

Effects of stream temperature on angling success for rainbow and brown trout
by Geoffrey Aaron McMichael

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
The objective of this study was to determine whether a relationship existed between stream temperature and angling success, and the associated angler satisfaction, of recreational trout anglers. Catch rates and angler satisfaction were determined via on-site creel survey while water temperatures were concurrently monitored within two sections of the Madison River, Montana during the springs and summers of 1987 and 1988. Results from 1,741 angler contacts showed significant correlations between water temperature and total catch rates of trout, catch rates of trout 30.5 cm and larger, anglers with zero catch, and angler satisfaction. Catch rates (trout/hour) for rainbow and brown trout were highest at stream temperatures between 8 and 15 C, and declined to levels that most anglers found unsatisfactory at 19 to 20 C. Several types of angler characteristics were significantly related to catch rates. These results confirm that elevated stream temperatures can seriously reduce availability of trout to anglers, and thereby impair the quality of a fishery, at levels considerably below lethal thermal limits for the species.

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

of

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in

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APPROVAL

of a thesis submitted by

Geoffrey Aaron McMichael

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

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Date 5/15/89

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ABSTRACT

The objective of this study was to determine whether a relationship existed between stream temperature and angling success, and the associated angler satisfaction, of recreational trout anglers. Catch rates and angler satisfaction were determined via on-site creel survey while water temperatures were concurrently monitored within two sections of the Madison River, Montana during the springs and summers of 1987 and 1988. Results from 1,741 angler contacts showed significant correlations between water temperature and total catch rates of trout, catch rates of trout 30.5 cm and larger, anglers with zero catch, and angler satisfaction. Catch rates (trout/hour) for rainbow and brown trout were highest at stream temperatures between 8 and 15 C, and declined to levels that most anglers found unsatisfactory at 19 to 20 C. Several types of angler characteristics were significantly related to catch rates. These results confirm that elevated stream temperatures can seriously reduce availability of trout to anglers, and thereby impair the quality of a fishery, at levels considerably below lethal thermal limits for the species.

INTRODUCTION

While it has long been recognized that angling catch rates for trout tend to be depressed at warm water temperatures, almost no data have been available from actual field study of this relationship. Physiological effects of water temperature on trout growth, metabolism and behavior have been studied (Brett 1956, Dickson and Kramer 1971, Elliot 1975a, 1975b, 1975c, Jobling 1981, Kaya 1977, Wurtzbaugh and Davis 1977), and popular sporting magazines have presented 'optimum' temperatures for trout fishing (e.g. Slaymaker 1981, Yaeger 1989), but there has been no direct scientific study of the relationship between water temperature and angling success. The Madison River is particularly well-suited to such study, as it has two sections, separated by a shallow reservoir, that represent markedly differing thermal regimes. Both sections support trout fisheries sustained by natural reproduction and attract many nonresident and resident anglers (Allen 1988, Duffield et al. 1987).

The primary objective of this study was to determine the effects of diel and seasonal changes in water temperature on angling catch rates for rainbow trout (Oncorhynchus mykiss, formerly Salmo gairdneri), and brown

trout (*Salmo trutta*), with particular emphasis on identifying temperatures above which catch rates decline to levels that anglers consider unsatisfactory. Minor secondary objectives were to determine whether there was a relationship between catch rate and flow, as well as to determine the effects of various angler characteristics on catch rate.

DESCRIPTION OF THE STUDY AREA

From its origin in Yellowstone National Park at the confluence of the Gibbon and Firehole Rivers, the Madison River flows northwest and enters Hebgen Reservoir approximately 3 km west of the Park. This reservoir was created in 1915. Regulation of its outflow controls much of the streamflow discharge in the river downstream. About 2 km downstream from Hebgen Reservoir, the Madison River enters Quake Lake, a small, narrow lake that was formed by an earthslide on August 17, 1959. The river then flows for nearly 65 km northward to enter Ennis Reservoir. Formed in 1900 by an earthfill dam, this reservoir is still used for power generation. Ennis Reservoir is too shallow to thermally stratify during the summer and contributes to significant summer warming of the river for some miles downstream (Heaton 1961, Vincent 1979, 1981, 1987). After leaving Ennis Reservoir, the Madison River flows northward for about 56 km to near Three Forks, Montana, where it is joined by the Jefferson River from the west and by the Gallatin River from the east, to form the beginning of the Missouri River.

This study was conducted in two sections of the Madison River: an upper section that is cooler (in summer) and a lower, warmer section below Ennis Reservoir (Fig. 1), the latter within the downstream reaches that experience elevated stream temperatures during summer (Frayley 1977, Heaton 1961, Vincent 1978, 1981, 1987). The Upper section was about 9 km long, and the West Fork of the Madison River entered it from the southwest near the middle of the section. The lower section began at the mouth of Warm Springs Creek and continued downstream for nearly 10 km.

The most recent population estimates available are from electrofishing surveys conducted by the Montana Department of Fish, Wildlife and Parks (MDFWP) during the fall of 1988 for the upper section, and the spring of 1987 for the lower section. Estimates of trout 17.8 cm (7 inches) and larger were 2,623 trout per km in the upper section, 73 percent rainbow and 27 percent brown trout, and 2,734 trout per km in the lower section, 44% rainbow and 56% brown trout (E. R. Vincent, MDFWP, pers. comm. 1988). Other species caught by anglers, but for which abundances have not been estimated, are mountain whitefish (Prosopium williamsoni), cutthroat trout (O. clarki, formerly Salmo clarki), brook trout (Salvelinus fontinalis), and longnose sucker (Catostomus catostomus) in the upper section, and all of the above except cutthroat trout in the lower section. In addition, the white sucker (C. commersoni)

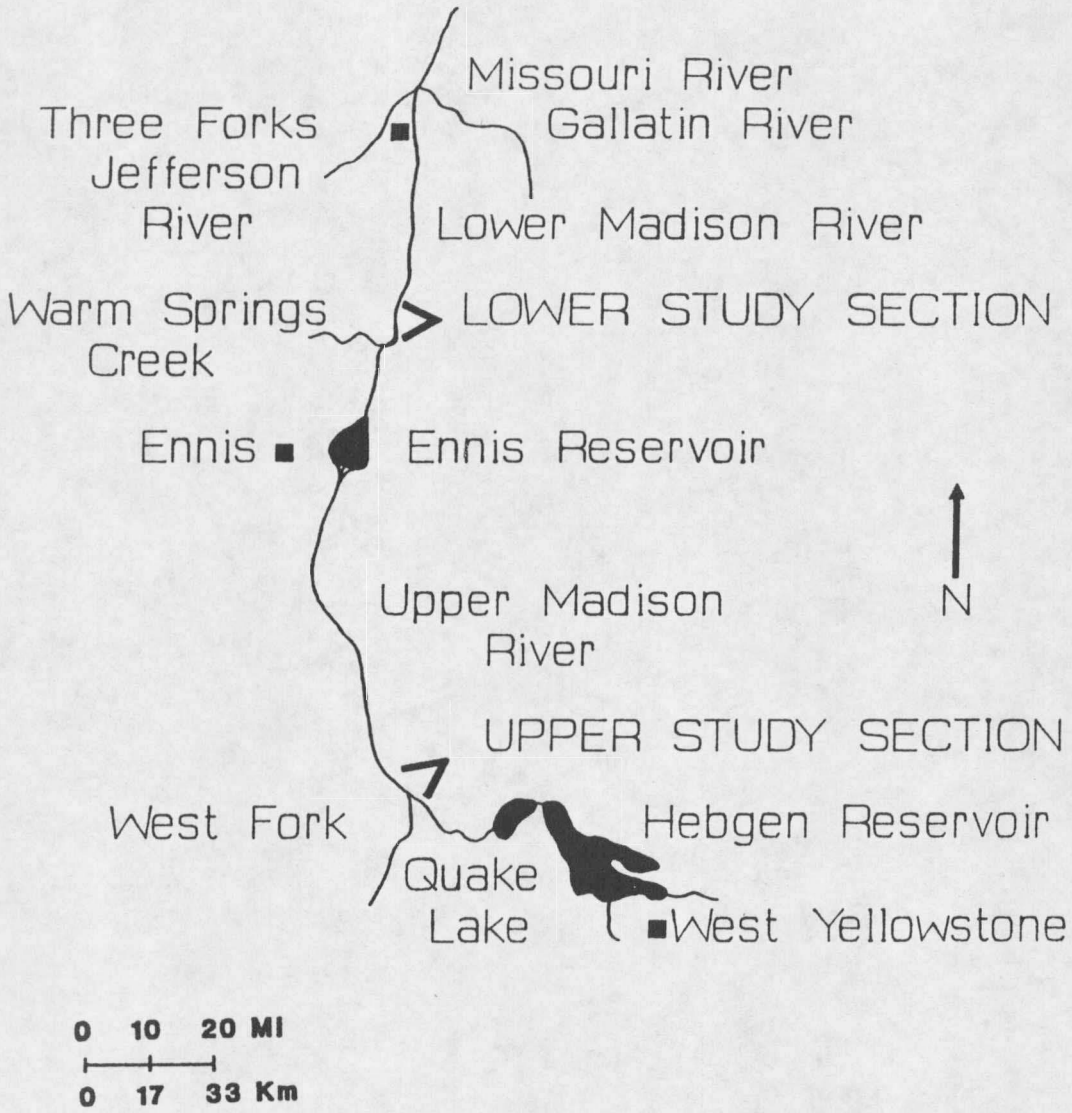


Figure 1. Map of the Madison River, with upper and lower study sections.

and Utah chub (Gila atraria) occurred in lower section catches. Rainbow and brown trout were the most prevalent and sought after species and are the only fishes considered in this study.

The fishing regulations in the upper section were catch-and-release with artificial lures only. In the lower section, there was a 5 trout limit, only one of which could be over 18 inches long. These regulations had been in effect since 1978. Fishing from a boat was allowed on the lower half of the upper section and throughout the lower section. There had been no stocking of hatchery-reared trout in the lower section since 1959 nor in the upper section since 1973 (E. R. Vincent, MDFWP, pers. comm. 1987).

METHODS

Water Temperature

Water temperatures were recorded by Taylor 30-day continuous-reading disc-chart thermographs located near the middle of each study section, one under Kirby Bridge in the upper section and the other under Norris Bridge in the lower section. The thermographs were calibrated weekly with a hand-held mercury laboratory-grade thermometer. The temperatures were recorded on a Fahrenheit scale on the thermograph charts. Temperature was read off the continuous record at two-hour intervals and converted to Centigrade. From these data I determined daily maxima and minima, 24-hour mean, and daytime (0600 to 1800 MDT) mean. Each sample day was divided into three 4-hour segments and the mean temperature calculated for each segment: 0600 to 1000 MDT, 1000 am to 1400 MDT, and 1400 to 1800 MDT. The estimated mean of the temperatures at which each angler fished was taken as the mean temperature of the 4-hour segment within which the angler's median fishing time occurred. This temperature is then referred to as that angler's "fishing temperature" (the term will be used hereafter in this report).

Catch Rates

Catch data were obtained from anglers by direct on-site "creel survey" interview. The same set of predetermined questions (Appendix B) was asked of each angler, and their responses were immediately recorded on the creel survey form. Anglers were asked to report the number, species, and sizes of trout they had landed, as well as the length of time they had been fishing. Lengths of trout kept by anglers were measured and recorded by the surveyor when possible. Anglers were also asked to report their tackle types, state of residence, and whether they had kept any trout. Various other demographic questions were also asked.

Angler Satisfaction

To quantify angler satisfaction, an angling quality rating question was asked. This question was worded differently in 1987 than in 1988 (Table 1, Appendix B). Angling quality ratings for both versions of the question were on a scale of 1 (lowest quality) to 6 (highest quality). The rating question was intended to elicit an expression of satisfaction based solely on the rate at which the angler landed trout, not on other factors in the recreational experience, such as scenery. Because the questions differed between years, the satisfaction ratings

for each year are treated separately in this report.

Table 1. Satisfaction rating questions as they appeared on the creel survey forms used during 1987 and 1988 on the Madison River.

1987:
In terms of the rates at which you caught fish (as opposed to overall outdoor experience, etc.), how would you rate your fishing success today?

highly satisfactory (6)
moderately satisfactory (5)
slightly satisfactory (4)
slightly unsatisfactory (3)
moderately unsatisfactory (2)
highly unsatisfactory (1)

1988:
In terms of the rates at which you caught fish (as opposed to overall outdoor experience, etc.), how would you describe today's fishing?

very fast, couldn't be better (6)
fast (5)
not fast, but okay (4)
slow (3)
very slow (2)
terrible, extremely slow (1)

Angler Characteristics

Anglers were considered to be fly fishing if they were observed casting artificial flies with a fly rod. Spin fishermen were those using artificial lures of any type on spinning, spincast, or casting equipment. Anglers were categorized as bait fishermen if they were using any type of live or dead bait with any type of tackle.

A wading or bank angler was one who had not previously

used a boat anytime on the day of the interview. A boat angler was one who had used a boat for fishing during at least part of the day of the interview. Some anglers in the 'boating anglers' group fished while wading at one or more times during the sample day.

I determined whether anglers were fishing with a guide based on my familiarity with the local guides. A few boating anglers that were fishing without a guide may have been erroneously included in the 'guided' category.

Sampling Schedule

Data were collected in two years during the season that included the most angling pressure, May 16 to September 20, 1987 and April 23 to July 30, 1988. The 1987 season of data collection covered more than four months (18 weeks), from May 16 to September 20. The 1988 data collection covered about 3 months (14 weeks), from April 23 to July 30. The 1988 season was ended earlier than originally planned due to the occurrence of thermal fish kills in the lower study section (Appendix C). For the first four weeks in 1987 (May 16-June 7) and the first five weeks in 1988 (April 23-June 4), anglers were sampled on weekends only. Beginning June 14 in the 1987 season, the survey was conducted four days per sample week (two weekdays and both weekend days), such that the weekdays were alternately changed. Tuesday and Wednesday were

sampled one week, and Wednesday and Thursday were sampled the next. In 1987 the sampling was done every week between June 14 and July 26, and the sampling was done every second week from August 4 to September 20. In 1988, after the initial period of weekend-only sampling, the same schedule was used as in the latter half of 1987. During the first three sample weeks of the 1988 field season, data were collected only on the lower section. Beginning May 14 (sample week 4), data were collected on the upper section.

The field days were blocked as two consecutive days. The first half of the first day and the second half of the second day were spent sampling the lower section, and the second half of the first day and first half of the second day were spent sampling the upper section. The sampling days were divided by the one-hour drive between sections. Sampling days began between 0800 and 0830 MDT and ended between 1630 and 1800 MDT.

Data Analyses

Catch rate (trout/hour) for each angler was calculated by dividing the reported number of trout landed by the number of hours the angler had fished. Trout size (reported and measured) information was used to determine catch rates for fish above and below 30.5 cm (12 inches). For each sample week, the angler having the highest catch

rate and the angler having the lowest catch rate (fished the longest without catching a trout) were omitted from the analyses. Because anglers occasionally reported catches that seemed improbable, omission of the highest catch rate for each sample week provided an objective method of minimizing data from anglers who might tend to exaggerate the number of fish landed. To prevent this procedure from biasing the mean catch rates downward, the lowest catch rate for each sample week was also omitted. These omissions had the effect of reducing data from both the most highly skilled and most unskilled anglers, anglers whose fishing success was most likely to be affected by factors other than water temperature. Fifty of the 1,791 creel survey records were thus omitted, leaving an effective sample size of 1,741. Of the 1,741 records used, 1,229 were collected in 1987 and 512 in 1988.

Water temperature and catch information were entered and manipulated in a spreadsheet personal computer program (Lotus 123). Statistical analyses were performed with SAS (1988) on the mainframe computer at Montana State University as well as with a program called MSUSTAT (Lund 1988) on a personal computer. Linear regressions were done on the comparisons between catch rates (total, and of trout 30.5 cm and larger) and fishing temperature. Analysis of variance tables, fitted regression lines and residual plots were generated and analyzed for these linear regressions.

Comparisons involving satisfaction ratings were, as previously mentioned, treated separately for 1987 and 1988. Contingency tables were created using the CATMOD (a categorized regression) procedure in SAS (1988) for the comparisons between satisfaction ratings and catch rates as well as for the comparisons between satisfaction ratings and fishing temperature. Chi-square tests were then run on these tables. Catch rates were grouped into the following four categories, 1) 0.0-0.45, 2) 0.46-0.95, 3) 0.96-2.45, and 4) 2.45-high trout per hour. Four categories were also chosen for fishing temperature, 1) low-9.5, 2) 9.6-16.6, 3) 16.6-18.5, and 4) 18.6-high degrees Centigrade.

Logistic regressions were performed on the relationships between zero catch and fishing temperature, catch rates of 0.5 or more trout per hour and fishing temperature, and catch rates of 1.0 or more trout per hour and fishing temperature. Data were input with responses of zero or one corresponding to each fishing temperature to represent a yes or no answer to a question of, for example, "Was the catch rate at this fishing temperature zero?". Sample sizes at each fishing temperature were weighted to eliminate possible bias toward the fishing temperatures with higher numbers of contacts. Maximum likelihood analyses and chi-square tests were performed based on these logistic regressions.

One way analyses of variance were run on the comparisons between the various angler characteristics and catch rates for each study section using MSUSTAT (Lund 1988). Analyses of variance were not run on the 'combined' categories for the comparisons between guided and nonguided and between resident and nonresident anglers because the angler distributions within these two categories were extremely unequal between the study sections and would not have made valid comparisons.

RESULTS

Water Temperature

For the entire study period (1987 and 1988 combined), water temperature averaged nearly 4 C higher in the lower section than in the upper section (Figs. 2 and 3). During both seasons, water temperature increased throughout most of the sample season.

In 1987, when sampling continued into September, mean stream temperature declined toward the end of the sample season. In 1988, when sampling was discontinued in late July, stream temperature generally increased throughout the sample season. In 1987, the mean water temperature was 13.8 C in the upper section and 17.4 C in the lower section, a difference of 3.6 C. During the period of peak fishing pressure, mid-June to mid-August, the means were 14.4 C for the upper section and 19.5 C for the lower section, a difference of 5.1 C. Mean temperatures were most similar between sections in mid-May (2.4 C warmer in lower section) and in September (1.5 C warmer in lower section). Mean water temperatures during the 1988 season, for the sample weeks common to both sections, were 12.5 C in the upper and 18.8 C in the lower section, a difference of 6.3 C.

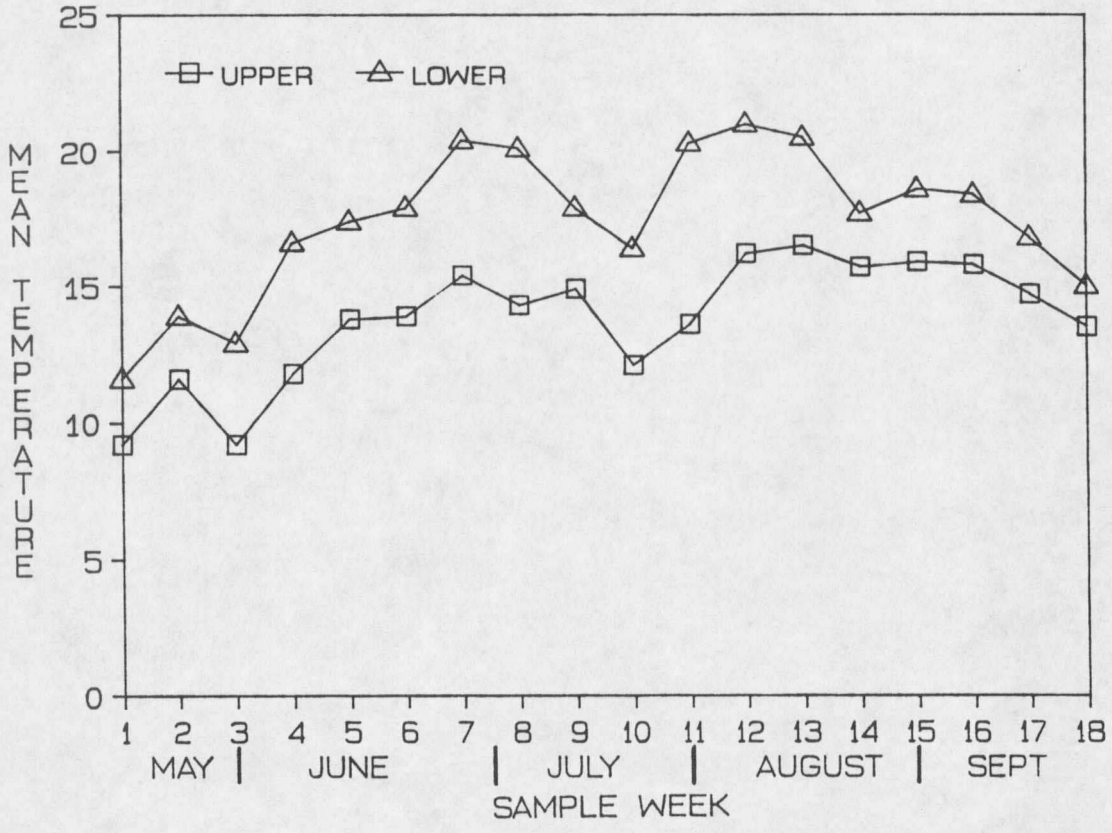


Figure 2. Weekly mean water temperatures (C) for the upper and lower study sections, of the Madison River, 1987.

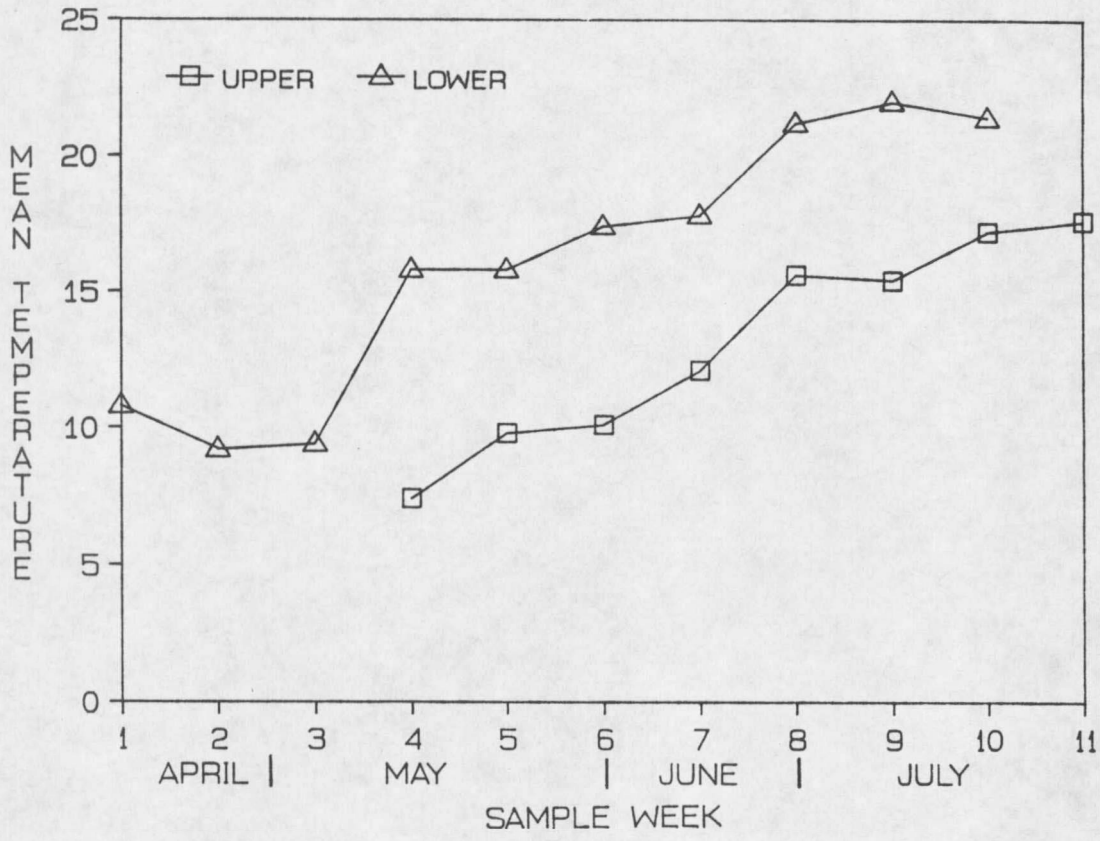


Figure 3. Weekly mean water temperatures (C) for the upper and lower study sections, of the Madison River, 1988.

Streamflow Discharge

Flows in the upper section averaged 32.2 cubic meters per second (cms) and ranged from 17.5 to 44.7 cms. Flows in the lower section averaged 40.8 cms and ranged from 21.6 to 68.5 cms (U. S. Geological Survey, unpub. data 1988) during the summers of 1987 and 1988 combined. In 1987 flows generally increased in both sections until the end of July, and then remained relatively stable until the end of the study season (Fig. 4). The lowest flows occurred during the second sample week (Memorial Day weekend) and peak flows occurred in mid-July. After August 1, flows stabilized in the lower section at about 42 cms. Data were not available for flows in the upper section after July 31, but it appears from the Hebgen Dam discharges that flows in this section also stabilized after August 1.

In 1988 flows began higher and reached a peak at the end of May then decreased throughout June, until leveling off around the first of July at about 30 cms in both sections (Fig. 5). Thus, flows during 1988 stabilized at about 12 cms lower than in 1987.

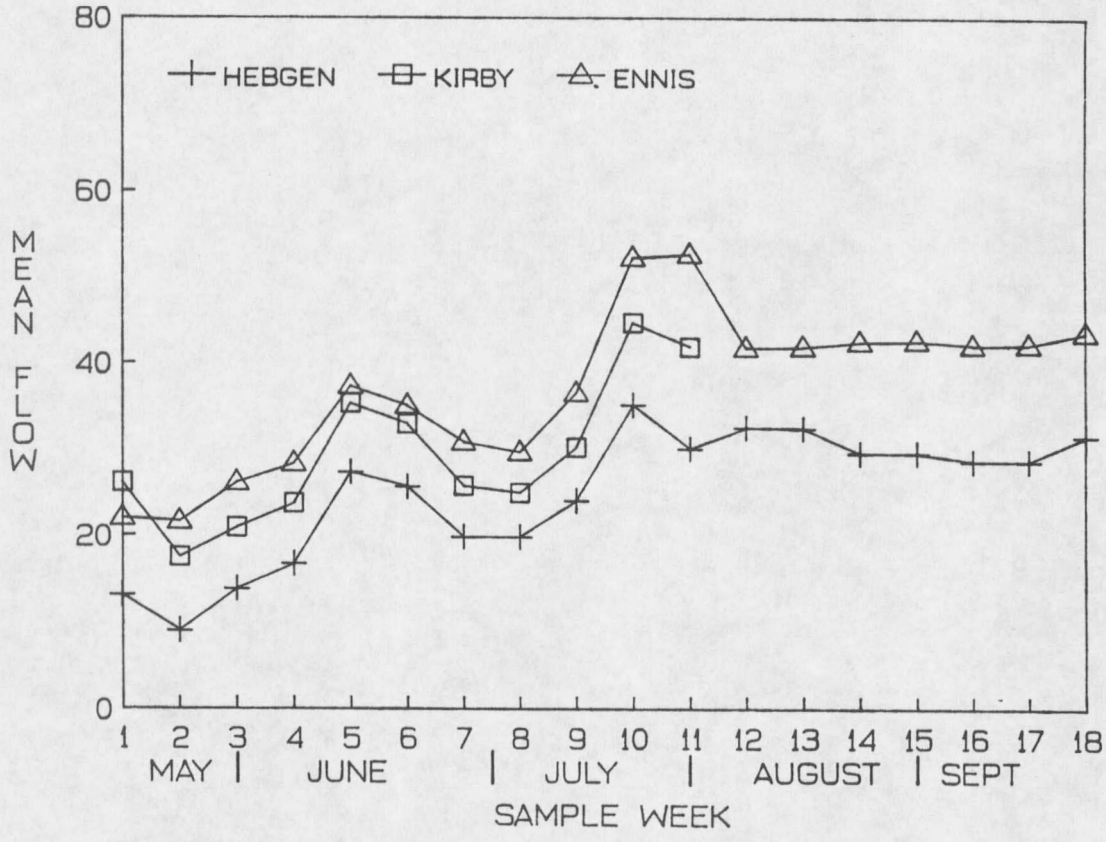


Figure 4. Weekly mean flows (cubic meters/sec) of the Madison River at Hebgen Dam, Kirby Bridge, and Ennis Dam, 1987.

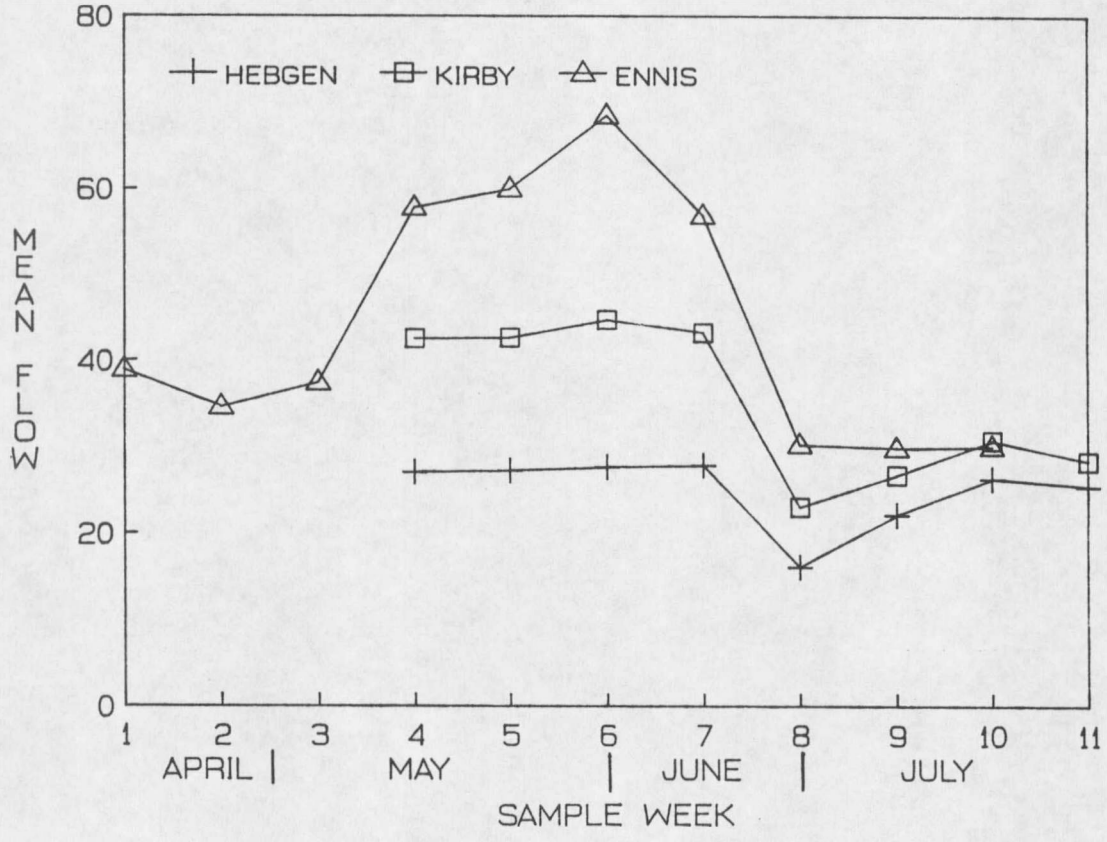


Figure 5. Weekly mean flows (cubic meters/sec) of the Madison River at Hebgen Dam, Kirby Bridge, and Ennis Dam, 1988.

Angler Satisfaction in Relation to Catch Rate

The satisfaction ratings of anglers correlated well with their catch rates (Fig. 6). As one would expect, anglers who landed more trout per hour were more satisfied with catch rate. The responses to the 1987 satisfaction rating question related significantly (chi-square=371.95, p=.000, N=1,229) to catch rates when run through the categorical regression described in the Data Analyses section of this report, as did the responses to the 1988 version (chi-square=155.68, p=.000, N=512). The satisfaction rating question was revised following the 1987 season because it was suspected that the question was eliciting responses that were partially based on factors other than the rate at which anglers landed trout. In 1987, minimally satisfactory ratings (rating of 4 on Figure 6 and Table 1) corresponded with average catch rates of 0.7 trout or more per hour, while in 1988, average catch rates of 1.4 trout or more per hour were required for a similar rating. Average catch rates for poor satisfaction ratings (a rating of 3 or less on Figure 6 and Table 1) were 0.5 or fewer, and 0.7 or fewer trout per hour in 1987 and 1988, respectively.

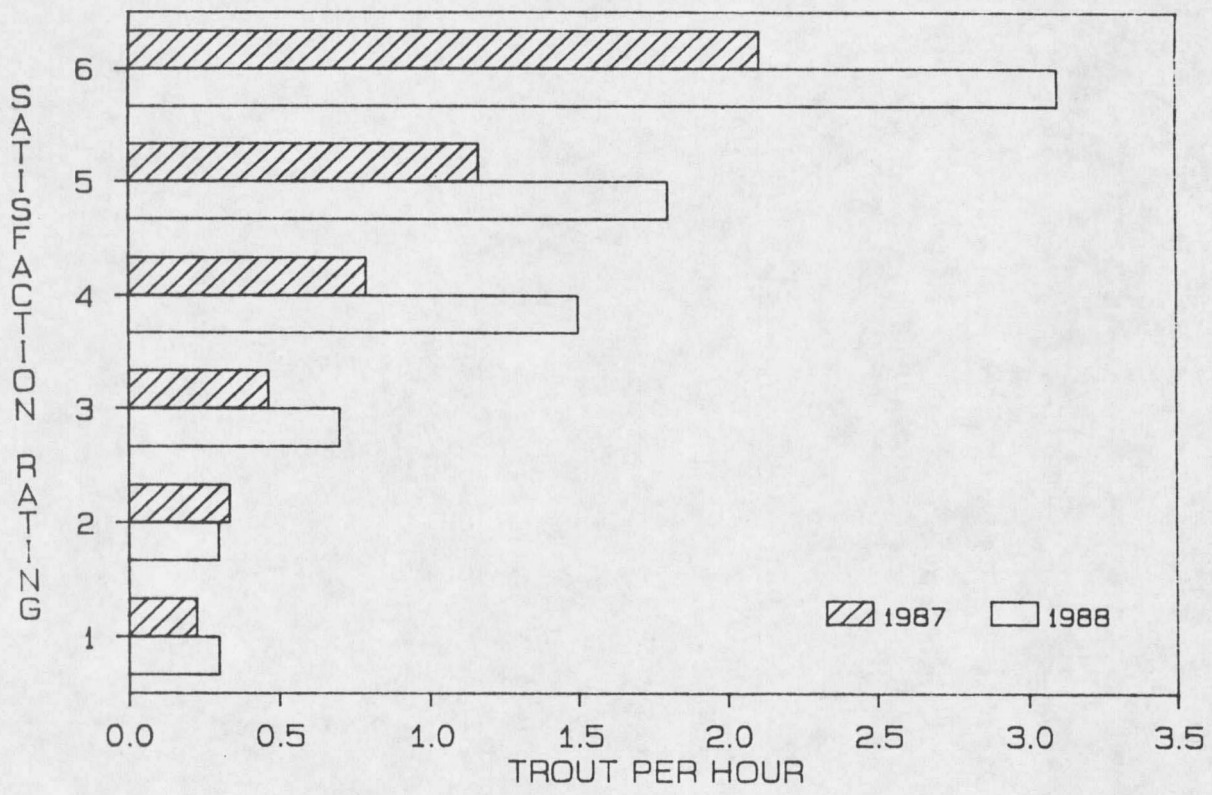


Figure 6. Mean satisfaction ratings corresponding to different catch rates in 1987 and 1988, both sections combined, on the Madison River.

Catch Rates in Relation to Temperature

Total Catch Rate

Catch rates tended to decrease as fishing temperature increased. The linear regressions preformed on these data in SAS (1988) show that when catch rates from both sections and both study years are combined and compared with the mean fishing temperatures for those catch rates, a negative relationship (R=-.082, p=.0001, N=1,741) is evident (Fig. 7, Table 2). Mean catch rates fell to below 0.5 trout per hour at fishing temperatures of 19 to 20 C. It appears that mean catch rate peaked at about 8 C and exhibited a general downward trend as fishing temperature increased.

Seventy-eight percent of the anglers contacted fished at water temperatures between 13 and 19 C (Fig. 8). Sample sizes are small at the higher and lower fishing temperatures (as well as at 10 C) and may not provide accurate representations of catch rates.

Upper section mean catch rates, both years combined, decreased significantly as stream temperature increased (R=-.068, p=.0004, N=982). Mean catch rates in the lower section, where fishing temperatures often exceeded 19 C, also correlated significantly with fishing temperature (R=-.063, p=.0001, N=759). Mean catch rates at most fishing temperatures were higher in the upper section than

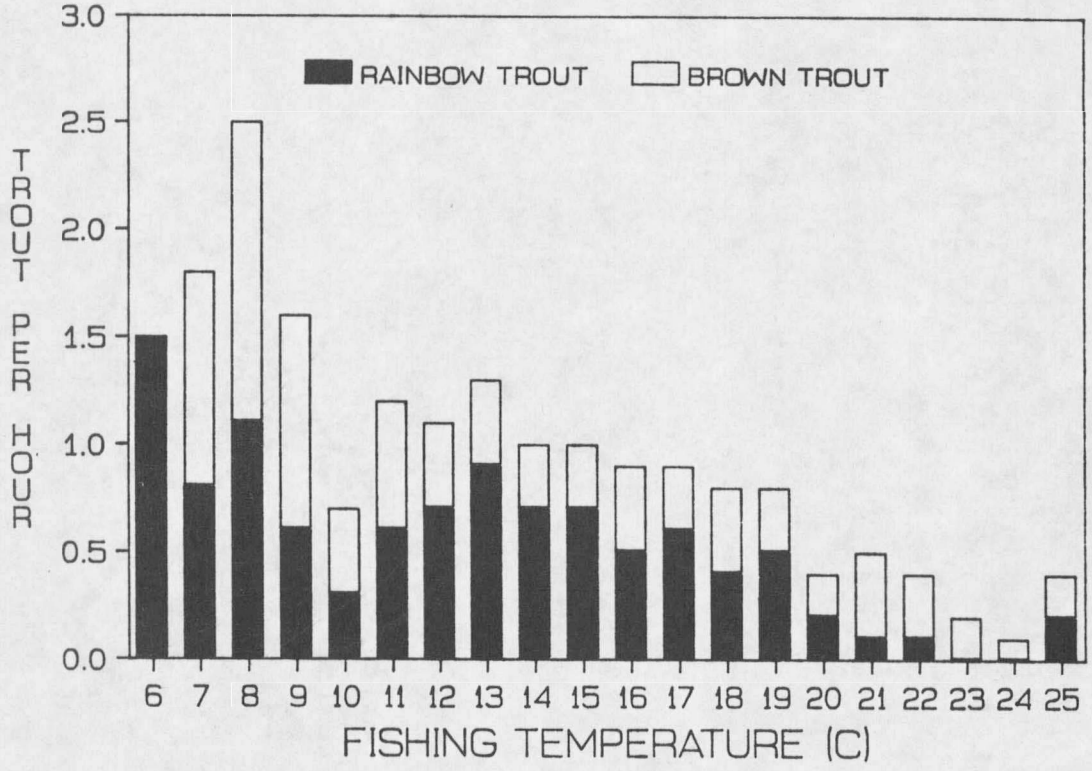


Figure 7. Mean catch rate versus fishing temperature on both sections of the Madison River, 1987 and 1988 combined.

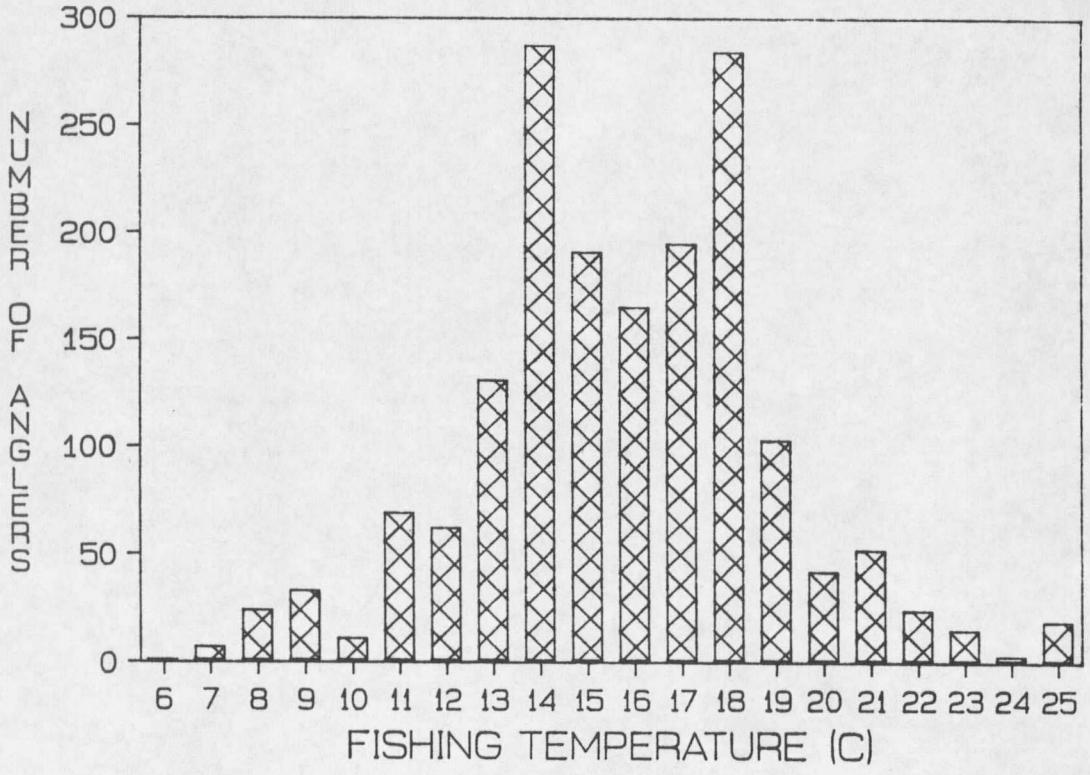


Figure 8. Numbers of anglers contacted at different water temperatures on both sections of the Madison River, 1987 and 1988 combined.

Table 2. Sample sizes (N), mean catch rates (trout/hour), and standard errors (SE [$\bar{x}$]) for total catch rate, catch rate on the upper section, and catch rate on the lower section on the Madison River at each fishing temperature (C), 1987 and 1988.

	Total			Upper			Lower		
Temp.	N	Mean	SE	N	Mean	SE	N	Mean	SE
6	1	1.50	*	1	1.50	*	0	-	-
7	7	1.74	0.60	7	1.74	0.60	0	-	-
8	24	2.52	0.75	11	3.99	1.53	13	1.28	0.28
9	33	1.64	0.20	8	1.61	0.44	25	1.65	0.23
10	11	0.64	0.24	0	-	-	11	0.64	0.24
11	69	1.24	0.20	25	1.46	0.38	44	1.12	0.24
12	62	1.10	0.17	53	1.01	0.17	9	1.62	0.63
13	131	1.26	0.13	104	1.40	0.15	27	0.71	0.13
14	287	1.01	0.06	208	1.12	0.08	79	0.72	0.10
15	191	0.99	0.09	156	1.13	0.10	35	0.38	0.08
16	165	0.95	0.08	111	1.03	0.11	54	0.79	0.10
17	195	0.93	0.10	111	1.12	0.12	84	0.66	0.13
18	284	0.83	0.07	102	1.10	0.12	182	0.68	0.08
19	103	0.77	0.11	57	0.97	0.17	46	0.52	0.13
20	42	0.43	0.10	3	2.08	0.08	39	0.30	0.07
21	52	0.48	0.11	2	0.43	*	50	0.48	0.11
22	24	0.42	0.10	0	-	-	22	0.42	0.11
23	15	0.17	0.07	0	-	-	15	0.17	0.07
24	3	0.12	*	0	-	-	3	0.12	*
25	19	0.42	0.19	0	-	-	19	0.42	0.19

* = no variance.

in the lower (Fig. 9).

Seventy-one percent of the anglers on the upper section fished at temperatures at or below 16 C, with the peak number fishing at 14 C (Fig. 10). Only 39% of the anglers on the lower section fished at temperatures at or below 16 C, and the greatest number fished at 18 C (Fig. 11). The 4-C difference in peaks is about the average temperature difference between sections during the main fishing season (May-September). The range of fishing temperatures was wider in the lower section than in the upper section.

On the upper and lower sections in 1987 and 1988, catch rates were significantly influenced by fishing temperature (Figs. 12, 13, 14, 15, Table 3). In both sections and both years, catch rate declined as fishing temperature increased. The least significant correlation was on the upper section in 1988 (Fig. 14) where fishing temperature seldom reached levels that negatively influenced catch rate. The variance of catch rates is apparent on these plots but, sample sizes (Table 3) on these figures are much larger than they appear due to the overlapping of points, especially at lower and zero catch rates.

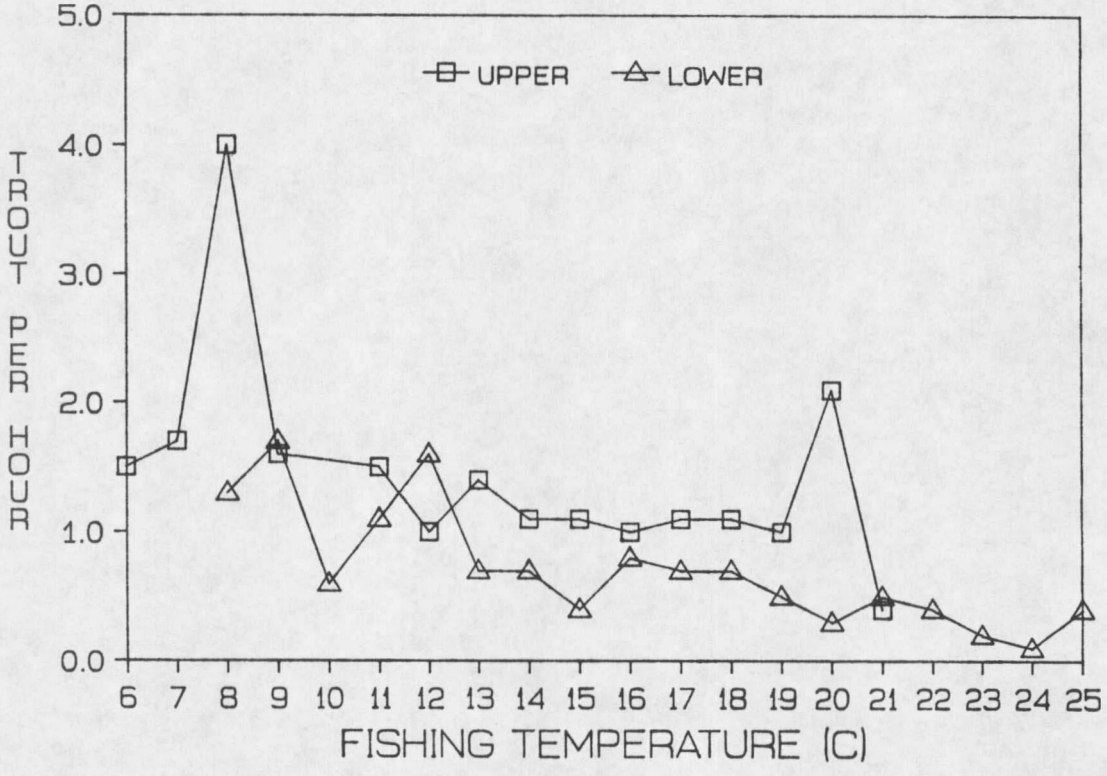


Figure 9. Mean catch rates for the upper and lower sections of the Madison River versus fishing temperature, 1987 and 1988 combined.

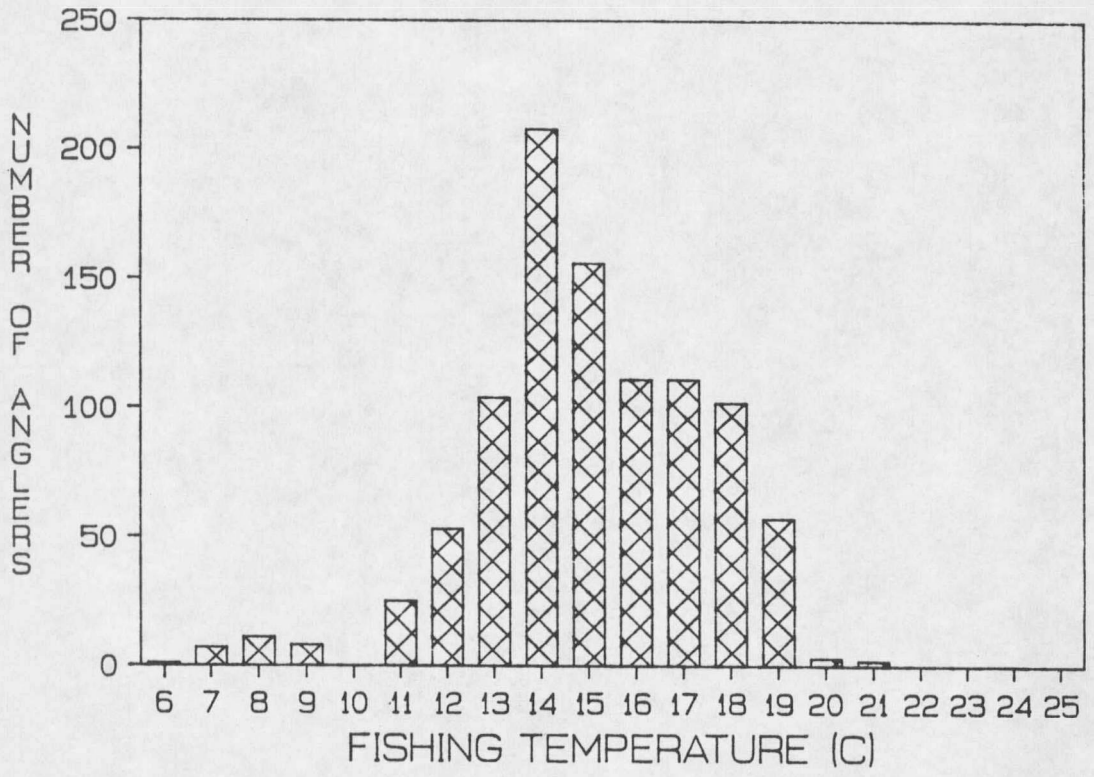


Figure 10. Numbers of anglers contacted at different water temperatures on the upper section of the Madison River, 1987 and 1988 combined.

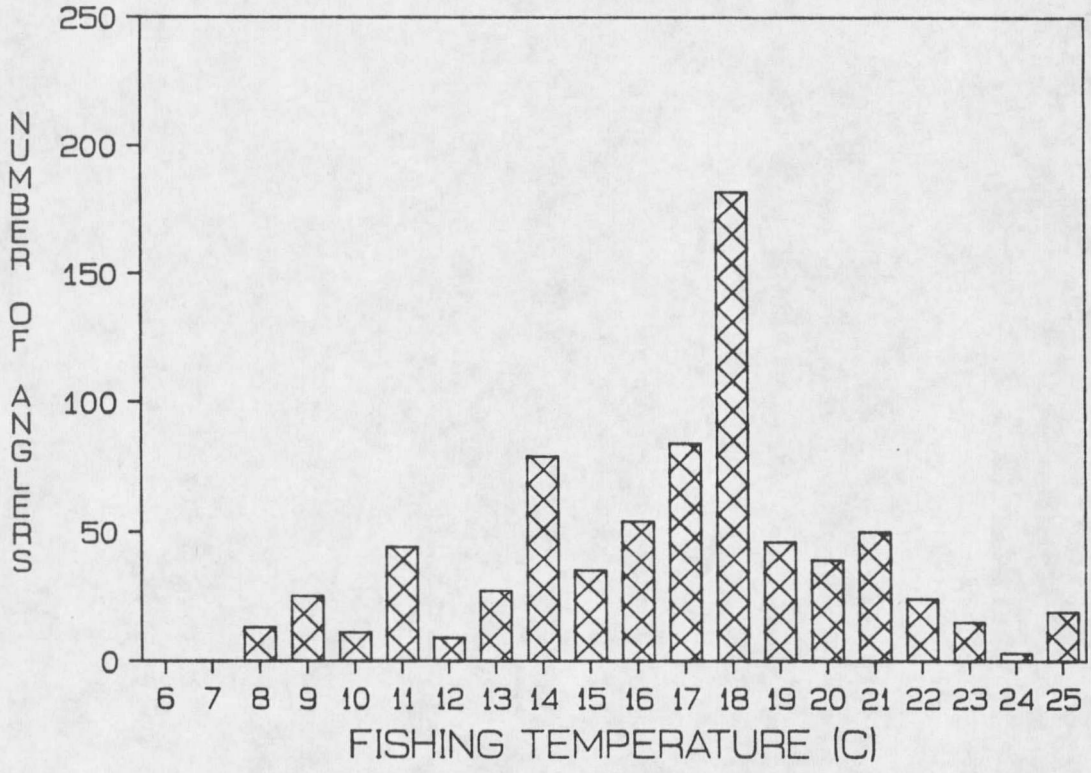


Figure 11. Numbers of anglers contacted at different water temperatures on the lower section of the Madison River, 1987 and 1988 combined.

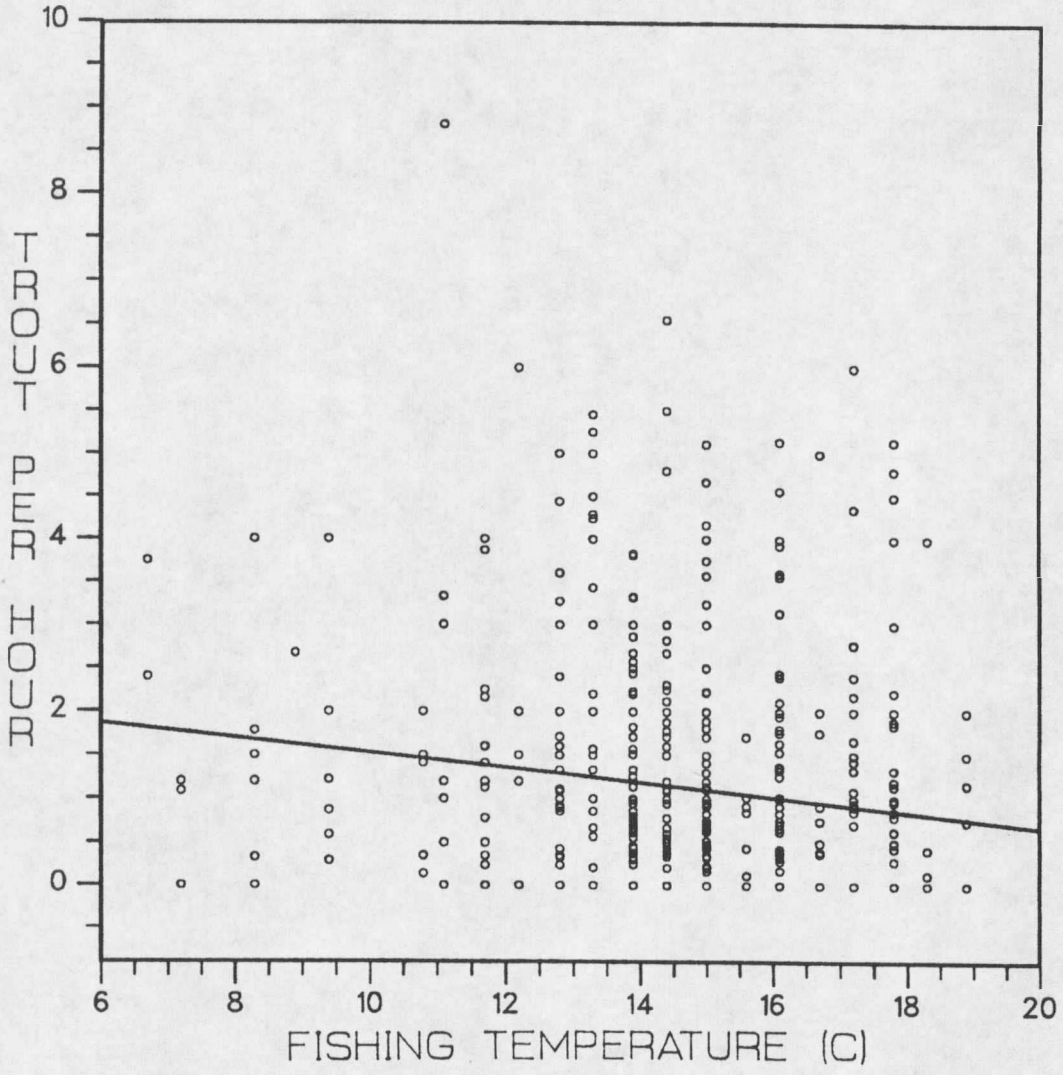


Figure 12. Catch rate versus fishing temperature on the upper section of the Madison River, 1987.

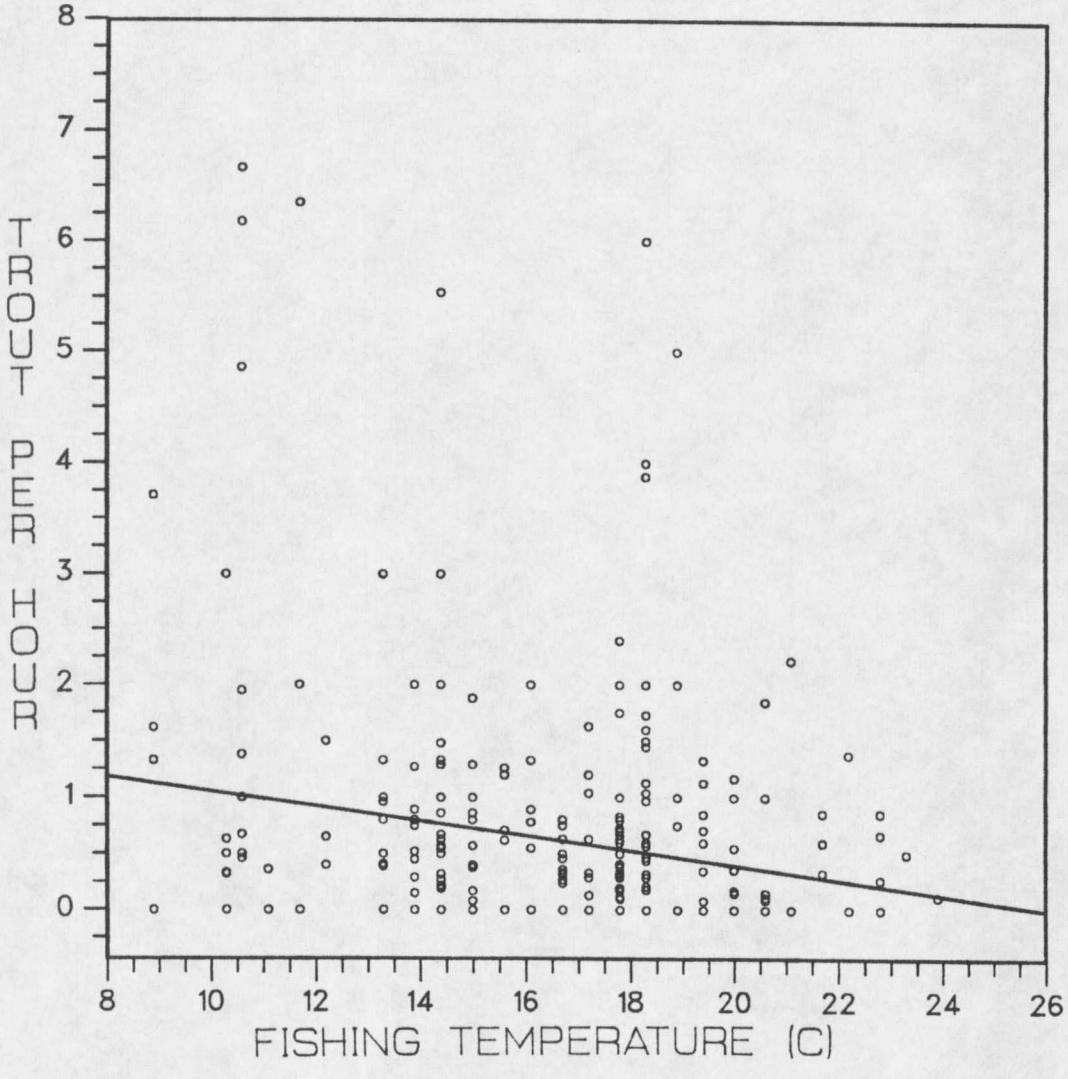


Figure 13. Catch rate versus fishing temperature on the lower section of the Madison River, 1987.

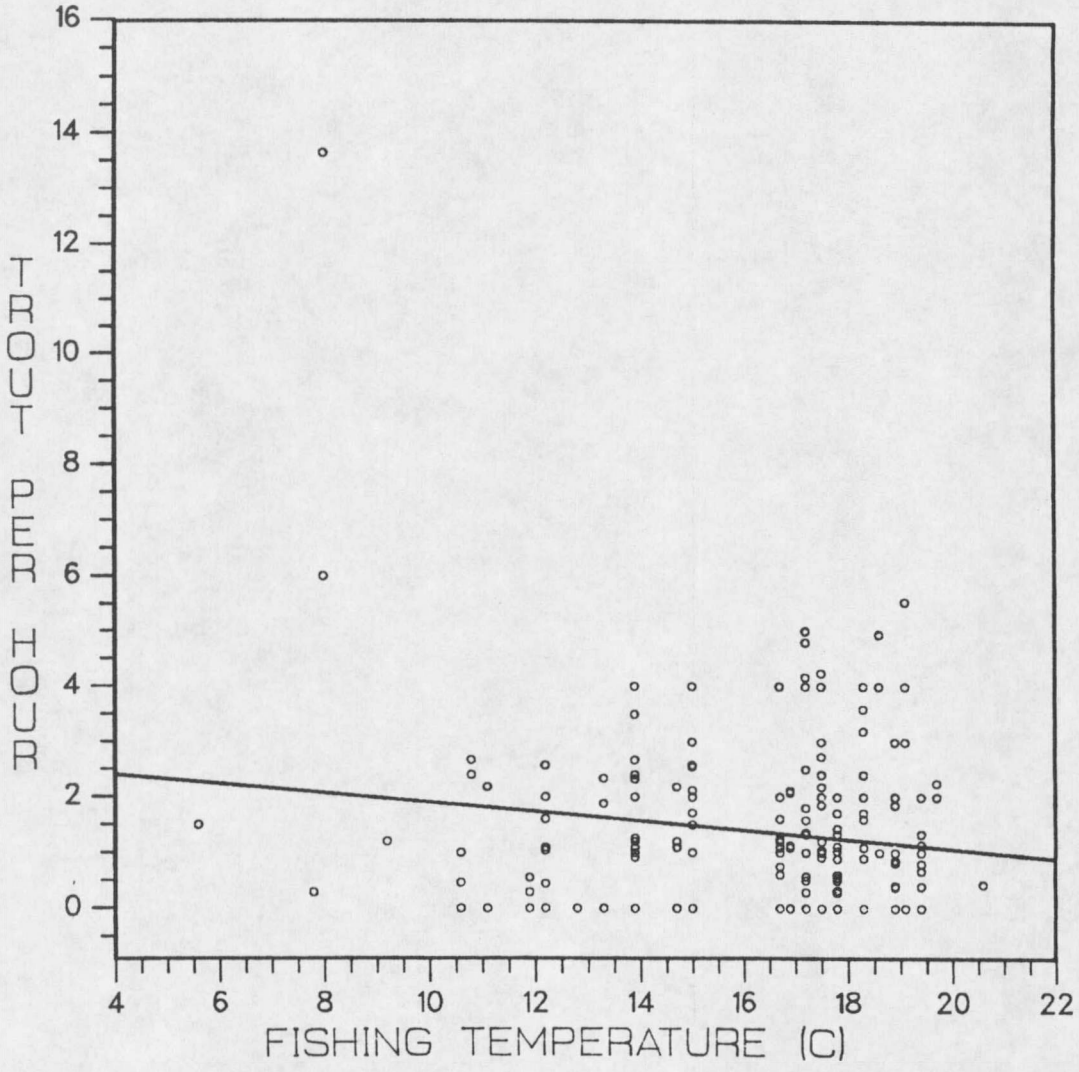


Figure 14. Catch rate versus fishing temperature on the upper section of the Madison River, 1988.

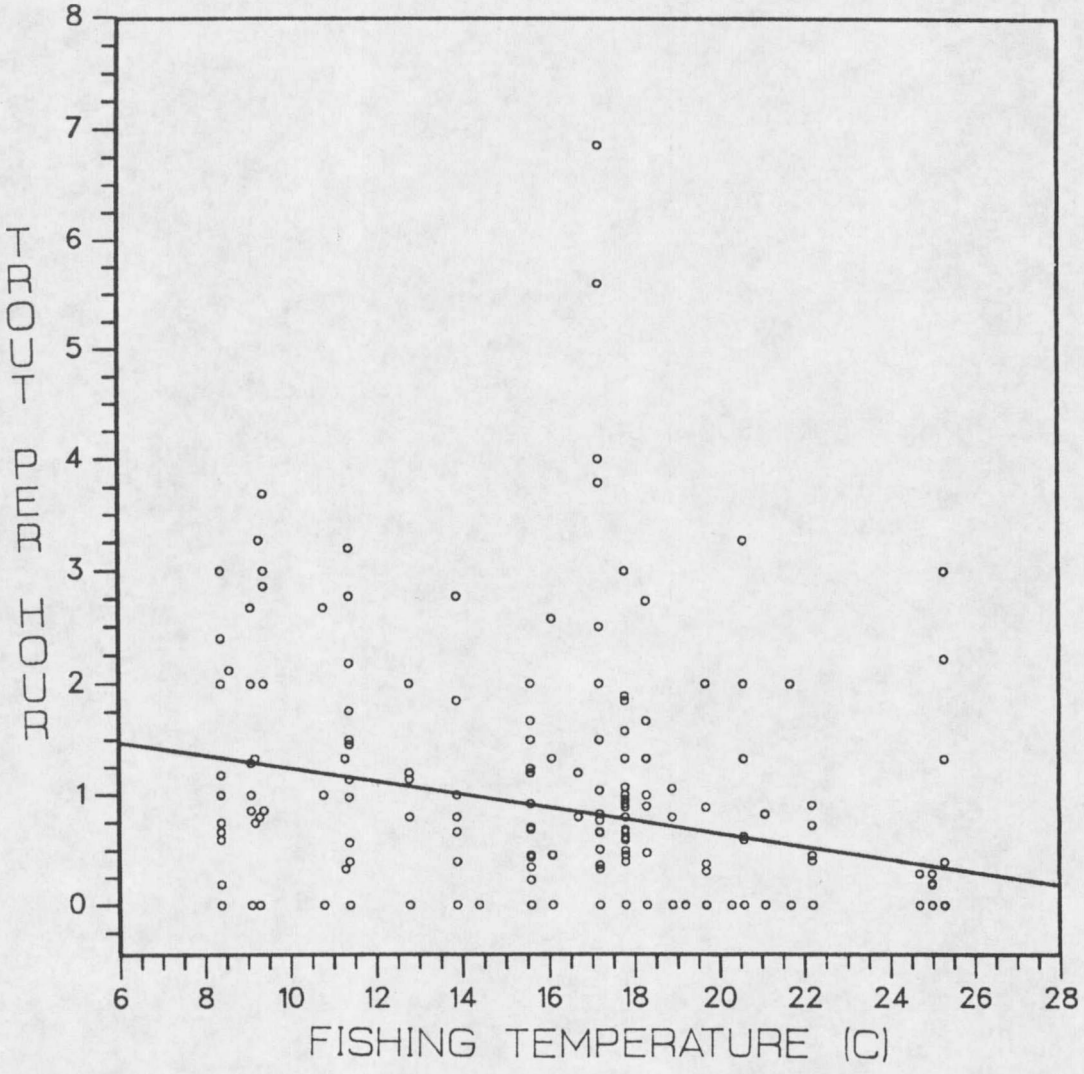


Figure 15. Catch rate versus fishing temperature on the lower section of the Madison River, 1988.

Table 3. Correlation coefficients (R), p values (p), and sample sizes (N) for regressions between catch rate (trout/hour) and fishing temperature (C) for both sections and years on the Madison River.

Section	Year	R	p	N
Upper	1987	-.1354	.0002	728
Lower	1987	-.1970	.0000	501
Upper	1988	-.1404	.0244	254
Lower	1988	-.2647	.0000	258

Catch Rates of 0.5 or more and 1.0 or more Trout Per Hour

The percentages of anglers landing trout at rates of 0.5 or more and 1.0 or more per hour decreased as fishing temperature increased (Figs. 16 and 17). The percentage of anglers on the upper section (both years combined) landing 0.5 or more trout per hour did not correlate significantly with fishing temperature but the percentage of anglers landing 1.0 or more trout per hour did (Fig. 16, Table 4). On the lower section, the percentage of anglers landing 0.5 or more and 1.0 or more trout per hour both correlated significantly with fishing temperature (Fig. 17, Table 4).

For both sections and years combined, the same comparisons are also significant (Fig. 18, Table 4). At fishing temperatures between 11 and 17 C, more than half of the anglers contacted had caught 0.5 or more trout per hour. At 19 C, 46% of the anglers landed 0.5 or more per

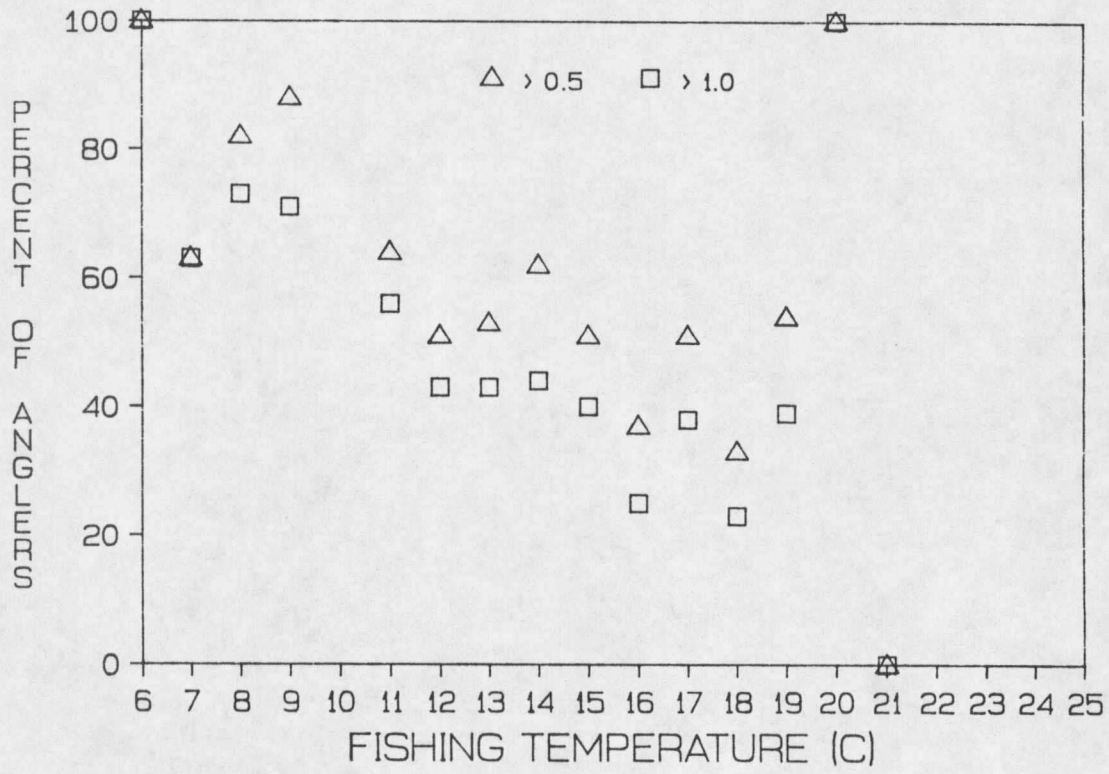


Figure 16. Percent of anglers landing 0.5 or more and 1.0 or more trout per hour on the upper section of the Madison River versus fishing temperature, 1987 and 1988 combined.

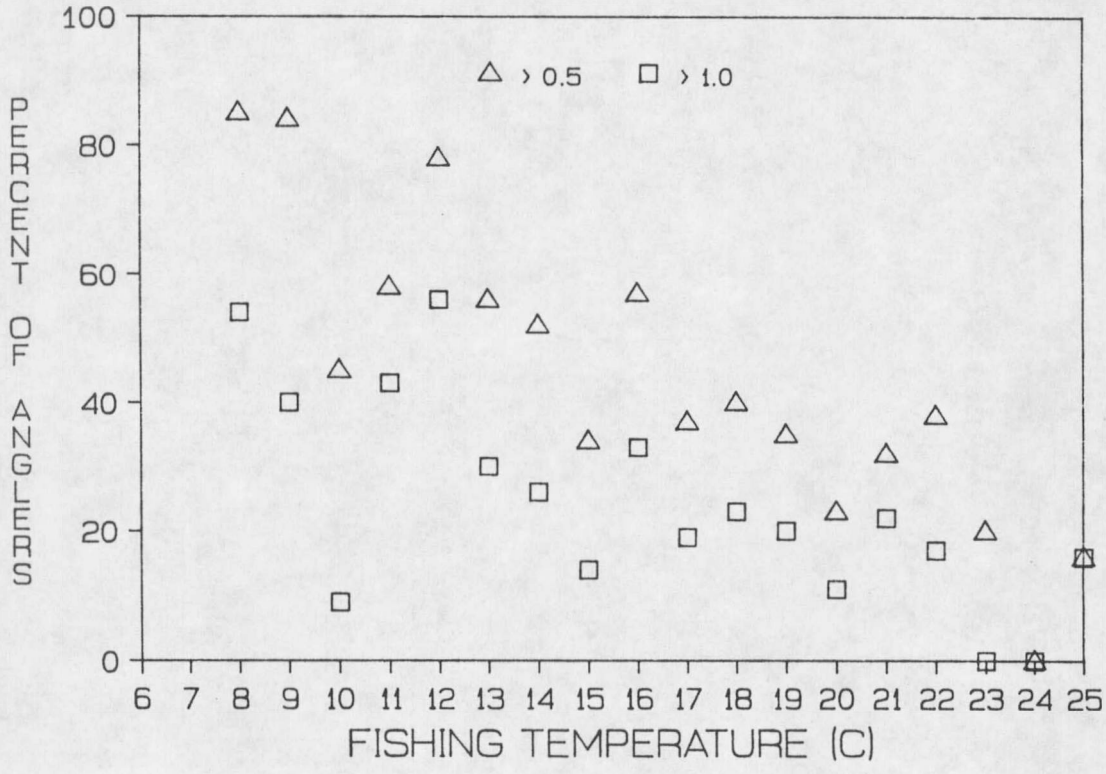


Figure 17. Percent of anglers landing 0.5 or more and 1.0 or more trout per hour on the lower section of the Madison River versus fishing temperature, 1987 and 1988 combined.

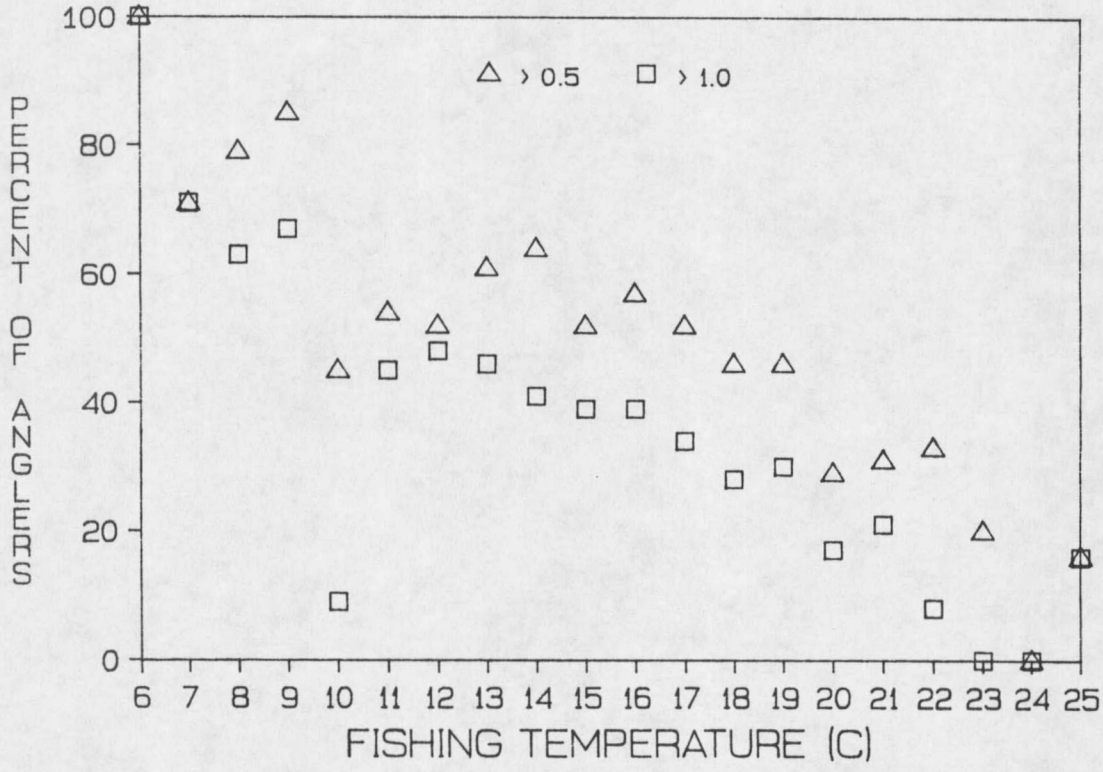


Figure 18. Percent of anglers landing 0.5 or more and 1.0 or more trout per hour on both sections of the Madison River versus fishing temperature, 1987 and 1988 combined.

hour, but at 20 C this measure dropped to 29%.

Table 4. Chi-square values, p values (p) , and sample sizes (N) for comparisons between percentages of anglers landing 0.5 or more and 1.0 or more trout per hour on the upper, lower, and both sections combined of the Madison River, 1987 and 1988 combined.

	≥ 0.5			≥ 1.0		
Section	Chi-square	p	N	Chi-square	p	N
Upper	2.77	.0963	982	6.09	.0136	982
Lower	35.87	.0001	759	32.75	.0001	759
Combined	55.09	.0001	1,741	50.42	.0001	1,741

Catch Rate of Trout 30.5 cm and Larger

Catch rate of trout exceeding 30.5 cm (12 inches) also declined with increasing water temperature. In both the upper and lower section, both years combined, the number of trout landed per hour that were 30.5 cm or larger was negatively correlated with fishing temperature (Figs. 19 and 20, Tables 5 and 6). The catch rate of trout in this size-class was, on average, higher on the upper section than the lower section. This is consistent with size structures of the respective populations (E. R. Vincent, MDFWP, pers. comm. 1988). For both sections combined, catch rate of trout 30.5 cm or larger correlated significantly with fishing temperature (Fig. 21, Tables 5 and 6). Again, the sample size at 10 C was relatively low.

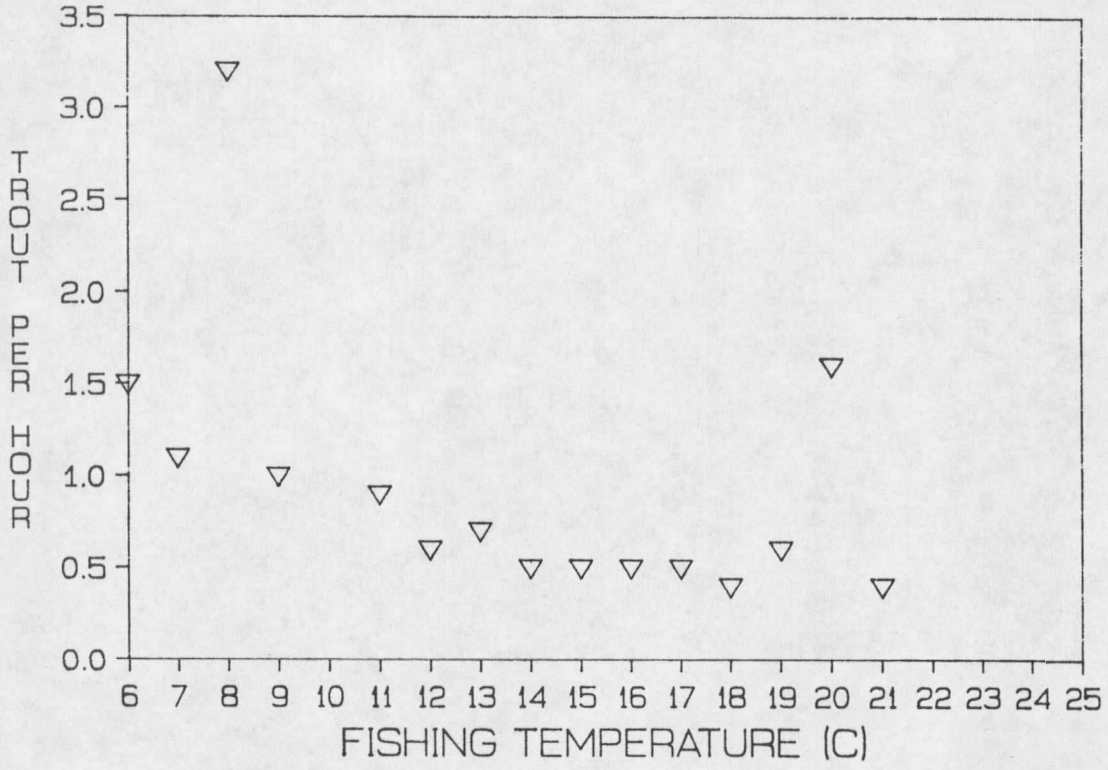


Figure 19. Mean catch rate of trout 30.5 cm and larger on the upper section of the Madison River versus fishing temperature, 1987 and 1988 combined.

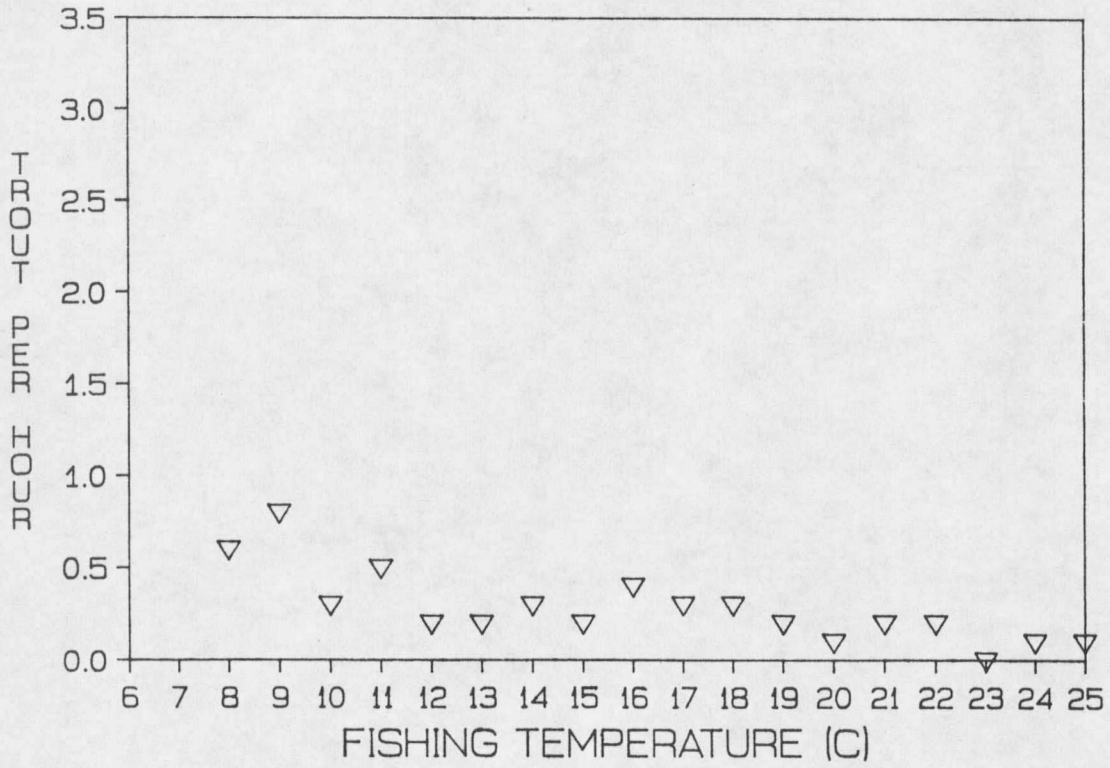


Figure 20. Mean catch rate of trout 30.5 cm and larger on the lower section of the Madison River versus fishing temperature, 1987 and 1988 combined.

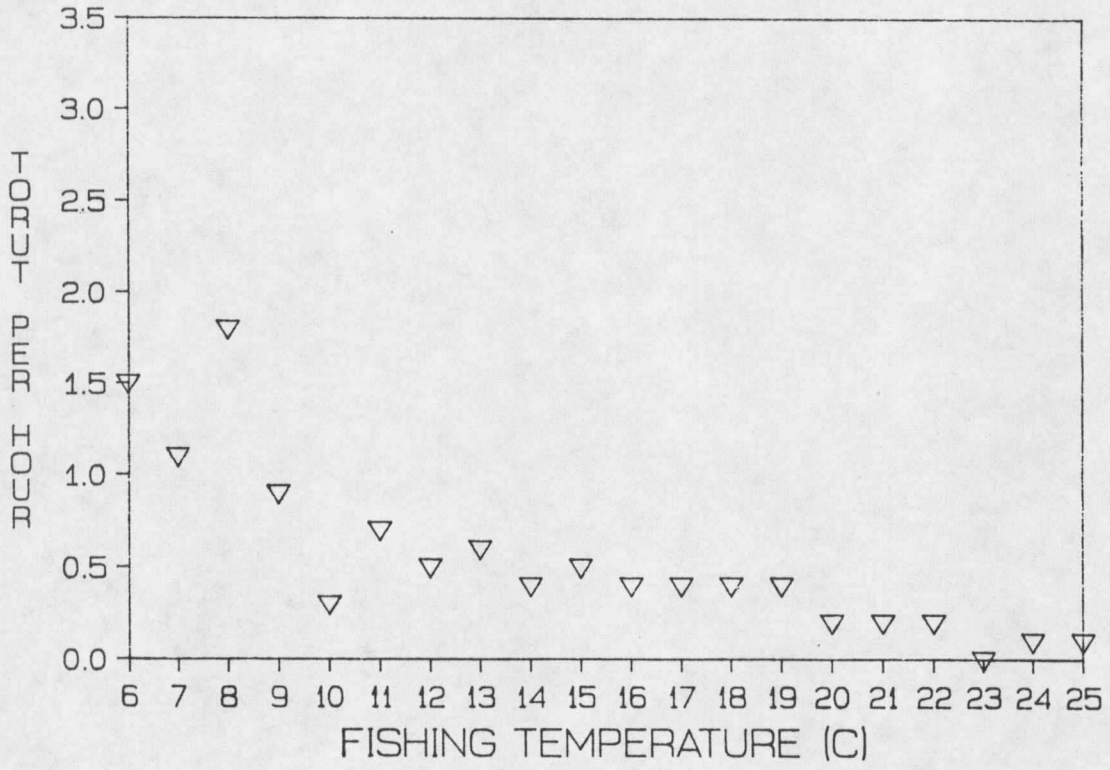


Figure 21. Mean catch rate of trout 30.5 cm and larger on both sections of the Madison River versus fishing temperature, 1987 and 1988 combined.

Table 5. Correlation coefficients (R), p values (p), and sample sizes (N) for the comparison between catch rate of trout 30.5 cm (12 inches) or larger and fishing temperature (C) on the upper, lower, and both sections combined of the Madison River, 1987 and 1988 combined.

Section	R	p	N
Upper	-.0613	.0001	982
Lower	-.0301	.0001	759
Combined	-.0503	.0001	1,741

Zero Catch Rate

The percentage of anglers landing no trout on the upper section did not correlate significantly with fishing temperature, whereas the percentage of anglers that caught no trout on the lower section did correlate significantly with fishing temperature (Fig. 22, Table 7). For the fishing temperatures common between the two sections (8 to 21 C), the lower section had a greater percentage of anglers landing no trout at most temperatures.

For both sections combined, the correlation between fishing temperature and the percentage of anglers landing no trout was significant (Fig. 23, Table 7). At fishing temperatures of 19 C and above, over 40% of the anglers contacted had not landed a trout. The reported zero percentages at 6 and 24 C were very likely due to the small sample sizes at those temperatures (1 and 3 anglers, respectively).

Table 6. Sample sizes (N), mean catch rates (trout/hour) of trout 30.5 cm or larger, and standard errors (SE [$\bar{x}$]) for the upper, lower, and both sections combined of the Madison River, 1987 and 1988 combined.

	Upper			Lower			Combined		
Temp.	N	Mean	SE	N	Mean	SE	N	Mean	SE
6	1	1.50	*	0	-	-	1	1.50	*
7	7	1.13	0.36	0	-	-	7	1.13	0.36
8	11	3.12	1.28	13	0.58	0.19	24	1.78	0.63
9	8	1.05	0.35	25	0.79	0.21	33	0.85	0.18
10	0	-	-	11	0.29	0.08	11	0.29	0.08
11	25	0.90	0.10	44	0.54	0.14	69	0.67	0.11
12	53	0.58	0.10	9	0.24	0.06	62	0.53	0.09
13	104	0.69	0.09	27	0.21	0.06	131	0.59	0.07
14	208	0.49	0.05	79	0.31	0.05	287	0.44	0.04
15	156	0.50	0.05	35	0.24	0.06	191	0.45	0.04
16	111	0.47	0.06	54	0.38	0.06	165	0.44	0.05
17	111	0.52	0.07	84	0.34	0.07	195	0.44	0.05
18	102	0.44	0.07	182	0.29	0.05	284	0.35	0.04
19	57	0.58	0.12	46	0.16	0.04	103	0.39	0.07
20	3	1.58	0.42	39	0.13	0.03	42	0.23	0.07
21	2	0.43	*	50	0.17	0.05	52	0.18	0.05
22	0	-	-	22	0.24	0.09	22	0.24	0.05
23	0	-	-	15	0.04	0.04	15	0.04	0.04
24	0	-	-	3	0.12	*	3	0.12	*
25	0	-	-	19	0.13	0.07	19	0.13	0.07

* = no variance.

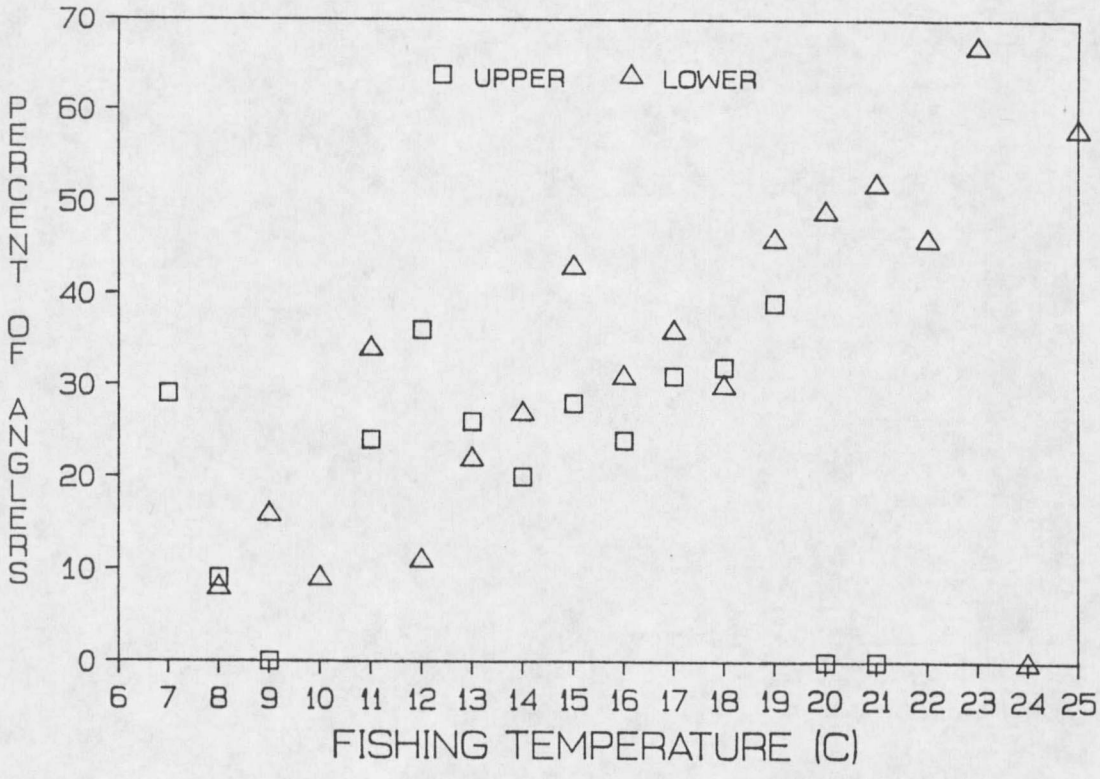


Figure 22. Percent of anglers with zero catch on the upper and lower sections of the Madison River versus fishing temperature, 1987 and 1988 combined.

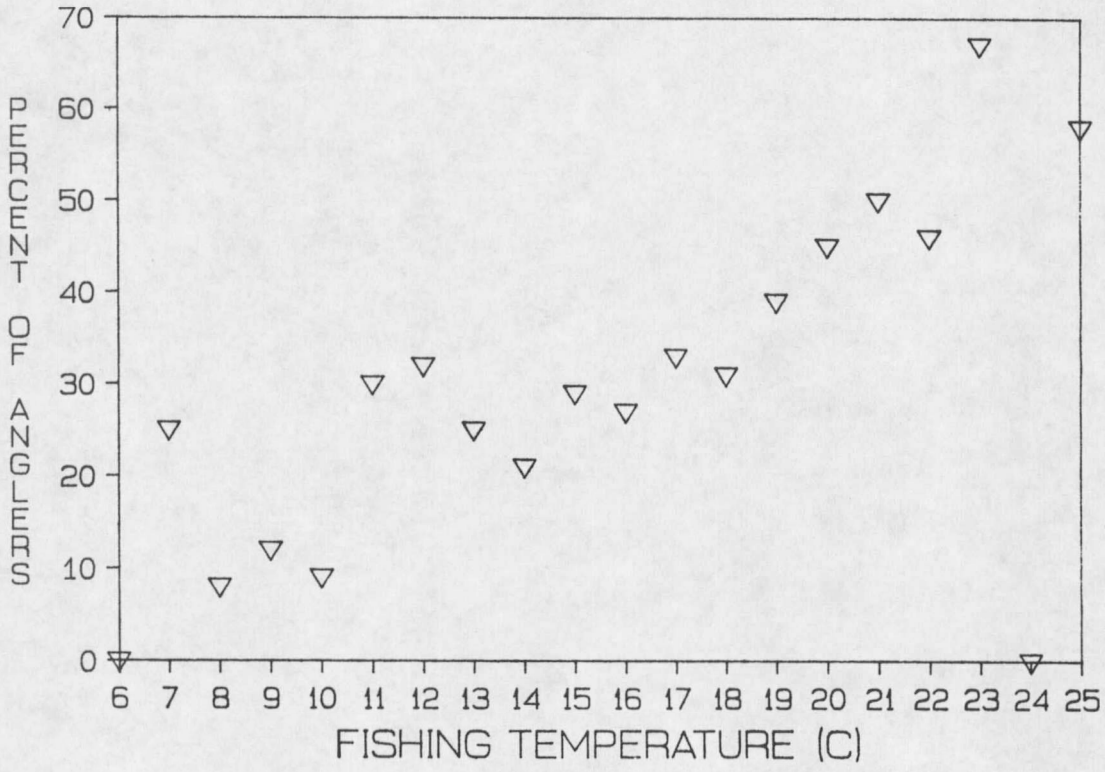


Figure 23. Percent of anglers with zero catch on both sections of the Madison River combined versus fishing temperature, 1987 and 1988 combined.

Table 7. Chi-square values, p values (p), and sample sizes(N) for the comparison between the percentage of anglers landing no trout and fishing temperature (C) on the upper, lower, and both sections combined of the Madison River, 1987 and 1988 combined.

Section	Chi-square	p	N
Upper	3.34	.0677	982
Lower	20.29	.0001	759
Combined	32.95	.0001	1,741

Catch Rate and Angler Satisfaction in Relation to Fishing Temperature

In 1987, catch rate and angler satisfaction decreased as fishing temperature increased (Fig. 24). Catch rates decreased significantly (R=-.099, p=.0001, N=1,229) as fishing temperature increased, as did satisfaction ratings (chi-square=63.43, p=.000, N=1,229). Mean catch rate in 1987 dropped below 0.5 trout per hour and mean angler satisfaction dropped below 3.5 (the division between minimally satisfactory and unsatisfactory ratings) when fishing temperatures approached 19 C. Numbers of anglers fishing at the various water temperatures in 1987, both sections combined, were bimodally distributed, with peaks at 14 and 18 C, which correspond to the greatest frequencies in the upper and lower sections, respectively (Fig. 25).

In 1988, catch rates correlated significantly (R=-.070, p=.0001, N=512) with fishing temperatures as did satisfaction ratings (chi-square=38.98, p=.001, N=512) (Fig. 26). Because the satisfaction rating question was different in 1988, a catch rate of at least 0.7 trout per hour was required to evoke at least a minimally satisfactory response (a rating of 3.5) from the average angler. Starting at about 12 C, satisfaction ratings remained relatively constant, at around 3 or 4 (between unsatisfactory and satisfactory), until fishing temperature increased beyond 19 C, then satisfaction declined as temperature increased. Angler contacts in 1988 were fewer than in 1987 (Fig. 27), and a higher proportion of the contacts came from anglers fishing at water temperatures above 15 C than in 1987.

Mean Weekly Catch Rates in Relation to Mean Weekly Temperatures

On the upper section in 1987, mean weekly water temperature did not exceed 16.5 C, and mean weekly catch rate did not show a consistent pattern of change with water

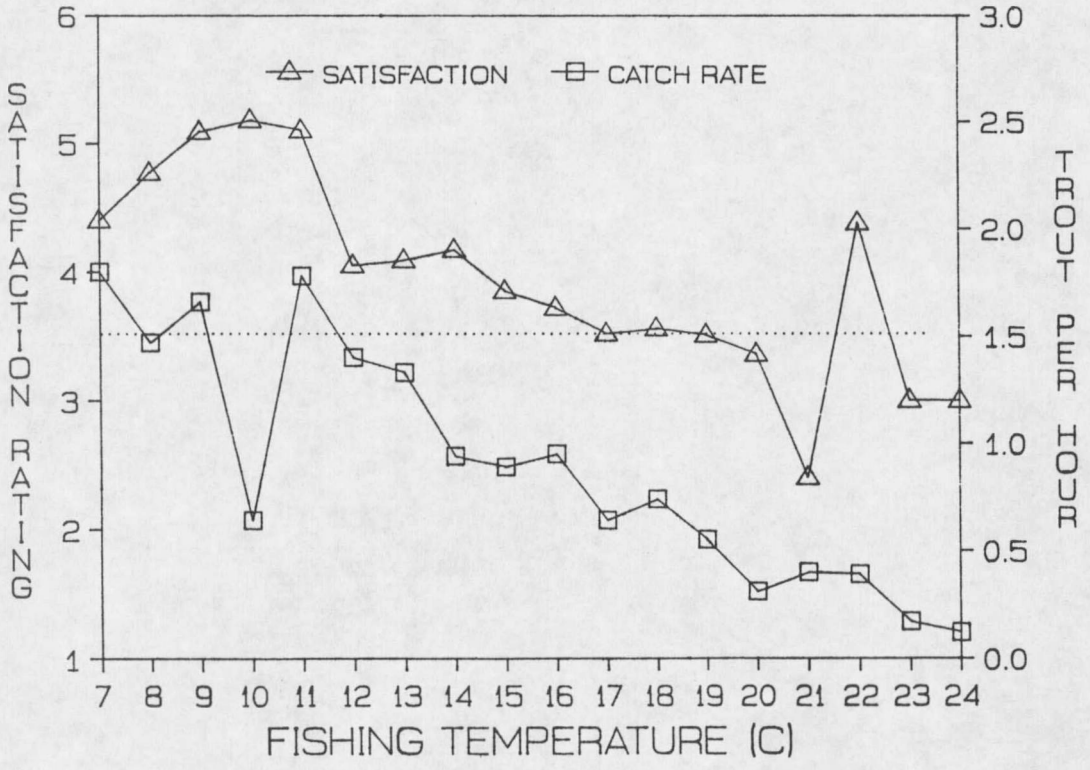


Figure 24. Mean satisfaction rating and catch rate on both sections of the Madison River versus fishing temperature, 1987. Dotted line represents division between minimally satisfactory and unsatisfactory ratings.

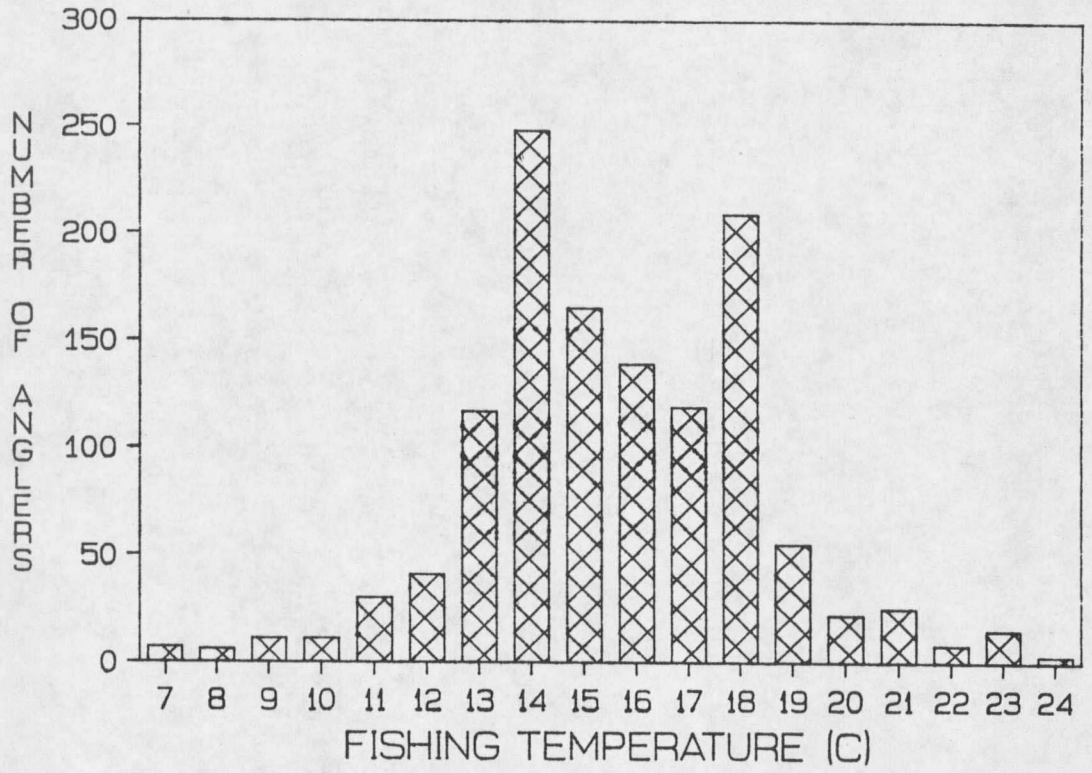


Figure 25. Number of anglers contacted at different water temperatures on both sections of the Madison River, 1987.

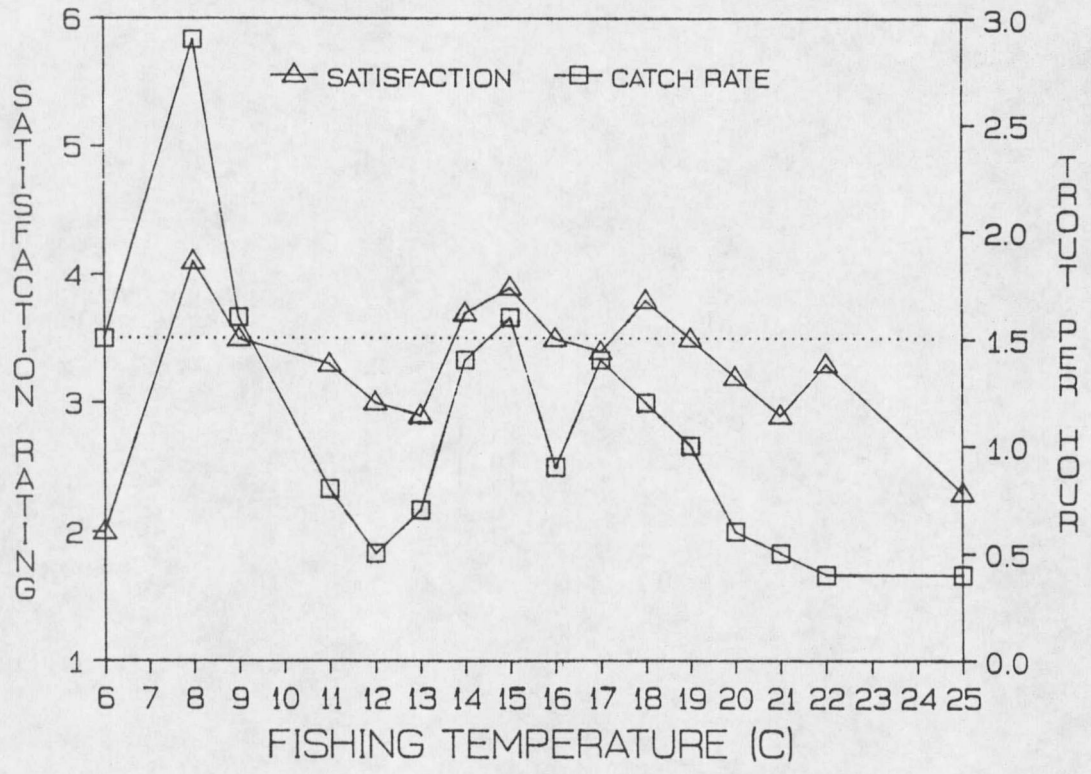


Figure 26. Mean satisfaction rating and catch rate on both sections of the Madison River versus fishing temperature, 1988. Dotted line represents division between minimally satisfactory and unsatisfactory ratings.

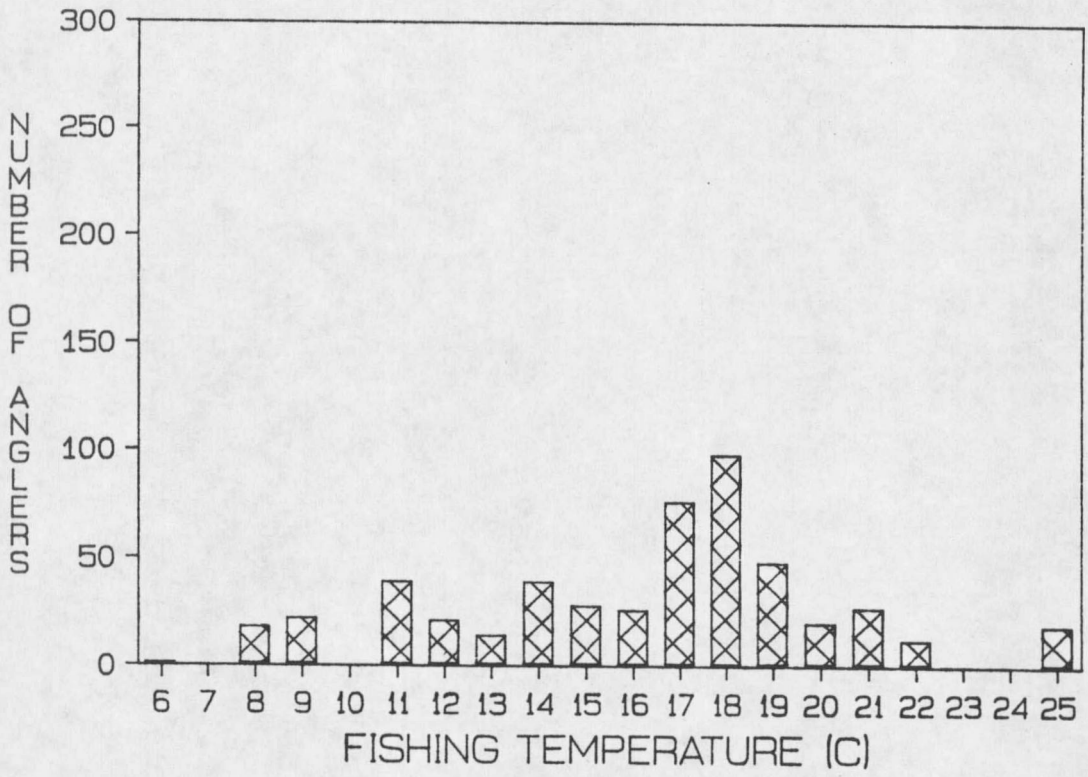


Figure 27. Number of anglers contacted at different water temperatures on both sections of the Madison River, 1988.

temperature as the fishing season progressed (Fig. 28). Angler numbers on the upper section were highest between mid-June and mid-July during the 1987 season (Fig. 29).

On the lower section in 1987, mean weekly catch rate decreased as mean water temperature increased from May to August, then when mean temperature began to drop in late August, catch rate correspondingly increased (Fig. 30). Thirteen of 18 (72%) sample weeks had mean water temperatures exceeding 16.5 C in the lower section, while during five of those weeks (28%) water temperature exceeded 19 C. Eleven of the 18 (61%) weeks had mean catch rates at or below 0.5 trout per hour, all of these coincided with weeks when mean water temperature was in excess of 16.5 C. The relatively high catch rate during week 8 was largely due to small sample size and one angler that reported landing 12 trout in one hour. Anglers on the lower section in 1987 were more evenly distributed throughout the period but not as numerous as on the upper section (Fig 31). Much of the fishing pressure on the lower section occurred between mid-May and mid-June before mean water temperature reached 20 C.

In the first 5 sample weeks of 1988 on the upper section, water temperature steadily increased to about 16 C but catch rates varied greatly and had no apparent relationship to water temperature. But as the mean weekly

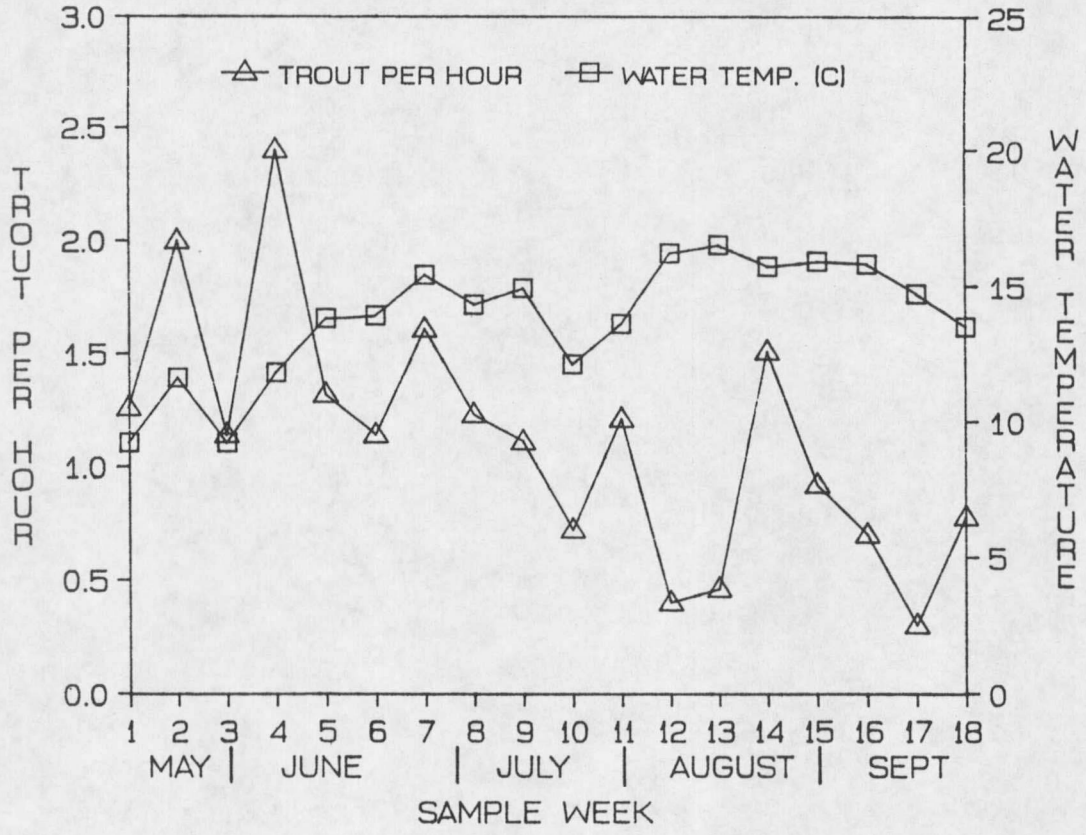


Figure 28. Mean weekly catch rate and water temperature (C) on the upper section of the Madison River, 1987.

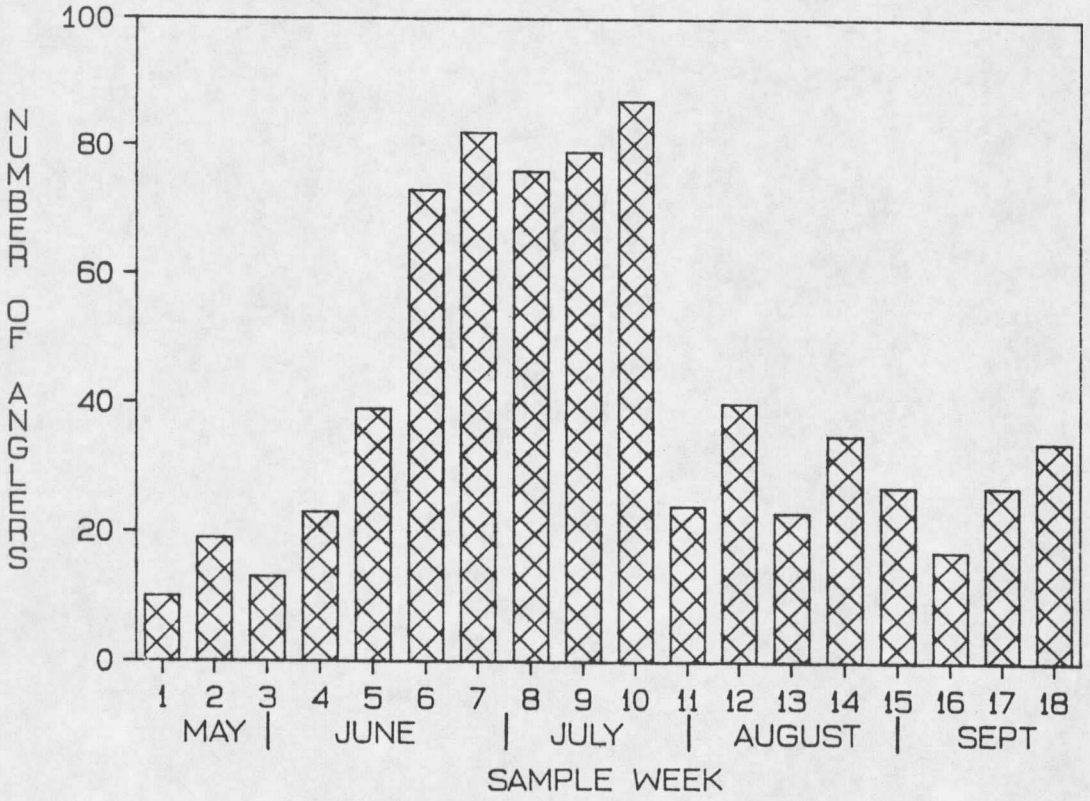


Figure 29. Weekly angler contacts on the upper section the Madison River, 1987.

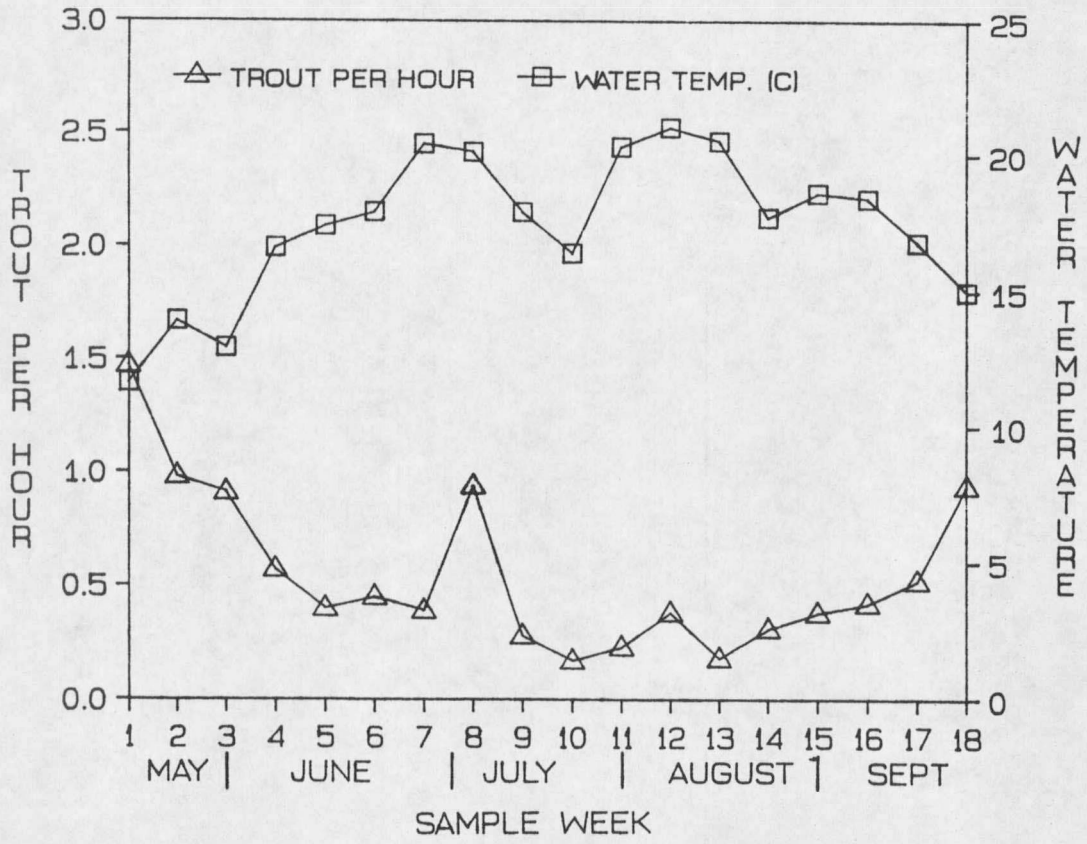


Figure 30. Mean weekly catch rate and water temperature (C) on the lower section of the Madison River, 1987.

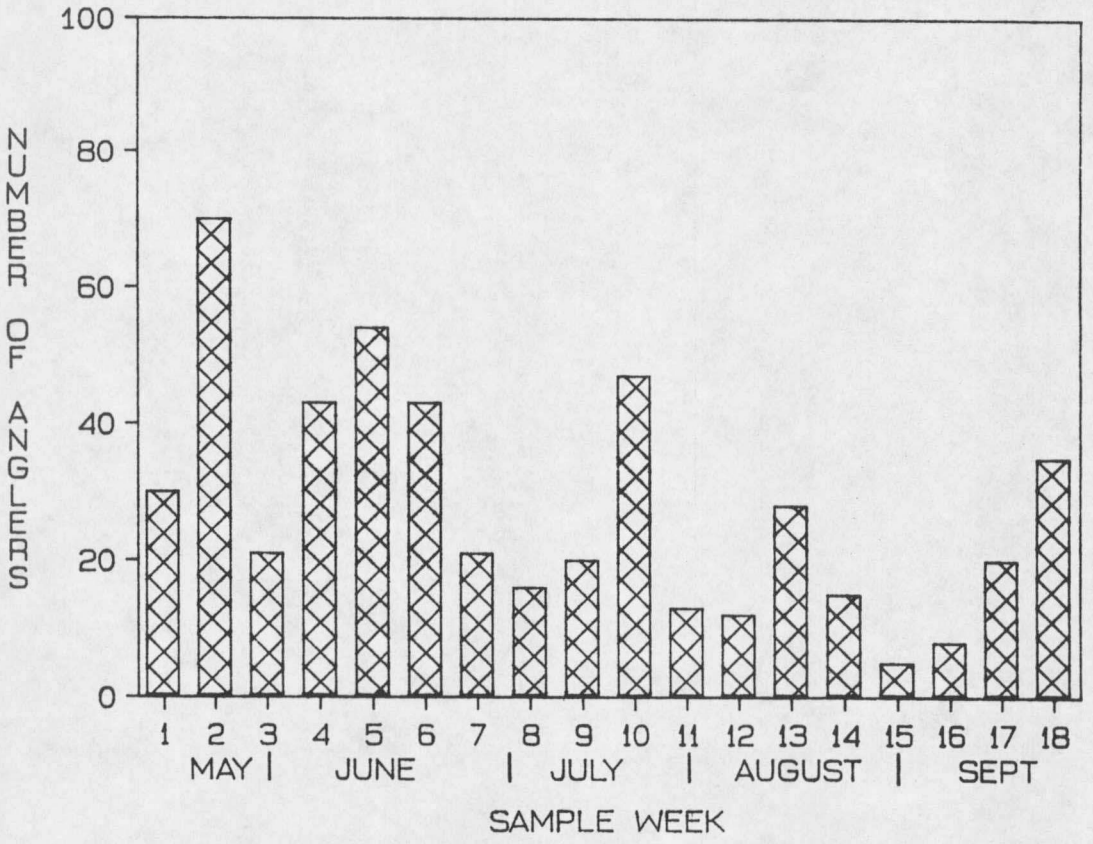


Figure 31. Weekly angler contacts on the lower section of the Madison River, 1987.

water temperature slowly increased from 15.6 to 17.6 C during the last four weeks sampled (Fig. 32), weekly mean catch rate decreased from 1.9 to 0.8 trout per hour. Mean weekly water temperature did not exceed 17.6 C during 1988 in the upper section and catch rate did not drop below 0.6 trout per hour. Angler numbers on the upper section in 1988 followed a similar pattern to that of 1987, in that peak angler numbers occurred between mid-June and mid-July (Fig. 33).

On the lower section in 1988, the first three sample weeks (April 23 to May 7) had relatively stable mean water temperatures, between 9.2 and 10.8 C (Fig. 34). Between weeks 3 and 4, the mean temperature increased by over 6 C, while the catch rate declined sharply. Catch rate rose to levels considered satisfactory by most anglers during weeks 5 through 7, while mean water temperature remained relatively constant (between 15.8 and 17.8 C). Mean water temperature increased from 17.8 to 21.2 C between weeks 7 and 8 and catch rate dropped from 1.1 to 0.6 trout per hour. It was during this period that the aforementioned thermally induced fish kills were observed. These fish kills occurred when daily stream temperature maxima exceeded 27 C for several hours. Rainbow and brown trout, mountain whitefish, and longnose suckers were observed dying (typically rolling along the streambed after having

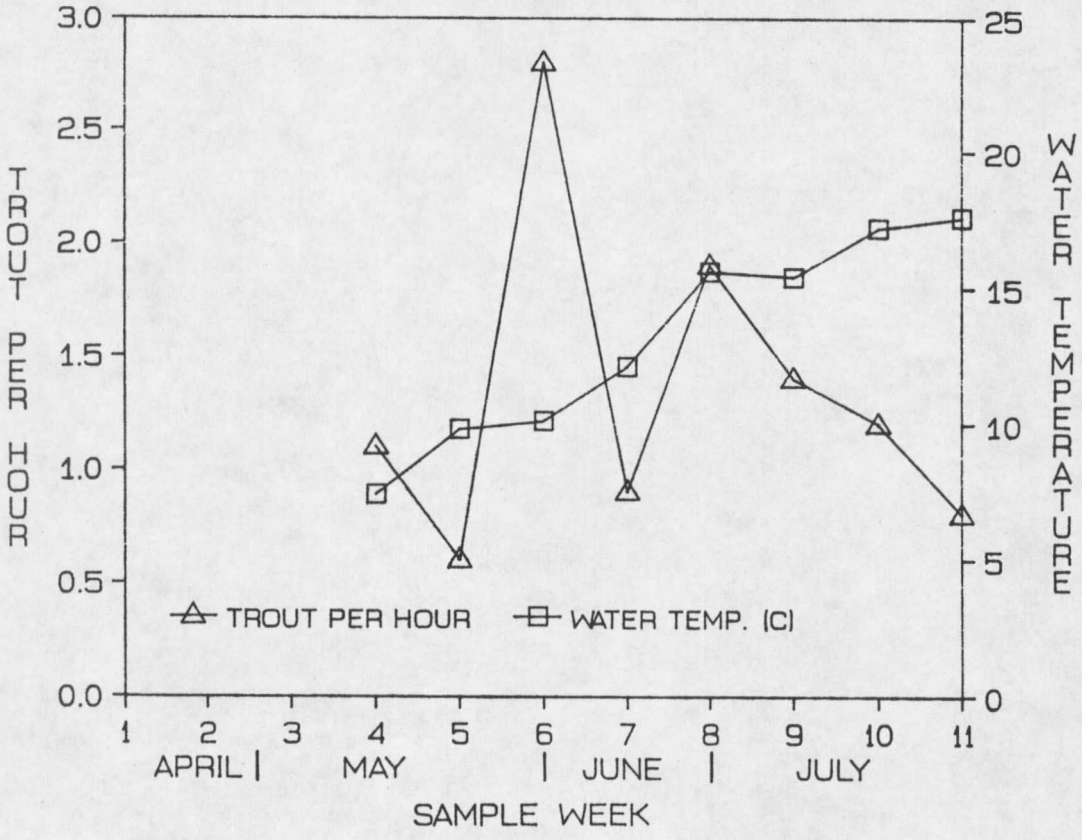


Figure 32. Mean weekly catch rate and water temperature (C) on the upper section of the Madison River, 1988.

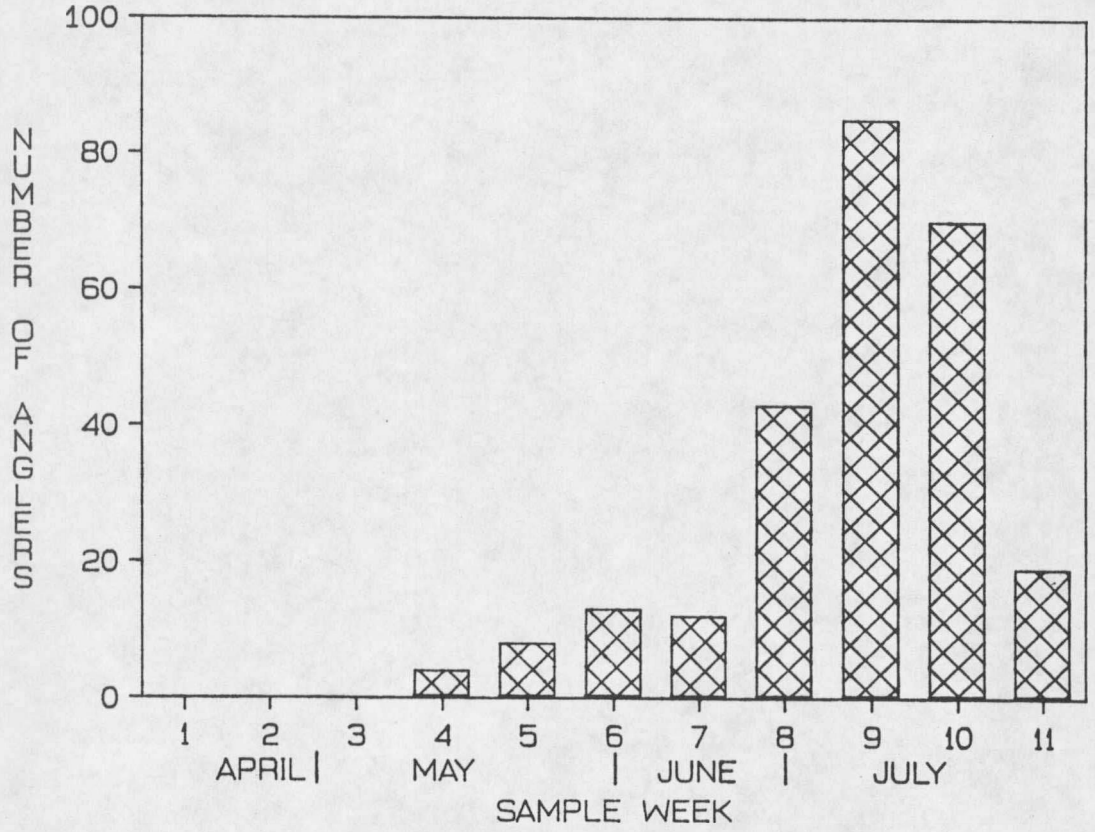


Figure 33. Weekly angler contacts on the upper section of the Madison River, 1988.

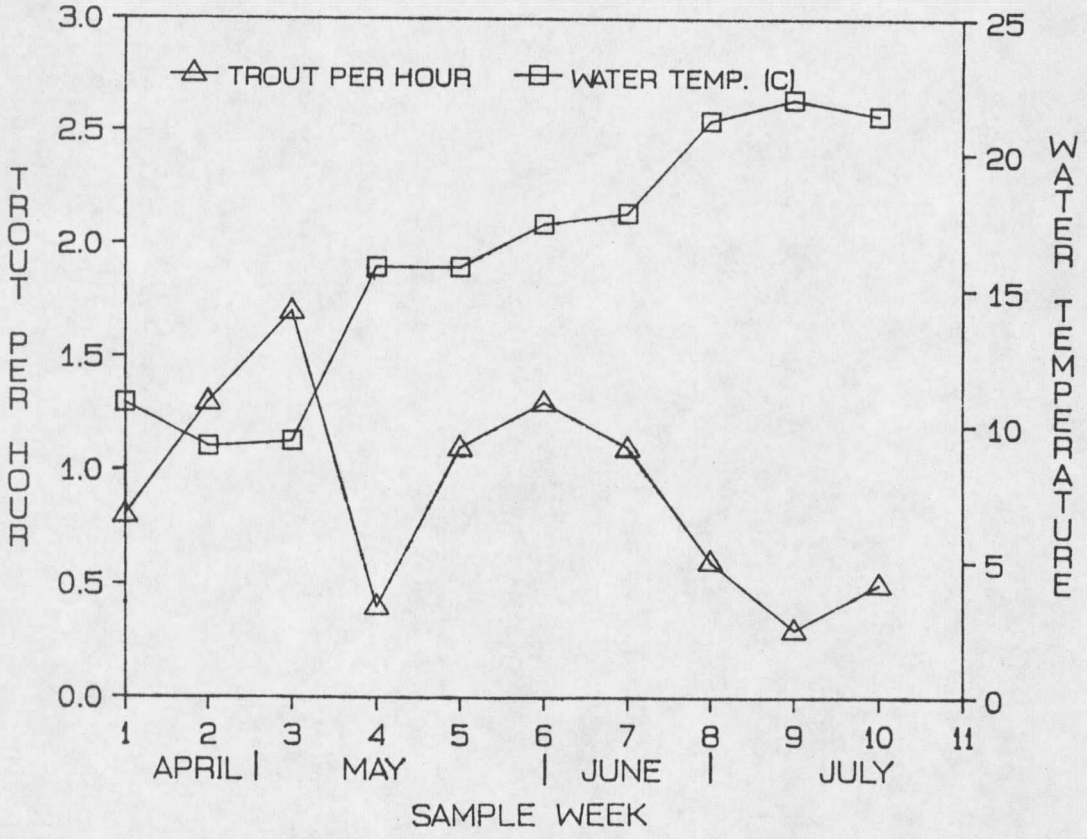


Figure 34. Mean weekly catch rate and water temperature (C) on the lower section of the Madison River, 1988.

lost their equilibrium) during this period. It appeared that mountain whitefish and longnose suckers were more severely affected by the excessive stream temperatures than were the trout, but these observations were not quantified. Cursory analysis of the data collected during the spring, 1989 population estimate on the lower section suggests that about ten percent (about 250 per km) of the trout (rainbow and brown combined) died as a result of the excessive stream temperature (E. R. Vincent, MDFWP, pers. comm. 1989). No data were collected on the lower section during the final week of the 1988 field season due to the thermal fish kills that were occurring in that section. Lower section angler numbers were more evenly distributed throughout the sample weeks, but fewer in total number, than on the upper section during 1988, as was also the case in 1987 (Fig. 35).

Mean Weekly Catch Rates in Relation to Mean Weekly Flow

Flows in the upper section during the 1987 season increased through the first 11 sample weeks, while catch rate varied (Fig. 36). Flow data were not available after week 11 (July 31) for the upper section. Flows in the lower section also increased throughout the 1987 field season, finally leveling off at about 42 cms, while catch rates slowly declined to a level between 0.1 and 0.4 trout

per hour (Fig. 37).

Discharge during the 1988 field season in the upper section was higher at the beginning of the sampling period and decreased throughout the period, while catch rates again showed a sporadic pattern that did not appear to be influenced by flow (Fig. 38). Flows in the lower section decreased after mid-June during the 1988 season. After the first three sample weeks on the lower section in 1988 catch rate very nearly paralleled flow (Fig. 39). Thus, there were opposing trends in 1987 and 1988 in the relationship between mean weekly catch rate and mean weekly flow in the lower study section. Decreasing catch rate was associated with increasing flow rate in 1987, but with decreasing flow rate in 1988.

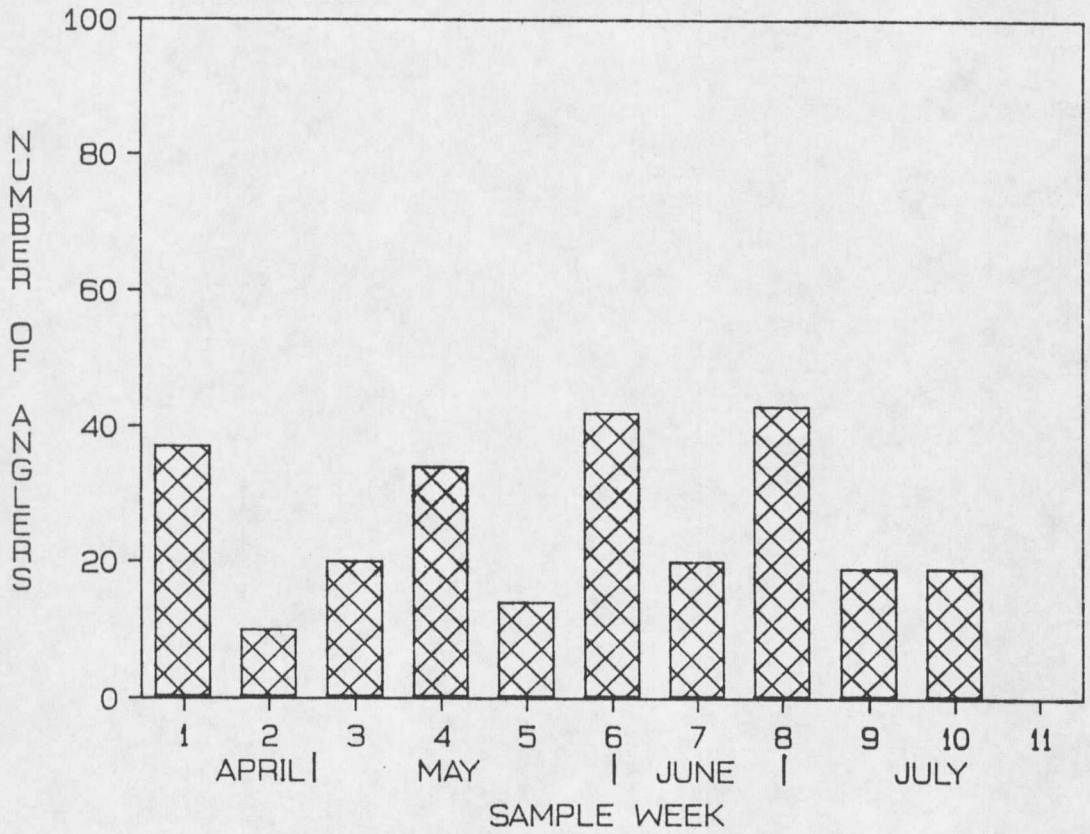


Figure 35. Weekly angler contacts on the lower section of Madison River, 1988.

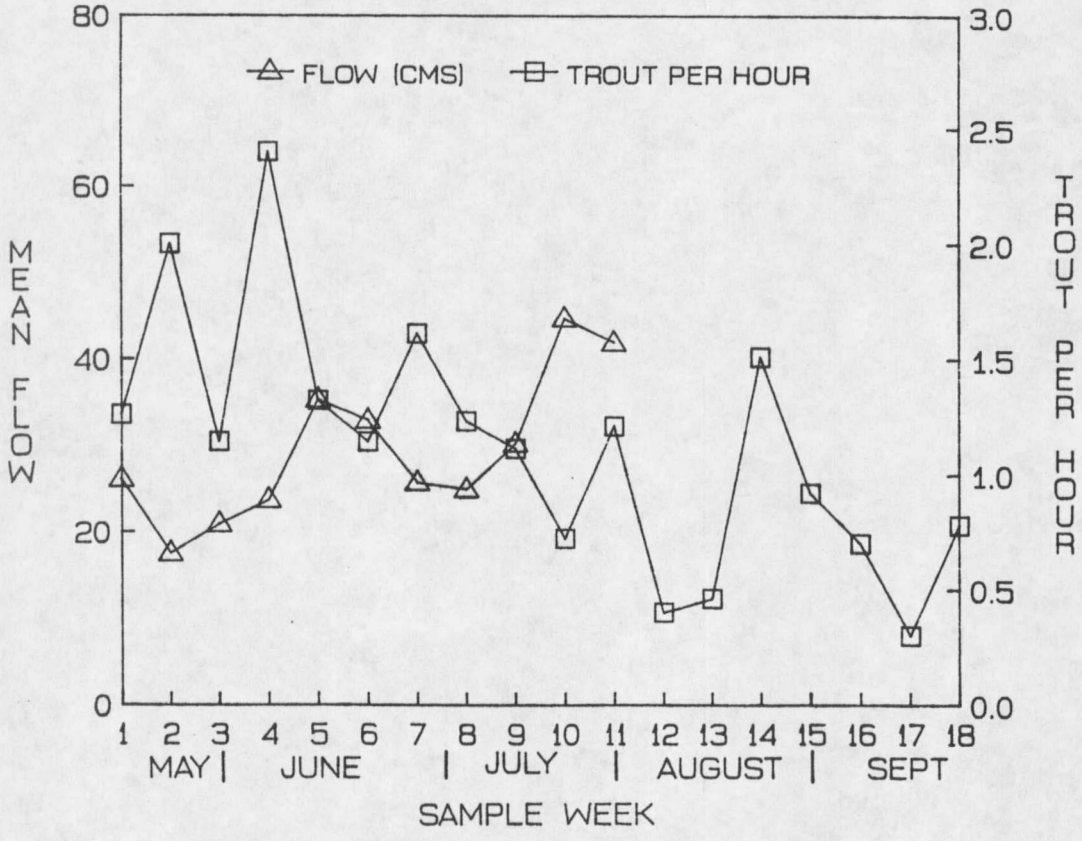


Figure 36. Mean weekly flows (cubic meters/sec) and catch rates on the upper section of the Madison River, 1987.

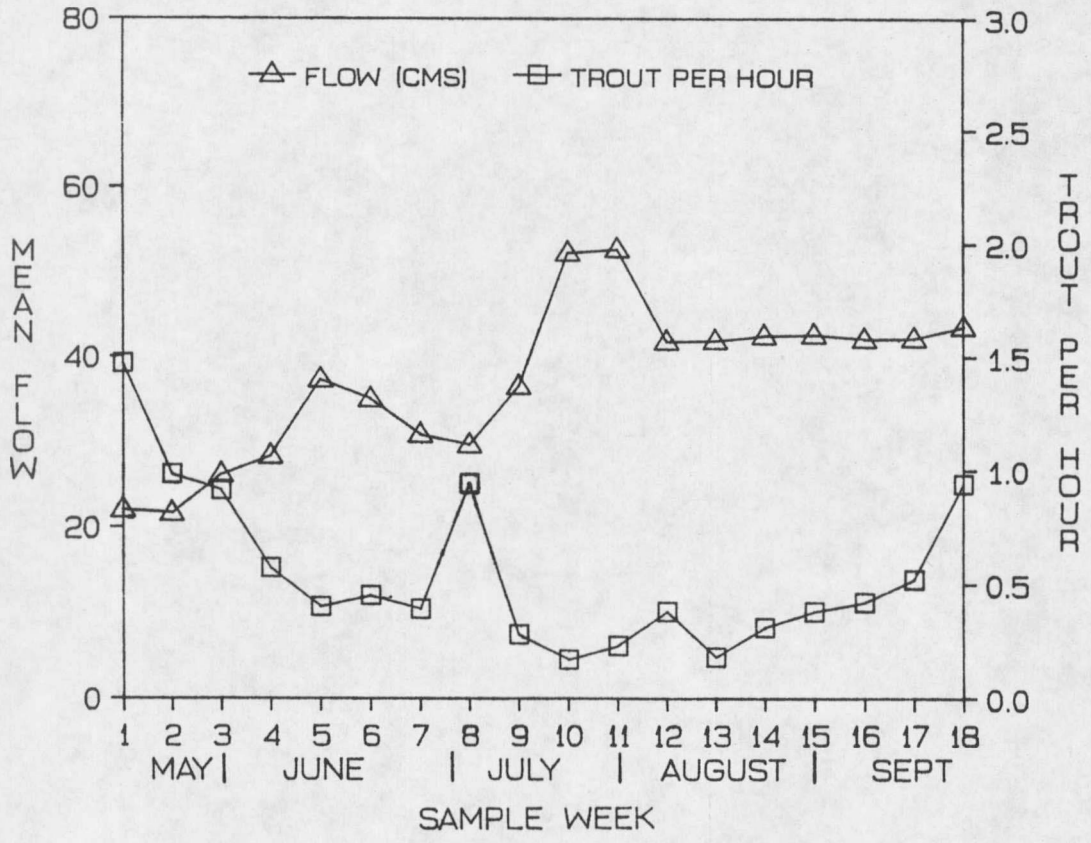


Figure 37. Mean weekly flows (cubic meters/sec) and catch rates on the lower section of the Madison River, 1987.

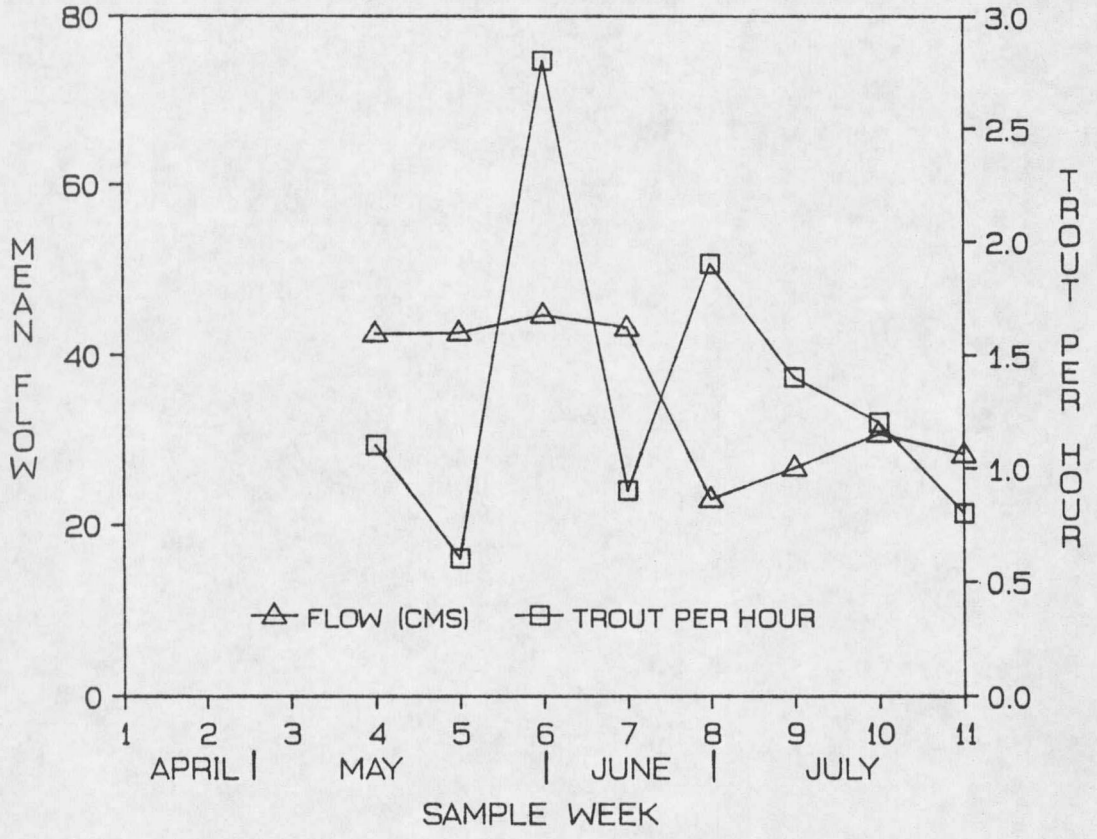


Figure 38. Mean weekly flows (cubic meters/sec) and catch rates on the upper section of the Madison River, 1988.

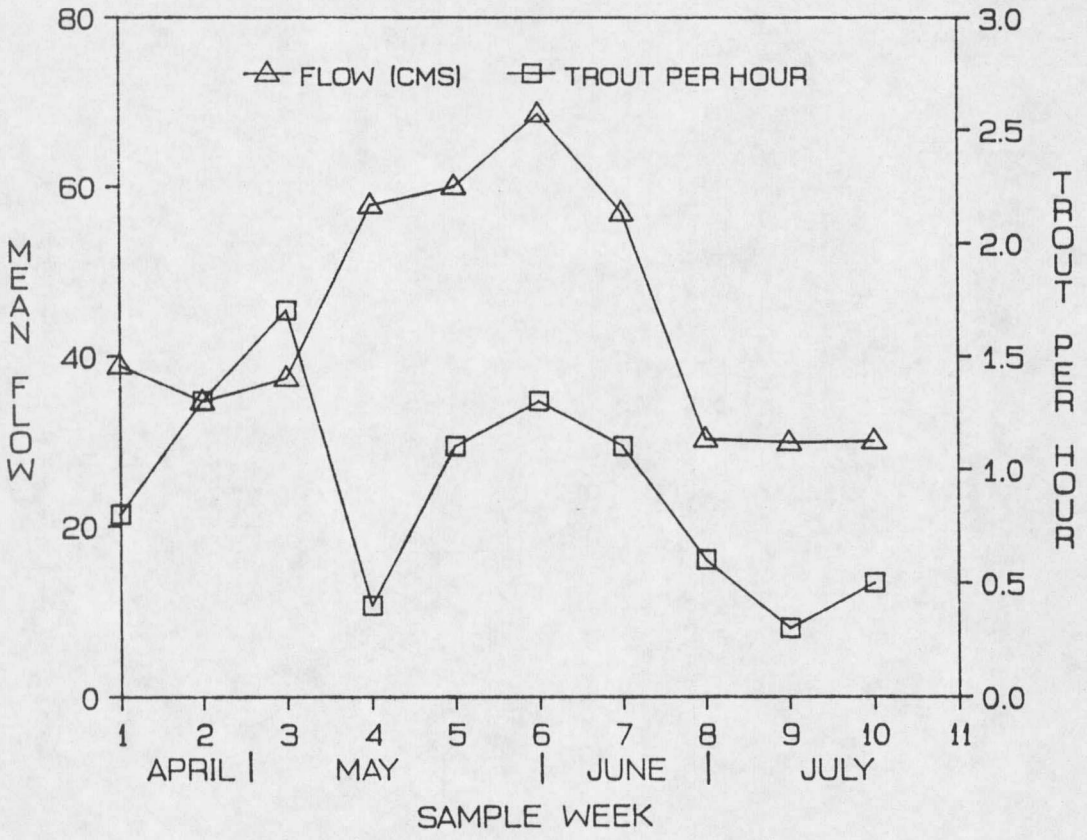


Figure 39. Mean weekly flows (cubic meters/sec) and catch rates on the lower section of the Madison River, 1988.

Catch Rate in Relation to Angler Characteristics

Fly anglers comprised 68% of all anglers sampled during the study, whereas spin and bait anglers made up 21% and 10%, respectively (Fig. 40, Table 8). Bait fishing was not permitted on the upper section and accounted for only 24% of the angler contacts on the lower section. Fly anglers constituted 94% of the anglers surveyed on the upper section, whereas the three angling methods were about evenly represented on the lower section. The small number of spin anglers on the upper section landed significantly more trout per hour, on average, than the other two groups of anglers considered (Fig. 41, Table 8).

Wading and bank anglers outnumbered anglers fishing from boats in both sections (Fig. 42). Catch rates were very nearly the same for people fishing from both types of locations (Fig. 43, Table 8).

About 80% of the anglers contacted were fishing without a guide (Fig. 44). Proportionately more anglers on the upper section (35%) fished with a guide than on the lower section (4%). Catch rates were slightly higher for nonguided anglers in both sections but the differences were not significant (Fig. 45, Table 8). The 'combined' category is not included in Figures 44, 45, 46, and 47 and Table 8 for reasons discussed in the Methods section of this report.

Table 8. Means and p values (p) for comparisons between angler characteristics and catch rates on the upper, lower, and both sections combined of the Madison River, 1987 and 1988 combined.

Section	Tackle Type		
	Fly Mean	Spin Mean	Bait Mean
Upper	1.114	1.802	*
	Fly vs. Spin ($p<.05$)		
Lower	0.912	0.624	0.466
	Fly vs. Spin ($p<.05$)		
	Fly vs. Bait ($p<.05$)		
	Spin vs. Bait ($p>.05$)		

Section	Fishing Location	
	Bank/Wading Mean	Boating Mean
Upper	1.203	1.165
	Bank/Wade vs. Boat ($p>.05$)	
Lower	0.647	0.754
	Bank/Wade vs. Boat ($p>.05$)	

Section	Guided and Not Guided	
	Guided Mean	Nonguided Mean
Upper	1.127	1.218
	Guided vs. Nonguided ($p>.05$)	
Lower	0.683	0.760
	Guided vs. Nonguided ($p>.05$)	

Section	Resident and Nonresident	
	Resident Mean	Nonresident Mean
Upper	1.386	1.165
	Resident vs. Nonresident ($p>.05$)	
Lower	0.709	0.606
	Resident vs. Nonresident ($p>.05$)	

* Bait fishing was not permitted in the upper section.

Sixty percent of all anglers contacted during the study were nonresidents and the remainder were residents of Montana. The upper and lower sections of the Madison River differed greatly in terms of the residency of the anglers that fished those sections. The upper section was dominated by nonresidents (89%), whereas the lower section had a greater proportion of resident anglers (78%) (Fig. 46). Mean catch rates appear to have been slightly higher for resident anglers in both sections but these differences were not statistically significant (Fig. 47, Table 8).

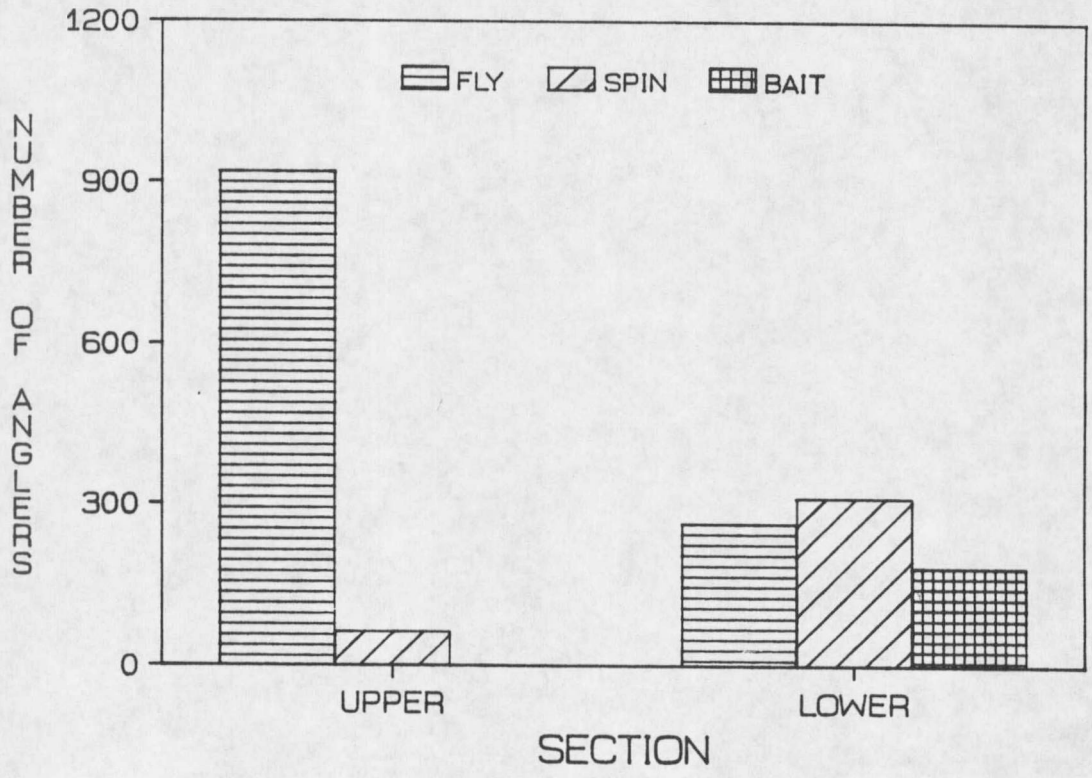


Figure 40. Numbers of fly, spin, and bait fishermen versus section on the Madison River, 1987 and 1988 combined.

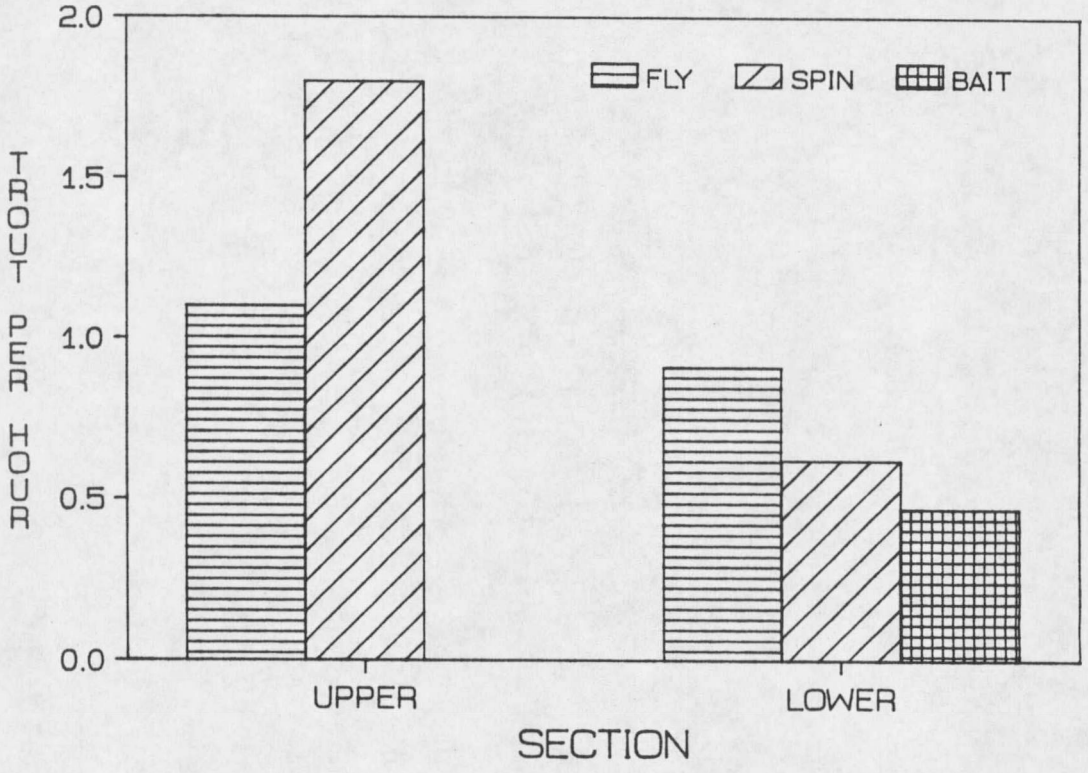


Figure 41. Mean catch rates for fly, spin, and bait anglers on the Madison River versus section, 1987 and 1988 combined.

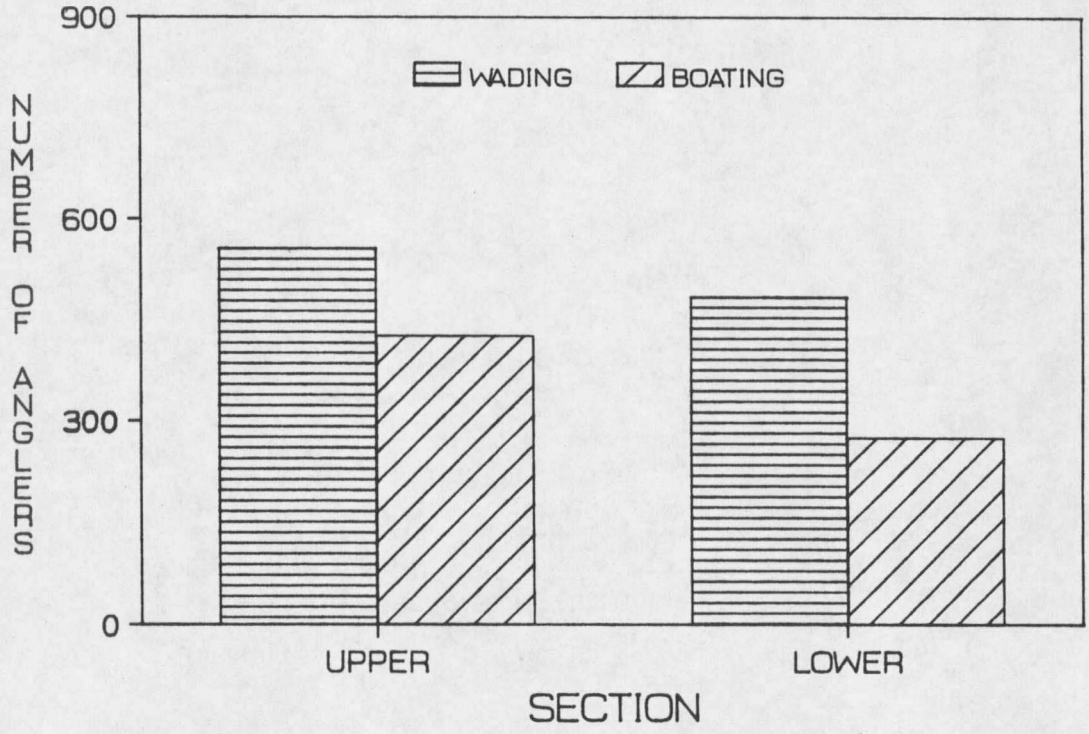


Figure 42. Numbers of wading and boating anglers versus section on the Madison River, 1987 and 1988 combined.

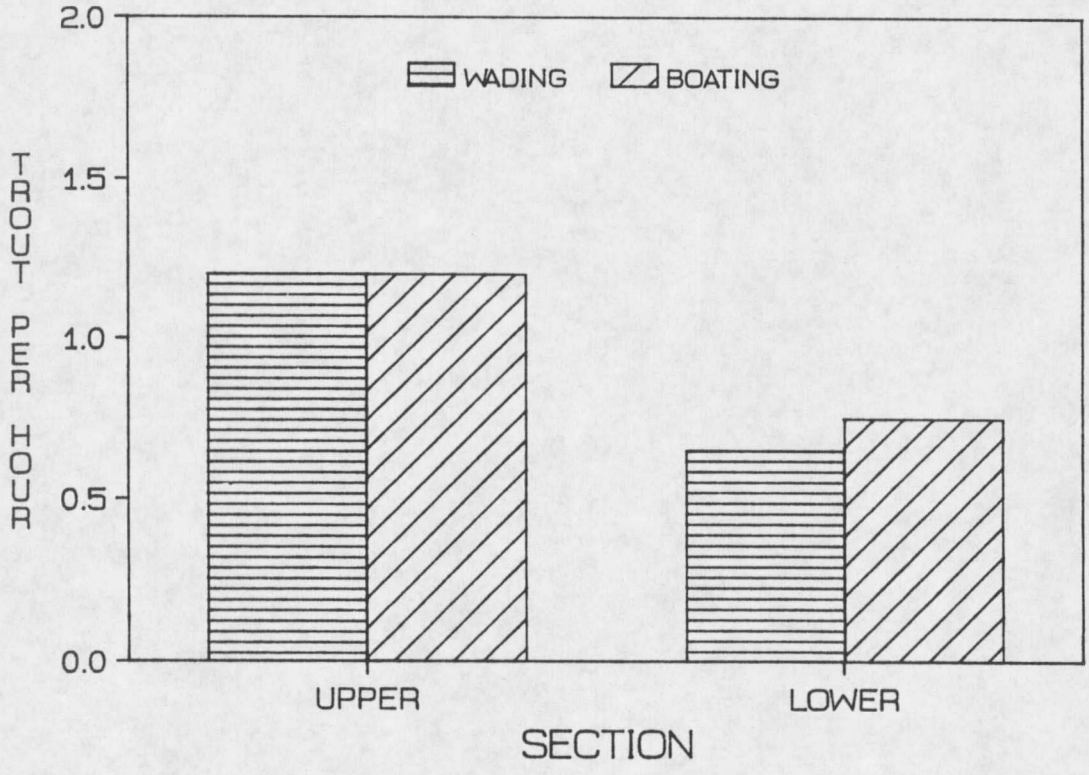


Figure 43. Mean catch rates of wading and boating anglers on the Madison River versus section, 1987 and 1988 combined.

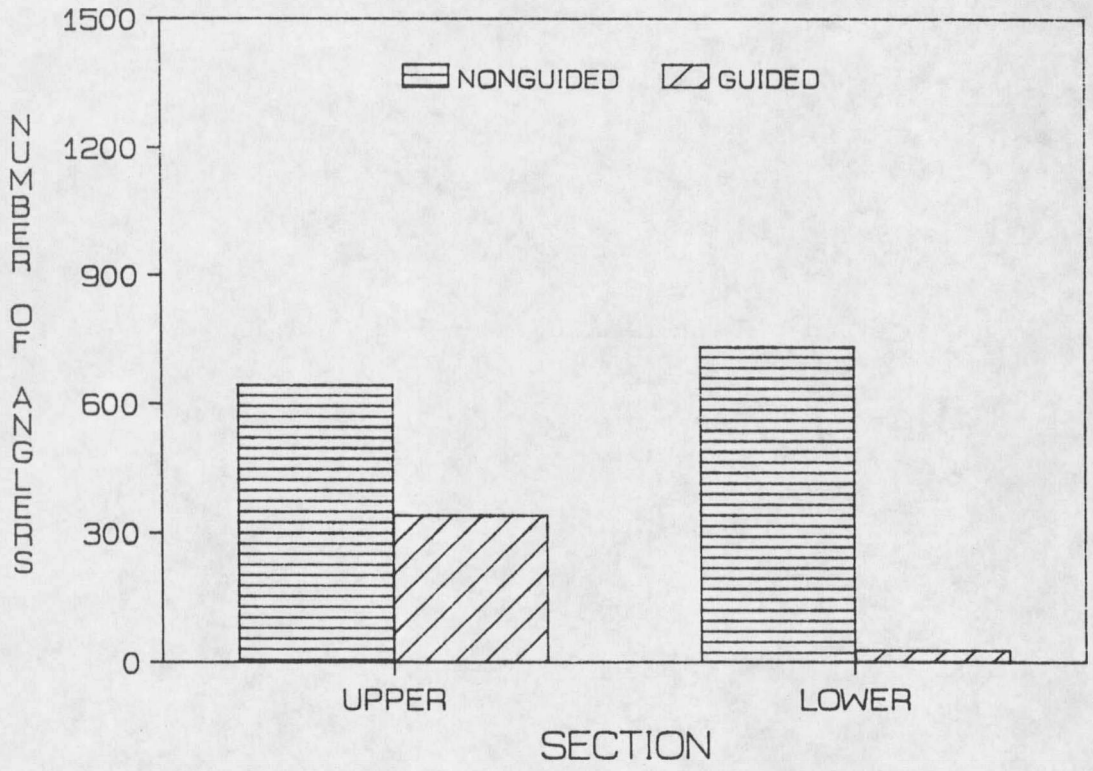


Figure 44. Numbers of guided and nonguided anglers on the Madison River versus section, 1987 and 1988 combined.

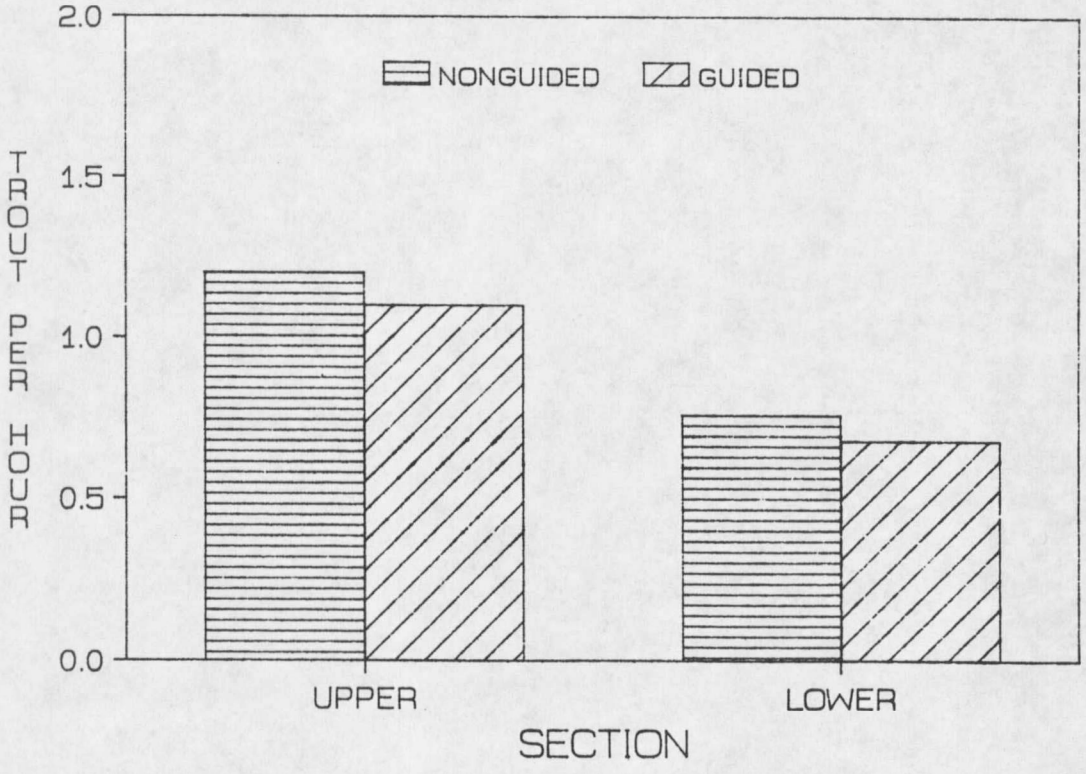


Figure 45. Mean catch rates of guided and nonguided anglers on the Madison River versus section, 1987 and 1988 combined.

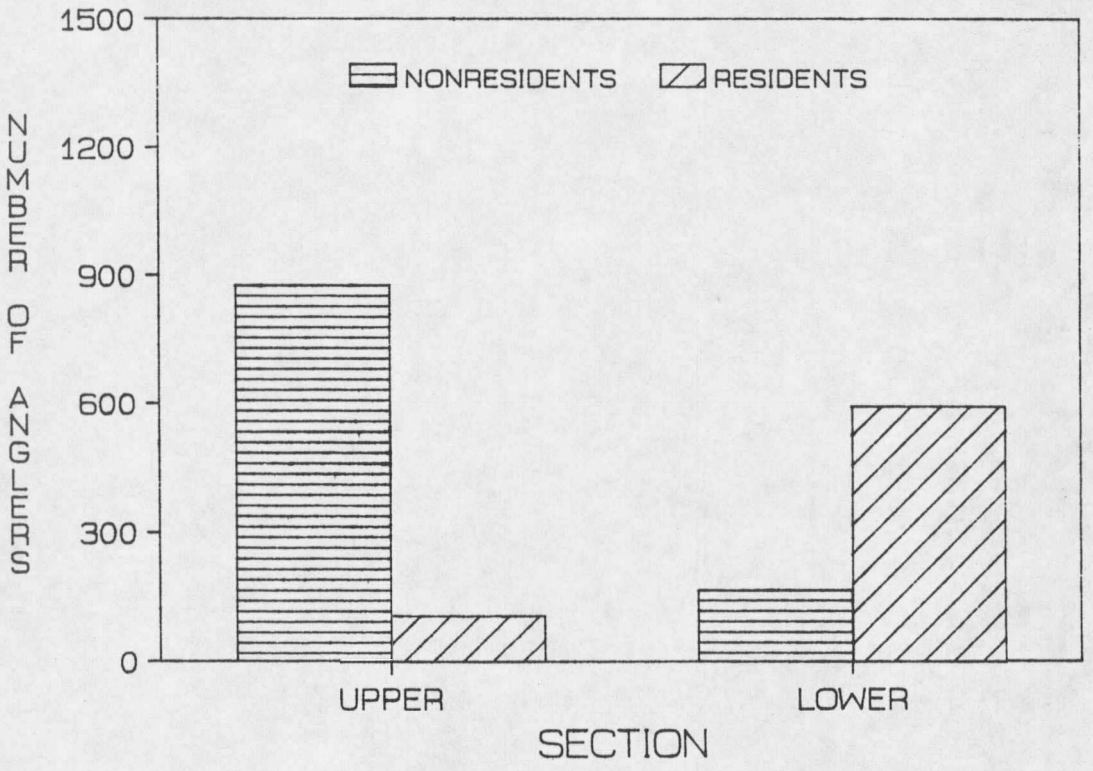


Figure 46. Numbers of resident and nonresident anglers on the Madison River versus section, 1987 and 1988 combined.

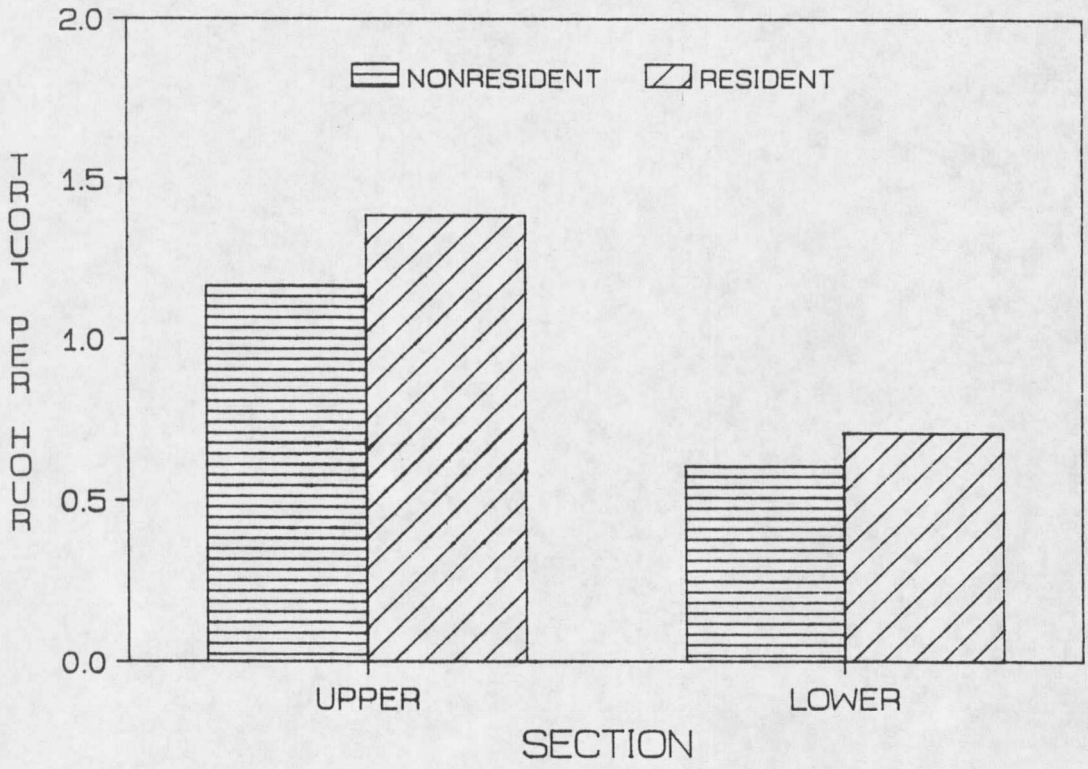


Figure 47. Mean catch rates of resident and nonresident anglers on the Madison River versus section, 1987 and 1988 combined.

DISCUSSION

Relations between Water Temperature and Angling Success

The results of this study confirm that angling success for brown and rainbow trout was adversely affected by elevated stream temperature, especially at temperatures above 19 to 20 C. Catch rates (trout per hour) decreased as water temperature increased. Total catch, catch of larger fish (30.5 cm or larger), and the proportion of catch rates exceeding 0.5 and 1.0 trout per hour all declined at warmer temperatures, whereas the proportion of anglers landing no trout increased with increasing stream temperature. Mean catch rate declined with seasonal increases in average weekly temperature from spring through summer, especially on the lower section, where water temperature more often exceeded 19 C. The stream temperature in the upper section rarely approached 19 C and catch rate there did not appear to be seriously depressed by elevated water temperature, however, the relationship between catch rate and fishing temperature was significant (Table 3). Angler numbers declined when water temperature increased beyond 20 C, indicating that anglers are less willing to fish when they have great difficulty catching trout on the Madison River.

The correlation coefficients (R values) for the regressions that compared catch rates to fishing temperatures were very small due to the great variance in the catch data, but these correlations were, in most cases, highly significant. The large variance in catch rates may be explained by differences in the skill and experience of anglers as well as by environmental factors other than water temperature, such as insect emergences, cloud cover, rain, wind, and water level fluctuations.

The purpose of this study was not to predict the catch rate an angler can expect at a given water temperature, but to determine whether there is a relationship between water temperature and catch rate. The significance of the correlations between catch rates and fishing temperatures indicate that water temperature is indeed related to the rate at which people land trout in the Madison River.

Data from the Bighorn River in southeastern Montana indicate that catch rate there may also be affected by water temperature. In 1987, catch rate on the Bighorn River increased throughout the period of May to September (Fredenberg 1988), while water temperature also increased. Daily maximum water temperature increased from 5 C (May 15) to 15 C (September 15) (U. S. Bureau of Reclamation-U. S. Geological Survey, unpub. data 1987) in a linear fashion, while catch rate tended to parallel this increase. From

this data it appears that catch rate on the Bighorn River may remain low until the water temperature rises later in the summer. Thus, while the lower Madison River (below Ennis Reservoir) appears to be too warm for satisfactory catch rates after about the first of July, the Bighorn River may be too cool until late August or early September (the lowest monthly catch rate reported for 1987 on the Bighorn River was 0.73 fish per hour during May and may not have been considered unsatisfactory by the average Madison River angler).

Mean weekly discharge did not exhibit a consistent relationship to catch rate. During 1987 there appeared to be a negative relationship between flow and catch rate on the lower section, similar to the relation between temperature and catch rate. During 1988, however, catch rate appeared to be positively related to stream flow, while catch rates continued to be inversely related to water temperature. These opposing relationships between catch rates and flows between the two years indicate that catch rate was not consistently influenced by flow on the Madison River. However, catch rates were negatively correlated with higher stream temperatures during both years. This also illustrates the importance of having at least two years of data when examining relationships such as these. With only one of these two years of data, one could have overestimated the relatedness of flow and catch

rate.

The adverse effects on catch rate of water temperatures exceeding 19 to 20 C are consistent with laboratory studies on the effects of water temperature on the feeding activity and growth of brown and rainbow trout. Feeding rates in brown trout decreased markedly when water temperatures rose above 18.4 and 19.3 C in two different studies by Elliot (1975a, 1975b). Wurtzbaugh and Davis (1977) found that rainbow trout ate less in 22.5 C water than in waters that were 3 and 6 C cooler. Dickson and Kramer (1971) reported that the scope for activity (metabolic energy available in excess of basal metabolic rate) in wild trout decreased in water temperatures between 20 and 25 C. Thus, as water temperatures increase and the feeding rates correspondingly decrease, the catchability of trout declines. The upper threshold for both trout feeding and satisfactory catchability appears to be around 19 to 20 C, with the peak being somewhere between 10 and 17 C.

Higher catch rates appear to be associated with temperatures that not only support good rates of feeding but also better growth rates of trout. In a review by Jobling (1981), optimal temperatures for growth reported were between 10.0 and 15.5 C for brown trout and between 16.5 and 17.2 C for rainbow trout. Specific growth rates (% weight/day) in juvenile rainbow trout dramatically

decreased when water temperatures exceeded about 21 C in a study by Hokanson et al. (1977). In that same study, the 40-day yield (kg) of 10,000 rainbow trout peaked at 17 C and decreased by about 60% between 19 and 21 C.

Angler satisfaction is obviously related to catch rate. Allen (1988) found that catch rate is only a small part of why most anglers choose a particular fishing location, but it is an important factor influencing the satisfaction they experience after they have chosen a location. Anglers who do not catch any trout are likely to be dissatisfied with their catch rates.

Average satisfaction ratings declined from minimally satisfactory to unsatisfactory at catch rates associated with temperatures above 19 to 20 C. With the two differing versions (1987 and 1988) of the satisfaction rating question, the catch rates were, in general, lower in 1987 than in 1988 for a given rating. However, the threshold between catch rates that were considered unsatisfactory (a rating of 3) and satisfactory (a rating of 4) during both years corresponded to fishing temperatures of between 19 and 20 C.

Expectation may be important in determining anglers' satisfaction with the rate at which they land trout. It seems apparent that an angler who had a higher catch rate than expected would be more satisfied than an angler who had a lower catch rate than expected, even if the catch

rates were the same for both anglers. The threshold between what the average Madison River angler considered minimally satisfactory and unsatisfactory (somewhere between 0.5 and 0.7 trout per hour) was associated with mean stream temperatures of between 19 and 20 C. This has important management implications in that it shows managers what types of catch rates (above about 0.7 trout per hour) are necessary to provide a minimal level of satisfaction to the average Madison River angler.

The National Academy of Sciences/National Academy of Engineering (NAS/NAE 1972) and the U. S. Environmental Protection Agency (EPA 1986) recommended that the maximum average weekly temperatures for rainbow trout should not exceed 19 C. Results of the present study indicate that, on the Madison River, a maximum average weekly temperature of 19 C or higher produced catch rates lower than those at cooler water temperatures, and that the lower catch rates were not satisfactory to the average angler. The EPA (1986) criteria might be stringent enough to ensure the survival of trout in a given water, but they may not be effective in ensuring that those trout are available (i.e. catchable) to anglers. If an important goal of managers is to provide quality angling opportunities, then the EPA (1986) criteria for maximum weekly average temperature may be too high.

The 1988 field season was discontinued earlier than originally planned due to thermal fish kills in the lower study section that began when daily water temperature maxima exceeded 27 C in late June (Appendix C). Upper incipient lethal temperatures have been established for rainbow trout at about 25 to 26 C (Bidgood and Berst 1969, Hokanson et al. 1977, Kaya 1978). An interesting observation made during these thermal fish kills was apparently active feeding of trout and whitefish when water temperature approached 25 C. Dead and dying fishes (that had lost their equilibrium) were observed drifting past concentrations of actively feeding fishes. Twenty-four whitefish, 5 rainbow, and 1 brown trout were landed by an angler in one hour of fishing, while using a small nymph imitation, during one of these thermal fish kills (this angler interview was omitted from that sample week's data). Similar activity has been observed in brown trout in a Michigan stream when water temperature reached an unusually high level (M. Enk, U. S. Forest Serv., pers. comm. 1988). One possible explanation for this apparent increased feeding activity is that macroinvertebrates with low upper incipient lethal temperatures may have been drifting in greater than normal abundance, and thus induced the feeding by trout and whitefish.

Relations between Angler Characteristics and Angling Success

Fly anglers were the most common type of fishermen on the Madison River during 1987 and 1988. Allen (1988) found nearly the same percentage (69.5%) of his respondents were fly anglers. The finding that spin anglers, followed by bait anglers were much less numerous was also supported by Allen (1988) but, the percentages of both spin and bait anglers in his report were about two and five times lower, respectively, than corresponding figures found in this study. The underestimation of spin and bait anglers in Allen's (1988) study may have been due to his inclusion of the 'combined' tackle category as well as the possibility that a greater percentage of the fly anglers may have responded to his mail survey. The Madison River had the highest percentage of fly anglers of the 19 Montana streams considered by Allen (1988).

Vincent (1969) reported that, "Bait fishermen were the most common type of angler on all sections of the Madison River" during 1966 and 1967. This was prior to the tackle restrictions that were implemented on the upper section in 1978. However, although bait fishing is still permitted on the lower section, only 24% of the anglers contacted there during 1987 and 1988 utilized this method, indicating that there may have been a shift in the 'favorite' method of

angling on the Madison River during the past 20 years.

Catch rates were higher, on average, for fly anglers, perhaps due to the average fly fisher being more experienced than either the average spin or bait fisherman. The high catch rate for spin anglers on the upper section may be related to the fact that so few anglers used spinning lures on this section and thus, trout there were not as wary of spinning lures as they might be in areas where these types of lures are more frequently used.

Fishing from a boat may make some areas more accessible, but it did not appear to increase the catch rates of boating anglers in this study. The percentage of anglers fishing from boats in this study was very similar to the percentage of anglers that Allen (1988) reported fishing from a boat or both from a boat and shore on the Madison River. The majority of anglers who fish the Madison River from boats also get out of the boat on bars and banks in some locations (pers. obs.). This explains why the grouping of Allen's (1988) two categories (boat and shore) corresponded so well with the percentage of boating anglers reported for this study.

The percentage of anglers contacted who were fishing with a guide on the Madison River in this study was similar to that reported by Allen (1988). Many fewer anglers fished with guides than fished without one. Catch rates

were slightly higher for nonguided than guided anglers, indicating it may not 'pay' to hire a guide on the Madison River if one is interested in catching more fish.

The proportion of resident and nonresident anglers has not changed over the past 20 years. Sixty percent of the anglers contacted during 1987 and 1988 were nonresidents, while 40% lived in Montana. Vincent (1969) reported that 60% of the anglers surveyed on the Madison River in 1967 were not residents of Montana. Allen (1988) found a similar relationship but he reported even a higher percentage of nonresidents (66.5%). The upper section was dominated by nonresidents, while the lower section was frequented by more resident anglers. Vincent (1969) found a similar, but less pronounced, relationship in 1966 and 1967. The lower section is nearer to a large town (Bozeman, Montana) than the upper section, which may account for the larger percentage of resident anglers on this lower section. Residents had slightly higher catch rates, in both sections, than did nonresidents.

The average catch rate of anglers contacted on the Madison River during the summers of 1987 and 1988 was 0.97 trout per hour. Vincent (1969), from an on-site creel survey on the Madison River, reported catch rates of 1.0 and 0.9 trout per hour for 1966 and 1967, respectively. In a mail survey, McFarland (unpub. report 1988) reported catch rates on the Madison River of 1.37 for 1984 and 1.71

for 1985. This may indicate that mail surveys overestimate catch rates due to things such as inaccurate memories, and poor response rate from anglers who had poor fishing. Vincent (1969) recommended the use of on-site creel clerks due to the exaggerated reports from mail surveys.

SUMMARY AND CONCLUSION

The primary objective of this study was to determine whether stream temperature was related to angling success for brown and rainbow trout (and the associated angler satisfaction) of recreational fishermen. Catch rates and angler attitudes were determined through on-site creel survey on upper and lower sections of the Madison River, while thermographs were concurrently recording water temperatures in both sections.

Different questions were asked during the two field seasons to evaluate angler satisfaction. Both versions of the question provided results that indicate the existence of a satisfaction threshold around 0.7 trout per hour on the Madison River. Catch rates above about 0.5 trout per hour were considered minimally satisfactory by the average angler in 1987, while catch rates of 0.7 trout per hour were required for the same rating in 1988 (Fig. 6). This threshold was associated with fishing temperatures between 19 and 20 C, with satisfactory ratings dominating below this level and unsatisfactory ratings occurring more often when the water temperature was above 19 to 20 C.

The results of this study confirm that elevated stream temperature decreases angler catch rates and subsequent

angler satisfaction. At water temperatures substantially below upper incipient lethal temperatures, trout catch rates are markedly depressed. Thermal criteria established by the EPA (1986) may ensure the survival of trout in an area but, it is possible that the catchability of these trout may be reduced enough that the average angler will not be satisfied with his or her catch rate. The data presented in this report indicate that water temperatures between 8 and 18 C should be considered satisfactory if one of an agency's goals is to provide brown and rainbow trout angling that will satisfy the average angler.

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APPENDICES

APPENDIX A

TABLES RELATED TO RESULTS

Table 9. Mean Weekly catch rate (trout/hour), angler satisfaction, mean water temperature (C), and mean discharge (cms) for the upper section of the Madison River, 1987 census period.

Week	Dates	Angler #	Catch Rate	Sat.	Temp.	Flow
1	5/16,17	10	1.3	4.9	9.2	26.1
2	5/23,24, 25	19	2.0	5.0	11.6	17.5
3	5/30,31	13	1.1	3.8	9.2	20.9
4	6/6,7	23	2.4	5.1	11.8	23.7
5	6/15,17, 18	39	1.3	4.4	13.8	35.3
6	6/20,21, 23,24	73	1.1	4.3	13.9	32.9
7	6/27,28, 7/1,2	82	1.6	4.6	15.4	25.7
8	7/4,5, 7,8	76	1.2	4.6	14.3	24.9
9	7/11,12, 15,16	79	1.1	4.0	14.9	30.2
10	7/18,19, 22,23	87	0.7	3.2	12.1	44.7
11	7/25,26	24	1.2	3.8	13.6	41.9
12	8/4,5	40	0.4	2.3	16.2	*
13	8/8,9	23	0.5	3.7	16.5	*
14	8/19,20	35	1.5	4.7	15.7	*
15	8/22,23	27	0.9	3.7	15.9	*
16	9/1,2	17	0.7	2.6	15.8	*
17	9/5,6	27	0.3	2.1	14.7	*
18	9/16,17, 19,20	34	0.8	3.5	13.5	*

* Discharge data were not available after July 31 for the upper section.

Table 10. Mean weekly catch rate (trout/hour), angler satisfaction, water temperature (C), and discharge (cms) on the lower section of the Madison River, 1987 census period.

Week	Dates	Angler #	Catch Rate	Sat.	Temp.	Flow
1	*	30	1.5	5.3	11.6	22.0
2	*	70	1.0	4.7	13.9	21.6
3	*	21	0.9	3.7	12.9	26.1
4	*	43	0.6	4.2	16.6	28.3
5	*	54	0.4	3.8	17.4	37.3
6	*	43	0.5	4.0	17.9	35.0
7	*	21	0.4	3.8	20.4	30.8
8	*	16	0.9	4.1	20.1	29.6
9	*	20	0.3	1.9	17.9	36.5
10	*	47	0.2	2.7	16.4	52.3
11	*	13	0.2	2.3	20.3	52.7
12	*	12	0.4	3.0	21.0	41.8
13	*	28	0.2	2.9	20.5	41.9
14	*	15	0.3	2.2	17.7	42.5
15	*	5	0.4	2.8	18.6	42.6
16	*	8	0.4	2.5	18.4	42.1
17	*	20	0.5	2.3	16.8	42.2
18	*	35	0.9	4.3	15.0	43.6

* See dates on Table 9.

Table 11. Mean catch rate (trout/hour), angler satisfaction, water temperature (C), and discharge (cms) for the upper section of the Madison River, 1988 census period.

Week	Dates	Angler #	Catch Rate	Sat.	Temp.	Flow
1	*	*	*	*	*	*
2	*	*	*	*	*	*
3	*	*	*	*	*	*
4	5/14,15	4	1.1	3.0	7.4	42.5
5	5/21,22	8	0.6	2.4	9.8	42.6
6	5/28,29	13	2.8	3.9	10.1	44.7
7	6/4,5	12	0.9	3.6	12.1	43.2
8	6/18,19, 22,23	43	1.9	3.8	15.6	23.0
9	7/2,3, 5,6	85	1.4	3.6	15.4	26.7
10	7/16,17, 20,21	70	1.2	3.5	17.2	30.7
11	7/30	19	0.8	3.7	17.6	28.3

* Data were not collected on the upper section until the fourth sample week of the 1988 field season.

Table 12. Mean weekly catch rate (trout/hour), angler satisfaction, water temperature (C), and discharge (cms) for the lower section of the Madison River, 1988 census period.

Week	Dates	Angler #	Catch Rate	Sat.	Temp.	Flow
1	4/23,24	37	0.8	3.1	10.8	38.9
2	4/30, 5/1	10	1.3	3.5	9.2	34.6
3	5/7,8	20	1.7	3.7	9.4	37.4
4	*	34	0.4	2.8	15.8	57.8
5	*	14	1.1	3.9	15.8	60.0
6	*	42	1.3	3.8	17.4	68.5
7	*	20	1.1	4.8	17.8	56.9
8	*	43	0.6	3.2	21.2	30.2
9	*	19	0.3	2.1	22.0	29.8
10	*	19	0.5	2.9	21.4	30.0
11	**	**	**	**	**	**

* See dates on Table 11.
** Data were not collected on the lower section during week eleven (11) of the 1988 field season.

Table 13. Mean catch rate (trout/hour) at each satisfaction rating, upper and lower sections of the Madison River, 1987.

	Rating *					
	1	2	3	4	5	6
Upper						
Angler Numbers	77	102	65	131	237	116
Percent of Anglers	11	14	9	17	33	16
Mean Catch Rate	0.3	0.4	0.6	0.9	1.5	2.2
Lower						
Angler Numbers	77	72	58	73	167	54
Percent of Anglers	15	14	12	15	33	11
Mean Catch Rate	0.1	0.3	0.4	0.5	0.8	1.6
Upper & Lower						
Angler Numbers	154	174	123	204	404	170
Percent of Anglers	13	14	10	16	33	14
Mean Catch Rate	0.2	0.3	0.5	0.7	1.2	2.1

* Satisfaction rating: 1 = highly unsatisfactory, 2 = moderately unsatisfactory, 3 = slightly unsatisfactory, 4 = slightly satisfactory, 5 = moderately satisfactory, 6 = highly satisfactory.

Table 14. Mean catch rates (trout/hour) at each satisfaction rating, upper and lower sections of the Madison River, 1988.

	Rating *					
	1	2	3	4	5	6
Upper						
Angler Numbers	6	34	82	79	45	8
Percent of Anglers	2	14	32	31	18	3
Mean Catch Rate	0.2	0.4	0.7	1.7	2.1	5.6
Lower						
Angler Numbers	15	67	56	73	33	13
Percent of Anglers	6	26	22	28	13	5
Mean Catch Rate	0.3	0.3	0.6	1.3	1.4	1.5
Upper & Lower						
Angler Numbers	21	101	138	153	78	21
Percent of Anglers	4	20	27	30	15	4
Mean Catch Rate	0.3	0.3	0.7	1.5	1.8	3.1

* Satisfaction ratings: 1 = terrible, extremely slow, 2 = very slow, 3 = slow, 4 = not fast, but okay, 5 = fast, 6 = very fast, couldn't be better.

Table 15. Mean catch rate (trout/hour) versus fishing temperature (C) for both sections of the Madison River, 1987 and 1988 combined.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
6	1	1.5	0.0	1.5	1.5
7	7	0.8	1.0	1.8	1.1
8	24	1.1	1.4	2.5	1.8
9	33	0.6	1.0	1.6	0.9
10	11	0.3	0.4	0.7	0.3
11	69	0.6	0.6	1.2	0.7
12	62	0.7	0.4	1.1	0.5
13	131	0.9	0.4	1.3	0.6
14	287	0.7	0.3	1.0	0.4
15	191	0.7	0.3	1.0	0.5
16	165	0.5	0.4	0.9	0.4
17	195	0.6	0.3	0.9	0.4
18	284	0.4	0.4	0.8	0.4
19	103	0.5	0.3	0.8	0.4
20	42	0.2	0.2	0.4	0.2
21	52	0.1	0.4	0.5	0.2
22	24	0.1	0.3	0.4	0.2
23	15	0.0	0.2	0.2	0.0
24	3	0.0	0.1	0.1	0.1
25	19	0.2	0.2	0.4	0.1

Table 16. Mean catch rate (trout/hour) versus fishing temperature (C) for both sections of the Madison River, 1987.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
7	7	0.8	1.0	1.8	1.1
8	6	1.3	0.2	1.5	1.0
9	11	1.1	0.5	1.6	1.1
10	11	0.3	0.4	0.7	0.3
11	30	1.0	0.8	1.8	1.0
12	41	0.9	0.6	1.5	0.6
13	117	0.9	0.4	1.3	0.6
14	248	0.6	0.3	0.9	0.4
15	165	0.6	0.3	0.9	0.4
16	139	0.6	0.4	1.0	0.4
17	119	0.4	0.2	0.6	0.3
18	209	0.4	0.4	0.8	0.3
19	55	0.2	0.3	0.5	0.2
20	22	0.1	0.2	0.3	0.2
21	25	0.1	0.3	0.4	0.1
22	8	0.1	0.3	0.4	0.2
23	15	0.0	0.2	0.2	0.0
24	3	0.0	0.1	0.1	0.1

Table 17. Mean catch rate (trout/hour) versus fishing temperature (C) for both sections of the Madison River, 1988.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
6	1	1.5	0.0	1.5	1.5
7	0	-	-	-	-
8	18	1.1	1.7	2.8	2.0
9	22	0.3	1.3	1.6	0.7
10	0	-	-	-	-
11	39	0.3	0.5	0.8	0.5
12	21	0.3	0.2	0.5	0.2
13	14	0.6	0.1	0.7	0.3
14	39	0.9	0.5	1.4	0.7
15	28	1.0	0.5	1.5	0.7
16	26	0.2	0.7	0.9	0.5
17	76	0.8	0.6	1.4	0.7
18	98	0.7	0.5	1.2	0.5
19	48	0.8	0.3	1.1	0.6
20	20	0.2	0.3	0.5	0.3
21	27	0.1	0.4	0.5	0.3
22	12	0.2	0.2	0.4	0.2
23	0	-	-	-	-
24	0	-	-	-	-
25	19	0.2	0.2	0.4	0.1

Table 18. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on the upper section of the Madison River, 1987.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
8	6	16	83	67
9	7	0	86	57
10	0	-	-	-
11	14	7	71	64
12	32	22	63	53
13	97	14	55	44
14	183	21	57	37
15	128	16	48	35
16	111	14	37	25
17	65	22	31	20
18	62	31	24	18
19	16	56	44	31

Table 19. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on the upper section of the Madison River, 1988.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
6	1	0	100	100
7	0	-	-	-
8	5	0	80	80
9	1	0	100	100
10	0	-	-	-
11	11	45	55	44
12	21	57	33	29
13	7	71	29	29
14	25	4	96	92
15	28	36	64	64
16	0	-	-	-
17	46	15	80	63
18	63	16	41	29
19	41	32	59	41
20	3	0	100	100
21	2	0	0	0

Table 20. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on the lower section of the Madison River, 1987.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
9	4	25	75	75
10	11	9	45	9
11	16	19	78	56
12	9	11	78	56
13	20	15	55	25
14	65	23	52	25
15	35	43	34	14
16	28	43	57	29
17	54	44	22	9
18	147	34	32	20
19	39	41	36	21
20	22	36	27	14
21	25	40	24	24
22	8	38	18	13
23	15	67	20	0
24	3	0	0	0

Table 21. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on the lower section of the Madison River, 1988.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
8	13	8	85	54
9	21	14	86	67
10	0	-	-	-
11	28	43	46	36
12	0	-	-	-
13	7	43	57	43
14	14	43	50	29
15	0	-	-	-
16	26	19	58	38
17	30	20	63	37
18	35	14	74	34
19	7	71	29	14
20	17	65	18	6
21	25	60	40	20
22	14	57	50	7
23	0	-	-	-
24	0	-	-	-
25	19	58	16	16

Table 22. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on both sections of the Madison River, 1987 and 1988 combined.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
6	1	0	100	100
7	7	25	63	63
8	24	8	79	63
9	33	12	85	67
10	11	9	45	9
11	69	30	54	45
12	62	32	52	48
13	131	25	61	46
14	287	21	64	41
15	191	29	52	39
16	165	27	57	39
17	195	33	52	34
18	284	31	46	28
19	103	39	46	30
20	42	45	29	17
21	52	50	31	21
22	24	46	33	8
23	15	67	20	0
24	3	0	0	0
25	19	58	16	16

Table 23. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on both sections of the Madison River, 1987.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
7	7	25	63	63
8	6	17	67	67
9	11	9	82	64
10	11	9	45	9
11	30	13	63	53
12	41	20	71	59
13	117	21	64	49
14	248	19	66	37
15	165	28	47	35
16	139	28	57	39
17	119	43	39	23
18	209	35	38	24
19	55	45	38	24
20	22	36	27	14
21	25	44	24	24
22	8	50	18	13
23	15	59	20	0
24	3	0	0	0

Table 24. Percent of anglers catching 0, ≥ 0.5, and ≥ 1.0 trout per hour versus fishing temperature (C) on both sections of the Madison River, 1988.

		Percent with Catch Rate		
Temp.	Angler #	0.0	≥ 0.5	≥ 1.0
6	1	0	100	100
7	0	-	-	-
8	18	6	83	61
9	22	14	86	68
10	0	-	-	-
11	39	44	46	39
12	21	57	33	29
13	14	57	43	36
14	39	18	79	69
15	28	36	64	64
16	26	19	58	38
17	76	17	74	53
18	98	20	53	31
19	48	38	54	38
20	20	55	30	20
21	27	56	37	19
22	12	42	58	8
23	0	-	-	-
24	0	-	-	-
25	19	58	16	16

Table 25. Mean catch rate (trout/hour) versus fishing temperature (C) on the upper section of the Madison River, 1987.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
7	7	0.8	1.0	1.8	1.1
8	6	1.3	0.2	1.5	1.0
9	7	1.2	0.3	1.5	1.2
10	0	-	-	-	-
11	14	1.3	0.6	1.9	1.1
12	32	1.0	0.4	1.4	0.7
13	97	1.0	0.4	1.4	0.7
14	183	0.8	0.3	1.1	0.4
15	128	0.7	0.3	1.0	0.5
16	111	0.6	0.4	1.0	0.5
17	65	0.7	0.2	0.9	0.4
18	62	0.8	0.3	1.1	0.4
19	16	0.3	0.3	0.6	0.2

Table 26. Mean catch rate (trout/hr) versus fishing temperature (C) on the lower section of the Madison River, 1987.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
8	0	-	-	-	-
9	4	0.7	0.9	1.6	1.0
10	11	0.3	0.4	0.7	0.3
11	16	0.6	1.1	1.7	0.9
12	9	0.4	1.2	1.6	0.2
13	20	0.2	0.5	0.7	0.2
14	65	0.2	0.5	0.7	0.3
15	35	0.1	0.3	0.4	0.2
16	28	0.4	0.3	0.7	0.3
17	54	0.1	0.2	0.3	0.1
18	147	0.2	0.4	0.6	0.3
19	39	0.2	0.3	0.5	0.2
20	22	0.1	0.2	0.3	0.2
21	25	0.1	0.3	0.4	0.1
22	8	0.1	0.3	0.4	0.2
23	15	0.0	0.2	0.2	0.0
24	3	0.0	0.1	0.1	0.1

Table 27. Mean catch rate (trout/hour) versus fishing temperature (C) on the upper section of the Madison River, 1988.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
6	1	1.5	0.0	1.5	1.5
7	0	-	-	-	-
8	5	2.9	4.1	7.0	5.7
9	1	0.0	1.2	1.2	0.0
10	0	-	-	-	-
11	11	0.6	0.3	0.9	0.7
12	21	0.3	0.2	0.5	0.4
13	7	0.5	0.1	0.6	0.4
14	25	1.3	0.5	1.8	0.9
15	28	1.0	0.5	1.5	0.7
16	0	-	-	-	-
17	46	1.2	0.2	1.4	0.7
18	63	1.0	0.4	1.4	0.6
19	41	0.9	0.3	1.2	0.7
20	3	1.4	0.7	2.1	1.6
21	2	0.4	0.0	0.4	0.4

Table 28. Mean catch rate (trout/hour) versus fishing temperature (C) on the lower section of the Madison River, 1988.

		Catch Rate, All Trout			
Temp.	Angler #	Rb	Br	Comb.	≥ 30.5 cm
6	0	-	-	-	-
7	0	-	-	-	-
8	13	0.4	0.8	1.2	0.6
9	21	0.4	1.3	1.7	0.8
10	0	-	-	-	-
11	28	0.2	0.6	0.8	0.4
12	0	-	-	-	-
13	7	0.7	0.1	0.8	0.3
14	14	0.3	0.4	0.7	0.3
15	0	-	-	-	-
16	26	0.2	0.7	0.9	0.5
17	30	0.3	1.0	1.3	0.7
18	35	0.3	0.7	1.0	0.4
19	7	0.1	0.2	0.3	0.2
20	17	0.0	0.3	0.3	0.1
21	25	0.1	0.5	0.6	0.3
22	14	0.1	0.3	0.4	0.3
23	0	-	-	-	-
24	0	-	-	-	-
25	19	0.2	0.2	0.4	0.1

Table 29. Angler numbers and catch rates (trout/hour) for three different tackle types for each section and year on the Madison River, 1987 and 1988.

	Upper		Lower		Combined	
	Angler Num.	Catch Rate	Angler Num.	Catch Rate	Angler Num.	Catch Rate
1987						
Fly	678	1.1	163	0.9	841	1.1
Spin	50	1.4	215	0.5	265	0.6
Bait	*	*	123	0.4	123	0.4
Combined	728	1.1	541	0.6	1229	0.9
1988						
Fly	241	1.3	101	0.9	342	1.2
Spin	13	3.5	97	1.0	110	1.3
Bait	*	*	60	0.6	60	0.6
Combined	254	1.4	258	0.9	512	1.2
1987 & 1988						
Fly	919	1.1	264	0.9	1183	1.1
Spin	63	1.8	312	0.6	375	0.8
Bait	*	*	183	0.5	183	0.5
Combined	982	1.1	759	0.7	1741	0.9

* Fishing with bait was prohibited in the upper study section.

Table 30. Angler numbers and catch rates (trout/hour) for bank/wading and boat anglers by section and year on the Madison River, 1987 and 1988.

	Upper		Lower		Combined	
	Angler Num.	Catch Rate	Angler Num.	Catch Rate	Angler Num.	Catch Rate
1987						
Bank/wade	418	1.2	313	0.6	731	0.9
Boating	310*	1.0	188	0.6	498	0.9
Combined	728	1.1	501	0.6	1229	0.9
1988						
Bank/wade	138	1.3	171	0.8	309	1.0
Boat	116*	1.5	87	1.0	203	1.3
Combined	254	1.4	258	0.9	512	1.1
1987 & 1988						
Bank/wade	556	1.2	484	0.7	1040	0.9
Boat	426*	1.2	275	0.8	701	1.0
Combined	982	1.2	759	0.7	1741	0.9

* Fishing from a boat was permitted in only the lower half of the upper section.

Table 31. Angler numbers and catch rates (trout/hour) for guided and nonguided anglers by section and year on the Madison River, 1987 and 1988.

	Upper		Lower		Combined	
	Angler Num.	Catch Rate	Angler Num.	Catch Rate	Angler Num.	Catch Rate
1987						
Guided	251	1.0	22	0.8	273	1.0
Nonguided	477	1.2	479	0.6	956	0.9
Combined	728	1.1	501	0.6	1229	0.9
1988						
Guided	89	1.6	5	0.8	94	1.5
Nonguided	165	1.3	253	0.9	418	1.0
Combined	254	1.4	258	0.9	512	1.1
1987 & 1988						
Guide	340	1.1	27	0.7	367	1.1
Nonguided	642	1.2	732	0.8	1374	0.9
Combined	982	1.2	759	0.8	1741	0.9

Table 32. Angler numbers and catch rates (trout/hour) for residents and nonresidents by section and year on the Madison River.

	Upper		Lower		Combined	
	Angler Num.	Catch Rate	Angler Num.	Catch Rate	Angler Num.	Catch Rate
1987						
Resident	78	1.5	359	0.6	437	0.8
Nonresident	649	1.1	143	0.6	792	1.0
Combined	727	1.1	502	0.6	1229	0.9
1988						
Resident	29	1.0	234	0.9	263	0.9
Nonresident	225	1.4	24	0.7	249	1.4
Combined	254	1.4	258	0.9	512	1.1
1987 & 1988						
Resident	107	1.4	593	0.8	700	1.1
Nonresident	874	1.2	167	0.6	1041	0.8
Combined	981	1.2	760	0.8	1741	0.9

APPENDIX B

SAMPLE CREEL SURVEY FORMS

Madison River Creel Census, MSU-MDFWP, 1987

Study section _____ Surveyor _____

Date _____ Interview time _____ am ___ pm ____ (MDT)

Methods: (a) bank _____ wading _____ boat _____

(b) flies_____ lures _____ bait _____

Residence: Montana _____ Other (specify) _____

Time started fishing _____

Total trout landed _____ (Rb _____ Br _____)

No. released _____ No. kept _____

About what time(s) were fish biting best? _____

In terms of the rates at which you caught fish (as opposed to overall outdoor experience, etc.), how would you rate your fishing success today?

highly satisfactory ____ slightly unsatisfactory ____
moderately satisfactory ____ moderately unsatisfactory ____
slightly satisfactory ____ highly unsatisfactory ____

Estimated and measured lengths of fish landed

	Rainbows	Browns
angler-estimated lengths (inches) of released fish		
measured lengths of creeled fish		

Creel survey form used on the Madison River during 1987.

Madison River Creel Census, MSU-MDFWP, 1988

Study section _____ Surveyor _____

Date _____ Interview time _____ am ___ pm ____ (MDT)

Methods: (a) bank _____ wading _____ boat _____

(b) flies_____ lures _____ bait _____

Residence: Montana _____ Other (specify) _____

Time started fishing _____

Total trout landed _____ (Rb _____ Br _____)

No. released _____ No. kept _____

Was there any particular time when fish were biting best? _____

In terms of the rates at which you caught fish (as opposed to overall outdoor experience, etc.), how would you describe today's fishing?

___ very fast, couldn't be better
___ fast
___ not fast, but okay
___ slow
___ very slow
___ terrible, extremely slow

Estimated and measured lengths of fish landed

	Rainbows	Browns
angler-estimated lengths (inches) of released fish		
measured lengths of creeled fish		

Creel survey form used on the Madison River during 1988.

APPENDIX C

NEWSPAPER ARTICLES RELATING TO THERMAL FISH KILL

Fish kill

Record hot water in Madison River deadly

By ERIC WILTSE
Chronicle Staff Writer

More than 2,000 fish were killed by record hot water in the lower Madison River between Friday and Monday, a state fisheries biologist said today.

The fish kill was the first one attributable to thermal pollution on the popular fishing and floating river, added Dick Vincent, a Montana Department of Fish, Wildlife and Parks biologist.

"It's something we've expected all along," Vincent said. "It's not an extremely large fish kill but it's disturbing."

Up to Monday, water temperatures went above 80 degrees on six days, he said. On Friday, the water stayed over 80 degrees for more than seven hours.

"That's a record," he said. Water temperatures had never stayed at 80 degrees for more than one hour in 16 years of monitoring, he said, "so you can see how extreme it was."

On Friday, the water stayed over 80 degrees for more than seven hours. In 16 years of monitoring it had never stayed at 80 degrees for more than one hour.

The fish killed started Friday night or Saturday morning when the water temperature reached a record 82.5 degrees. Downstream from the temperature gauge at the Norris Bridge, the water temperature probably got up above 83 degrees, which is lethal to trout, Vincent said.

He found dead fish from along Highway 84 about four miles below Norris Bridge to the Cobblestone Fishing Access, more than 10 miles downstream. It's difficult to determine the extent of the kill because dead fish float, he said.

About 90 percent of the dead fish were whitefish, he said, while all the trout he found were browns, including a 3-pounder. His "conservative" estimate is about 2,000 fish killed in all.

"It's the first time I'm reasonably certain it's a thermal kill," he said. "I can't trace any other cause for it."

There have been fish kills before in the lower Madison, he said, but they might have been caused by other factors.

One indication of a thermal kill was that no suckers, which can withstand higher temperatures, were found dead. "If suckers were dead, I would say it was a pollutant," Vincent explained.

Whitefish, of which there are 12,000 per mile in the lower Madison, are more susceptible to heat stress than trout, Vincent said.

There are 2,500 trout per mile, of which 60 percent are rainbows. At water temperatures of 83 degrees, the weakest trout start to die, and at 84 degrees, "it gets everybody," he said.

See FISH KILL, page 8

Fish kill/ *from page 1*

Ennis Lake, about 10 miles upstream from the fish kill, causes thermal pollution in the Madison River downstream. The shallow lake acts as a solar collector, heating up the water before it discharges into the Bear Trap Canyon.

Water flowing into Ennis Lake from the upper Madison River probably was 4-5 degrees cooler than the outflow when the fish kill occurred, Vincent said.

Montana Power Co., which owns Ennis Dam, was releasing 1,100 cubic feet per second from the reservoir. The FWP considers that an adequate flow to maintain trout in the lower Madison. Although higher flows might keep water cooler in the river, low snowpack and runoff this year means "there's no more water to be had," he said.

"I wouldn't anticipate higher flows the rest of the summer."

Vincent said he is concerned that a fish kill and record hot water in June is "a bad omen" for the rest of the summer. Normally, the hottest period in the lower Madison River is July 15 to Aug. 15, he said.

"We're really not certain what's in store for the rest of the summer," he said. "We're not going to get more water unless the weather changes. The only other help we can get is if we don't get more hot weather."

However, he noted that forecasts for this weekend call for 90-degree days.

For the last two years, water temperatures never reached 80 degrees in the lower Madison, he said. "Most years, you don't hit 80. If you hit it once in a whole year, it's a big deal, and we had six days in a row," he said.

Fishermen over the weekend reported seeing whitefish turning on their side and swimming upside down, he said. By Monday, anglers reported dead fish floating in the river.

"Unless the weather turns around, I'd expect more of these occurring," he said.

Bozeman Daily Chronicle. Vol. 77 (156). Wednesday, June 29, 1988.

No easy solutions to fish kill

By ERIC WILTSE
Chronicle Staff Writer

There are no immediate solutions to thermal pollution on the lower Madison River that killed thousands of fish this week and long-term answers would cost millions, say local experts.

"It's pretty much out of our hands," said Dick Vincent, a fisheries biologist for the Montana Department of Fish, Wildlife and Parks. "There are no short-term solutions."

At least 2,000 whitefish and trout died between Friday and Monday on about 10 miles of the Madison River between Norris Bridge and the Cobblestone fishing access. Ninety percent were whitefish and the rest brown trout, including a 3-pounder.

"People will not be upset over whitefish," Vincent noted, but they do get mad when trout are killed.

"It makes me upset to see a fish kill occur and I got plenty of calls about it," he said.

A study released in 1984 said that water temperatures in the lower Madison would reach killing high levels just once every 100 years.

That year apparently has arrived. Vincent said this was the first fish kill in the lower Madison that he is attributing to thermal pollution.

The 1984 study was too optimistic about the thermal situation, he said, adding that the report's "predictions were not as bad as reality."

"This summer will give us a pretty good idea of how bad it can get," he said.

The Lower Madison River Thermal Study found that shallow Ennis Lake increases water temperatures in the river for 10-15 miles downstream by 4-5 degrees.

The report said that building a dike system could divert cool river water around the lake and to the river below the Montana Power Co. dam and powerhouse there. But the $11 million pricetag on the dike could not be economically justified, the report said.

Bozeman consultant Joel Shouse, who worked on the thermal study, said Thursday that it would be speculation to blame Ennis Dam for the fish kill.

The study found that the effects of thermal pollution from Ennis Lake last for just 10-15 miles below the dam, he said, and the fish kill happened downstream from there.

According to the study, the wide, shallow river 15 miles downstream from Ennis Lake to Three Forks may have always had thermal problems even before the dam was built.

"The study's conclusion was something like this could happen ... with the right set of temperature conditions," Shouse said. "I can't say (the fish kill) is anything more than a function of the weather and low flow."

He said he doubts that the fish kill will revive interest in pursuing construction of a dike around Ennis Lake.

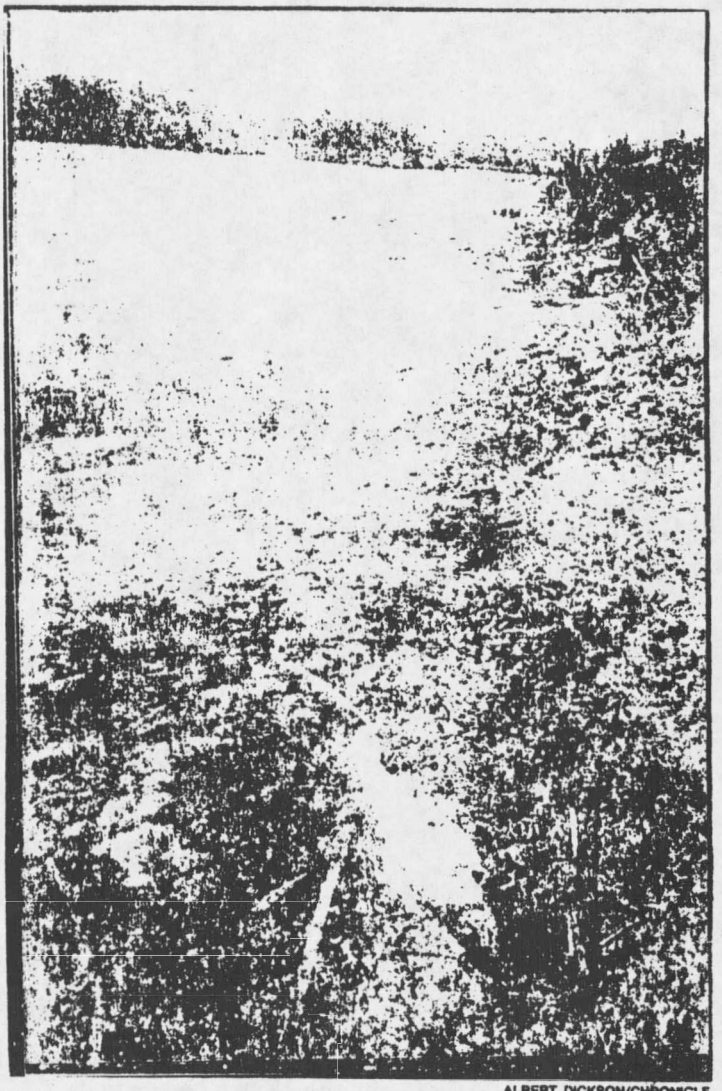
"In these times of short money ... it will be difficult to come up with the dollars to go there and do something," Shouse said.

FWP official Fred Nelson said, "the solution is obviously there has to be something done with Ennis Reservoir." But, Nelson added, "that's not as easy as it sounds."

The lake benefits waterfowl, bald eagles and other wildlife, he said. And if Montana Power Co. abandoned its dam there and drained the lake, there would still be a problem with sediment, he said.

Any solution would be expensive and require federal aid, which is becoming

See FISH, page 10



ALBERT DICKSON/CHRONICLE

A dead trout lies along the banks of the Madison River at the Greycliff fishing access. Thermal pollution killed more than 2,000 whitefish and trout last weekend along 10 miles of the river.

Bozeman Daily Chronicle. Vol. 77 (158). Friday, July 1, 1988.

Fish/ *from page 1*

scarce, Nelson said.

"With the temperatures we're getting, a couple more years like this and we'll get more fish kills," he said. "Maybe the bad publicity will generate pressure to do something."

Dave Corcoran of The River's Edge said his outfitting business takes at least 100 clients a year to the lower Madison, accounting for more than $20,000 in guide fees alone. Add on the costs of airplane tickets, motel and car rentals, meals and souvenirs, and the value of the lower Madison to Bozeman increases, he said.

"It's a very important dimension to our operation here in Bozeman," Corcoran said, mainly as a spring and fall fishery. When the water warms up in summer, fishing falls off, he said.

"The thermal problem we've known about for years, but when we actually see the effects, the reality, it really concerns us," he said.

Unless the weather turns cooler, more fish kills could happen in July and August, normally the hottest months of the year, Vincent said.

The FWP will electroshock the lower Madison next spring, but may do some spot checks this fall to check the condition of trout, he said.

"It's a nice trout fishery in spring and late fall and I'd hate to lose it," he said.

Bozeman Daily Chronicle. Vol. 77 (158). Friday, July 1, 1988 (Continued).

Heat and irrigation kill fish

Jefferson River trout left high and dry; heat kills Madison browns

By JOAN HAINES
Chronicle Staff Writer
And the Associated Press

Two miles of the Jefferson River south of Silver Star went dry Friday, killing trout there, although some trout are still alive in isolated pools, according to a Fish, Wildlife and Parks biologist.

Fish also were dying Friday in the lower Madison River because of extremely low water combined with high temperatures. Montana Power Company is attempting to come to the fishes' rescue by releasing dam water, an official said Friday.

Brad Shepard of Twin Bridges, a biologist with Fish, Wildlife and Parks who viewed the river today, said he didn't know how many trout had been killed because, once they die, they are rapidly eaten by birds.

"The trout in the pools are most likely to die because of high temparatures and low oxygen," Shepard said.

Fish kills also have been reported in low water along a 30-mile stretch of the Jefferson River between Whitehall and Twin Bridges, Fred Nelson of Bozmean, a FWP employee, said Friday.

The Montana Fish and Game Commision Friday tightened its brown trout creel limits on the Jefferson, reducing from five to two the number of fish that can be kept. Anglers can still keep only one fish longer than 18 inches. The rainbow trout rules of catch-and-release only remain in effect.

"I've seen about a dozen dead whitefish and suckers, but no trout," said Dale Nicholls, who runs Nicholls General Store at Silver Star.

High irrigation demands and low rainfall have combined to deplete the Jefferson, officials said.

"The irrigators have the right to dry up the river and they're exercising that right," Nelson said.

"The farmers are in bad financial shape and they've got a crop out there. It's a difficult situation where the irrigation demands exceed supply.

Nelson called the situation "horrible." "Just think of what's going to happen in August if we don't have any rain," he said.

At Three Forks, where the Jefferson joins the Madison and Gallatin rivers to form the Missouri, the Jefferson's stream flow is the lowest ever recorded for July.

In the lower Madison River a few whitefish and trout were dying because of higher water temperatures.

The fish were seen dying in the lower Madison between the Norris Bridge and Greycliff, according to Montana Power spokesman Cort Freeman.

Montana Power is releasing water from the Madison Dam this weekend in hopes of lowering the river's temperature. "If we can lower the water temperature two to three degrees, it will help the fish survive these extreme heat spells," Freeman said.

Power company officials also are releasing water from the Hebgen reservoir, which will make the upper Madison waters higher, too, he said.

Bozeman Daily Chronicle. Vol. 77 (177). Sunday, July 24, 1988.

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