MONTANA FISH AND GAME DEPARTMENT
FISHERIES DIVISION
HELENA, MONTANA

JOB COMPLETION REPORT
INVESTIGATIONS PROJECTS

State of Montana

Name Southwest Montana Fishery Study

Project No. F-9-R-15

Title Evaluation of River Fish Populations

Job No. VII

Period Covered July 1, 1966, to June 30, 1967.

ABSTRACT:

The three basic types of electric current used in electrofishing are: alternating current, continuous direct current, and pulsed direct current. Pulsed direct current appears to be the most satisfactory type for electrofishing in streams because it produces the strongest galvanotaxic response for easy fish capture and there is little harmful effect on the fish. The negative should have approximately thirty times more surface area than the positive and should be kept within fifteen feet of the positive to achieve maximum use of the electrical field. As the conductivity of the water increases, less voltage is required to achieve a good galvanotaxic response by the fish. Low water temperatures also improve the response of trout to an electrical field. The basic Peterson-type mark and recapture formula was determined to be the most satisfactory method for estimating river populations where shocking efficiencies are less than 50%. Sample size, shocking efficiency, and approximate population size must be known in order to determine the length of the shocking section.

Population estimates were made on five sections of the East Gallatin River and one section on Thompson Creek, a tributary to the East Gallatin River. No young-of-the-year trout were found in the shocking samples in the upper fifteen miles of the East Gallatin. Two-year-old fish were more abundant than yearlings in section XIVb-XII of the East Gallatin. Rainbow were the most numerous trout in the upper reaches of the river, with browns being more numerous in the lower river. Tagging information from four hundred recaptured trout showed that at least 5% had detectable movements greater than 3,000 feet. Preliminary survey shocking was initiated on the Madison and West Gallatin Rivers.

RECOMMENDATIONS:

There should be continued work to improve shocking equipment and techniques. A pulsating direct current electrofisher should be tested under various large river conditions. Other rivers and streams should be shocked to determine if sample sizes and shocking efficiencies are adequate to make satisfactory population estimates. Population estimates, mortality rates, species composition and movement should be determined for the Madison and West Gallatin Rivers. Shocking should also be continued on the East Gallatin River to obtain more population data, especially in relation to pollution and land use practices.

OBJECTIVES:

The purpose of this job is to develop shocking gear and sampling techniques necessary to estimate fish populations in the larger streams and rivers. The present electrofishing equipment and sampling techniques have not been adequate to sample the larger streams. The specific objectives are: (1) to develop and modify existing electrofishing gear to utilize its maximum effectiveness; (2) to determine the proper mathematical techniques and minimum sample size necessary to estimate such population parameters as: total population, age structure, size composition, species composition, growth rates, recruitment, and natural and angler mortality; and, (3) to determine by the use of tags the movement of fish within the river system.

TECHNIQUES USED:

Electrofishing gear was used to sample fish populations in the East Gallatin River; Thompson Creek, a tributary to the East Gallatin River; Madison River; and West Gallatin River. These streams were divided into sections and subsections which ranged in length from 1.8 miles to 6.4 miles. Electrofishing was carried out while floating through a section of stream in a flat-bottomed aluminum boat. This shocking boat contained a generator, a mobile positive electrode, a stationary negative electrode, and a tub in which captured fish were retained. The shocking crew usually consisted of one man who operated the mobile positive electrode, one or two men operating dip nets, and one man who manipulated the boat (Figure 1).

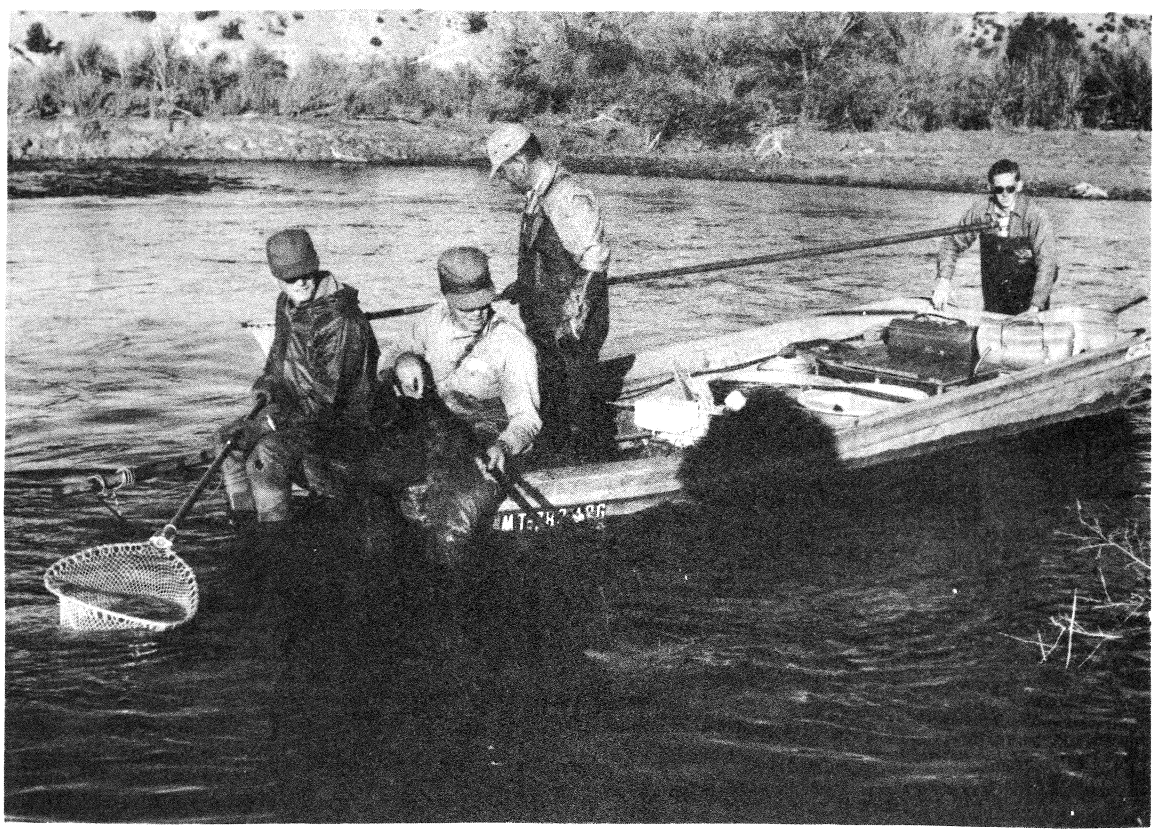

Figure 1. Electrofishing crew and equipment used in river shocking.

Population estimates were made by using a mark and recapture method. Fish were marked with temporary fin clips, plastic jaw tags, or plastic dart tags (Figure 2).

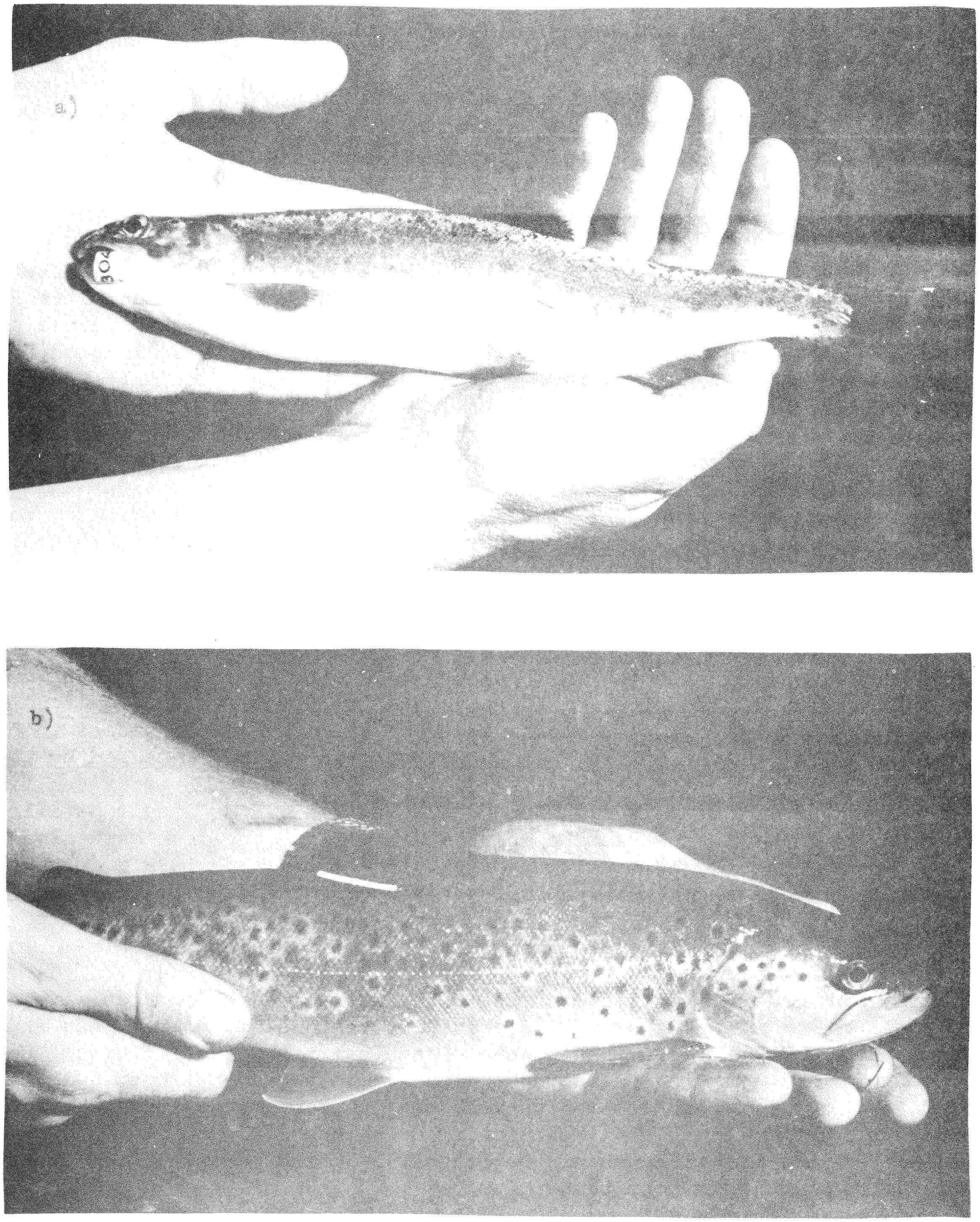

Figure 2. Fish tags used in movement studies. a) A jaw tag used on a rainbow. b) A dart tag inserted below the dorsal fin on a brown trout.

Dart tags were inserted in the fish just below the dorsal fin, with the barbs of the tag engaging the pterygiophores. These tagged fish were used for both population work and movement information.

Shocking efficiency was defined as the proportion of the total population that was captured during a single trip.

FINDINGS:

Electrofishing Principles

Effects of basic types of electric current on trout

The three basic types of electric current used in electrofishing are alternating current, continuous direct durrent, and pulsating direct current. When alternating current is introduced into the water, it sets up an electrical field which has a continual reversal of poles. Alternating current stimulates the fish to react in such a way that it aligns itself parallel to a line between the poles or perpendicular to the lines of electrical force between the poles (oscillotaxis - Van Harreveld, 1938). Alternating current causes no unidirectional swimming of the fish because of the continual reversal of poles, but it can cause either fright or flight with low field intensities or narcosis in a high voltage gradient. Under most stream shocking conditions, alternating current is quite unsatisfactory because: (1) the absense of unidirectional swimming toward the anode makes capture difficult - this is particularly evident in deep, turbid or brushy streams; (2) tissue damage in the fish is more common than with direct current; and (3) there is more danger to the personnel operating the electrofisher.

The most commonly used form of electrical power is continuous direct current, which sets up an electrical field between the positive pole (anode) and the negative pole (cathode). This type of electrical current causes the fish to align itself parallel to the lines of force between the electrodes; thus any swimming motion causes the fish to move toward the anode (galvanotaxis). The galvanotropic reflex is caused by the contraction of the muscles on the side of the fish facing the anode which turns the fish into a position with its head toward the anode. When the fish aligns itself parallel to the lines of force, then muscle contraction is at a minimum and the fish must remain aligned in this position because of the electrical field (Van Harreveld, 1938). Direct current is more commonly used than alternating current in stream sampling because: (1) the unidirectional swimming facilitates capture; (2) there is little tissue damage to the fish; and (3) there is less danger to the personnel operating the electrofisher.

Pulsating and continuous direct current both have similar electrical fields when introduced into the water. The basic difference is that pulsed current has an intermittent power flow. The reaction of the fish to the electrical field is similar to continuous direct current, except that the pulsating action stimulates the fish to swim more vigorously toward the anode. This reaction to pulsating current makes it more effective than either alternating or continuous direct current. Taylor, Cole and Sigler (1957) stated that pulsed direct current will produce a good galvanotaxic reaction with about 25-45% of the voltage required with continuous D. C.

There are several factors which affect the efficiency of pulsating current, such as the number of pulses per second, duration of pulse (duty cycle), and the shape of the pulse. Under most shocking conditions, 48-100 pulses per second is considered adequate to achieve maximum efficiency (Taylor, Cole and Sigler, 1957). Haskell and Adelmann (1955) stated that slow pulsations (40-60) are more effective than faster pulsations (180 or more) since the fast pulsations produce quicker anesthesia and somewhat more erratic migrations toward the anode, producing a condition much like alternating current. The duration of the pulse should be about 33% of the time, or at a duty cycle of 0.33. The most effective pulse shape appears to be rectangular pulse which gives peak current flow immediately and then drops down to zero voltage before another pulse begins (Patten and Gillaspie, 1966). Pulsating D. C. appears to be the most satisfactory type of current for electrofishing since: (1) it produces a stronger galvanotaxic response than continuous D. C.; (2) lower voltages result in good galvanotaxic reactions; and, (3) since it is effective with less power than continuous current the electrofishing unit can be smaller and lighter in weight.

Electrodes and electrode arrangement

The electric current is introduced into the water by means of the positive and negative electrodes. The number, size, shape, and spacing of these electrodes affects the size and strength of the electrical field, which in turn affects the galvanotropic response of the fish. Various combinations of multiple electrode systems were tried, such as double positive with a single negative, double negative with one positive, and two or more positives with two or more negatives. These electrodes were placed on a boom which was parallel to the bow of the boat. Most arrangements using multiple positive electrodes were quite unsatisfactory because the effective voltage around the anode was reduced, making capture of the fish more difficult. The most satisfactory arrangement was one anode and one cathode. The negative was suspended from a boom which was fastened perpendicular to the bow of the boat, and the positive was on a mobile probe. The negative should be kept upstream from the positive when floating because the field around the negative can act as a "fright" field to the fish, causing them to move away and avoid capture. The size relationship of the electrodes is quite important. Patten and Gillaspie (1966) recommended that the cathode be about thirty times larger than the anode. In float shocking, the negative had a total effective surface area of about four square feet and the positive had an area of 0.2 square foot. The triangular anode creates the strongest field around the electrode, but the field may be so strong close to the electrode that narcosis occurs, making capture difficult. The oval shaped electrode seems to be more efficient in that galvanotaxis is strong and little narcosis occurs. With the use of a voltmeter, it was determined that the two electrodes should remain within 10-15 feet of each other to maintain an optimum field strength and galvanotaxis.

Factors affecting the response of fish to an electrical field

Water conductivity affects the response of fish to an electrical current in water. As the conductivity increases, the voltage necessary to cause a good galvanotropic reaction decreases, and as the conductivity decreases, more voltage is necessary (Flux, 1967). The voltage necessary to adequately stimulate the fish at 200 micromhos was approximately three times greater than that required at 1,000 micromhos. Conductivities of waters tested in southwestern Montana rivers range from 180-650 micromhos.

Water temperature also has a significant influence on the response of fish to an electrical current. The East Gallatin River was shocked during both the summer, when water temperatures were warm (60-70° F.), and during the winter when water temperatures were colder (35-45° F.). On one section of the East Gallatin, the shocking efficiency was 18% during the summer and 32% during the winter at approximately the same volume of flow. Fisher and Elson (1950) found that trout have a maximal response to an electrical stimulus at about 50° F. Flux (1967) found that fish had a decreasing sensitivity to an A. C. field at increasing temperatures. Flux (1967) stated that the effectiveness of continuous D. C. decreased with increasing water temperatures, while the effectiveness of pulsed D. C. increased.

Population Statistics

Methods of estimation

The Peterson-type mark and recapture method is widely used to estimate fish populations in stream and river work. The basic Peterson formula is as follows:

$$N = \frac{MC}{R}$$

where: M = the number of fish marked.

C = the number of fish in the recapture sample.

R = the number of marked fish in the recapture sample (C).

Various modifications of this formula have been suggested, such as adding one to each factor in the numerator and denominator as Bailey (1951) has done to reduce the bias of the estimate:

$$N = \frac{(M+1)\ (C+1)}{R+1} - 1$$

This modification was made to reduce the chance of overestimating the population, especially populations of 1,000 or less. Bailey's formula must be used with care, as certain conditions concerning sample size must be met to produce an accurate estimate. Robson and Reiger (1964) stated that the total size of the mark and recapture samples (M+C) must equal or exceed the population size (N) or the condition $MC > 4N$ must be met, if you desire to be exactly unbiased.

Sample size

To select the most satisfactory formula to use for population estimation, knowledge of sample size is necessary. Several factors must be considered to obtain the most suitable sample size for the accuracy desired. The two most important factors are population size and shocking efficiency. Bailey's modification can be used where population sizes are small or the number of the marked recaptures is small (less than four).

The basic Peterson formula produces the most satisfactory population estimate for larger rivers where shocking efficiencies are low. In these rivers the population size is usually large (1,000 or more), but the shocking efficiencies are low, which makes the sample sizes quite low in relation to the size of the population. This situation can affect the accuracy of the population estimate. Estimates are more accurate when the sample size is large in relation to the total population or when population sizes are quite large. Robson and Reiger (1964) constructed charts to determine adequate sample sizes for given population sizes for certain levels of confidence and precision.

When using this formula, certain basic principles should be met in determining the correct sample size. The product of the number of fish in the mark and recapture samples must exceed the population by a factor of 3 or 4 (Robson and Reiger, 1964). If MC=N, then the Peterson formula underestimates the population (N) by approximately 37%, while if MC=4N the bias is less than 2%.

Shocking sections

Sample size, shocking efficiency, and approximate population size are considered in determining the length of a shocking section. To determine these three criteria, survey shocking is carried out. After the shocking efficiency, sample size, and a rough population estimate are determined, the most satisfactory shocking section can be delimited. If the efficiencies are low (3-15%), longer sections should be used to include a large population. A combination of large populations and low efficiencies maintain the same precision of the estimate as smaller populations with high efficiencies.

Population Data

East Gallatin River and tributaries

The East Gallatin River was divided into fourteen sections ranging in length from 8,125 to 21,374 feet (Figure 3). Each of these sections was then divided into subsections. Fish were tagged in each section to determine movement. Population estimates were also made on several of the sections.

Population estimates

Population estimates were made on five sections of the East Gallatin River and on one tributary spring creek. These estimates were made by using the Peterson-type mark and recapture method. Two or more "marking" trips were required in those sections where shocking efficiencies were low. the shocking efficiencies for the seven areas were as follows: XIV, 49%; XIII, 44%; XII, 16%; VII (July), 16%; VII (Feb.), 32%; VI, 11%; and Thompson Creek, 29%. Confidence intervals at the 95% level were calculated for each estimate by formula 6 of the Michigan Institute for Fisheries Research, Methods Memo 18 (1960). A summary of the population estimates for the five sections are presented in Table 1.

Habitat conditions

The East Gallatin River has several serious habitat problems which probably affect the standing crop of trout. Two of the more serious problems are water pollution and bank erosion. The outlet of the Bozeman Municipal Sewage Treatment Plant enters the East Gallatin River about 1,500 feet below the confluence of Bozeman Creek at the end of subsection XIVa (Figure 3). In subsection XIVa, which is above the effluent, the standing crop of trout was 196 pounds per acre of which 29 pounds were brown trout and the remainder rainbow. In subsections XIVb-XIII, which are below the sewage outlet, there were 51 pounds per acre of rainbow and a negligible amount of brown trout. The standing crop increased downstream until it had reached 272 pounds per acre (173 rainbow and 99 brown trout) in section VII. Serious bank erosion and the destruction of woody bank vegetation which serves as trout cover is evident along most of the East Gallatin River. This condition is exceptionally severe in section VI, in which approximately 70% of the banks are seriously eroded. The standing crop in this section was only 105 pounds per acre (61 rainbow and 44 brown trout).

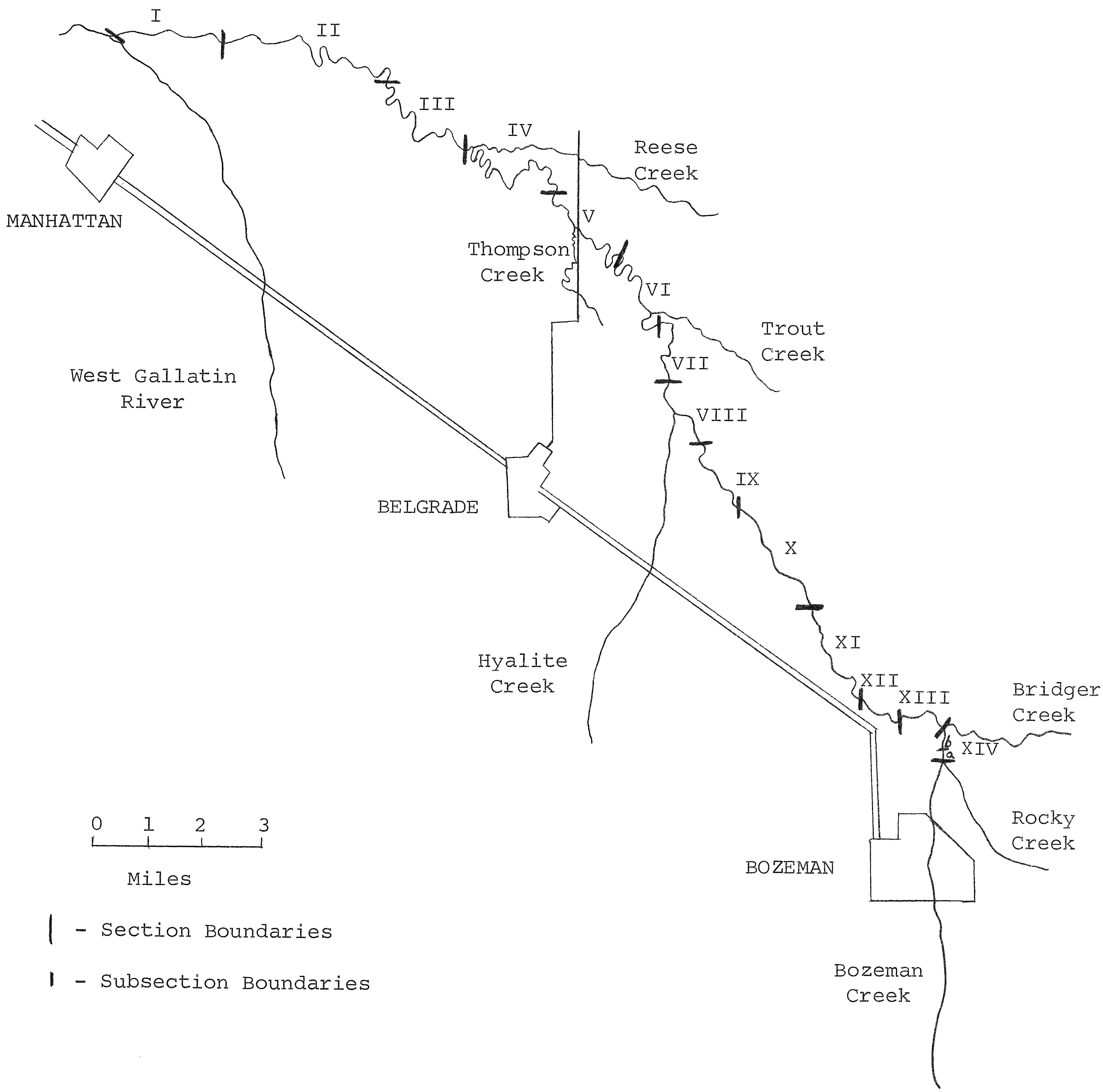

Figure 3. Map of the East Gallatin River showing study sections.

TABLE 1. Estimated trout populations for four sections of East Gallatin River and Thompson Creek. Pounds are shown in parentheses. Confidence intervals expressed at the 95% level.

Species	XIVa Sept. 1966	XIVb-XIII Sept. 1966	XII July 1966	VII July 1966	VI Aug. 1966	Thompson Cr. Sept. 1966
Total rainbow trout	315	722	2686	2139	2072	1225
	(111)	(323)	(1006)	(1038)	(824.90)	(310.90)
Confidence interval (±)	62	130	892	580	816	236
Total brown trout	17	-	-	304	728	1651
	(18)			(594)	(583.17)	(364.21)
Confidence interval (±)	6			162	306	430
Total brook trout	-	-	-	-	-	203
						(42.34)
Confidence interval (±)						79
Rainbow trout						
Number/acre	525	115	461	358	155	-
Pounds/acre	(167)	(51)	(172)	(173)	(61.3)	
Brown trout						
Number/acre	28	-	52	81	54	-
Pounds/acre	(29)		(27)	(99)	(43.5)	
Brook trout						
Number/acre	-	-	-	-	-	-
Pounds/acre						
Total trout						
Number/acre	553	115	513	439	225	-
Pounds/acre	(196)	(51)	(199)	(272)	(104.5)	

Age structure

Age composition and age group strength were calculated for each of the sections and subsections which had population estimates. The method utilized was adapted from Ketchen (1950). Scales were collected from fish in each inch-group to determine the percent age group composition for every inch-group. This information was then applied to the population estimates for each inch-group to obtain a population estimate for each age group. A summary of the population estimates for each age group of rainbow and brown trout for six sections is given in Table 2.

The strength of each age group varies considerably within the East Gallatin River system. Subsection XIVa had the largest number of rainbow trout per surface acre in age groups I and II of all sections in the East Gallatin. Subsections XIVa and XIVb-XIII in the upper portion of the river support more four-year-old and older rainbow than do sections in the middle portion of the river (sections VII and VI). Growth rates in the upper portion of the river were considerably slower than in the middle portion. Some two-year-old fish in the middle portion of the river were equivalent in size to four-year-old fish in the upper portion. Although there are more older fish per acre in the upper regions, there are more large fish in sections VII and VI. The number of trout greater than 14.0 inches for each section expressed in fish per surface acre are: XIVa, 24; XIVb-XIII, 13; XII, 17; VII (July 1966), 72; and VI, 26.

TABLE 2. Estimated age structure of rainbow and brown trout for each section or sub-section. (Number per acre are shown in parentheses). The size range for each age group is given in inches.

Section	Age Groups					
	0	I	II	III	IV+	Total
			Rainbow Trout			
		4.7- 7.9	8.0-11.9	9.0-13.9	>11.9	
XIVa Sept. 1966	-	138 (230)	125 (208)	43 (72)	9 (15)	358 (525)
XIVb-XIII Sept. 1966	-	211 (35)	247 (39)	169 (26)	96 (15)	722 (115)
XII July 1966	-	1145 (196)	977 (167)	514 (88)	57 (10)	2686 (461)
		5.0- 9.9	7.0-14.9	12.0-15.9	>14.9	
VII July 1966	-	1314 (219)	411 (69)	351 (59)	63 (11)	2139 (358)
VI Aug. 1966	-	1257 (94)	552 (41)	193 (15)	70 (5)	2072 (155)
	1.0- 6.9	7.0-11.9	11.0-14.9	14.0-16.9	>15.9	
Thompson Cr. Sept. 1966	781	321	80	28	15	1225
			Brown Trout			
		6.0-11.9	10.0-15.9	14.0-17.9	>15.9	
VI Aug. 1966	-	379 (27)	220 (17)	99 (7)	30 (3)	728 (54)
	2.0- 5.9	6.0-11.9	11.0-14.9	14.0-15.9	>15.9	
Thompson Cr. Sept. 1966	1395	163	44	16	33	1651

Table 3 shows the relative abundance of each age group within the six sections in which population estimates were made. No young-of-the-year trout (age group 0) were found in any section of the river above section V. Both brown and rainbow young-of-the-year begin to appear in the shocking samples from section V downstream. In section XIVb-XIII, the two-year-old rainbow are the most abundant fish with the yearlings being fewer in number. The yearling rainbow are the most abundant age group in all other sections which had population estimates. The yearling rainbow increase in relative abundance downstream from section XIVb-XIII and reach their greatest relative abundance in section VI. The age composition of brown trout shows section VII having more three- and four-year-old fish than one- or two-year-olds. The relative abundance of yearling browns increased downstream in section VI. Thompson Creek has a greater relative abundance of yearling rainbow and brown trout than any section in the East Gallatin which was estimated. Thompson Creek also had an abundance of age group 0. This indicates some factors are suppressing natural reproduction in the East Gallatin River. Pollution from the Bozeman Municipal Treatment Plant appears to be one of these factors. An intensive study of the effects of this plant on the river was undertaken in 1967.

TABLE 3. Relative abundance for each age group of rainbow and brown trout expressed as percent of total numbers.

Section	Age Groups			
	I	II	III	IV+
		Rainbow Trout		
XIVa	44	40	14	2
XIVb-XIII	29	34	23	14
XII	43	36	19	2
VII	61	19	16	4
VI	64	26	5	5
Thompson Creek	72	18	6	4
		Brown Trout		
VII	16	19	34	31
VI	39	31	17	13
Thompson Creek	64	17	6	13

Angler mortality

Angler mortality was determined by the use of tagged fish. A total of 279 trout were tagged during the July sampling of section VII. Five of these were caught and returned by anglers. This indicates that at least two percent of the population were caught and reported by anglers. Not all tagged fish caught by anglers are reported, but this low level of tag returns would indicate that angler harvest accounted for only a small part of the total mortality. There was no winter fishing season during this period, and therefore the angler harvest was confined to a four month period. Late summer and fall pressure is light on this stream. It appears that this trout population could withstand a much greater harvest without harming the standing crop.

Species composition

There is considerable variation in the species composition of trout within the East Gallatin drainage. Data concerning species composition was obtained from survey shocking data and from population estimates. Table 4 shows the percent composition of three species of trout for each section of the East Gallatin River and for Thompson Creek. The upper reaches of the East Gallatin are primarily inhabited by rainbow trout. Brown trout become the most abundant trout approximately twenty miles downstream from the mouth of Sourdough Creek. Brook trout were found in most sections of the East Gallatin, except in sections XIVb and XIII and section I, but they are never numerous. Cutthroat were found occasionally in some sections.

TABLE 4. Species composition of trout for each section shocked in the East Gallatin River and Thompson Creek. Figures are given in percent.

Species	XIVa	XIVb-XIII	XII	XI	IX	VII	VI	IV	III	II	Thompson Creek
Rainbow	95	100	91	78	75	75	74	55	35	9	40
Brown	5	Tr.	7	22	23	24	26	45	65	91	54
Brook	Tr.	-	2	Tr.	2	1	Tr.	Tr.	Tr.	-	6

Movement

A total of 2,544 rainbow, brown, and brook trout have been tagged in the East Gallatin River from August, 1965, to April, 1967. Trout have been tagged in every section except X and I. During this period, 400 tagged trout were recaptured by means of electrofishing and these were used to analyze movement. The returns were from trout which had been tagged 0-19 months prior to recapture. A summary of the movements of the 400 recaptured trout is presented in Table 5.

TABLE 5. Movement of trout within the East Gallatin drainage. Those fish showing detectable movement greater than 3,000 feet are in parentheses.

Species	Period of time from tagging to recapture (months)						Total
	0-3	4-6	7-9	10-12	13-15	16-19	
Brook	1 (1)	-	-	-	-	-	1 (1)
Brown	35 (2)	18 (1)	31 (1)	8 (2)	9 (0)	3 (0)	104 (6)
Rainbow	146 (4)	56 (2)	58 (6)	17 (0)	18 (0)	-	295 (12)
Total	182 (7)	74 (3)	89 (7)	25 (2)	27 (0)	3 (0)	400 (19)

Of the 400 recaptured trout, only nineteen showed detectable movement greater than 3,000 feet.

Most of these movements were by fish which had been marked near section boundaries. Since some subsections are greater than 3,000 feet in length and the total movement between adjacent sections cannot be detected, there may be some fish that move a greater distance than 3,000 feet. Of the nineteen trout showing major movement, fifteen moved upstream and four downstream. The maximum movement upstream was by a brown which traveled twelve miles, while the maximum downstream movement was ten miles by a rainbow. Five of the nineteen fish were rainbow which were recovered in tributary streams during their spring spawning period. This information indicates that a minimum of 5% of the recaptured trout show detectable movements greater than 3,000 feet, and part of these are probably spawning movements. Forty-six trout showed minor movements between adjacent sections, of which eighteen moved upstream and twenty-eight downstream. Most of these fish were ones which were tagged and released near section boundaries.

Madison River and tributaries

Preliminary survey shocking and fish tagging was started on the Madison River and O'Dell Creek. Six sections of the Madison River were shocked, with two sections below Ennis Reservoir and four above. A total of 304 rainbow and brown trout were tagged in these six sections. Two sections of O'Dell Creek were shocked and a total of 245 brown and rainbow were tagged.

West Gallatin River

Preliminary survey shocking and fish tagging was initiated on the West Gallatin River. Four sections were shocked to determine adequate sample sizes. In addition, 385 brown, rainbow and brook trout were tagged.

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