THE TROUT FISHERY OF THE BIGHORN RIVER BELOW YELLOWTAIL DAM, MONTANA

by

HAROLD RICHARD STEVENSON

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

of

MASTER OF SCIENCE

in

Fish and Wildlife Management

Approved:

_____
Chairman, Examining Committee

_____
Head, Major Department

_____
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

March, 1975

VITA

The author, Harold Richard Stevenson, was born May 26, 1943 in Crosby, North Dakota to Harold William and Hazel Verra Stevenson. He graduated from Billings Senior High School, Billings, Montana, in 1961. In September, 1962 he enrolled at Eastern Montana College at Billings from which he graduated with a Bachelor of Science degree in Biology in 1969. In January, 1972 he began graduate studies at Montana State University.

ACKNOWLEDGMENT

The author wishes to extend his appreciation to those who assisted him during the course of the study. Drs. Richard J. Graham directed the study and assisted in field work, William R. Gould assisted in the preparation of the manuscript and field work. Drs. Don C. Quimby and Robert L. Eng critically reviewed the manuscript. Mr. Steve Swedberg, Mr. Russell Penkal and other Montana Fish and Game Department personnel, National Park Service personnel, and fellow graduate students assisted with field work. Mr. Robert Chew assisted in data analysis and the Montana State University Statistics Laboratory furnished the computer programs. The Montana Fish and Game Department and the National Park Service loaned equipment. The Montana Cooperative Fishery Unit and the Montana Fish and Game Department financed the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

ABSTRACT

The fishery in three sections of the Bighorn River below Yellowtail Dam was studied during 1972 and 1973. Estimates of catch rates of trout by fishermen on weekends and holidays were made during 1972 and estimates of fishing intensity, catch rates, and yield on weekends, holidays and weekdays were made during 1973. The growth rates of trout were calculated from scale samples taken during both years. Catch rates during 1972 and 1973 and fishing intensity and yield during 1973 increased as the season progressed. During the study, the catch of brown, rainbow and cutthroat trout ranged from 0.00 to 0.07, 0.26 to 0.67 and 0.00 to 0.05 fish per hour, respectively. During 1973, the estimated total number of fisherman days was 37.4 per surface acre in the afterbay below the dam (Section A) and 3,720 and 630 per stream mile in Sections B and C below the afterbay, respectively. During 1973, the estimated total yield was 37,321 trout caught during 18,648 fisherman days for an average of 2.00 fish per fisherman day. Rainbow trout made up 90.1 percent while hatchery rainbow made up at least 59.4 percent of the total yield. However, the percent of rainbow trout in the yield decreased with downstream progression while the percent of brown and cutthroat trout increased. Brown trout in the study area averaged 22.5 inches in total length at the fourth annulus. Wild brown and marked hatchery rainbow trout grew from approximately 7 to 13 and 6 to 12 inches, respectively, in a period of 5 months.

37,000

13

HRt
= 60% or more

INTRODUCTION

The construction of Yellowtail Dam and a deep water release from Bighorn Lake have allowed a trout fishery to develop in a reach of the Bighorn River below the dam. The purpose of this study was to determine the importance of the fishery by estimating fishing intensity, catch statistics and growth rates of trout in 14 miles of the Bighorn River immediately below Yellowtail Dam. Field work was conducted from June to September, 1972 and from April to September, 1973.

DESCRIPTION OF STUDY AREA

The Bighorn River originates in Wyoming and flows through Bighorn and Treasure counties in southcentral Montana. From below Yellowtail Dam it flows 80 miles northeast to join the Yellowstone River near Bighorn, Montana. The 14 and 38 miles of the river immediately below the dam lie in the Bighorn Canyon National Recreation Area and the Crow Indian Reservation, respectively.

Land use along the Bighorn River is primarily agricultural with at least 40,800 acres being irrigated from the river. Principally wheat and cattle are raised on non-irrigated land. Several oil wells are located on Soap Creek which enters the Bighorn River in the study area. Montana State Fish and Game Department Fishing Access sites are located at points on the river about 14 and 30 miles below Yellowtail Dam.

Seasonal preimpoundment flows of the Bighorn River during the 1964-1965 water year are presented in Figure 1. Mean flows were greater than 10,000 cfs 2 months and less than 4,000 cfs 9 months (U.S.G.S., 1965). Since regulation began in November, 1965, the river has had lower maximums and higher minimums. During the 1971-1972 water year (Figure 2) all mean monthly flows were less than 7,000 cfs and only four were less than 4,000 cfs (U.S.G.S., 1972).

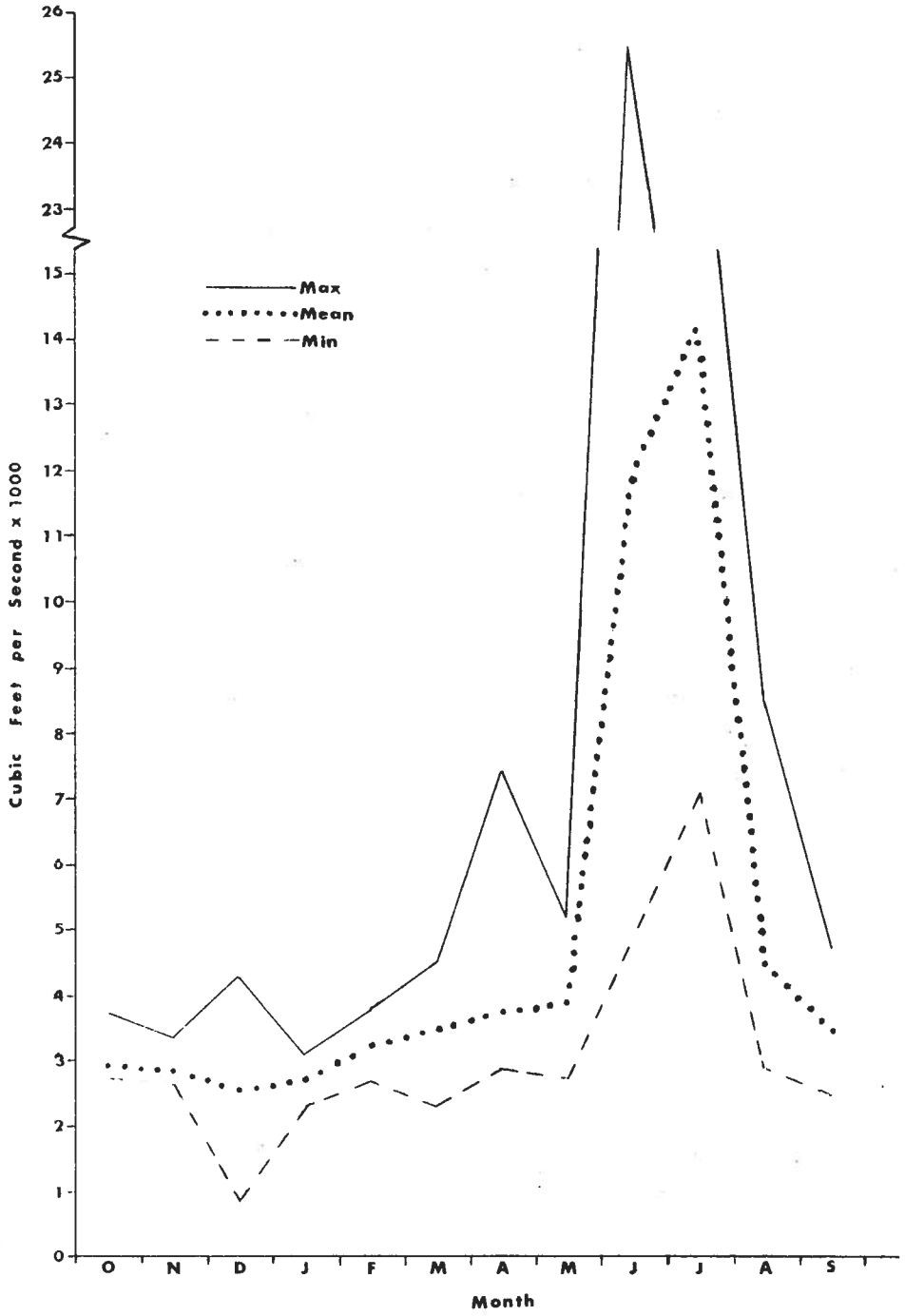

Figure 1. Monthly flows in the Bighorn River from October, 1964 through September, 1965 (Data from U.S.G.S.).

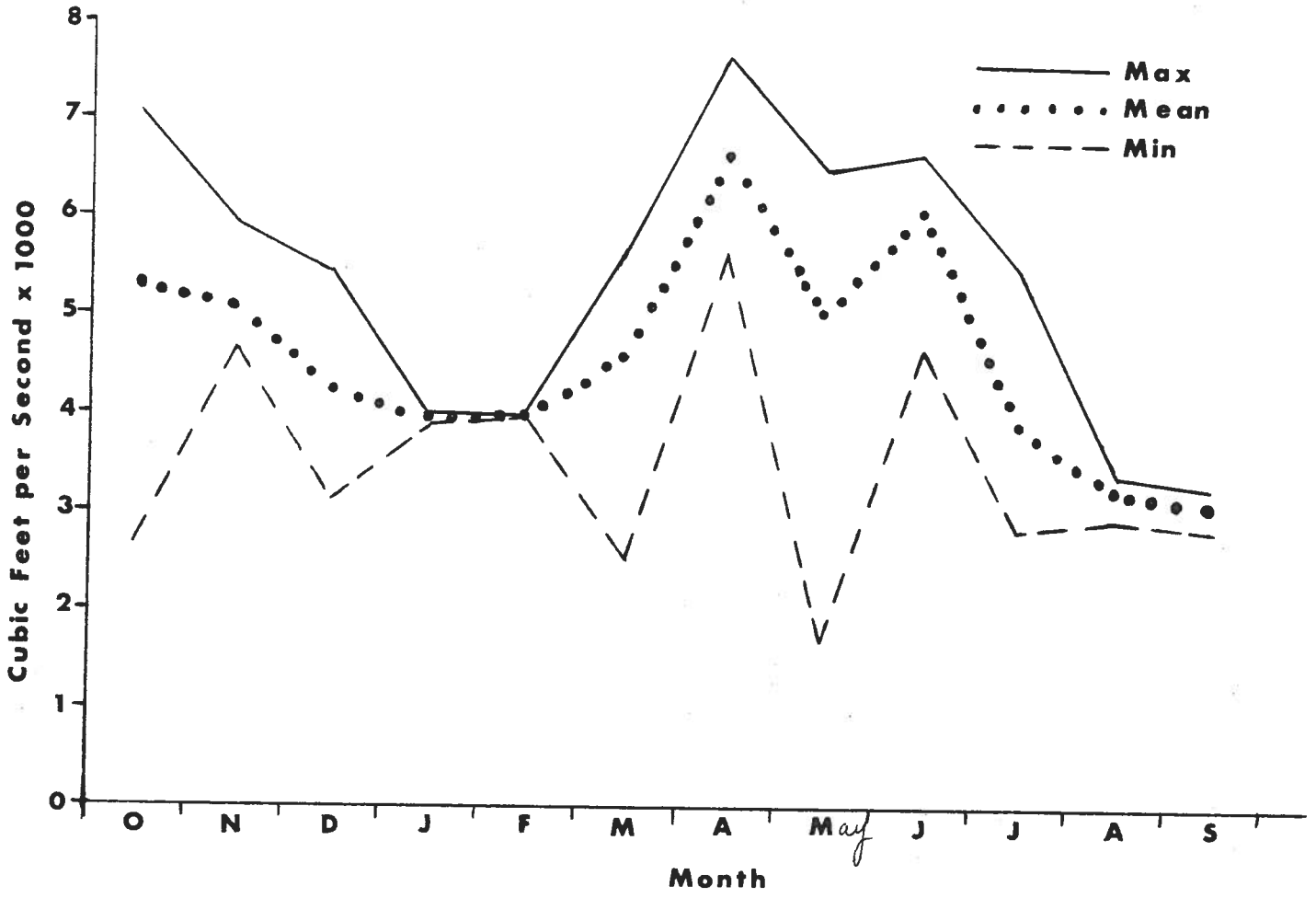

Figure 2. Monthly flows in the Bighorn River from October, 1971 through September, 1972 (Data from U.S.G.S.).

Daily fluctuations of flows in the Bighorn River are greatly moderated by the presence of the Yellowtail Afterbay Dam located 2.3 miles below Yellowtail Dam. Although water levels in the afterbay fluctuate as much as 15 feet daily, little change occurs in the river below.

Water temperatures in the river below the afterbay measured from January, 1963 through September, 1965 and from January, 1971 through September, 1973 (U.S.G.S., 1964, 1965, 1971, 1972, 1973 and Agaard, 1969) are presented in Figures 3 and 4, respectively. Following impoundment, the maximum temperatures were decreased, minimum temperatures were increased and changes occurred more slowly than before impoundment.

The nitrogen-phosporus ratio is favorable (Wright and Soltero, 1973) and levels of calcium, alkalinity, total hardness and conductivity in the Bighorn River are relatively high (Table 1) indicating the river has a high potential of biological productivity (Stumm, 1970). However, supersaturation of nitrogen gas extends for at least 20 miles downstream from the afterbay dam (Bur. of Rec., 1973).

Although reservoir influents carried heavy sediment loads, the discharge from Yellowtail Dam had a maximum turbidity of 30 Standard Jackson Turbidity Units during 1968 and 1969 (Wright and Soltero, 1973). However, turbidity is progressively added to the river from the afterbay to its mouth by tributary streams and irrigation returns.

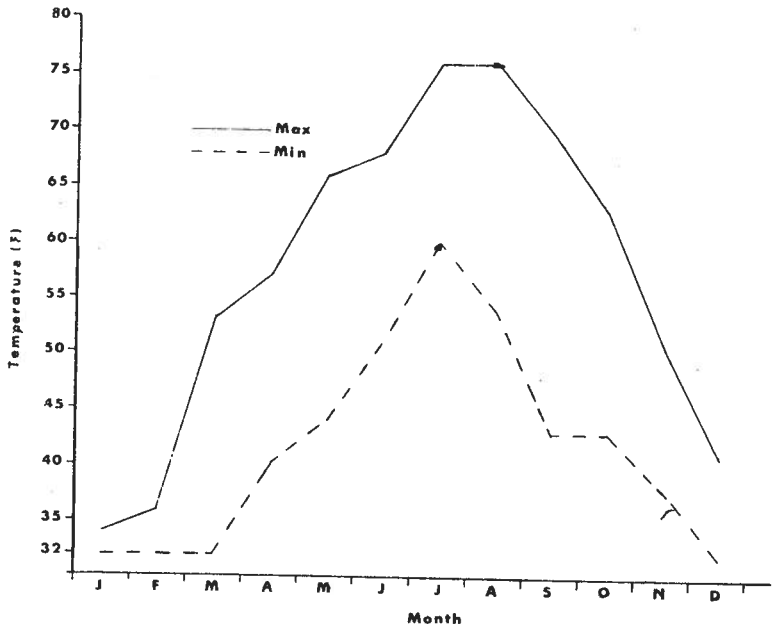

Figure 3. Preimpoundment water temperatures by month from January, 1963 through September, 1965 (Data from U.S.G.S.).

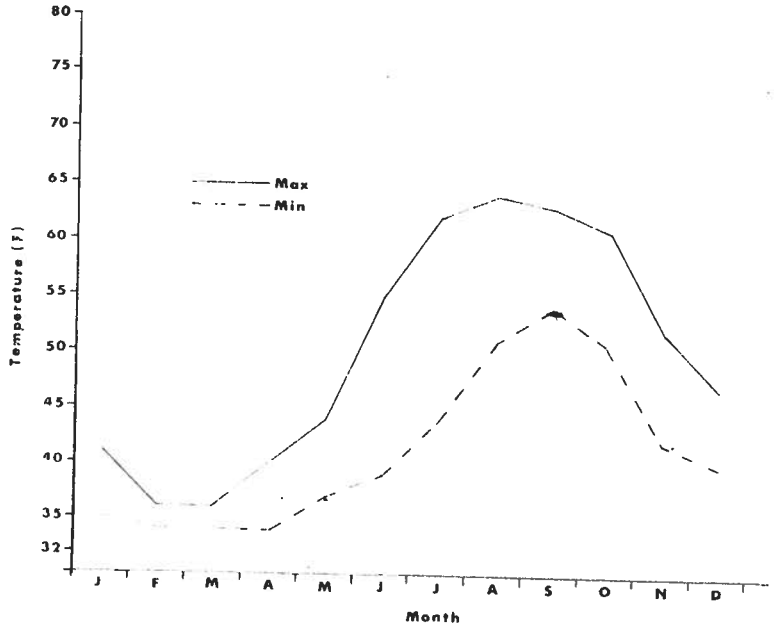

Figure 4. Postimpoundment water temperatures by month from January, 1971 through September, 1973 (Data from U.S.G.S.).

TABLE 1. SELECTED CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE BIGHORN RIVER FROM DAILY MEASUREMENTS MADE FROM OCTOBER, 1971 THROUGH SEPTEMBER, 1972 (U.S.G.S., 1972).

Characteristic	Range (mean)
Calcium (ppm Ca)	53-72 (66)
Total Alkalinity (ppm HCO_3)	153-201 (185)
Total Hardness (ppm Ca, Mg)	200-270 (253)
Conductivity (micromhos)	585-865 (753)
pH	7.0-8.4 (7.9)
Temperature (F)	34-62[1] (46)

[1]Data for June and July were incomplete.

The portion of the river studied began 3,160 feet below Yellowtail Dam and extended downstream 13.7 miles to the Bighorn Fishing Access of the Montana State Fish and Game Department (Figure 5). The study area was divided into three study sections. Section A, the uppermost section, began in the afterbay 3,160 feet below Yellowtail Dam and extended downstream 1.7 miles to the afterbay dam. The streambed gradient in this study section is approximately 11.7 feet per river mile. However, because the afterbay is an impoundment no gradient is evident. All parts of the afterbay open to fishing are accessible to shore fishermen from two maintained roads, one bridge, and vehicle and foot trails. A cement boat ramp and three campgrounds maintained by

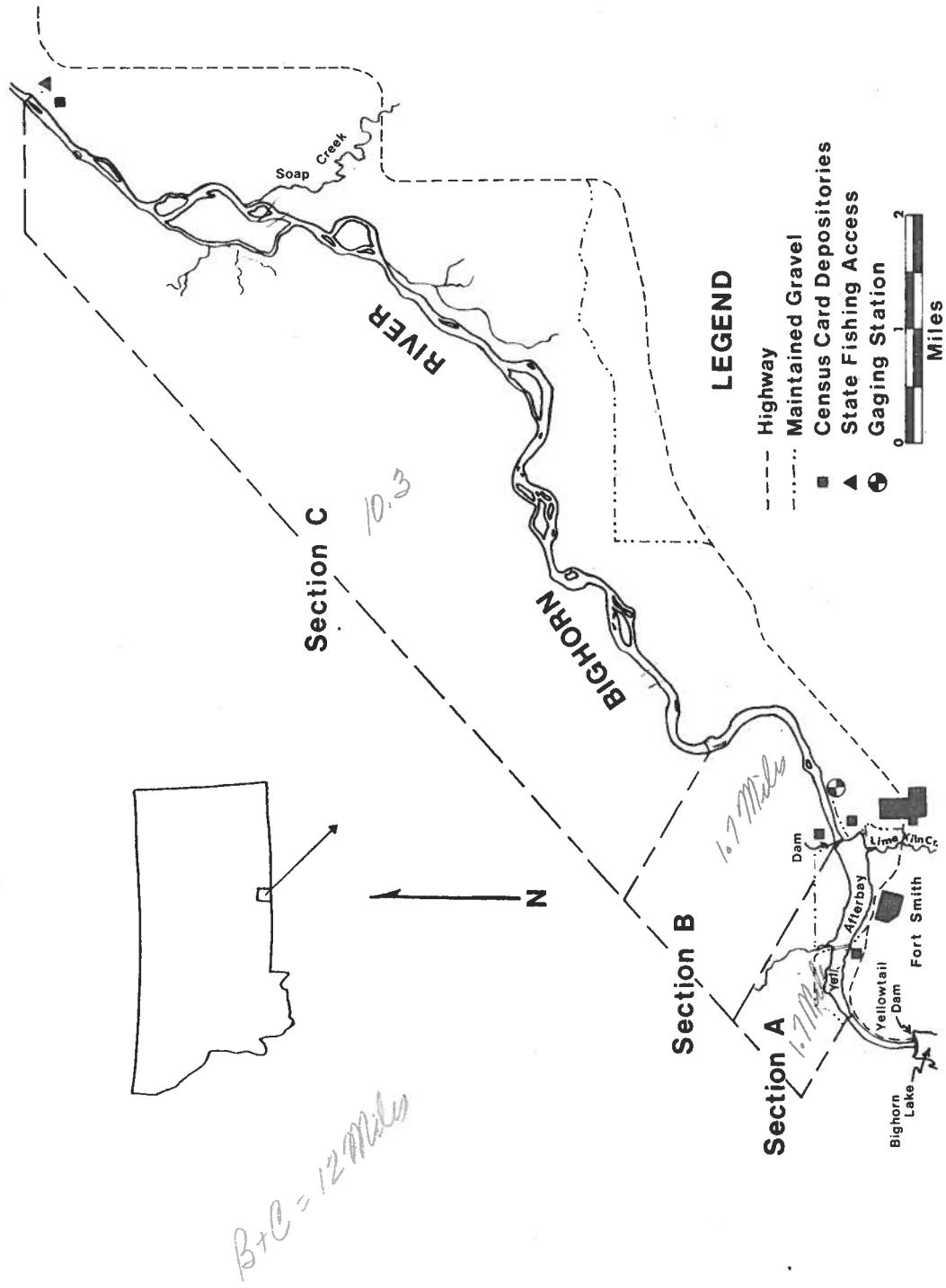

Figure 5. Map of study area showing location of study Sections A, B, and C.

the National Park Service are present in this section.

Section B began immediately below the afterbay dam and extended 1.7 river miles downstream terminating between the first and second bends of the river. Except for one small island, the first mile of the river channel was nearly straight and unbraided. The river had an average width of 205.5 feet immediately below the afterbay dam (U.S.G.S., unpublished data) and was noticeably wider at the lower end of the section. Two maintained gravel roads, one on each shore, provided access to the river immediately below the afterbay dam with the Bighorn Indian Canal Road providing continued access for 1.1 miles downstream on the south shore. A foot trail provided access downstream below the afterbay on the north shore.

Section C began at the lower boundary of Section B and extended 10.3 river miles downstream to the Bighorn Fishing access maintained by the Montana State Fish and Game Department. The river in this section is braided, with frequent pools, riffles and islands. The gradient is 6.3 feet per river mile. The lack of easy access limits fishing from the shore; however, fishermen float this area.

Several species of warmwater fish and brown trout *(Salmo trutta)* were reported present in the Bighorn River below Bighorn Canyon before impoundment (B.S.F.W., 1962). During this investigation, the following species of fish were found: brown trout, rainbow trout *(Salmo gairdneri)*, cutthroat trout *(Salmo clarki)*, walleye *(Stizostedion*

vitreum), northern pike *(Esox lucius)*, mountain whitefish *(Prosopium williamsoni)*, yellow perch *(Perca flavescens)*, burbot *(Lota lota)*, longnose dace *(Rhinicthys cataractae)*, flathead chub *(Hybopsis gracilis)*, black bullhead *(Ictalurus melas)*, goldeye *(Hiodon alosoides)*, carp *(Cyprinus carpio)*, river carpsucker *(Carpiodes carpio)*, longnose sucker *(Catostomus catostomus)*, mountain sucker *(Catostomus platyrhyncus)* and shorthead redhorse *(Moxostoma macrolepidotum)*. Brown trout were also present in Lime Kiln Creek, a tributary to the afterbay, and rainbow trout, suckers, flathead chubs and longnose dace were found in Soap Creek, a tributary to the river in Section C.

The brown trout present were wild fish. Wild cutthroat and rainbow trout were present in the drainage; however, 12,000 and 102,000 cutthroat and rainbow trout, respectively, have been planted in the river below the afterbay dam and 93,000 cutthroat and 530,000 rainbow were planted in the afterbay from May, 1966 to August, 1973.

METHODS

As many boat and shore fishermen as practicable were interviewed in Sections A, B and C on 92 percent of all weekends and holidays from June 17 to September 10, 1972. The party size, residence of fishermen and time fished was obtained from interviews. The catch of each party was examined to determine the number, total length and weight of trout taken by species. No counts of fishermen and, consequently, no estimates of fishing pressure or harvest were made during 1972.

From April 28 through September 9, 1973, fishermen were both counted and interviewed in a sampling design similar to that used by Neuhold and Lu (1957) but with more than twice as many counts as they used. The census period was stratified into 10 periods with the first nine being two weeks and the last being one full week plus one weekend. Each period was further stratified into weekends-holidays and weekdays. All holidays were censused. Fifty percent of the weekends and weekdays were selected for censusing in each period. The first weekend day of the census period was randomly selected and all subsequent weekend days were taken in alternate order. Counts supplemental to the basic design were made by censusing all weekend days in Periods 1, 2, 3 and 10 and three weekend days in Period 9 bringing the coverage of weekend days during 1973 to 73 percent. Weekdays to be censused were randomly selected without repetition with the restriction that counts

be made on at least two weekdays each week. This method of sampling allowed censusing on each day of the week (Monday, Tuesday, etc.) once during each two week period.

Four counts of fishermen were made on each census day. The first count began at either 6, 7, 8 or 9 a.m. with each of the three subsequent counts made that day following at four hour intervals. The hour of the initial count for the first weekend-holiday to be sampled in each period was randomly selected. Each of the other three starting times were assigned to the next three weekend-holidays sampled as convenience dictated. This pattern was repeated every 4 weekend-holidays sampled. The same method was used to select hours for weekday counts. Staggering starting times over four hours, and making three more counts at four hour intervals, allowed sampling of all the hours (in the interval from 5:30 a.m. to 9:30 p.m.) considered to represent the maximum fisherman day. Hunt (1966), Peterson (1970 and 1974) and Lyden (1973) found fishing pressure was insignificant during early morning and late evening hours.

In each two week period fishermen were counted on 8 of the 16 hours of the designated fishing day on weekends and on all of 16 hours once and on 4 hours a second time on weekdays.

Counts were made in sequence from Section A through C. Since each count in each section was made in less than one hour, each was considered to be instantaneous (Neuhold and Lu, 1957). Only shore

fishermen actually fishing or walking to the river with rod in hand and boats being operated were counted.

Additionally, in Section B and the state fishing access at the lower boundary of Section C the number of vehicles parked, boats docked, boats on carriers and boat carriers without boats were counted.

In Sections A and B and at the fishing access in Section C counts were made readily from an automobile with the aid of binoculars. It was impossible to observe shore fishermen or boats operating upstream from the access in Section C from an automobile so counts of them were made from a jet boat used to cover the section on 10 weekends and on 10 weekdays. Approximately 25 minutes were required to cover both Sections B and C by this method.

As many fishermen as practicable were interviewed between the hours of 6 a.m. and 10 p.m. The size of fishing party, number of fishermen per boat, residence of each fisherman and time spent fishing was obtained from interviews. The total length, weight and species of a sample of trout caught was determined. Addressed and stamped census cards were given to fishermen who indicated they would continue fishing after the interview.

Methodology of data analysis is presented in the Appendix. Data from Sections A, B and C were analyzed in a computer program designed at the Montana State University Statistics Laboratory based upon the application of Normal Theory and means as cited in Neuhold and Lu

(1957). Counts of fishermen in Section C were estimated by a step-wise linear regression computer program which correlated fishermen counts made from the jet boat with the counts regularly made at the fishing access in Section C.

About 92 percent of the fish planted in the river (Sections B and C) were distributed over the study sections from a jet boat while the remainder of fish were planted at access points from trucks. All fish planted in the river both years and in the afterbay in 1973 were marked with various fin clips. However, only 3 percent of the trout planted in the afterbay in 1972 were marked. The abbreviations of species designations and fin clips used to mark hatchery fish observed in this study are presented in Table 2.

The surface acreage of water in each study section was estimated gravimetrically from U.S.G.S. quadrangle maps scaled 1:24,000. A check using a computer digital apparatus was in close agreement. Both methods took into account channel braiding.

TABLE 2. ABBREVIATIONS FOR EACH KIND OF TROUT AND FIN CLIPS USED TO MARK HATCHERY FISH.

Abbreviation	
LL	Wild brown trout
Rb(W)	Rainbow trout, unmarked wild appearing
Rb(H)	Rainbow trout, unmarked hatchery appearing
Rb(Lp)	Rainbow trout, left pelvic fin clip
Rb(Rp)	Rainbow trout, right pelvic fin clip
Rb(Ad)	Rainbow trout, adipose fin clip
Rb(Ad,Lp)	Rainbow trout, adipose and left pelvic fin clip
Ct(W)	Cutthroat trout, unmarked wild appearing
Ct(H)	Cutthroat trout, unmarked hatchery appearing
Ct(Lp)	Cutthroat trout, left pelvic fin clip
Ct(Ad)	Cutthroat trout, adipose fin clip

RESULTS

Age and Growth

Scale samples for age and growth determinations were collected from fish taken from Sections B and C. Samples from brown and known age hatchery rainbow trout were taken during 1972 and 1973 while scales from known age cutthroat trout were only taken in 1973. Since the growth rates of brown and hatchery rainbow trout, respectively, were similar between years, the scale data for each species were pooled. The unmarked hatchery rainbow and cutthroat trout planted in the study area could not be identified from wild specimens of their respective species by fin erosion alone. Of the marked hatchery fish planted at 6.8 and from 2.6 to 4.4 inches total length, 20.5 and 66.7 percent, respectively, showed no observable fin erosion and appeared to be wild fish except for the identifying mark.

The sample size, average back calculated total length at each annulus and average total length at capture for the brown trout aged are presented in Table 3. The growth rate of brown trout taken during this study was greater than for those reported in other streams in Montana by Peters (1964). However, data collected since Peters' publication show trout in the Beaverhead River, Montana, have growth rates similar to those in the Bighorn River (Miller, unpublished data).

TABLE 3. AVERAGE CALCULATED TOTAL LENGTH AT EACH ANNULUS FOR WILD BROWN TROUT TAKEN FROM THE BIGHORN RIVER DURING 1972 AND 1973.

Age Group	Number	Average Total Length at Capture	Annulus 1	2	3	4
0	1	6.0				
I	164	11.0	5.9			
II	93	15.3	6.2	13.9		
III	12	19.0	5.8	13.6	17.6	
IV	5	22.5	5.5	11.9	17.4	22.5

The average total length (Figure 6) and weight (Figure 7) at capture of 106 brown trout of the 1971 year class and 204 adipose marked hatchery rainbow trout are presented graphically by month from July, 1972 to mid-October, 1973. Annual growth of trout appears to begin about May and extend through December. During this time water temperatures ranged from approximately 40 to 62 F. According to Weatherley (1972), the literature shows that good growth in trout can only be expected in the temperature range between 44 and 66 F. The summer and fall periods of slow growth or weight loss could be due to periods of peak activity and metabolic rates equal to or exceeding body maintenance requirements (Weatherley, 1972).

Assuming growth of brown trout begins in May, a comparison of the average calculated growth rates of brown and planted rainbow and cutthroat trout is presented in Figure 8. The growth rates of brown and hatchery rainbow trout appeared to be similar while cutthroat trout

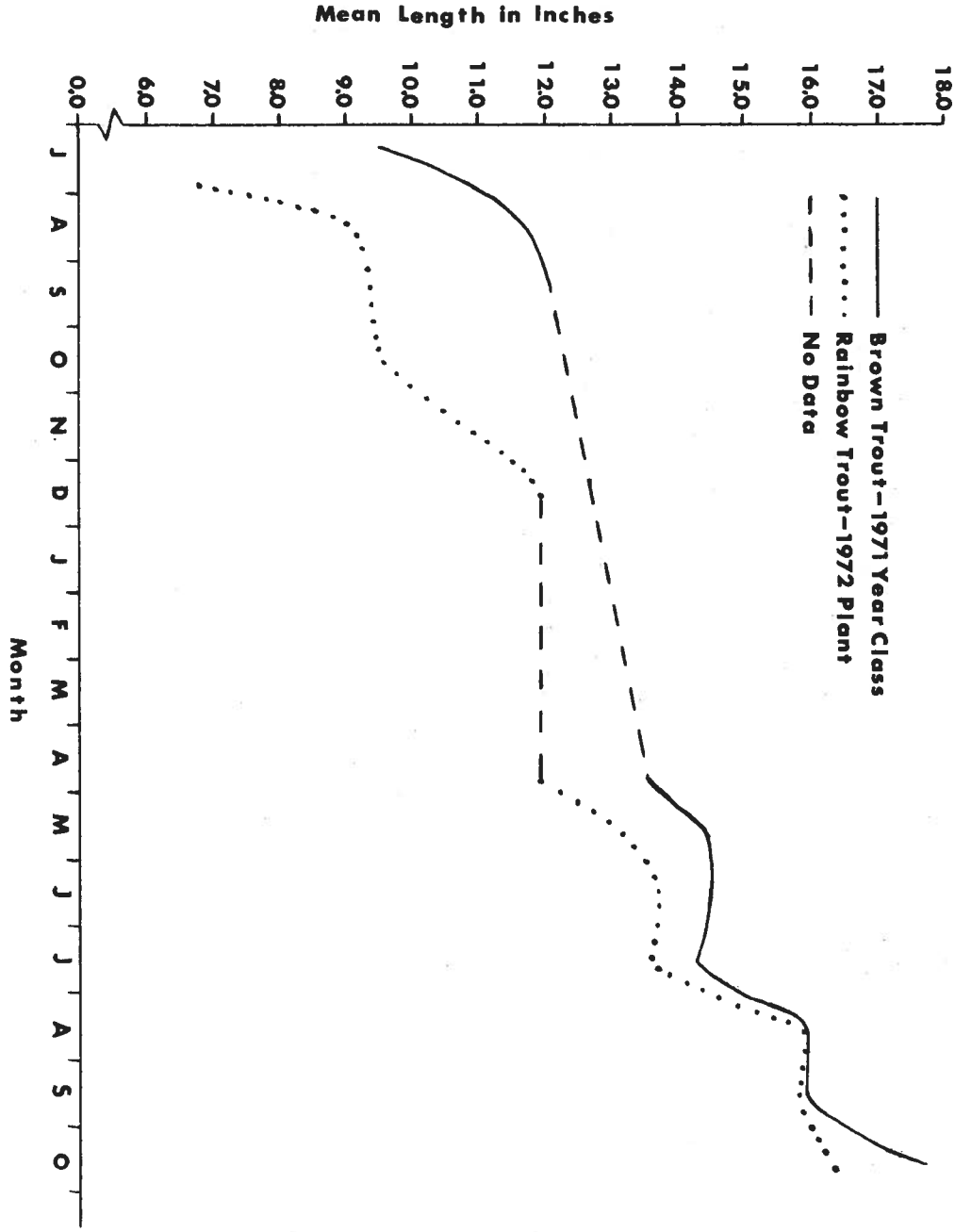

Figure 6. Average total length at capture of brown and hatchery rainbow trout by month taken from the Bighorn River from July, 1972 to October, 1973.

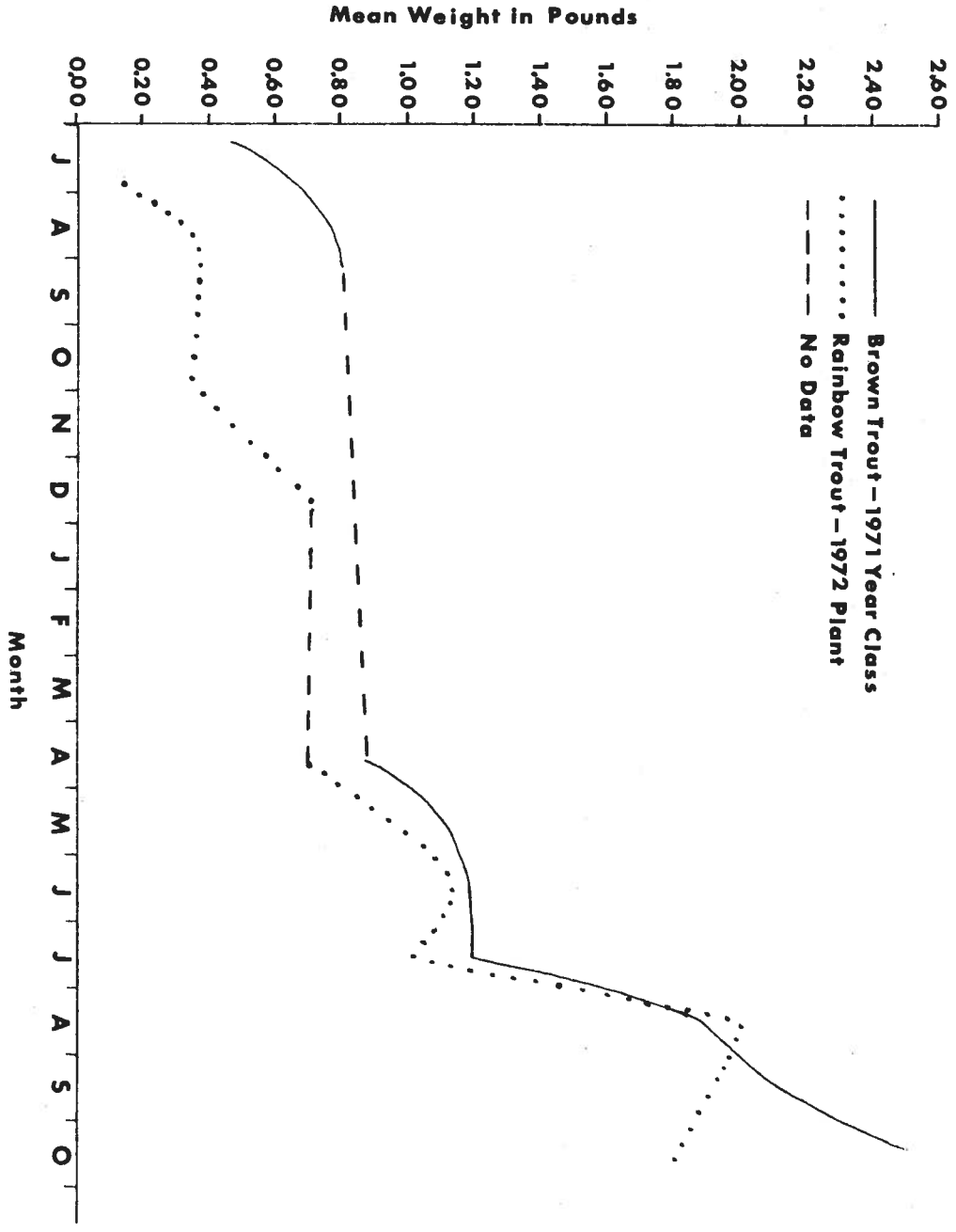

Figure 7. Average weight at capture of brown and hatchery rainbow trout by month taken from the Bighorn River from July, 1972 to October, 1973.

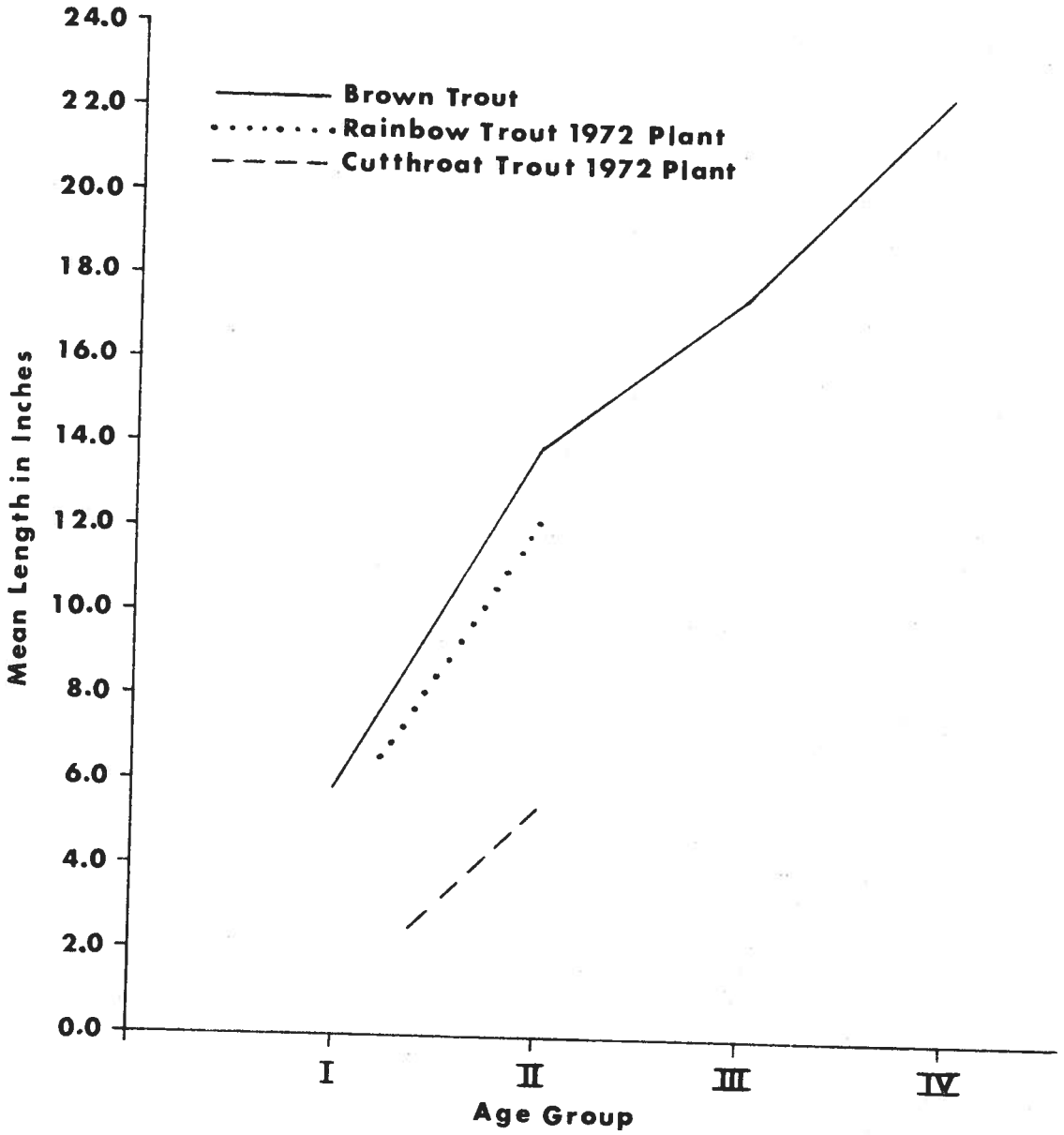

Figure 8. Average calculated growth rate of brown and hatchery rainbow and cutthroat trout taken from the Bighorn River during 1972 and 1973.

(sample size 8) grew at a slower rate. From July 26, 1972, when the rainbow trout were planted, both the brown and rainbow trout grew about 6.0 inches over a period of five months. According to Miller (1972), hatchery rainbow trout planted at six inches, had a similar increment of growth in a period of six months in Clark Canyon Reservoir. Hatchery cutthroat trout in the Bighorn River grew about 2.9 inches in about 3.5 months.

Composition of Fishing Parties

Individuals interviewed were classified according to residence. Fishermen residing within one hours drive of the study area were termed locals. Fishermen residing in Montana excluding locals were called residents. All fishermen residing outside the state of Montana were classified tourists.

During 1972, 457 parties were interviewed on weekends-holidays. The number of fishermen per party ranged from one to eight with a mean of 2.35. The fishermen interviewed were 12.1 percent locals, 80.0 percent residents and 8.0 percent tourists. Individuals from Billings made up 87.2 percent of all resident fishermen and individuals from Wyoming, Colorado and Minnesota made up 59.1 percent of all tourists. Adult males, adult females, and unlicensed juveniles made up 67.8, 17.9 and 14.2 percent of the fishermen.

During 1973, 1,009 parties representing 14.7 percent of the estimated total number of fishermen were interviewed on weekends-

holidays and weekdays. Of all the cards given to parties continuing to fish after the interview, 62.5 percent were returned, with shore and boat fishermen returning 67.2 and 55.9 percent of their cards, respectively. The number of fishermen per party ranged from one to nine, respectively, with a mean number of 2.66.

Local residents and tourists composed 11.4, 73.4 and 15.1 percent of all fishermen, respectively. Fishermen from Billings accounted for 80.6 percent of the residents and fishermen from Wyoming, Colorado and Minnesota were 43.1 percent of the total number of tourists. On weekends-holidays locals, residents and tourists comprised 10.1, 78.6 and 11.2 percent of the fishermen, respectively. On weekdays locals, residents and tourists made up 14.8, 60.3 and 24.9 percent of the fishermen, respectively.

During 1973, adult males, adult females and unlicensed juveniles made up 67.8, 16.4 and 15.8 percent of the fishermen, respectively. This composition is comparable to that found on weekends-holidays in 1972.

Fishing Intensity

Fishing intensity data from each study section was stratified into categories of shore fishermen, boat fishermen, weekends-holidays and weekdays within five consectutive periods of four four week periods and one three week plus one weekend period. Estimates for

each stratum were summed to arrive at totals. The number of shore fisherman hours in each period was calculated as the product of the average number of shore fishermen per count and the total possible fishing hours in that period. The number of fishermen in a boat was difficult to discern by direct count at times, especially when fishing intensity was high and during inclement weather. Therefore, the mean number of boat fishermen per count was estimated as the product of the mean number of boats per count and the mean number of fishermen per boat as taken from interviews. The number of boat fisherman hours per period was then calculated as the product of the average number of boat fishermen per count and the total possible fishing hours for that period. The mean number of fishermen per boat, based on 45 interviews in Section A, was 2.61 and on 302 interviews in Sections B and C combined, 2.57. These estimates are similar to the averages of 2.40 and 2.52 fishermen per boat found by Johnson and Wroblewski (1962) and Neuhold and Lu (1957), respectively.

The number of fisherman hours, with 95 percent confidence limits, is given in Table 4. Confidence limits for total fisherman hours expended in the study area were ±11.8 percent. The confidence limits on summed weekend-holiday and weekday fisherman hours were ±8.6 and ±14.4 percent, respectively. Confidence limits for total shore and boat fisherman hours were ±11.6 and ±20.6 percent, respectively. Peterson (1974), using Neuhold and Lu's (1957) method, found confidence

TABLE 4. ESTIMATED NUMBER OF FISHERMAN HOURS, WITH 95 PERCENT CONFIDENCE LIMITS, DURING 1973.

	Shore			Boat		
Period	Weekends-Holidays	Weekdays	Total	Weekends-Holidays	Weekdays	Total
Section A						
1	1,358 ± 391	560 ± 203	1,918 ± 430	281 ± 107	64 ± 77	345 ± 129
2	1,895 ± 686	966 ± 296	2,861 ± 730	645 ± 312	0 0	645 ± 312
3	1,483 ± 358	1,117 ± 374	2,600 ± 504	622 ± 325	296 ± 276	918 ± 414
4	2,512 ± 627	2,160 ± 610	4,672 ± 843	1,536 ±1,037	480 ± 319	2,016 ±1,023
5	3,465 ± 1,041	2,416 ± 584	5,881 ±1,172	1,728 ± 789	1,045 ± 627	2.773 ± 989
Total	10,713 ± 1,418	7,219 ± 961	17,932 ±1,714	4,812 ±1,294	1,885 ± 738	6,697 ±1,489
Section Total	24,629 ±6,464					
Section B						
1	1,395 ± 352	1,104 ± 368	2,499 ± 505	200 ± 104	48 ± 72	248 ± 124
2	1,745 ± 533	1,531 ± 408	3,276 ± 657	519 ± 324	442 ± 323	961 ± 448
3	2,347 ± 566	2,196 ± 506	4,543 ± 737	704 ± 353	399 ± 223	1,103 ± 403
4	2,672 ± 1,098	3,008 ± 672	5,680 ±1,226	1,033 ± 671	1,125 ± 662	2,158 ± 909
5	3,055 ± 728	2,952 ± 687	6,007 ± 985	752 ± 339	530 ± 311	1,282 ± 453
Total	11,214 ± 1,471	10,791 ±1,129	22,005 ±2,391	3,208 ± 838	2,544 ± 807	5,752 ±1,163
Section Total	27,757 ±4,496					
Section C						
1	275 ± 171	377 ± 494	652 ± 515	1,411 ± 919	1,053 ±1,552	2,464 ±1,775
2	421 ± 213	516 ± 398	937 ± 444	3,620 ±1,665	2,868 ±2,302	6,488 ±2,789
3	433 ± 258	373 ± 437	806 ± 498	4,568 ±1,832	1,716 ±1,855	6,284 ±2,536
4	400 ± 218	383 ± 426	783 ± 469	3,856 ±1,728	3,375 ±3,100	7,231 ±3,471
5	345 ± 197	376 ± 278	721 ± 336	3,229 ±1,486	2,841 ±1,922	6,070 ±2,395
Total	1,874 ± 450	2,025 ± 895	3,899 ±1,001	16,684 ±3,287	11,853 ±4,792	28,537 ±5,811
Section Total	32,436 ±6,167					
Grand Total	84,822 ±10,001					

of ±12.7 percent for total fisherman hours, ±17.7 percent for weekend-holiday fishermen and ±18.7 percent for weekday fishermen.

The length of the boat fisherman day in each stratum in Section A was estimated by using the average length of the fishermen day over the entire census period because too few interviews were obtained to calculate them by stratum. Since most boat fishermen fished both Sections B and C, the same average length of the fisherman day was applied to each stratum in these two sections. Due to limited access, not enough interviews were taken from shore fishermen in Section C so the average length of the fisherman day of shore fishermen interviewed in Section B was applied to this group. The average length of the fisherman day ranged from 3.96 hours for total boat fishermen in Section A to 5.17 for total boat fishermen in Sections B and C combined. Shore fishermen in Section B spent less time fishing per day (4.16 hours) than did boat fishermen in Sections B and C combined (5.16 hours). However, in Section A shore fisherman days (4.25 hours) were longer than boat fisherman days (3.96 hours). The average length of the fisherman day averaged over all sections and periods was nearly the same on weekdays (4.56 hours) and on weekends-holidays (4.54 hours).

Fisherman Days and Fishermen Per Day

The number of fisherman days and average number of fishermen per day for each stratum is given in Table 5. The number of fisherman

TABLE 5. ESTIMATED NUMBER OF FISHERMAN DAYS AND AVERAGE NUMBER OF FISHERMEN PER DAY (in parenthesis) DURING 1973.

	Shore			Boat		
Period	Weekends-Holidays	Weekdays	Total	Weekends-Holidays	Weekdays	Total
Section A						
1	326(40.7)	192(9.6)	518(18.5)	71(8.9)	16(0.8)	87(3.1)
2	536(59.5)	201(10.5)	737(26.3)	163(18.1)	0(0.0)	163(18.1)
3	461(51.2)	278(14.6)	739(26.3)	157(17.5)	75(3.9)	232(8.2)
4	528(66.0)	440(22.0)	968(34.6)	388(48.5)	121(6.1)	509(18.2)
5	777(86.3)	390(27.9)	1167(50.7)	436(48.5)	264(18.8)	700(30.4)
Total	2628(61.1)	1501(16.3)	4129(30.5)	1215(28.3)	476(5.17)	1691(12.5)
Section Total 5820(43.1)						
Section B						
1	339(42.3)	275(13.7)	614(21.9)	44(5.4)	12(0.6)	56(2.0)
2	447(49.7)	345(18.1)	792(28.3)	96(10.7)	90(4.8)	186(6.6)
3	613(68.1)	635(33.4)	1248(44.6)	144(16.0)	75(3.9)	219(7.8)
4	571(71.4)	608(30.4)	1179(42.1)	181(22.6)	198(9.9)	379(13.5)
5	726(80.6)	674(48.1)	1400(60.9)	148(16.0)	106(7.6)	254(11.0)
Total	2696(62.7)	2537(27.6)	5233(38.8)	613(14.3)	481(5.22)	1094(8.1)
Section Total 6327(46.1)						
Section C						
1	67(8.3)	94(4.7)	161(5.8)	307(38.4)	263(13.1)	570(20.4)
2	108(12.0)	116(6.1)	224(8.0)	673(74.8)	587(30.9)	1260(45.0)
3	113(12.6)	108(5.7)	221(7.9)	936(104.0)	321(16.9)	1257(44.9)
4	85(10.7)	84(4.2)	169(6.0)	674(84.3)	593(29.7)	1267(45.2)
5	82(9.1)	86(6.1)	168(7.3)	636(70.6)	568(40.6)	1204(52.3)
Total	455(10.6)	488(5.3)	943(7.0)	3226(75.0)	2332(25.3)	5558(41.2)
Section Total 6501(48.2)						
Grand Total 18,648(138.1)						

days was estimated by dividing the total fisherman hours in each stratum by the corresponding length of the average fisherman day. The average number of fishermen per day was derived by dividing the number of fisherman days in each stratum by the number of days in each corresponding period.

The fisherman days expended in Sections A, B and C were 31.2, 33.9 and 34.8 percent of the total, respectively. Although weekends-holidays accounted for only 31.9 percent of the total days in the census period, they made up 58.1 percent of the fisherman days. In all sections total fishing pressure on weekends-holidays was greater than on weekdays. In Section A, 66.0 percent of the total number of fisherman days occurred on weekends and holidays and the average number of fishermen per day on weekends-holidays was 4.2 times greater than on weekdays. The number of fisherman days in Sections B and C during weekends-holidays were 52.3 and 56.6 percent of the respective total fisherman days and the average number of fishermen per day was 2.3 and 2.8 times larger in Sections B and C, respectively, on weekends-holidays than on weekdays. The average number of fishermen per day on weekends-holidays was higher than on weekdays in all strata.

Shore fishing made up 55.3 percent of the total fisherman days expended during the census. In Sections A and B shore fishing made up the greatest part of the fishing pressure with boat fishing providing the greatest proportion in Section C. Shore fishermen

accounted for 70.9 percent of the total number of fishermen days in Section A, 82.7 percent in Section B, and only 14.5 percent in Section C. The average number of shore fishermen per day was 2.4 and 4.8 times as large as for boat fishermen in Sections A and B, respectively. However, the average number of boat fishermen per day in Section C was 5.9 times larger than for shore fishermen. Limited access to the shore made Section C primarily a boat fishery. In Sections A and B the numbers of shore fisherman days and shore fishermen per day in all strata were greater than for those of boat fishermen. In Section C the numbers of boat fisherman days and boat fishermen per day in all strata were greater than corresponding values for shore fishermen.

Fisherman Days Per Acre and Per Mile

Fishing intensities, as number of fisherman days per surface acre, for Section A and per stream mile for Sections B and C were estimated for each stratum (Table 6). The total number of fisherman days per acre for the 155 surface acres in Section A was more than 10 times as great as Lund (1974) found on Elk Lake, Montana having 283 surface acres and more than twice as great as Spence (1971) found for Georgetown Lake, Montana with 3,000 surface acres.

The total number of 1,069 fisherman days per stream mile for the 12 miles of Sections B and C combined was comparable to Vincent's (1969) findings for the most intensively used 5 mile section of 67 miles censused on the Madison River. The total number of fishermen

TABLE 6. ESTIMATED NUMBER OF FISHERMAN DAYS PER SURFACE ACRE (SECTION A) AND PER STREAM MILE (SECTIONS B AND C) DURING 1973.

	Shore			Boat		
Period	Weekends-Holidays	Weekdays	Total	Weekends-Holidays	Weekdays	Total
Section A						
1	2.1	1.2	3.3	0.5	0.1	0.6
2	3.4	1.3	4.7	1.0	0	1.0
3	3.0	1.8	4.8	1.0	0.5	1.5
4	3.4	2.8	6.2	2.5	0.8	3.3
5	5.0	2.5	7.5	2.8	1.7	4.5
Total	16.9	9.6	26.5	7.8	3.1	10.9
Section Total 37.4 per Acre						
Section B						
1	199	162	361	26	7	33
2	263	203	466	56	53	109
3	361	374	735	85	44	129
4	335	358	693	106	116	222
5	427	396	823	87	62	149
Total	1585	1493	3078	360	282	642
Section Total 3,720						
Section C						
1	7	9	16	30	26	56
2	10	11	21	65	57	122
3	11	10	21	91	31	122
4	8	8	16	65	58	123
5	8	8	16	62	55	117
Total	44	46	90	313	227	540
Section Total 630						

days per acre in Section B was about three times greater than the same 5 mile section of the Madison River. The intensity per stream mile in Section C was slightly greater than the use Vincent (1969) reported for the entire 67 mile section censused on the Madison River and Banks *et al.* (1974) found for 73 miles of the Green River in Wyoming. The 6 times

greater intensity in Section B than C was primarily the result of very high shore fishing intensity in Section B and very low shore fishing intensity in Section C. The slightly higher boat fishing intensity per stream mile in Section B than in C probably resulted from fishermen with power boats returning upstream after fishing Section B and those not continuing to float through Section C.

The total number of fisherman days per acre in Section A and per mile in Sections B and C progressively increased from Periods 1 through 5 (Table 6). Of the total fisherman days per acre in Section A, 10.4, 15.2, 16.8, 25.4 and 32.1 percent occurred during Periods 1 through 5, respectively. In Sections B and C combined, these respective percentages were 10.7, 16.5, 23.1, 24.2 and 25.4 for fisherman days per mile. Shore fishing intensity in Section C was an exception with relatively uniform low effort expended throughout the census period. Total boat fishing intensity in Sections B and C increased from Periods 1 through 4, then decreased during Period 5. This decrease during Period 5 was associated with inclement weather.

Hourly Intensity Curves

Fishing intensity curves were constructed to describe the hourly distributional patterns of fishing intensity for shore fishing and boat fishing on weekends-holidays and weekdays in each study section over the census period (Figures 9-14). The high fishing intensity curves of shore fishermen on weekends-holidays in Sections A (Figure 9)

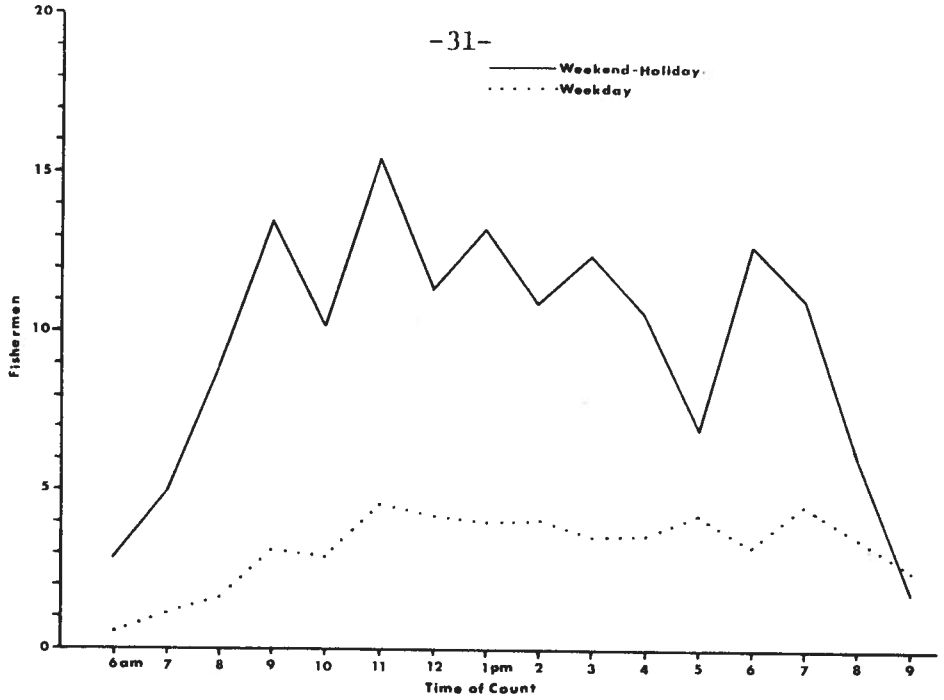

Figure 9. Fishing intensity curves of the average number of shore fishermen per count per mile of Section A.

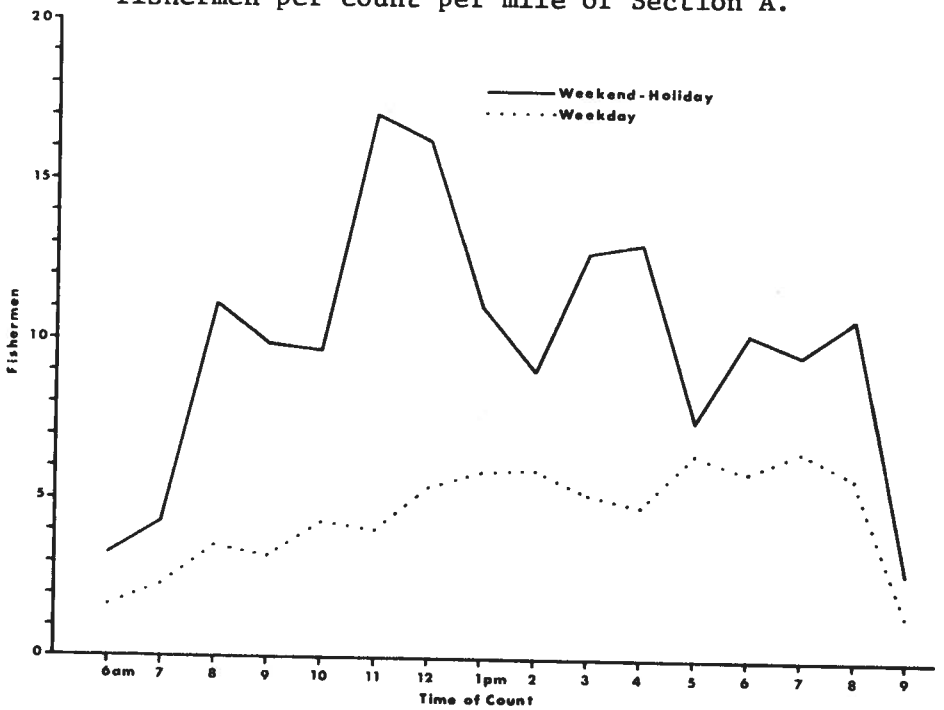

Figure 10. Fishing intensity curves of the average number of shore fishermen per count per mile of Section B.

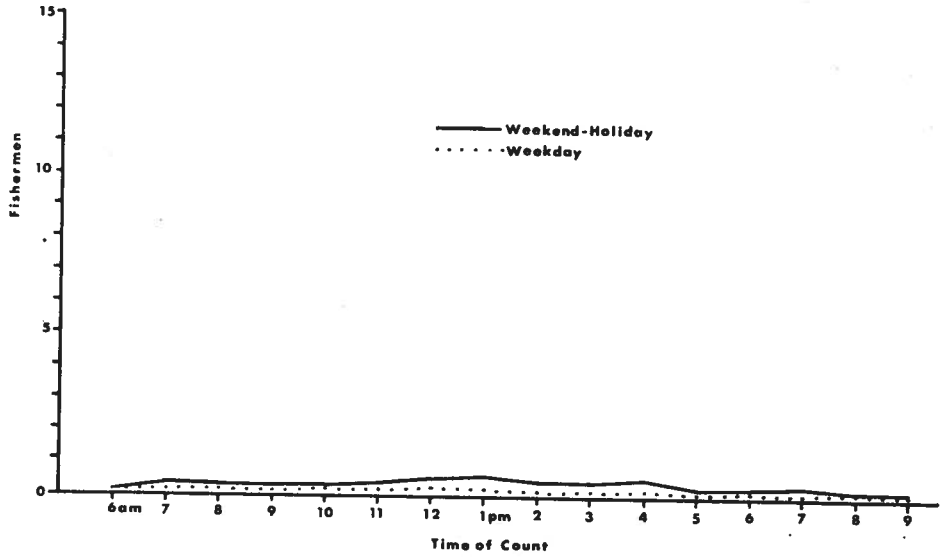

Figure 11. Fishing intensity curves of the average number of shore fishermen per count per mile of Section C.

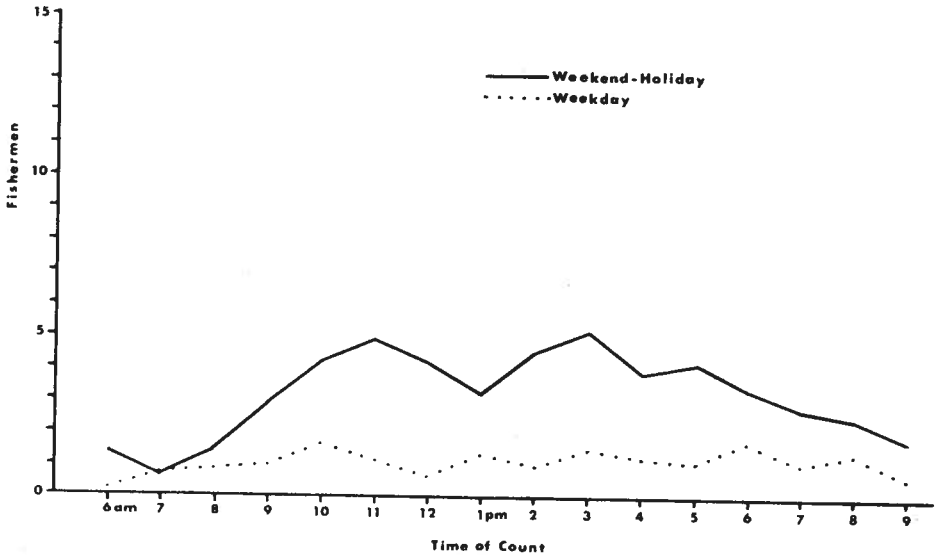

Figure 12. Fishing intensity curves of the average number of boat fishermen per count per mile of Section A.

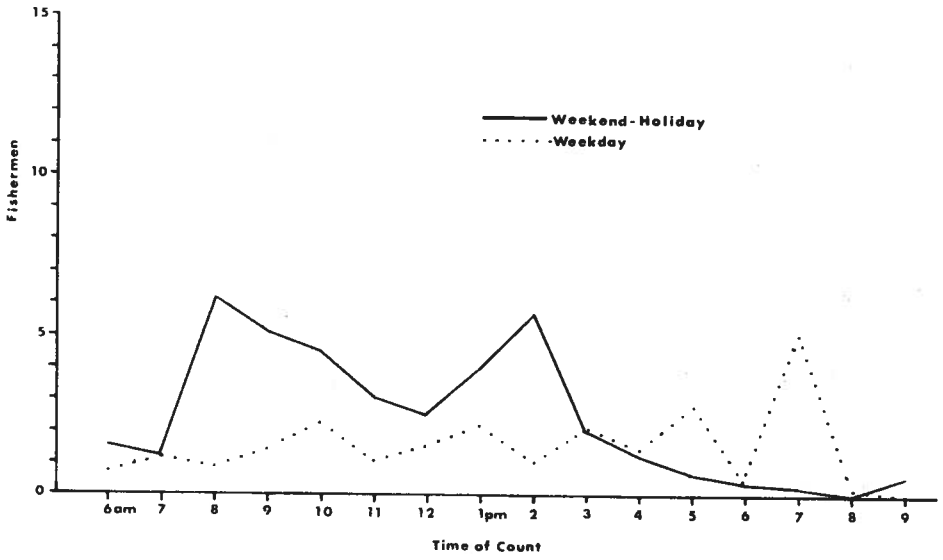

Figure 13. Fishing intensity curves of the average number of boat fishermen per count per mile of Section B.

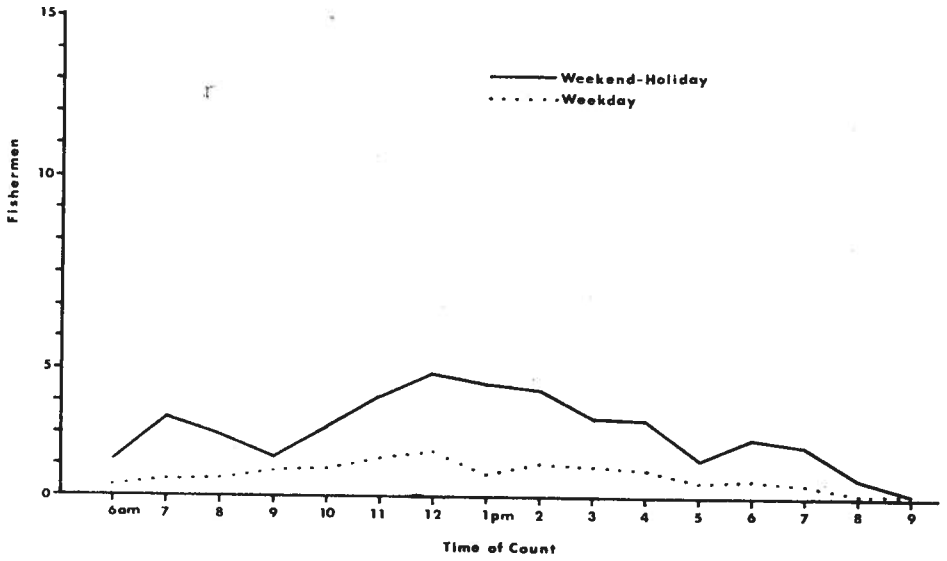

Figure 14. Fishing intensity curves of the average number of boat fishermen per count per mile of Section C.

and B (Figure 10) were multimodal. Cope (1955) described a trimodal distribution for the high intensity fishery on Yellowstone Lake and Peterson (1970) and Lyden (1973) have also found bimodal and trimodal distributions associated with high fishing intensities in their studies.

The moderate intensity of shore fishermen on weekdays in Section B (Figure 10) produced a bimodal curve with the greatest intensity during evening hours. The lower intensities of shore fishermen on weekends-holidays in Section C (Figure 11) and on weekdays in Sections A (Figure 9) and C (Figure 11) produced nearly bell shaped distributions. Peterson (1970) and Lyden (1973) have also described bell shaped distributions of fishing intensity associated with low fishing intensity.

The distributions of boat fishermen on weekends-holidays in Sections A, B and C (Figures 12, 13, 14) were basically bimodal. The drop in boat fishing intensity on weekends-holidays after 2 p.m. in Section B (Figure 13) probably occurred because few fishermen began fishing after this time as a minimum of three hours was required to float downstream to the state fishing access in Section C. The fishermen causing the two modes in Section B probably caused the later essentially bell shaped mode in Section C as they continued fishing downstream.

On weekdays boat fishing intensity was relatively low in Sections A and C (Figures 12 and 14, respectively) and their distributions were

nearly bell shaped. Boat fishing intensity in Section B (Figure 12) on weekdays was also low but with a pronounced evening mode. This mode was due to a marked increase in fishing primarily during Period 4, probably by fishermen floating to a lesser known private take out point three miles below the afterbay. Peterson (1970) and Lyden (1973) have suggested pressure in pronounced evening modes were made up primarily of local fishermen.

Catch Rate

Catch statistics in this creel census were projected from information obtained from interviews only. No information from card returns was used to calculate catch rates.

No estimate could be made of the catch rate of boat fishermen in Section A during 1972, and only an average catch rate over the entire 1973 census period could be calculated for this stratum because of the small sample sizes of interviews. During both years, only a catch rate of boat fishermen for Sections B and C combined could be calculated because most boat fishermen fished both sections together and were interviewed only at the lower boundary of Section C. Limited access in Section C did not permit contact with enough shore fishermen to obtain an estimate of their catch rate during either year of study.

Catch rates (fish caught per hour) during 1972 for periods 2 through 5 on weekends-holidays were calculated for shore fishermen in Sections A and B and for boat fishermen in Sections B and C combined

(Table 7). Catch rates during 1972 progressively increased from Periods 2 through 5. This appears to be related to water temperatures which increased from 43 F in Period 2 to 63 F in Period 5. Catch rates ranged from 0.08 to 0.94 fish per hour.

TABLE 7. ESTIMATED CATCH PER HOUR OF TROUT OF PERIODS 2 THROUGH 5 ON WEEKENDS-HOLIDAYS DURING 1972.

Period	Section A Shore	Section B Shore	Sections B & C Boat
2	0.18	0.40	0.08
3	0.44	0.54	0.13
4	0.57	0.80	0.38
5	0.61	0.94	0.44
Weighted Average	0.50	0.74	0.33

Catch rates during 1973 for each section and stratum are presented in Table 8. Catch rates were calculated for Periods 1 through 5 on weekends-holidays and weekdays for shore fishermen in Sections A and B and for boat fishermen in Sections B and C combined. The catch rates of boat fishermen in Sections B and C combined were applied to boat fishermen for Periods 1 through 5 in Sections B and C and to shore fishermen in Section C. Although the applied catch rates are the same in each period for these strata, in some cases the weighted average catch rates differ because fishing intensities differed between strata.

The 95 percent confidence limits on the weighted average catch rate calculated from all interviews taken was ±11.4 percent.

TABLE 8. ESTIMATED CATCH PER HOUR OF TROUT WITH 95 PERCENT CONFIDENCE LIMITS OF PERIODS 1 THROUGH 5 ON WEEKENDS-HOLIDAYS AND ON WEEKDAYS DURING 1973.

	Shore			Boat		
Period	Weekends-Holidays	Weekdays	Weighted Average	Weekends-Holidays	Weekdays	Weighted Average
Section A						
1	0.18 ±0.15	0.05 ± .07	0.14 ±0.08	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
2	0.19 ±0.11	0.29 ±0.56	0.22 ±0.05	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
3	0.22 ±0.13	0.46 ±0.20	0.32 ±0.07	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
4	0.51 ±0.19	0.55 ±0.45	0.53 ±0.13	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
5	0.61 ±0.22	0.46 ±0.12	0.55 ±0.07	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
Weighted Average	0.40 ±0.09	0.43 ±0.14	0.41 ±0.07	0.71 ±0.28	0.71 ±0.28	0.71 ±0.28
Section B						
1	0.64 ±0.22	0.34 ±0.15	0.51 ±0.02	0.17 ±0.09	0.56 ±0.67	0.24 ±0.07
2	0.33 ±0.23	0.50 ±0.26	0.41 ±0.05	0.38 ±0.13	0.45 ±0.25	0.41 ±0.04
3	0.62 ±0.33	0.66 ±0.32	0.64 ±0.10	0.21 ±0.08	0.38 ±0.46	0.27 ±0.10
4	0.55 ±0.18	0.82 ±0.42	0.69 ±0.09	0.14 ±0.05	0.19 ±0.17	0.16 ±0.02
5	0.53 ±0.18	0.54 ±0.18	0.53 ±0.05	0.58 ±0.05	0.40 ±0.20	0.51 ±0.08
Weighted Average	0.53 ±0.11	0.62 ±0.12	0.55 ±0.08	0.30 ±0.04	0.31 ±0.13	0.31 ±0.04
Section C						
1	0.17 ±0.09	0.56 ±0.67	0.39 ±0.07	0.17 ±0.09	0.56 ±0.67	0.33 ±0.07
2	0.38 ±0.13	0.45 ±0.25	0.42 ±0.04	0.38 ±0.13	0.45 ±0.25	0.41 ±0.04
3	0.21 ±0.08	0.38 ±0.46	0.29 ±0.10	0.21 ±0.08	0.38 ±0.46	0.26 ±0.10
4	0.14 ±0.05	0.19 ±0.17	0.16 ±0.02	0.14 ±0.05	0.19 ±0.17	0.16 ±0.02
5	0.58 ±0.05	0.40 ±0.20	0.48 ±0.08	0.58 ±0.05	0.40 ±0.20	0.50 ±0.08
Weighted Average	0.30 ±0.04	0.40 ±0.13	0.35 ±0.04	0.30 ±0.04	0.36 ±0.13	0.33 ±0.04

Confidence limits on weekend-holiday and weekday catch rates were ±11.9 and ±17.1 percent, respectively. The confidence limits on shore and boat fishermen catch rates, respectively, were ±13.8 and ±12.9 percent. Peterson (1974) found confidence limits of ±25.4 percent for weekends-holidays and weekdays combined and ±37.4 percent for weekends-holidays and ±25.4 percent for weekdays separately.

Catch rates during 1973 increased as the season progressed and water temperatures increased from 38 F in Period 1 to 56 F in Period 5. However, the increase in catch rates was not as consistent in 1973 as during 1972. In 1973, a prolific algal bloom occurred in Section C during Periods 3 and 4, making fishing difficult and lowering catch rates during these strata. During 1973, catch rates ranged from 0.05 to 0.82. Peterson (1970) and Lyden (1973) found catch rates ranging from 0.31 to 1.24 and from 0.25 to 0.97, respectively, during their two year censuses.

Catch rates of all trout caught and kept in Periods 2 through 5 in 1972 and 1973 were similar for shore fishermen in Section A (0.50 and 0.45, respectively) and for boat fishermen in Sections B and C combined (0.33 and 0.32, respectively). However, the average catch rate for shore fishermen in Section B was higher during 1972 (0.74) than 1973 (0.58). There was little difference between weighted average catch rates on weekends-holidays compared to weekdays during the 1973 census. Peterson (1970) and Lyden (1973) also found

small differences in catch rates between weekends-holidays and weekdays.

The average catch rate of each species of trout and group of marked hatchery fish during 1972 and 1973 is presented in Tables 9 and 10, respectively. Rainbow trout had the highest catch rates during both years. Adipose clipped rainbow trout were only returned at the rate of 0.02 fish per hour or less and were the only known hatchery fish contributing to the catch in 1972. In 1973, known hatchery rainbow trout contributed to the catch at rates varying between 0.15 to 0.49 fish per hour. The catch rate of brown and cutthroat trout was greatest in Sections B and C.

TABLE 9. ESTIMATED CATCH PER HOUR OF EACH KIND OF TROUT DURING 1972.

Kind of Fish	Section A Shore	Section B Shore	Sections B & C Boat
LL	0.00	0.01	0.04
Rb	0.45	0.65	0.26
Rb(Lp)	0.00	0.00	0.00
Rb(Ad)	0.00	0.02	0.01
Ct	0.05	0.05	0.02
Ct(Lv)	0.00	0.00	0.00
Ct(Ad)	0.00	0.00	0.00

Known hatchery cutthroat trout did not make a measurable contribution to the catch rate either year. Hatchery fish were identified by clipped fins in 1972 and by clipped fins or fin erosion in 1973. However, the separation of wild from hatchery fish based on fin

TABLE 10. ESTIMATED CATCH PER HOUR OF EACH KIND OF TROUT DURING 1973.

Kind of Fish	Section A			Section B			Section C		
	Shore	Boat	Shore & Boat	Shore	Boat	Shore & Boat	Shore	Boat	Shore & Boat
LL	0.00	0.00	0.00	0.03	0.05	0.03	0.09	0.07	0.07
Rb(W)	0.15	0.22	0.17	0.19	0.08	0.16	0.09	0.08	0.09
Rb(H)	0.24	0.48	0.30	0.32	0.09	0.27	0.08	0.09	0.09
Rb(Lp)	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Rb(Rp)	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00
Rb(Ad)	0.01	0.00	0.00	0.02	0.07	0.02	0.07	0.07	0.07
Rb(Ad,Lp)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ct(W)	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Ct(H)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ct(Lp)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ct(Ad)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

erosion proved to be unsatisfactory and catch rates of unmarked hatchery fish are likely underestimated.

Had data from voluntary card returns been included, catch rates would have been higher than those in Table 8 calculated from interviews only. In Section A catch rates for shore fishermen were 0.45 from cards and 0.41 from interviews and for boat fishermen 0.87 and 0.71, respectively. Voluntary and interview catch rates for shore fishermen in Section B were 0.60 and 0.55, respectively. The catch rate for boat fishermen in Sections B and C combined was 0.41 from cards and 0.31 from interviews. Lyden (1973) and Vincent (1969) also found catch rates from voluntary information were higher than from interviews. However, Peterson (1970) found catch rates from card information were lower than those from interviews.

Yield

The yield (trout caught and kept) for each stratum (Table 11) was estimated as the product of its catch rate and number of fisherman hours. Totals were estimated from the sums of the appropriate strata. Confidence limits are not presented because variances calculated for several point estimates of yield had a negative value and, as a result, the validity of confidence limits of point estimates for which positive variances were calculated is questionable. The cause of negative variances is not known, however, the Montana State University

TABLE 11. ESTIMATED YIELD OF TROUT DURING 1973.

Period	Shore			Boat		
	Weekends-Holidays	Weekdays	Total	Weekends-Holidays	Weekdays	Total
Section A						
1	240	26	266	199	45	244
2	359	276	635	457	0	457
3	319	512	831	441	210	651
4	1,281	1,189	2,470	1,089	340	1,429
5	2,121	1,118	3,239	1,225	741	1,966
Total	4,320	3,121	7,441	3,411	1,336	4,747
Section Total 12,188						
Section B						
1	890	379	1,269	34	27	61
2	572	763	1,335	197	197	394
3	1,450	1,447	2,897	151	150	301
4	1,463	2,481	3,944	142	213	355
5	1,611	1,592	3,203	438	214	652
Total	5,986	6,662	12,648	962	801	1,763
Section Total 14,411						
Section C						
1	47	209	256	239	585	824
2	160	230	390	1,374	1,279	2,653
3	93	141	234	976	647	1,623
4	55	72	127	530	638	1,168
5	201	151	352	1,879	1,144	3,023
Total	556	803	1,359	4,998	4,293	9,291
Section Total 10,650						
Grand Total 37,321						

14,411
10,650
23,061

Statistics Laboratory is continuing to investigate this and other difficulties associated with creel census design and analysis.

Estimates of yield of shore fishermen in Section C are subject to bias because the catch rate for this group was estimated by using the catch rate of boat fishermen from Sections B and C combined. However, the bias introduced is probably small since the number of fisherman hours for shore fishermen in Section C is small. Only estimates of yield in Sections B and C combined are presented because catch rates for the individual sections could not be estimated.

During the 1973 census, the total yield was 37,321 trout caught during 18,648 fisherman days for an average of 2.00 fish per fisherman day. Of this total, weekend-holiday fishermen caught 54.3 percent (20,233) while weekday fishermen caught 45.7 percent (17,016). Shore fishermen caught 57.6 percent (21,488) and boat fishermen caught 42.4 percent (15,801)of the total yield. The yield of trout in Sections A and in B and C combined were 32.7 percent (12,188) and 67.3 percent (25,061) of the total, respectively. Of the total yield in Section A, 63.4 percent (7,731) were taken on weekends-holidays and 36.6 percent (4,457) on weekdays. In Sections B and C combined, 49.9 percent (12,502) of the yield was taken on weekends-holidays and 50.1 percent (12,559) on weekdays. In Section A, shore fishermen accounted for 61.1 percent (7,441) and boat fishermen 38.9 percent (4,747) of the yield. In Sections B and C combined, shore fishermen accounted for

55.9 percent (14,007) and boat fishermen 44.1 percent (11,054) of the total yield.

The yield of trout in Sections A, and in B and C combined, progressively increased from Period 1 through 5. Of the total yield in Section A, 4.1, 8.9, 12.1, 32.0 and 42.7 percent were taken during periods 1 through 5, respectively. Yields from Sections B and C combined were 9.6, 19.0, 20.2, 22.3 and 28.8 percent for respective Periods 1 through 5.

The average number of fish caught per fisherman day on weekends-holidays and weekdays was 1.87 and 2.18, respectively. The average number of fish caught per fisherman day between weekends-holidays, weekdays, shore fishermen and boat fishermen within Sections A, and in B and C combined, varied from 1.78 to 2.25. However, the average number of fish caught per fisherman day between periods in Sections A and in B and C combined ranged from 0.78 to 4.08.

The yield of trout by species and group of hatchery fish (Table 12) was estimated by multiplying species catch rate by fishing pressure. Confidence limits are not presented because of the occurrence of negative variances as before. Since data show that a proportion of unmarked wild appearing trout were actually hatchery fish, the number of unmarked hatchery trout in the catch was likely underestimated.

TABLE 12. ESTIMATED YIELD OF EACH KIND OF TROUT DURING 1973.

Fish Category	Shore		Boat		Total	
	Number	Percent	Number	Percent	Number	Percent
Section A						
LL	7	0.1	0	0.0	7	0.1
Rb(W)	2,686	36.1	1,476	31.1	4,162	34.1
Rb(H)	4,241	57.0	3,218	67.8	7,459	61.2
Rb(Lp)	67	0.9	57	1.2	124	1.0
Rb(Rp)	231	3.1	0	0.0	231	1.9
Rb(Ad)	98	1.3	0	0.0	98	0.8
Rb(Ad,Lp)	0	0.0	0	0.0	0	0.0
Ct(W)	104	1.4	0	0.0	104	0.9
Ct(H)	0	0.0	0	0.0	0	0.0
Ct(Lp)	0	0.0	0	0.0	0	0.0
Ct(Ad)	0	0.0	0	0.0	0	0.0
Section B						
LL	670	5.3	288	16.1	958	6.6
Rb(W)	4,098	32.4	463	26.3	4,561	31.6
Rb(H)	7,070	59.9	550	31.2	7,620	52.9
Rb(Lp)	152	1.2	35	2.0	187	1.3
Rb(Rp)	228	1.8	11	0.6	239	1.7
Rb(Ad)	354	2.8	377	21.4	731	5.1
Rb(Ad,Lp)	13	0.1	0	0.0	13	0.1
Ct(W)	38	0.3	30	1.7	68	0.5
Ct(H)	0	0.0	1	0.0	1	0.0
Ct(Lp)	0	0.0	0	0.0	0	0.0
Ct(Ad)	25	0.2	12	0.7	37	0.3
Section C						
LL	367	27.0	1,867	20.1	2,234	21.0
Rb(W)	347	25.5	2,425	26.1	2,772	26.0
Rb(H)	308	22.7	2,527	27.2	2,835	26.6
Rb(Lp)	16	1.2	158	1.7	174	1.6
Rb(Rp)	5	0.4	46	0.5	51	0.5
Rb(Ad)	281	20.7	2,044	22.0	2,325	21.8

TABLE 12. Continued.

Fish Category	Shore		Boat		Total	
	Number	Percent	Number	Percent	Number	Percent
Section C (Continued)						
Rb(Ad,Lp)	0	0.0	0	0.0	0	0.0
Ct(W)	26	1.9	167	1.8	193	1.8
Ct(H)	1	0.1	9	0.1	10	0.1
Ct(Lp)	0	0.0	0	0.0	0	0.0
Ct(Ad)	5	0.4	56	0.6	61	0.6

Rainbow trout made up 90.1 percent while hatchery rainbow made up at least 59.4 percent of the total yield. However, data indicate the percent of rainbow trout in the yield progressively decreased downstream from Sections A through C while the percent of brown and cutthroat trout increased (Table 13). Since 83% of the boat fisherman

TABLE 13. SPECIES COMPOSITION OF TROUT IN THE YIELD DURING 1973.

	Section A Percent	Section B Percent Shore	Sections B & C Percent Boat
Brown	0.1	5.3	19.5
Wild Rainbow	34.1	32.4	26.1
Hatchery Rainbow	64.9	55.9	52.0
Cutthroat	0.9	0.5	2.5

hours in Sections B and C combined were expended in Section C, the species composition of trout caught was probably biased toward Section C. The composition of the catch of boat fishermen in Sections B and C combined is similar to the 21 percent brown, 17 percent wild rainbow, 59 percent hatchery rainbow and 3 percent other species found by Vincent (1969) on 67 miles of the Madison River during 1966. The percent of unmarked rainbow trout identified as hatchery fish decreased downstream from 64.2 percent in Section A and 63.3 percent for shore fishermen in Section B to 51.6 percent for boat fishermen in Sections B and C combined.

In Section A, the average total length at capture for wild appearing and unmarked hatchery rainbow trout was 11.4 and 11.2 inches,

respectively. In Sections B and C combined, the average length at capture for wild appearing and unmarked hatchery rainbow trout was 11.9 and 11.2 inches, respectively. For boat fishermen in Sections B and C, the average length at capture of unmarked wild appearing rainbow and unmarked hatchery rainbow trout was 13.4 and 12.6 inches, respectively. Length frequencies (2 inch intervals) of this group of fish revealed 22 percent of the wild appearing rainbow trout and only 9 percent of the hatchery rainbow were from 16 to 26 inches in length. A chi-square test showed the length frequencies of these groups of unmarked rainbow trout were different ($p<.005$).

The estimated length frequency of the yield of brown trout during 1973 in Sections B and C combined and the mean and range of the total length of each age group is presented in Figure 15. Although the range for age groups is wide, it appears that II was the most common age group in the catch followed by age groups III and I, respectively. Length frequencies constructed for the catch of each period, indicate most of the age group I brown trout were caught during the last eight weeks of the census. Only 19 brown trout less than 11 inches were caught the first 12 weeks of the census but an estimated 123 brown trout from 7.0 to 8.9 inches in length were taken during the last eight indicating recruitment of a younger age group to catchable size. Young of the year may even have entered the catch following the census period. Brown trout averaged 15.2 inches at capture in Sections B and

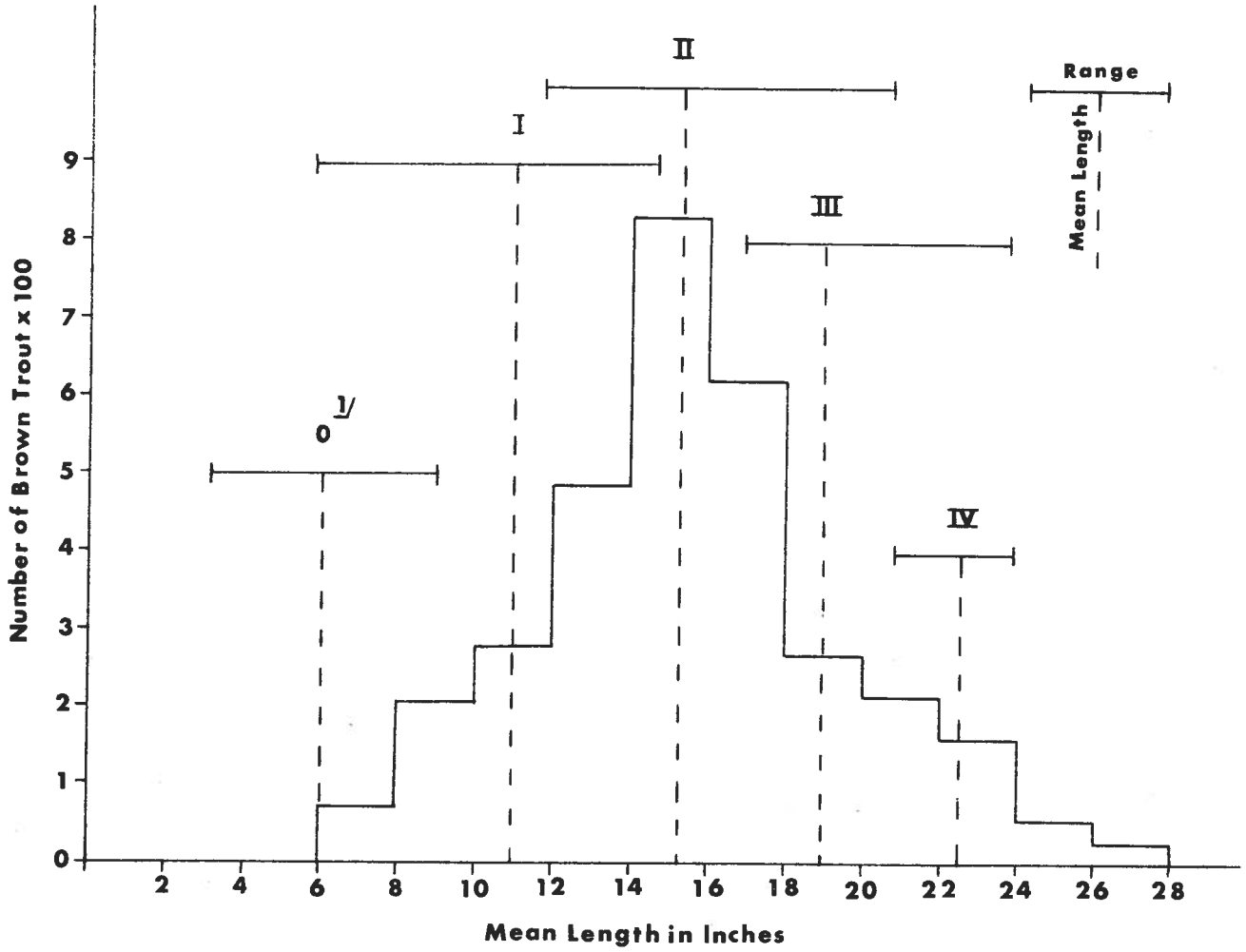

Figure 15. Estimated length frequency in the yield of brown trout from Sections B and C, during 1973, and the estimated mean and range of the total length of each age group at capture. 1/ Mean and range of estimated length at annulus 1.

C combined. Of the total yield of brown trout in Sections B and C combined, an estimated 1,457 (45.6 percent) were from 14.0 to 18.0 inches in length and 458 (14.3 percent) were from 20.0 to 28.0 inches.

The estimated number of hatchery fish planted during 1972 and 1973 and returned to the fisherman's creel during the 1973 census is presented in Table 14. Assuming none of the 150,000 trout planted at 3 to 8 inches during 1971 entered the catch, at least 8.2 percent of the fish planted in the study area during 1972 and 1973 combined were creeled during the 1973 census. Of all marked fish planted during 1972 and 1973 an estimated 5.2 percent were creeled with the largest fish at planting providing the highest return. Other workers have also found this relationship between size and returns to the creel. Benson *et al.* (1958) found that planted 3-5 inch brown and rainbow trout were returned at a rate of less than 1 percent in the Madison River system in Yellowstone National Park. Pfitzer (1960) found returns one year after planting of 37.2 and 4.2 percent for 7-10 and 3 inch rainbow trout, respectively, in a 72 acre reservoir while 2-4 inch rainbow trout planted in two tailwater streams combined produced a return of 5.9 percent. However, direct comparisons of returns between different sized marked hatchery fish of the same species could not be made in the present study and the lower cost of planting equal numbers of small fish compared to larger fish must be considered in evaluating a stocking program. The smaller return of the same sized plants from

TABLE 14. ESTIMATED RETURN OF MARKED AND UNMARKED HATCHERY RAINBOW AND CUTTHROAT TROUT TO THE FISHERMAN'S CREEL DURING THE 1973 CENSUS.

Date Planted	Section Planted	Group of Fish	Ave. Total Length (inches)	Number Planted	Estimated Number Caught	1973 Percent Return A	1973 Percent Return B,C	1973 Percent Return A,B,C
7/26/72	B,C	Rb(Ad)	6.8	12,000	3,154	0.8	25.5	26.3
9/13/72	B,C	Ct(Ad)	2.6	12,000	98	0.0	0.8	0.8
9/13/72	A	Rb(Lp)	6.8	3,000	485	4.1	12.0	16.2
9/13/72	A	Ct(Lp)	2.6	3,000	0	0.0	0.0	0.0
Total 1972 Marked Plantings				30,000	3,737	0.7	11.7	12.5
4/17/73	A	Rb(Rp)	4.2	40,000	521	0.6	0.7	1.3
7/26/73	B,C	Rb(Ad,Lp)	4.4	12,000	13	0.0	0.1	0.1
Total 1973 Marked Plantings				52,000	534	0.0	1.0	1.0
Total Marked Plantings (1972 & 1973)				82,000	4,271	0.6	4.7	5.2
3/4/72-7/5/72	A	Rb(H)	3.8	189,184[1]	17,914	3.9	5.5	9.5
Total 1972 Marked and Unmarked Plantings				219,184	21,651	3.5	6.3	9.9
GRAND TOTAL (1972 & 1973)				271,784	22,185	2.9	5.2	8.2

[1]Total unmarked hatchery fish planted during study.

Section A than from Sections B and C combined may be due to differences in catchability of fish from these sections. Butler and Borgeson (1965) found the catchability of "catchable" size hatchery trout in lakes was less than in streams.

Although overall returns of hatchery fish numbers were low during the 1973 census, the total return was unboubtedly higher. On December 27, 1972, between the two censuses, ten adipose clipped rainbow trout were collected by hook and line at the fishing access in Section C averaging 12.0 inches in length and 0.70 of a pound. Additional numbers of this group of hatchery fish were likely harvested before and after the 1973 creel census. The estimated return in pounds of this group of hatchery fish was 278 percent during the 1973 census.

Marked hatchery fish moved between sections. The number of marked fish planted in Section A and returned in Sections B and C was 651 while those planted in Sections B and C and returned in Section A numbered 98.

Using the average weight and estimated total number of trout caught, a total yield of 30,124 pounds of trout was estimated taken from the study area during 1973. Of the 6,687 pounds taken in Section A, brown trout, wild appearing rainbow, hatchery rainbow and cutthroat trout made up 0.1, 34.2, 64.9 and 0.8 percent of the total. Of the 23,437 pounds taken in Sections B and C combined, brown trout, wild

appearing rainbow, hatchery rainbow and cutthroat trout contributed 21.4, 17.5, 59.7 and 1.5 percent of the total.

The yield in pounds of trout per surface acre is given in Table 15. Total yield over the study area was 43.4 pounds per surface acre with Sections A, and B and C combined, yielding 43.0 and 43.5 pounds per acre, respectively. The yield of trout including hatchery fish from 73 miles of the Fontenelle tailwater of the Gree oming, a river of comparable size, was 9 pounds per acre (Ba (1974). The West Gallatin River produced 28.9 and 28.0 pound per acre during 1971 and 1972 including hatchery fish. 970) found yields of 133 and 116 pounds per acre of wil g Spring Creek which was stocked with hatchery fish

Not all fish caught were kept. The total number of trout aught and released in Sections A and in B and C combined was 1,383 and 2,225, respectively. The number of fish other than trout caught in Sections A, and in B and C combined, was 18 and 2,727, respectively.

TABLE 15. ESTIMATED YIELD IN POUNDS PER SURFACE ACRE OF EACH KIND OF TROUT DURING 1973.

Fish Category	Section A			Section B			Section C		
	Shore	Boat	Total	Shore	Boat	Total	Shore	Boat	Total
LL	0.03	0.00	0.03	17.05	6.87	23.92	1.31	6.18	7.49
Rb(W)	9.69	5.04	14.73	30.74	10.02	40.76	0.95	2.52	3.47
Rb(H)	15.31	11.53	26.84	38.96	10.39	49.35	1.22	11.96	13.18
Rb(Lp)	0.24	0.00	0.24	1.11	0.70	1.81	0.04	0.40	0.45
Rb(Rp)	0.45	0.00	0.45	0.87	0.10	0.97	0.01	0.05	0.06
Rb(Ad)	0.42	0.00	0.42	8.91	9.11	18.02	0.78	5.91	6.69
Rb(Ad,Lp)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ct(W)	0.33	0.00	0.33	0.22	0.64	0.86	0.07	0.43	0.50
Ct(H)	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.02
Ct(Lp)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ct(Ad)	0.00	0.00	0.00	0.00	0.13	0.13	0.01	0.08	0.08
Total	26.47	16.57	43.04	97.86	37.98	135.84	4.39	27.55	31.94

DISCUSSION

The trout fishery in the Bighorn River below Yellowtail Dam is strategically located near a large population center. It received a high level of use during this study and probably will receive increased utilization if present and proposed construction of roads into the area is completed. Because this fishery provides much recreation, every attempt should be made to realize its full potential.

The planting of trout in the study area may be keeping the wild populations present from reaching their maximum numbers. A population of wild brown trout is present and the occurrence of rainbow trout in spawning condition and redds in the spring with an increasing proportion of wild appearing rainbow accompanied by a decrease of unmarked hatchery rainbow trout with downstream progression suggests the presence of a wild population of this species. Vincent (1974) recently demonstrated that hatchery-reared rainbow trout exerted depressive effects on self sustaining wild trout populations in the Madison River.

Gas bubble disease, caused by nitrogen supersaturation may also presently be adversely affecting fish populations in the study area. Trout found dead in the Bighorn River and many observed in the fishermen's catch had symptoms of gas bubble disease. Personnel of the Bureau of Reclamation and Montana Department of Fish and Game conducted saturometer tests and trout bioassays in the Bighorn River in July and August, 1973 and in April, 1974 to determine the severity of

this problem. During 1973, nitrogen saturations ranged from 113 to 124 percent. Of the 37 fish retained throughout the bioassay, one died without superficial symptoms of gas bubble disease and 36 survived with 5 of these having symptoms of gas bubble disease. During 1974, nitrogen saturations ranged from 111 to 121 percent. Of the 39 caged fish, 21 died without showing superficial symptoms of gas bubble disease, one died with obvious symptoms and 17 survived with 10 of these having superficial symptoms of the disease. A number of these 21 fish may also have been killed by gas bubble disease which did not manifest itself upon gross examination. Demont (1972) reported dead black crappie *(Pomoxis nigromaculatus)* did not show external symptoms of gas bubble disease while autopsies of dying crappie revealed gas emboli in the larger capillaries of their gills.

RECOMMENDATIONS

1. All hatchery fish planted in the system should be marked so returns of hatchery fish can be evaluated and wild fish can be identified without question.
2. A creel census estimating fishing intensity and yield should be conducted each year (year-round if practical).
3. Although high conductivity hampers electrofishing in the Bighorn River, further experimentation with this technique should be carried out to determine if estimates of fish populations can be made.
4. Chemical and physical parameters and their effect on recruitment and survival of trout should be measured. The effects of Calcite ($CaCo_3$) precipitation in relation to cementation of the substrate and spawning and nitrogen supersaturation to survival of trout are most important.
5. Unless it is shown that natural recruitment of trout in the Bighorn River is not sufficient to support a high quality fishery, a no stocking experiment should be conducted to evaluate the self sustaining capabilities of this fishery.

APPENDIX

The following methodology was used to compute fishing intensity and yield estimates of Sections A and B and catch rate estimates of A, B, and C.

I. Estimation of fishing intensity (fisherman hours)

A. Shore fishing intensity

i) Point estimate

$$P_s = h\bar{f}_s$$

where: h = number of fishing hours in the period of interest

$\bar{f}_s$ = mean number of shore fishermen per count for that period

ii) Estimate of the variance of the point estimate

$$s^2_{\bar{f}_s} = h^2 \frac{s^2_f}{n}$$

where: $$s^2_f = \frac{\Sigma_{i=1}^{n}(f_i - \bar{f})^2}{n-1}$$

where: f_i = number of fishermen counted on the $i^{\underline{th}}$ count

n = number of counts

B. Boat fishing intensity

i) Point estimate

$$P_B = h\bar{B}\bar{\theta}$$

where: h = number of fishing hours in the period of interest

$\bar{B}$ = mean number of boats per count for that period

θ = mean number of fishermen per boat for that period

ii) Estimate of the variance of the point estimate

$$s^2_{P_B} = (P_B)^2 \left[\frac{s^2_B}{\bar{B}^2} + \frac{s^2_\theta}{\theta^2} \right]$$

where: $s^2_B = \frac{\Sigma^n_{i=1}(B_i - \bar{B})^2}{n-1}$

B_i = number of boats counted on $i^{\underline{th}}$ count

n = number of counts

$s^2 = \frac{\Sigma^m_{i=1}(\theta_i - \bar{\theta})^2}{m-1}$

θ = number of fishermen in boat for $i^{\underline{th}}$ boat sampled

m = number of boats sampled to determine the number of fishermen per boat

II. Estimation of the catch rate (fish caught per hour)

A. Separate point estimates were calculated for shore and boat fishermen

i) Point estimate

$$R_s = \frac{\bar{F}_s}{\bar{H}_s} \quad \text{and} \quad R_B = \frac{\bar{F}_B}{\bar{H}_B}$$

where: $\bar{F}$ = mean number of fish caught by fishermen interviewed during the period of interest

$\bar{H}$ = mean number of hours fished by fishermen interviewed during the period of interest

ii) Estimate of the variance of the point estimate

$$s_R^2 = R^2 \left[\frac{s_F^2}{\bar{F}^2} + \frac{s_H^2}{\bar{H}^2} - \frac{2\ \mathrm{Cov}(F,H)}{\bar{F}\ \bar{H}} \right]$$

where: $s_F^2 = \frac{\Sigma_{i=1}^{n}(F_i - \bar{F})^2}{n-1}$

F_i = number of fish caught by $i^{\underline{th}}$ fisherman interviewed

n = number of fishermen interviewed for that period

$s_H^2 = \frac{\Sigma_{i=1}^{n}(H_i - \bar{H})}{n-1}$

H_i = number of hours fished by $i^{\underline{th}}$ fishermen interviewed

iii) $\mathrm{Cov}(F,H) = \frac{\Sigma_{i=1}^{n}(F_i - \bar{F})(H_i - \bar{H})}{n-1}$

III. Estimate of the yield

A. Separate point estimates were calculated for shore and boat fishermen

i) Point estimates

$$Y_s = P_s \cdot R_s \text{ and } Y_B = P_B \cdot R_B$$

with: P as in (I), and R as in (II)

ii) Due to the occurrence of negative variances, formulas for the calculation of variances of yield point estimates are not presented

IV. The following methodology was used to compute fishing intensity and yield estimates in Section C

A. Shore fishing intensity

i) The mean number of shore fishermen of Section C was estimated by linear regression (BMD02R, MBD Biomedical Computer Programs. W.J. Dixon ed., V.C. Press., 1970. "Stepwise Linear Regression Program")

$$\bar{f}_s = .74 + .32\bar{C} \quad \text{(regression estimate)}$$

where: $\bar{C}$ is the mean number of cars parked at the fishing access at the lower boundary of Section C

Note: Cars at the access site was found to be the variable most highly correlated with the number of shore fishermen

ii) Comments on the goodness of this estimate

$R = 0.3538$ is relatively low

$F_{1,18} = 2.576$ not significant at the .10 level

iii) Estimate of the variance of the point estimate

$$s^2_{\hat{f}} = (.32)^2 \, s^2_{\bar{C}}$$

$$s^2_C = \frac{\Sigma_{i=1}^{m}(C_i - \bar{C})}{(m-1)m}$$

when: m = number of car counts

C_i = number of cars counted on the $i^{\underline{th}}$ count

iv) Point estimate of shore fishing intensity

$$P_s = h \cdot \bar{f}_s$$

with $h, \bar{f}_s$ as in (I), (A), (i)

Estimate of the variance of the point estimate

$$s^2_{P_s} = h^2 \, s^2_{\hat{f}_s}$$

B. Boat fishing intensity

i) The number of boats operating in Section C was also estimated by Linear Regression (BMD02R, Stepwise Linear Regression)

$$\hat{B} = -.642 + 1.50\bar{C}$$

with $\bar{C}$ as in (IV), (A), (i)

Note: Cars at the access site was again the most highly correlated variable

ii) Comments on the goodness of this estimate

$R = 0.84$ (60% of variation accounted for)

$F_{1,18} = 43.58$ significant at the .005 level

iii) Estimate of the standard error of the point estimate

$$s^2_{\hat{B}} = (1.50s)^2 s^2_C$$

with s^2_C as in (IV), (A), (i)

iv) Point estimate of boat fishing intensity

$$P_B = \bar{\theta} \cdot \bar{B} \cdot h$$

with $\bar{\theta}$, h as in (I), (B), (i)

Estimate of the variance of the point estimate

$$s^2_{P_B} = P^2_B \left[\frac{s^2_B}{\bar{B}^2} + \frac{s^2_\theta}{\bar{\theta}^2} \right]$$

C. Estimate of the yield

i) Separate point estimates were calculated for shore and boat fishermen

$$Y_s = P_s \cdot R^*_s \text{ and } H_B = P_B \cdot R^*_B$$

where: R^*_{sB} = catch rate of Section C

P,H as before

Note: 1) The computations presented in this appendix were performed in each stratum and the point estimates of fishing intensity and yield were added to arrive at their respective totals

2) Variances of fishing intensity point estimates in each stratum were added to arrive at totals

3) Variances of catch rates by strata were combined as follows

$$\Sigma_{i=1}^{n}(w_i^2)(Var_i)$$

where: w_i = weight of the $i^{\underline{th}}$ strata

Var_i = variance of the $i^{\underline{th}}$ strata

n = number of strata combined

LITERATURE CITED

Agaard, F. C. 1969. Temperature of Surface Waters in Montana. U. S. Dept. of the Interior, Geol. Surv., Helena, Montana. 613 pp.

Banks, R. L., J. W. Mullan, R. W. Wiley and D. J. Dufek. 1974. The Fontenelle Green River trout fisheries-considerations in its enhancement and perpetuation, including test flow studies of 1973. U. S. Fish Wildl. Serv. 74 pp.

Benson, N. G., O. B. Cope and R. V. Bulkley. 1958. Fishery management studies on the Madison River System in Yellowstone National Park. U. S. Fish Wildl. Serv., Spec. Rept. 307. 29 pp.

Bureau of Reclamation. 1973. Gas supersaturation below Yellowtail Afterbay Dam, Montana. MAPP Environmental Monitoring Workshop, November 28, 1973.

Butler, R. L. and D. P. Borgeson. 1965. California "catchable" trout fishery. Calif. Dept. of Fish and Game. Fish. Bull. 127, 47 pp.

Cope, O. B. 1955. Six years of catch statistics of Yellowstone Lake. Trans. Amer. Fish. Soc. 65: 207-223.

DeMont, D. J. and R. W. Miller. 1972. First reported incidence of gas-bubble disease in the related effluent of a steam generating station. Proc. of 25th Ann. Conf. Southeastern Assoc. of Game and Fish Commissioners, October 17-20, 1971, pp. 392-399.

Fish and Wildlife Service. 1962. Fish and wildlife resources and the Yellowtail Unit. U. S. Dept. of the Interior. Office of Missouri River Basin Studies. Billings, Montana. 34 pp.

Hunt, R. L. 1966. Production and angler harvest of wild brook trout in Lawrence Creek, Wisconsin. Wisc. Cons. Dept. Bull. 35, 52 pp.

Johnson, M. W. and L. Wroblewski. 1962. Errors associated with a systematic sampling creel census. Trans. Amer. Fish. Soc. 91: 201-207.

Lund, J. A. 1974. Elk Lake-Narrows Creek study. Annual progress report. Mont. Fish and Game Dept. 19 pp.

Lyden, R. S., Jr. 1973. Fisherman use and fish harvest on the West Gallatin River, Montana. M.S. Thesis, Mont. St. Univ. 33 pp.

Miller, H. W. 1972. 1971 summary of Clark Canyon-Beaverhead River Project, Montana Fish and Game Dept. 8 pp.

Neuhold, J. M. and K. H. Lu. 1957. Creel census method. Utah State Department of Fish and Game, Publication No. 8, Salt Lake City, Utah. 36 pp.

Peters, J. C. 1964. Age and growth studies and analysis of bottom samples in connection with pollution studies. Project F-23-R-6. Mont. Fish and Game Dept. 76 pp.

Peterson, N. W. 1970. The yield of wild and hatchery trout from Big Spring Creek, Montana. M.S. Thesis, Mont. St. Univ. 35 pp.

_____. 1974. Inventory of waters of the project area. Project F-9-R-21. Mont. Fish and Game Dept. 12 pp.

Pfitzer, D. W. 1960. Investigation of waters below large storage reservoirs in Tennessee. Tenn. Game and Fish Comm. DJ F-1-R Final Report, 233 pp.

Spence, L. 1971. Georgetown Lake summer creel census. Project F-12-R-17. Mont. Fish and Game Dept. 11 pp.

Stumm, W. and J. J. Morgan. 1970. Aquatic chemistry. John Wiley and Sons, Inc., New York. 583 pp.

United States Geological Survey. 1964. Water quality records in Montana. 124 pp.

_____. 1965. Water resources data for Montana. Part 1. Surface water records. 289 pp.

_____. 1965. Water resources data for Montana. Part 2. Water quality records. 150 pp.

_____. 1971. Water resources data for Montana. Part 2. Water quality records. 218 pp.

United States Geological Survey. 1972. Water resources data for Montana. Part 1. Surface water records. 283 pp.

_____. 1972. Water resources data for Montana. Part 2. Water quality records. 240 pp.

_____. 1973. Water resources data for Montana. Part 2. Water quality records. 242 pp.

Vincent, E. R. 1969. Madison River creel census. Project F-9-R-16. Mont. Fish and Game Dept. 12 pp.

_____. 1974. Effect of stocking catchable trout on wild trout populations. Wild Trout Symposium, Mammoth, Wyoming, September 26, 1974.

Weatherley, A. H. 1972. Growth and ecology of fish populations. Academic Press, New York. 280 pp.

Wright, J. C. and R. A. Soltero. 1973. Limnology of Yellowtail Reservoir and the Bighorn River. U. S. Envt. Prot. Agency Report EPA-R3-73-002. Washington, D. C. 105 pp.