Observations of distribution, abundance and production related aspects of aquatic macro-invertebrates in natural thermal gradients
by Richard Allen Oswald

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Zoology
Montana State University

Abstract:
The aquatic macroinvertebrate communities of the thermal gradients produced by the Ringling-Drumheller, Norris and Potosi hot springs were investigated in 1974 and 1975. The three thermal gradients differed in chemical composition, size and age. Macroinvertebrate samples were collected with Surber and Hester-Dendy samplers and an Ekman grab.

Macroinvertebrate life was excluded by temperatures in excess of 40°C. The communities typical of high thermal regimes appeared to be formed by an exclusion, rather than addition, of genera or species as temperature increased.

Macroinvertebrate numbers, taxa and biomass were found to be negatively correlated with temperature. Despite the observed depression of standing crop at elevated temperatures, higher substrate colonization rates and larger sizes of selected taxa at higher temperatures suggested that production rate may increase with temperature.

Data compiled at the genus-species level indicated that most forms were eurythermal. Cold, hot and intermediate stenothermal forms were also observed. The eurythermal group was further analyzed to yield patterns of cold preference, warm preference, preference for intermediate temperatures or a lack of preference within broader ranges of tolerance.

Abundance at the total, ordinal and genus-species levels was affected by an interaction between temperature and season. Patterns of abundance did not respond the same for all levels of temperature when taken over all seasonal levels.

Data suggest community avoidance of, rather than adaptation to, high temperatures at a relatively small thermal plume. It was speculated that longer adaptation time resulted in a higher thermal tolerance for invertebrate communities at Potosi than at Ringling although this higher tolerance may have been influenced by differences in water chemistry or stability of thermal regime. Data further suggest a higher thermal tolerance for communities of pools or slower flows than for riffle communities.

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Date May 29, 1979

OBSERVATIONS ON DISTRIBUTION, ABUNDANCE AND PRODUCTION
RELATED ASPECTS OF AQUATIC MACROINVERTEBRATES
IN NATURAL THERMAL GRADIENTS

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RICHARD ALLEN OSWALD

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

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INTRODUCTION

Environmental temperature has long been considered one of the most important factors affecting life in the aquatic ecosystem. Aquatic communities from similar habitats within similar latitudinal, longitudinal and elevational regions would be expected to be subject to a similar set of thermal regimes. In recent years, biologists have become increasingly concerned with the upward alteration of many of these thermal regimes due to human activities. The primary focus of this concern has been on heated effluents produced by cooling waters discharged from fossil fuel and nuclear-powered electrical generating plants.

Krenkel and Parker (1969) predicted that increased needs for electrical generation would require that approximately one-fifth of the total surface runoff of the contiguous United States would be required for cooling purposes by 1980. This amount could be reduced by the increased use of cooling towers and closed cooling systems; however, these systems could pose an additional threat through their consumptive use of water. The thermal problem could be aggravated by an impending shortage of fossil fuels because nuclear-powered generating plants produce larger amounts of waste heat than fossil fuel plants (Krenkel and Parker 1969).

Concern over possible effects of waste heat on aquatic communities has led to many investigations of effects of increased heat on benthic macroinvertebrates. Laboratory studies have been conducted on metabolic effects (Newell 1973, Vernberg and Vernberg 1974), lethal limits (Gaufin and Hern 1971, Martin and Gentry 1974, Nebeker and Lemke 1968), growth and development (Lutz 1968, Nebeker 1973, Newell 1975) and emergence (Nebeker 1971a). However, application of laboratory results to field situations should be done with caution (Lehmkuhl 1974, Wurtz and Renn 1965).

Numerous field studies have been conducted on thermal effluents produced by power plants. Thermal effects on drift, development, emergence, distribution and abundance of macroinvertebrates have all been investigated below power plant discharges. Much of this literature has been reviewed on an annual basis (Coutant and Talmage 1975, Coutant and Pfuderer 1974, Coutant and Pfuderer 1973, Coutant and Goodyear 1972). Many of these studies have been complicated, however, by sampling difficulties due to substrate and depth differences (Masengill 1976), variable thermal regimes due to power plant operational requirements (Wurtz and Renn 1965), the presence of other forms of pollutants (Langford 1971, Wurtz 1969) and relatively small elevations in temperature (Wurtz 1969).

Relatively little work has been done on natural thermal effluents produced as a result of hot spring or geyser activity. Hot springs have been defined as those issuing at or above 38°C (Mariner et al. 1976). Some descriptive work has been done on macroinvertebrates inhabiting hot springs (Brues 1924 and 1932, Mason 1939, Provonsha and

McCafferty 1977, Robinson and Turner 1975, Stoner 1923). Work on macroinvertebrate distribution, abundance and production has been done on two rivers, the Firehole and Gibbon in Yellowstone National Park, which receive natural thermal effluents (Armitage 1958 and 1961, Jones 1967, Vincent 1966).

Discharges of hot spring effluents into small spring streams provide unique situations for the study of thermal effects on macroinvertebrates. Advantages lie in the stability of the thermal gradient produced, the ease of sampling due to small size and the long adaptation time involved (Brock 1967). Three such heated springs in southwestern Montana provided an opportunity to compare distribution, abundance, development and production of macroinvertebrates in thermal gradients ranging in temperature from approximately 45°C down to normal ambient temperatures.

DESCRIPTION OF STUDY AREAS

Three southwest Montana hot springs were investigated during the course of the study: the Ringling-Drumheller Well, the Norris Hot Spring and the Potosi Hot Spring. All waters under study were small spring streams, 1 to 4 meters wide. Streams of this size and origin belong to the rheocrene in the classification of Illies (Hynes 1970).

The most intensive study was conducted on the Ringling-Drumheller Well and its resultant thermal plume in the south fork of the Smith River. This well is located in western Meagher County, Montana (SE 1/4, NE 1/4, Sec. 25 T7N R7E) in a semi-arid region with 47 cm of precipitation per year and an average annual temperature of 5.4°C (Groff 1965). The Ringling well had an unusual man-made origin. It was formed in September, 1929 when an attempt to drill for oil produced hot water.

The spring originates at a surface elevation of 167.4 m (5500 ft) with a discharge of approximately .05 m^3 sec^{-1} (1.8 cfs). A discharge of this magnitude places the Ringling well among the larger hot springs of Yellowstone National Park (Allen and Day 1935). Temperature of the spring at the outflow ranged from 43 to 47°C during the study period. The hot artesian water is believed to acquire its heat from deep circulation in the cave forming zone or a deep fault or fissure and originates in Devonian limestone over dolomite (Groff 1965).

The hot stream flows down a moderate gradient for approximately 500 m where it merges with the upper south fork of the Smith River producing elevated temperatures which are measurable for approximately 2 km downstream. The combined effects of the elevated temperature and the larger volume of the hot spring as compared to the receiving stream (Table 1) acts to produce this relatively large thermal plume.

Table 1. Mean discharges at low (summer and fall) flows of the hot springs and their receiving streams at Ringling and Norris.

	Hot Spring	S. Fk. Smith River
Ringling	.050 m^3/sec (1.80 cfs)	.027 m^3/sec (.98 cfs)
	Hot Spring	Hot Spring Creek
Norris	.008 m^3/sec (.31 cfs)	.200 m^3/sec (7.12 cfs)

Eight biological sampling stations were selected along this thermal gradient based on temperature differences (Fig. 1). Maximum, minimum and mean observed temperatures are listed in Table 2. Sites 5, 4 and 3 were located within the flow of the hot spring, Site 2 was located above the inflow of the hot spring and Sites 1, 6, 7 and 8 were located in the Smith River below the inflow of the hot spring. Sites 2 and 8 were the upper and lower cold water references, respectively. These two sites became cold enough in winter to be largely ice covered

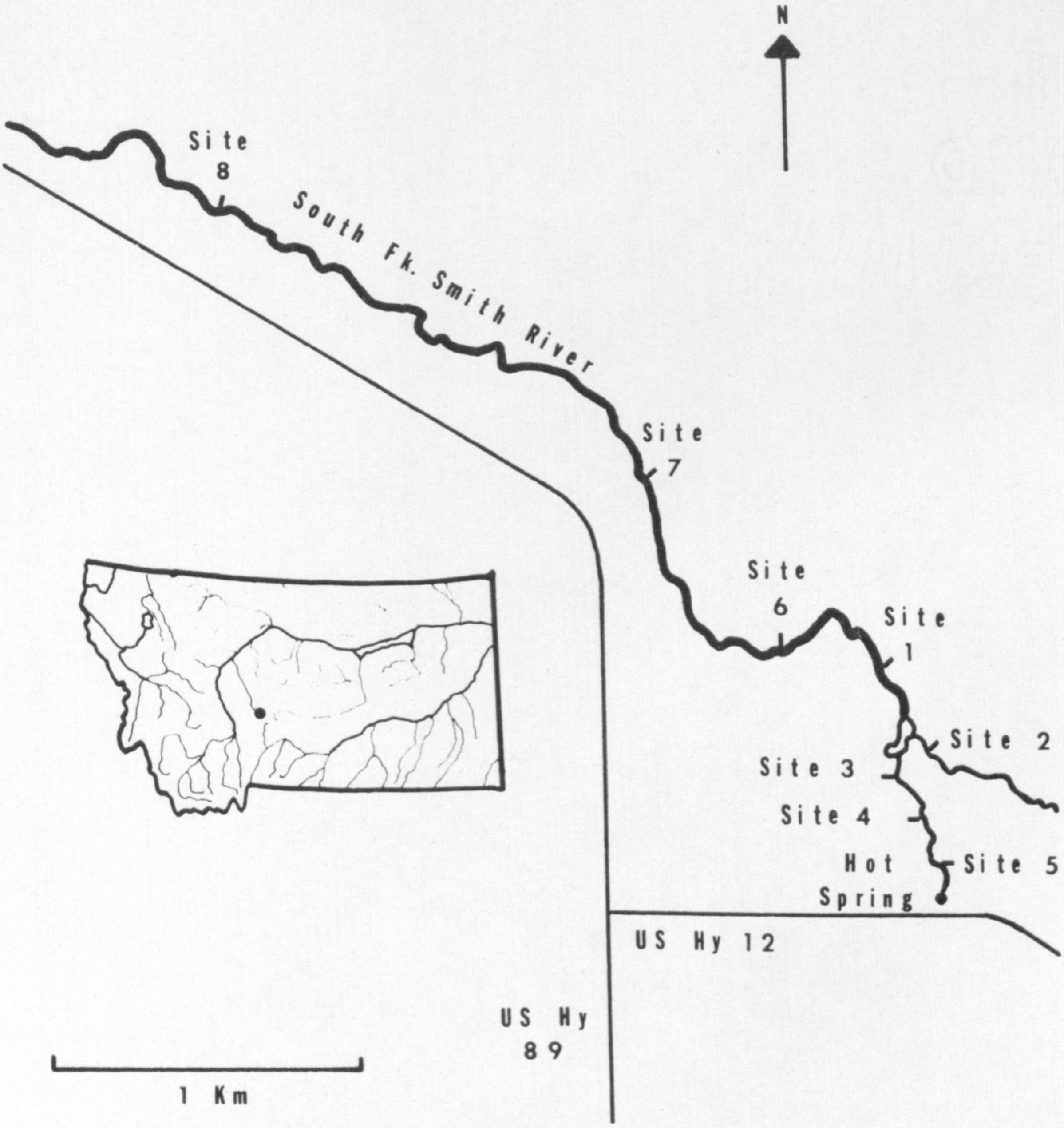

Figure 1. Map of Ringling study area showing macroinvertebrate sample sites.

Table 2. Maximum, minimum and mean observed temperatures (°C) for sample sites at Ringling, Norris and Potosi.

RINGLING	5	4	3	1	6	7	8	2
Maximum	47.0	43.0	41.0	36.0	32.0	28.0	23.0	24.0
Mean Maximum	----	----	35.7	27.0	20.0	15.0	10.0	10.0
Mean Median	45.0	38.0	34.0	24.8	18.6	11.9	8.2	7.9
Mean Minimum	----	----	32.3	23.0	17.0	9.0	7.0	6.0
Minimum	43.0	37.0	29.0	10.0	9.0	2.0	0.0	0.0

NORRIS	5	3	2	1	4
Maximum	48.0	32.0	16.0	10.0	10.0
Mean Median	38.8	24.3	10.5	5.3	5.3
Minimum	29.0	15.0	5.0	0.0	0.0

POTOSI	2	1	3	4	5
Maximum	34.0	29.0	24.0	17.0	13.0
Mean	33.3	27.8	22.5	16.5	12.3
Minimum	32.0	26.0	21.0	15.0	10.0

and frazil or slush ice was observed during the winter of 1974-75 at Site 8. All other sites were considered hot or warmer than ambient. An annual temperature profile for some of these sites is given in Appendix Table 27.

Each sample site was divided into an erosional (riffle) and a depositional (pool) area. The riffles were characterized by fast flows (.30-1.22 m/sec), shallow depths (5-15 cm) and a rubble or cobble substrate bearing filamentous green or, in upper hot spring sites, blue green algae. The pools were characterized by slower flows, deeper water (15-50 cm) and a substrate composed of silt, sand and detritus with some larger algae (*Chara* or *Nitella*) and a few macrophytes.

Chemical data (Table 3) show that the Ringling hot spring is a calcium, magnesium, bicarbonate and sulphate spring. This corresponds to the rarest of the major types of hot spring found in Yellowstone National Park (Allen and Day 1935). The Smith River above the inflow of the hot spring is a calcium, sodium and bicarbonate water. The effect of the Ringling hot spring is to increase the importance of calcium, magnesium and sulphate and decrease the importance of sodium and chloride in the Smith River. The system is characterized by high alkalinities and conductivities throughout. Mean dissolved oxygen levels (Table 4) decrease with increasing temperatures. Chemical and physical parameters measured in the hot spring and the Smith River at Ringling compare favorably with data compiled by Groff (1965) and L.

Table 3. Selected chemical parameters at Ringling, Norris and Potosi.

	Ringling					Norris					Potosi
	5	3	1	7	2	6	5	2	1	4	4
pH	7.42	8.23	8.25	8.38	8.18	8.26	8.27	8.12	8.12	7.98	8.35
K_{s25}(μmho/cm)	1420	1421	1417	1390	1012	879	877	586	340	323	381
Tot. Alk. (me/l)	2.62	2.67	3.22	3.09	3.17	6.30	6.30	4.32	3.05	2.99	.95
Ca^{+2} (mg/l)	302	307	276	156	121	18.4	18.4	37.6	42.4	44.8	10.8
Mg^{+2} (mg/l)	63.7	60.8	45.2	34.0	24.0	3.4	3.4	6.3	8.8	11.2	0.2
Na^{+} (mg/l)	8.6	8.4	42.0	39.0	59.0	189	187	96.0	27.0	22.0	17.4
K^{+} (mg/l)	8.0	7.6	5.1	5.0	3.6	14.0	13.8	7.3	5.5	5.2	2.8
SO_4^{-2} (mg/l)	958	918	788	408	357	137	114	42.0	26.0	31.0	104
Cl^{-} (mg/l)	1.8	1.7	2.8	2.8	5.3	22.0	22.0	12.0	9.2	8.7	6.6
F^{-} (mg/l)	3.1	3.4	2.9	3.2	0.9	8.7	8.7	2.4	1.1	0.8	6.9
SiO_2 (mg/l)	28.8	28.8	28.0	26.0	28.0	94.0	94.0	50.0	44.0	40.0	49.2