conditions were present, which might affect growth differently in one Section than another. The data (Table XII) showed no great variation between Sections. Dissolved oxygen was adequate in all cases. Methyl orange alkalinity tests showed the waters to be moderately hard at all stations, and hydrogen-ion concentration was in the alkaline range.

Table XII

Chemical analysis of the water of the Bridger-Spring Creek system, July 19, 1948

STATION	D. O. ppm.	Phenophth alk. p.p.m.	M. O. alk. p.p.m.	pH	H_2O Temp. °F
Section II	8.4	6	168	8.2	55°
Section III	8.5	6	156	8.2	53°
Section IV	8.2	3	129	8.1	53°

The Relationship between Growth Rate, Elevation, and Water Temperature

Comparisons of the growth rates, elevations, and water temperatures in Sections of the West Gallatin River, indicated that at each higher elevation there were smaller annual length increments, and lower water temperatures. The variations in growth rate have been shown to be significant for rainbow trout. Definite trends have also been established for rainbow-cutthroat hybrid trout and cutthroat trout. Trout from Bridger Creek showed no consistent differences in annual length increments and no great temperature variations were found in the stream.

Belding (1928) says, "growth is governed by...the rate of metabolism of the fish", and further, "cessation of growth apparently depends upon the reduction of metabolism by the temperature." Needham (1938) cited extreme fluctuations of water temperature as a cause of lowered growth rate. In the West Gallatin there was a marked seasonal variation in temperature and in the upper Sections the daily fluctuation was quite pronounced, probably due to the lack of shade. The variations found between the upper and lower Sections may be sufficient to account for the differences in yearly length increments, although other environmental factors not determined may also have affected the rate of growth. Bridger Creek temperature and growth data are too limited to be more than suggestive of

the part played by temperature.

If temperature is the determining factor, then it does not have the same effect on condition (K) as it does on length. No significant difference in K was shown between the various Sections of either stream system.

Summary

1. Studies were made of the growth rates of 758 trout from the West Gallatin River and 184 trout from Bridger Creek.

2. Each stream was divided into Sections on the basis of altitude; The West Gallatin into three Sections by 1000 foot elevations; Bridger Creek into five Sections by 500 foot elevations;

3. Growth rates, condition factors (K), and water temperature determinations were made for each Section of stream.

4. Rainbow trout from the upper and lower Sections of the West Gallatin River showed the following differences in length at the end of each year: 0.3 inch the first year, 1.3 inches the second year, 2.1 inches the third year, 2.5 inches the fourth year, and 4.0 inches the fifth year.

5. Growth rates of 121 hybrid (rainbow-cutthroat) trout and 113 cutthroat trout from the West Galbtin River were slower in the upstream Sections.

6. Growth rate of brown trout was higher than any other species in Section I.

7. Ninety-eight rainbow trout and 86 brook trout from Bridger Creek exhibited no consistent variations in growth rate between Sections.

8. There was no correlation between condition factors and the Section of stream from which the trout were taken.

9. Average minimum water temperatures during the summer in

Section III of the West Gallatin River were 9.6° F lower than in Section I.

10. Incomplete water temperature data from Bridger Creek showed variations from 2° to 7° F between the upper and lower Sections of the stream.

Literature Cited

American Fisheries Society
1948. A list of the common and scientific names of the better known fishes of the United States and Canada. Spec. Publ. No. 1, 45 pp.

American Public Health Association
1946. Standard methods for the examination of water and sewage, 9th edition. New York, 286 pp.

Belding, David L.
1928. Water temperature and fish life. Trans. Am. Fish. Soc., Vol. 58, pp. 98-105.

Davis, H. S.
1946. Care and diseases of trout. U. S. D. I., Research Report 12, 98 pp., (illus.) rev. ed. 1946.

Hazzard, A. S.
1932. Some phases of the life history of the Eastern brook trout, Salvelinus Fontinalis Mitchell. Trans. Am. Fish. Soc. Vol. 62, pp. 344-350.

Hazzard, Albert S. and David S. Shetter
1938. Results from experimental plantings of legal-sized brook trout (Salvelinus fontinalis) and rainbow trout (Salmo Irideus). Trans. Am. Fish. Soc. Vol. 68, pp. 196-208.

McHugh, J. L.
1941. Growth of the Rocky Mountain whitefish. Jour. Fish. Res. Bd. Can. 5(4), pp. 337-343.

Needham, Paul R.
1938. Trout streams. Comstock Publishing Company, Inc. Ithaca, New York. 233 pp.

Pearson, Frank A. and Kenneth R. Bennett
1942. Statistical Methods. John Wiley and Sons, Inc., New York. 443 pp.

Watts, R. L., G. L. Trembley, and G. W. Harvey
1942. Brook trout in Kettle Creek and tributaries. Penn. Agric. Ex. Sta. Bull. 437 (Dec. 1942). 41 pp.

West, Raymond M. and A. G. Stubblefield
1948. A five-year fish distribution and management plan 1948-1952. Bozeman and Ennis hatcheries district-Montana. U. S. Dept. Agric. Forest Service Region 1. 93 pp.