Effects of elevated summer water temperatures below Ennis Reservoir on the macroinvertebrates of the Madison River, Montana
by John Joseph Fraley

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University

Abstract:
The effects of Ennis Reservoir on the chemistry, thermal regime and aquatic macroinvertebrates of the Madison River were studied during 1976 and 1977. Only small differences in pH, total alkalinity, hardness, conductivity, dissolved oxygen, turbidity, ammonia, nitrate, nitrite, orthophosphate and total phbsphorus were measured at the five stations. Mean water temperatures from June through August, 1977 at stations below the reservoir averaged 3.5 C higher than at stations above the reservoir. Water temperatures were above 17 C at least 31% more of the time at stations below the reservoir. Diurnal temperature fluctuations immediately below the reservoir were reduced by more than 80%. A total of 56 taxa of aquatic macroinvertebrates were collected on artificial substrate samplers. Of these four occurred only at stations above the reservoir, 14 were found only at stations below the reservoir and 38 were taken both above and below. The average number of taxa per sampler was significantly lower at the station immediately below the reservoir than at all other stations ($p<.01$). The average total numbers collected at stations below the reservoir were significantly greater than at stations above ($p<.01$). A greater composition of Trichoptera and a lower composition of Plecoptera were found on artificial substrates immediately below the reservoir. Cold water preference taxa and eurythermal taxa dominated invertebrate numbers on artificial substrates at stations above the reservoir. Warm water preference taxa and eurythermal taxa were numerically dominant at stations below. Total oven dried weights of invertebrates on artificial substrate samplers averaged about 100% higher at stations below the reservoir than at stations above. A total of 54 taxa were collected in bottom samples. Of these four were taken only in the river above the reservoir, 15 were found only below the reservoir and 35 were collected in both sections. The average number of taxa per bottom sampler was significantly lower ($p<.01$) at the station immediately below the reservoir than at all other stations. The numerical composition of Trichoptera was larger and Plecoptera smaller immediately below the reservoir than at all other stations. Cold water and eurythermal preference taxa numerically dominated the invertebrate fauna at stations above the reservoir. Warm water and eurythermal forms dominated the fauna below. Biotic index values indicated stress on macroinvertebrate communities at stations below the reservoir. Coefficients of similarity indicated distinct invertebrate communities at stations above the reservoir, immediately below the reservoir and at stations further downstream. Some species of adult aquatic insects appeared two weeks to one month earlier at stations below the reservoir than at stations above. Pteronaroys oalifomica did not emerge, in the 4 km of the river below Ennis Reservoir where thermal constancy existed.

STATEMENT OF PERMISSION TO COPY

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

Signature John J. Fraley

Date 12-7-78

EFFECTS OF ELEVATED SUMMER WATER TEMPERATURES BELOW ENNIS RESERVOIR ON THE MACROINVERTEBRATES OF THE MADISON RIVER, MONTANA

by

JOHN JOSEPH FRALEY

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

of

MASTER OF SCIENCE

in

Fish and Wildlife Management

Approved:

William R. Gould
Chairperson, Graduate Committee

George Ruemhild
Head, Major Department

Henry L Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

December, 1978

ACKNOWLEDGMENT

The author wishes to express appreciation to those who assisted him during the study. Dr. William R. Gould directed the study and assisted in preparation of the manuscript. Drs. George R. Roemhild and John C. Wright critically reviewed the manuscript. Dr. Wright provided laboratory equipment for chemical analyses. Dr. Roemhild confirmed the identifications of selected aquatic invertebrates. Dalton Burkhalter assisted in statistical analyses, Richard Oswald provided identifications of the Chironomidae and Steve Whalen aided in chemical analyses.

Thanks are extended to my parents for their moral and financial support during my college years.

This study was funded by the Montana Cooperative Fishery Research Unit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The effects of Ennis Reservoir on the chemistry, thermal regime and aquatic macroinvertebrates of the Madison River were studied during 1976 and 1977. Only small differences in pH, total alkalinity, hardness, conductivity, dissolved oxygen, turbidity, ammonia, nitrate, nitrite, orthophosphate and total phosphorus were measured at the five stations. Mean water temperatures from June through August, 1977 at stations below the reservoir averaged 3.5 C higher than at stations above the reservoir. Water temperatures were above 17 C at least 31% more of the time at stations below the reservoir. Diurnal temperature fluctuations immediately below the reservoir were reduced by more than 80%. A total of 56 taxa of aquatic macroinvertebrates were collected on artificial substrate samplers. Of these four occurred only at stations above the reservoir, 14 were found only at stations below the reservoir and 38 were taken both above and below. The average number of taxa per sampler was significantly lower at the station immediately below the reservoir than at all other stations ($p<.01$). The average total numbers collected at stations below the reservoir were significantly greater than at stations above ($p<.01$). A greater composition of Trichoptera and a lower composition of Plecoptera were found on artificial substrates immediately below the reservoir. Cold water preference taxa and eurythermal taxa dominated invertebrate numbers on artificial substrates at stations above the reservoir. Warm water preference taxa and eurythermal taxa were numerically dominant at stations below. Total oven dried weights of invertebrates on artificial substrate samplers averaged about 100% higher at stations below the reservoir than at stations above. A total of 54 taxa were collected in bottom samples. Of these four were taken only in the river above the reservoir, 15 were found only below the reservoir and 35 were collected in both sections. The average number of taxa per bottom sampler was significantly lower ($p<.01$) at the station immediately below the reservoir than at all other stations. The numerical composition of Trichoptera was larger and Plecoptera smaller immediately below the reservoir than at all other stations. Cold water and eurythermal preference taxa numerically dominated the invertebrate fauna at stations above the reservoir. Warm water and eurythermal forms dominated the fauna below. Biotic index values indicated stress on macroinvertebrate communities at stations below the reservoir. Coefficients of similarity indicated distinct invertebrate communities at stations above the reservoir, immediately below the reservoir and at stations further downstream. Some species of adult aquatic insects appeared two weeks to one month earlier at stations below the reservoir than at stations above. *Pteronarcys californica* did not emerge in the 4 km of the river below Ennis Reservoir where thermal constancy existed.

INTRODUCTION

The Madison River is one of Montana's important trout streams. It contains 116 km of the 727 km of blue ribbon trout water in Montana (Brown 1965). In 1967 the river supported an estimated 124,298 hours of fisherman use and yielded 89,767 trout (Vincent 1969).

Shortly after 1900 the Madison River was impounded to form Ennis Reservoir. Water from the reservoir is used to produce power at the Madison Power Plant located immediately below Ennis dam.

Ennis Reservoir raises summer temperatures in the Madison River below it. Early morning temperatures in July and August, 1950-51 (U.S.F.W.S. 1954) averaged 4 C higher in the river below the reservoir (lower river) than in the river above the reservoir (upper river). Heaton (1961) reported daily minimum temperatures in the lower Madison River during July and August averaged about 4 C higher than in the upper river. The maximum temperatures he recorded were 24 C in the upper river and 27 C in the lower river. Vincent (1977) monitored temperatures in the Madison River from 1972 through 1976 and found Ennis Reservoir elevated the mean July and August temperature of the lower river 4 C. Maximum temperatures during these years were 22 C in the upper river and 27 C in the lower river.

Recent studies (Vincent 1977) have shown rainbow and brown trout 27 cm or more in total length had slower growth rates in the lower

river than in the upper river. Conversely, rainbow and brown trout less than 27 cm grew faster in the lower river. The reason for these differences in growth rates were not clearly understood, but the effects of high summer water temperatures on the trout's metabolism or food supply have been cited as possible causes.

The primary purpose of this study was to evaluate the effects of Ennis Reservoir on the chemical and thermal regimes and the aquatic macroinvertebrate communties of the lower Madison River. The secondary purpose was to determine if the macroinvertebrate food supply was responsible for the observed differences in growth rates of trout in the upper and lower river. Fieldwork was conducted from July, 1976 through October, 1977.

DESCRIPTION OF THE STUDY AREA

The Madison River arises in northwestern Yellowstone National Park, Wyoming, and flows through Madison and Gallatin Counties in southwestern Montana. It is formed by the confluence of the Gibbon and Firehole Rivers in Yellowstone National Park at an elevation of 2074 meters. The river flows approximately 220 kilometers northward across broad valleys and joins the Jefferson and Gallatin Rivers to form the Missouri River near Three Forks, Montana. The elevation is about 1235 m at the river's mouth. The river passes through Hebgen Reservoir, Quake Lake and Ennis Reservoir, which are 33, 61, and 151 km below its headwaters, respectively.

The Madison River drains a total land area of 6480 km^2. Approximately two-thirds of the drainage area in Montana is in national forest lands. Major land uses in the Madison basin are livestock grazing, wheat farming and recreation (U.S.F.W.S. 1954).

The study area was located on the lower 90 km of the river. It extended from the Varney Bridge, 22 km upstream from Ennis Reservoir, to the U.S. Highway 10 Bridge, 56 km downstream from Ennis Reservoir. Five stations were established on the study area (Fig. 1). Stations 1 and 2 were located above Ennis Reservoir. In this area the river flows through the wide upper Madison Valley. Riparian vegetation at these stations consisted of cottonwood (*Populus*), willow (*Salix*), alder (*Alnus*), rose (*Rosa*) and grasses (*Gramineae*). Here the river

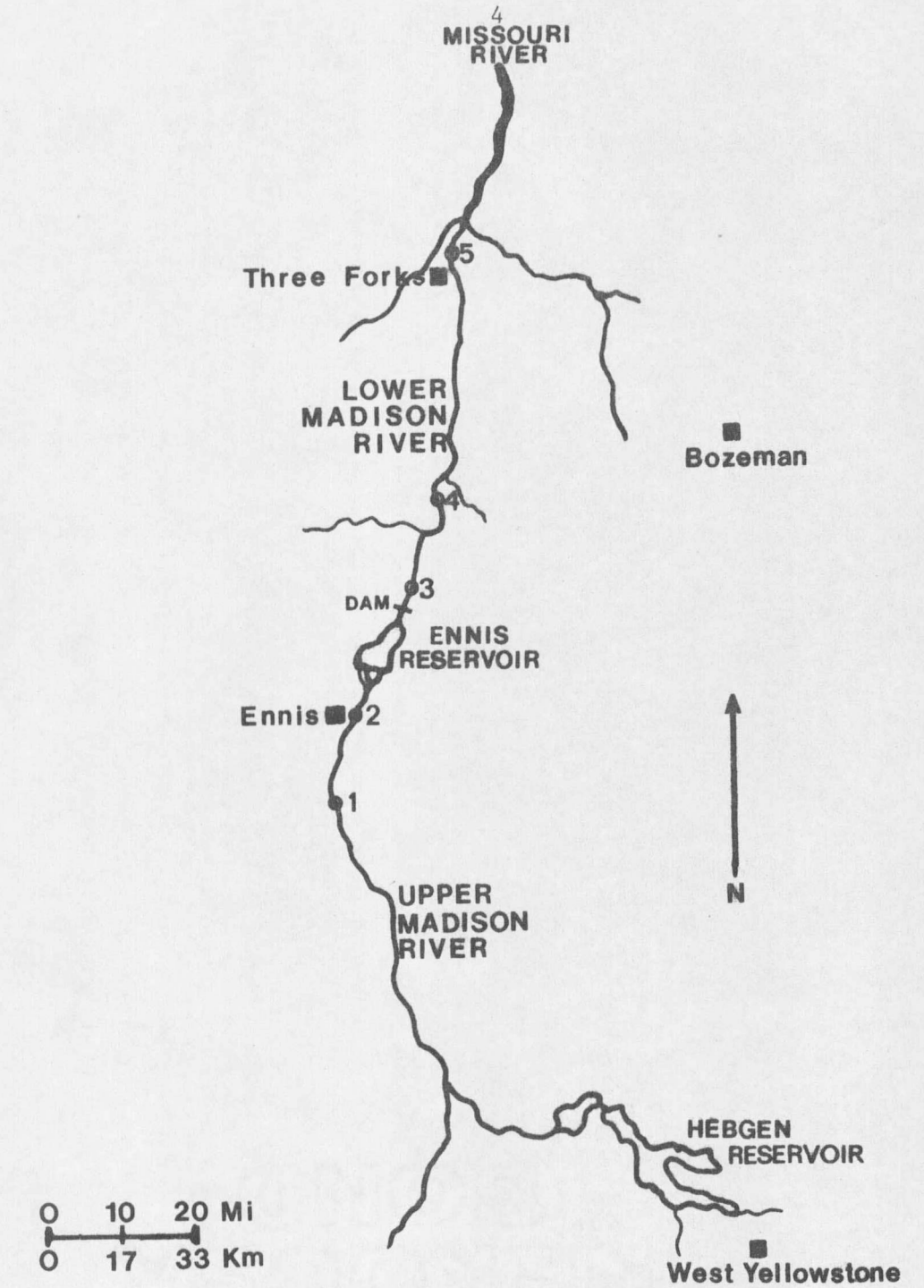

Figure 1. Map of the study area. Numbers indicate the location of the sampling stations.

averaged about 60 m wide and was composed mostly of riffles and rapids with few large pools. The substrate consisted of large cobble and boulders interspersed with small cobble, gravel and sand. *Cladophora* occurred sparesely on the substrate. The average gradient of the river in this area was 5.7 m per km. Station 1 was located 100 m below the Varney Bridge, 22 km above Ennis Reservoir. Its approximate elevation was 1585 m. Station 2 was located 150 m below the U.S. Highway Bridge at Ennis, Montana, 7 km above Ennis Reservoir. Its elevation was about 1505 m.

Ennis Reservoir is located between Stations 2 and 3 and lies 7 km north of Ennis, Montana. It has a surface area of 1530 hectares (U.S.F.W.S. 1954). It is wide and shallow, especially in the southern end and is approximately 8 km long.

Three stations were established below Ennis Reservoir. Station 3 was located approximately 3 km below Ennis Reservoir and 0.5 km below the Madison Power Plant. Its approximate elevation was 1430 m. In this area the river flowed through the Beartrap Canyon in which steep cliffs and rockslides commonly extend to the river's edge. Riparian vegetation consisted primarily of conifers and shrubs. Substrate in this area consisted primarily of boulders with interspersed cobble, gravel and sand. It supported a heavy growth of algae which was mainly *Cladophora*. The average gradient in the 20 km long Beartrap Canyon was 6.5 m/km.

Stations 4 and 5 were located in the lower Madison Valley. Riparian vegetation was composed of cottonwood, grasses and shrubs. The river in the lower valley averaged about 90 m wide and was characterized by riffles and rapids, with some large pools. *Cladophora* and *Myriophyllum* grew in relatively heavy densities in this area during the summer. The average gradient of this 39 km portion of the river was 3 m/km. Station 4 was located 150 m below the Norris Bridge, 20 km downstream from Ennis Reservoir. Its approximate elevation was 1355 m. The substrate there consisted of large cobble and boulders, with interspersed small cobble, gravel and sand. Station 5 was located 150 m below the U.S. Highway Bridge near Three Forks, Montana. It was situated 56 km downstream from Ennis Reservoir and 3 km above the headwaters of the Missouri River. Its elevation was 1240 m and its substrate was composed of small rubble and gravel, with interspersed sand and silt.

The flow of the Madison River is regulated by Hebgen and Ennis Reservoirs and is relatively stable compared to unregulated streams of similar size. Ennis Reservoir is maintained at a nearly constant level so the inflow and outflow at the reservoir are similar. Mean, minimum and maximum flow of the river at Ennis Reservoir for a 38 year period of record ending in 1976 were 50 m^3/sec(1766 ft^3/sec), 6 m^3/sec(210 ft^3/sec) and 270 m^3/sec(9550 ft^3/sec), respectively (U.S.G.S. 1976). Flows during the study period were below normal.

The mean, minimum and maximum flows were 46.9 m^3/sec(1656 ft^3/sec), 21.2 m^3/sec(749 ft^3/sec) and 86.8 m^3/sec(3068 ft^3/sec), respectively (Madison Power Plant unpublished data). Mean monthly flows from May, 1976 through October, 1977 appear in Fig. 2.

Trail, Moore, Cedar, O'Dell and Jack Creeks are tributaries to the upper Madison River. Tributaries to the lower river are Beartrap, Warm Springs, Cherry and Elk Creeks.