



Factors affecting the distribution and abundance of aquatic macrophytes in parts of the Madison, Firehole and Gibbon rivers
by Abraham Andrew Horpestad

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Botany
Montana State University
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Abstract:

A study was made during the summer of 1966 of the floral distribution and of some physical and chemical factors which may have been responsible for this distribution in parts of the Madison River and its tributary streams, the Firehole and Gibbon Rivers, Yellowstone National Park, Wyoming.

Five transects were run across each of eleven stations, two on the Firehole, one on the Gibbon, and eight on the Madison River. Physical factors and taxa present at one meter intervals were determined. Some chemical factors were determined at three hour intervals for a 24 hour period on each of the 10 weeks of the study period.

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of

MASTER OF SCIENCE

in

Botany

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August, 1969

ACKNOWLEDGMENTS

The author expresses his appreciation and gratitude to Dr. John C. Wright for his guidance and constructive criticism throughout the course of this study.

Gratitude is extended to Charles E. Bair, Bernard L. Fisher and Frank J. Pickett for their assistance during the summer of 1966. Thanks are also given to Dr. William E. Booth for his identification of some of the plants collected.

Thanks are due to the officials of the National Park Service in Yellowstone National Park for their cooperation and support. The assistance of the Yellowstone Park Company in providing quarters and laboratory space is hereby acknowledged.

This research was supported with funds from Public Health Service Research Grant WP-00125 and Training Grant 5T1-WP-1 from the division of Water Supply and Pollution Control.

The author thanks his wife for her patience, understanding and encouragement during the course of this study.

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ABSTRACT

A study was made during the summer of 1966 of the floral distribution and of some physical and chemical factors which may have been responsible for this distribution in parts of the Madison River and its tributary streams, the Firehole and Gibbon Rivers, Yellowstone National Park, Wyoming.

Five transects were run across each of eleven stations, two on the Firehole, one on the Gibbon, and eight on the Madison River. Physical factors and taxa present at one meter intervals were determined. Some chemical factors were determined at three hour intervals for a 24 hour period on each of the 10 weeks of the study period.

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INTRODUCTION

The growing scarcity of water has in recent years caused an increased interest in the productivity of streams, the organisms involved, and the factors affecting these organisms. The macrophytic communities of streams have been largely overlooked in spite of this increased interest.

The effects of the substrate on the growth of aquatic plants has been pointed out by several workers including Pond (1903), Pearsall (1920), Misra (1938), and Curtis (1959). Current speed has been mentioned as the most important factor affecting the distribution of aquatic macrophytes in the English rivers by Butcher (1933). The effects of interspecific competition on the aquatic community has been discussed by Misra (1938) and Bourn (1937) among others. The study of Wright and Mills (1967) indicated the possibility that the downstream decrease in macrophyte standing crop in the Madison River was related to the downstream decrease in the concentration of free carbon dioxide as they could detect no appreciable changes in the other chemical parameters.

This study is an attempt to determine how various physical and chemical factors and interspecific competition affected the distribution of aquatic macrophytes in part of the Madison River system.

Description of the Study Area

Eleven sampling stations were established on the Madison River and its headwater streams, the Firehole and Gibbon Rivers. These streams are located in the west-central part of Yellowstone National Park in north-

western Wyoming and adjacent areas of Montana and Idaho (Figure 1).

The Firehole River originates from Madison Lake at an elevation of 2,500 m (8,209 ft) MSL and flows 34.6 km (21.5 miles) before joining with the Gibbon River to form the Madison River. The bedrock throughout these 34.6 km is composed of a Pleistocene plateau flow of rhyolite (Boyd 1961). The Firehole receives the discharge of many geysers and hot springs. The total amount of thermal water entering the river has been estimated at $1.55 \text{ m}^3/\text{sec}$ ($54.92 \text{ ft}^3/\text{sec}$) by Allen and Day (1935).

Two sampling stations were established on the Firehole River: the upper station (1) was located 3.22 km (2 miles) above the confluence of the Firehole and Gibbon Rivers. This is below all discernible thermal discharges and just above the Firehole Canyon. The other sampling station (2) was located 0.8 km (0.5 miles) above the confluence of the Firehole and Gibbon Rivers.

The Gibbon River originates from Grebe Lake at an elevation of 2,338.6 m (8,028 ft) MSL in an area of Pliocene rhyolite tuff and Quaternary alluvial deposits. It flows approximately 45 km (27.9 miles) before joining the Firehole River. In the lower reaches of the river the parent materials are rhyolite on the south and welded rhyolite tuff on the north (Boyd 1961). The total discharge of thermal water flowing into the Gibbon River has been estimated at $0.19 \text{ m}^3/\text{sec}$ ($6.85 \text{ ft}^3/\text{sec}$) by Allen and Day (1935).

The sampling station (3) on the Gibbon River was located 91 m (300 ft) above the confluence of the Gibbon and Firehole Rivers.

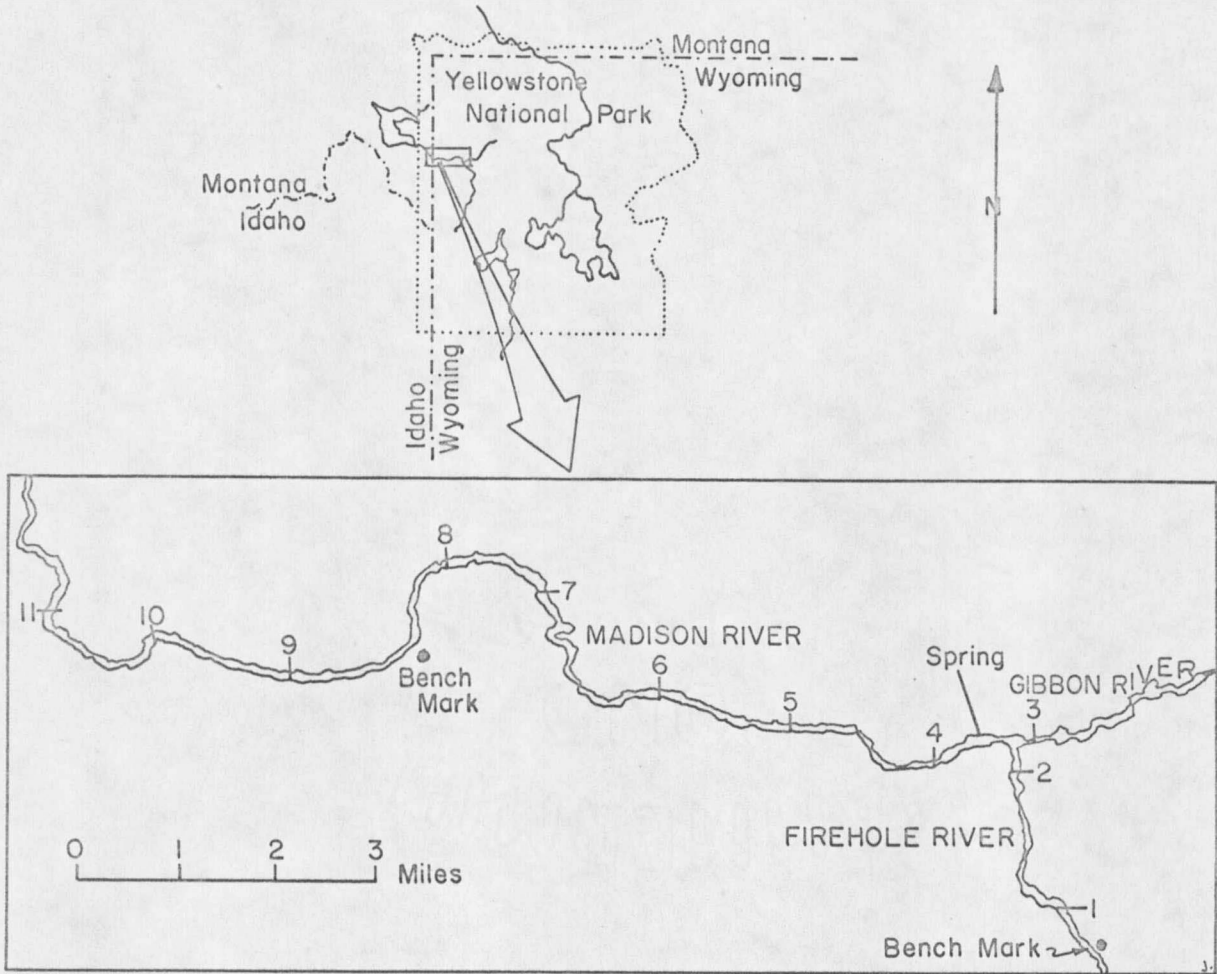


Figure 1: Map of study area

The upper 10 km (6.2 miles) of the Madison River are in a canyon formed of cliffs and hills of welded tuff on the north and more rugged cliffs of rhyolite on the south. Below the canyon the river flows through an area of decomposed rhyolite and tuff (Boyd 1961).

Eight stations (4-11) were established on the Madison River. Station 4 was located 1.89 km (1.18 miles) below the confluence of the Firehole and Gibbon Rivers. About 0.8 km (0.5 miles) above this station is an area where thermal discharges occur both on shore and in the stream channel (Figure 1).

Station 5 was located 5.18 km (3.22 miles) below the river's source and about 0.8 km (0.5 miles) below a small unnamed creek which flows into the river from the south.

Station 6 was located 7.76 km (4.82 miles) below the river's source.

Station 7 was located 11.02 km (6.85 miles) below the river's source.

Station 8 was located 12.95 km (8.05 miles) below the river's source near the lower end of a large, deep pool.

Station 9 was located 16.15 km (10.04 miles) below the river's source.

Station 10 was located 18.89 km (11.74 miles) below the river's source.

Station 11 was located 21.24 km (13.20 miles) below the river's source.

This sampling area is near the lower end of a long riffle which extends nearly to station 8.

The chemical composition of the water in these rivers is directly related to the sodium and potassium aluminosilicates which comprise the rhyolite bedrock of this region. The decomposition of this type of rock is intensi-

fied by the thermal waters present which tend to leach out the sodium and potassium. The rate of solubilization of the potassium is lower than for sodium, and other processes tend to return it to the solid phase (Boyd 1961). These thermal waters are also enriched in chloride, fluoride, carbon dioxide, bicarbonate and boron by magmatic gases (Allen and Day 1935).

Due to the composition of the bedrock and the thermal enrichment, these rivers can be classified as sodium-bicarbonate-chloride waters (Wright and Mills 1967).

The discharge rate of the Madison River measured between stations 10 and 11 has averaged $13.35 \text{ m}^3/\text{sec}$ ($477 \text{ ft}^3/\text{sec}$) for the fifty-one years of record (1915-1966). The average yearly fluctuation in rate is from $8.5 \text{ m}^3/\text{sec}$ ($300 \text{ ft}^3/\text{sec}$) in the winter to $43.9 \text{ m}^3/\text{sec}$ ($1550 \text{ ft}^3/\text{sec}$) in the spring. Throughout the study (6 June - 8 September, 1966) the rate of discharge averaged $13.58 \text{ m}^3/\text{sec}$ ($485.3 \text{ ft}^3/\text{sec}$) and ranged from $14.98 \text{ m}^3/\text{sec}$ ($535 \text{ ft}^3/\text{sec}$) to $10.1 \text{ m}^3/\text{sec}$ ($360 \text{ ft}^3/\text{sec}$) (U. S. Geological Survey 1966).

Methods

Water Chemistry

Water samples were collected at weekly intervals from July 6, through September 7, 1966. Surface samples were taken near the center of the river at each of the eleven stations. On each sampling date collections were made at 1500 hours. All samples were collected in one liter polypropylene plastic screw cap bottles which were rinsed with water from the sampling point before being filled.

Immediately after returning to the field laboratory, samples were analyzed for pH, total alkalinity and electrical conductivity. A Beckman Model 76 Expanded Scale pH meter was used to determine pH. Total alkalinity of each sample was determined titrimetrically according to the procedures given in Standard Methods for the Examination of Water and Waste Water, 11th Edition (1960). The electrical resistance of each water sample was determined using a Yellow Springs Instrument Co. Model 31 conductivity bridge and an Industrial Instruments Model CEL 4 dipping cell. The specific conductance at 25°C of all water samples collected on all sampling dates was computed from the observed resistance, temperature and cell constant.

Concentration of free carbon dioxide was calculated for all samples by converting the milliequivalents per liter total alkalinity to parts per million alkalinity as HCO_3^- and using the formula derived by Rainwater and Thatcher (1960):

$$\text{ppm CO}_2 = 1.589 \times 10^6 \text{ H}^+ \times \text{ppm alkalinity as HCO}_3^-$$

Concentrations of total carbon were calculated for all samples using the method of Saunders, Trama and Bachman (1962).

Temperature

The temperature of the river water at each station was measured with a standard laboratory thermometer at 0600 hours on all sampling dates.

Elevations and Gradients

The elevation at each station and at two points on the river above the uppermost stations (Figure 1) were determined using a Short and Mason Sur-

veying Aneroid Compensated Barometer (No. A 19360). Two local bench marks were used as controls (Figure 1).

The gradient at each station was computed as follows:

$$G = \frac{E_u - E_d}{D}$$

Where G = gradient,

E_u = the elevation at the nearest upstream station,

E_d = the elevation at the station for which the gradient is being determined,

D = the river distance between two stations.

Plant Canopy Cover and Substrate Texture

A water telescope was constructed by replacing the bottom of a plastic water pitcher with transparent plastic and installing two sets of cross hairs. This device was used to determine the presence or absence of plants contacting a vertical line from the water's surface to the bottom of the river. (Hereafter these line intercepts shall be referred to as points).

Five transects were established within 100 meters of each station. An attempt was made to have these transects include both fast and slow water. At each transect a line marked at one meter intervals was strung across the river. No attempt was made to place the first mark on the line in any particular relationship to the bank.

The water telescope was placed under a mark on the line. The point under the cross hairs, when they first lined up, was used in an attempt to avoid bias in the selection of the point. After the species present were recorded the texture of the substrate adjacent to the point was also record-

ed. The substrate texture was coded from 1 to 4, with 1 being rocky (over 2 centimeters in diameter), 2 being gravel (0.2 to 2 centimeters in diameter), 3 being sand (0.0625 to 2 millimeters in diameter), and 4 being silt (less than 0.0625 millimeters in diameter).

Depth and Current Speed

The current speed was determined at each point 15 cm (0.5 feet) above the bottom (or above any plants present) using a rod supported Gurley Current Meter (No. 622) and its rating table. The depth at each point was then determined and recorded using graduated marks 3.1 cm (0.1 feet) apart on the rod supporting the velocity meter.

These methods made possible the computation of mean depth, current speed, substrate texture, and the per cent of the ground covered by each taxon under each of 55 transects.

Mean free carbon dioxide, total carbon dioxide, total alkalinity, conductivity, and the pH range at 1500 hours and the mean river temperature at 0600 hours were determined for each station. It was assumed that these chemical values did not change appreciably within 100 meters of each station. Therefore, the chemical data for each station was applied to 5 transects. Although the gradient was calculated for each station, it must be applied to the five transects occurring at each station with caution because the gradient may change appreciably in 100 meters.

Results and Discussion

Chemical Data

The mean specific conductance, total alkalinity, free carbon dioxide, and total soluble inorganic carbon present at each station at 1500 hours are given in Table I. The mean temperature at 0600 hours at each station are also given in Table I.

Because the Firehole River (stations 1 and 2) had a larger fraction of chemically enriched thermal water than did the Gibbon River, the mean specific conductance, total alkalinity, and river temperature were higher at stations 1 and 2 than at station 3. The mean total alkalinity, specific conductance, and temperature of the Madison River were more closely related to the Firehole than the Gibbon since the Firehole contributed a larger discharge to the Madison than did the Gibbon River. These values were higher at station 5 than at station 4. This indicates that the discharge of the thermal spring (see Wright and Mills (1967) for a partial listing of chemical values) above station 4 did not mix completely with the river water until it was below station 4. From station 5 downstream there was a progressive decline in mean total alkalinity, specific conductance, and temperature (Table I).

The Gibbon River (station 3) had a much higher mean concentration of free carbon dioxide at 1500 hours than did the Firehole River (stations 1 and 2). Thus, the free carbon dioxide concentration of the first station on the Madison River was intermediate between the values for the Firehole and Gibbon Rivers. The Madison River is enriched in free carbon dioxide

