



Factors affecting the distribution of stoneflies in the Yellowstone River, Montana
by Lelyn Stadnyk

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:

Ecological factors affecting stonefly (Plecoptera) distribution were investigated for the upper Yellowstone River, Montana. Adult stoneflies were collected at seven locations from July, 1969 to June, 1971. Nymphs were collected with a large Surber-type sampler at three selected stations from November, 1969 to April, 1971.

The number of species of stoneflies, the dominant species, and their percentage by weight in relation to other invertebrates decreased from the upper to the lower stations.

Certain ecological factors were investigated in relation to stonefly distribution. Velocity, discharge, and gross substrate size did not appear to influence distribution, and temperature, likewise, was not of prime importance in the distribution of *Ptevonavcys californica*, *Acroneuria pacifica*, and *Claassenia sabulosa* within the study section. Significant differences in ion concentration were found in the study section with alkalinity, Mg, and Ca increasing downstream and Na, K, and Cl highest at the upstream station. The autotrophic index (AI) was highest at the downstream station indicating more eutrophic conditions. Ice action caused large changes in the aufwuchs community at the lower stations and the amount of inorganic material in the aufwuchs mat increased downstream.

Eutrophic conditions and changes in the aufwuchs community were considered to be major factors influencing stonefly distribution in the upper Yellowstone River.

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IN THE YELLOWSTONE RIVER, MONTANA

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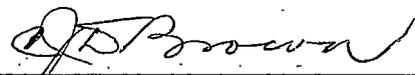
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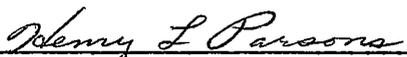
Approved:



Head, Major Department



Chairman, Examining Committee



Graduate Dean

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TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGMENT	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
ABSTRACT	vii
INTRODUCTION	1
DESCRIPTION OF THE STUDY SECTION	3
METHODS AND MATERIALS	7
RESULTS	11
Stoneflies	11
Characteristics of the Aufwuchs	17
Physical Factors	20
Chemical Factors	23
DISCUSSION	29
LITERATURE CITED	33

LIST OF TABLES

Table	Page
I. SOURCES OF DOMESTIC POLLUTION IN THE STUDY SECTION OF THE YELLOWSTONE RIVER	5
II. SAMPLING STATIONS IN THE STUDY SECTION OF THE YELLOWSTONE RIVER	6
III. DISTRIBUTION OF ADULT STONEFLIES COLLECTED ON THE YELLOWSTONE RIVER (July, 1969 - June, 1971)	13
IV. AVERAGE NUMBER OF STONEFLY NYMPHS/SQUARE METER OF BOTTOM AT THREE STATIONS IN THE YELLOWSTONE RIVER	15
V. PERCENTAGE (WET WEIGHT) OF STONEFLIES IN RELATION TO THE TOTAL BENTHIC FAUNA OF THE YELLOWSTONE RIVER	16
VI. AVERAGE MONTHLY DISCHARGE (m^3/sec) OF THE YELLOWSTONE RIVER FOR THE 1968-69 AND 1969-70 WATER YEARS	22
VII. AVERAGE MONTHLY TEMPERATURES (C) AND EXTREMES FOR THREE AREAS OF THE UPPER YELLOWSTONE RIVER. DATA FROM AAGAARD (1969)	25
VIII. SPECIFIC CONDUCTANCE ($\mu mhos$) AT THREE STATIONS ON THE YELLOWSTONE RIVER. DATA FOR THE PERIOD JULY, 1970 TO JUNE, 1971	26
IX. AVERAGE CONCENTRATION AND RANGES (meq/l) FOR MAJOR CATIONS AND ANIONS AND AVERAGE pH AT THREE STATIONS IN THE YELLOWSTONE RIVER. JULY, 1970-JUNE, 1971	27

LIST OF FIGURES

Figure	Page
1. Yellowstone River Study Section	4
2. Average monthly Autotrophic Index (AI) and ranges for three stations in the Yellowstone River. AI X 100	18
3. Percentage of inorganic and organic material associated with the aufwuchs community at three stations in the Yellowstone River	21
4. Percentage of larger substrate material at three stations in the Yellowstone River	24

ABSTRACT

Ecological factors affecting stonefly (Plecoptera) distribution were investigated for the upper Yellowstone River, Montana. Adult stoneflies were collected at seven locations from July, 1969 to June, 1971. Nymphs were collected with a large Surber-type sampler at three selected stations from November, 1969 to April, 1971.

The number of species of stoneflies, the dominant species, and their percentage by weight in relation to other invertebrates decreased from the upper to the lower stations.

Certain ecological factors were investigated in relation to stonefly distribution. Velocity, discharge, and gross substrate size did not appear to influence distribution, and temperature, likewise, was not of prime importance in the distribution of *Pteronarcys californica*, *Acroneuria pacifica*, and *Claassenia sabulosa* within the study section. Significant differences in ion concentration were found in the study section with alkalinity, Mg, and Ca increasing downstream and Na, K, and Cl highest at the upstream station. The autotrophic index (AI) was highest at the downstream station indicating more eutrophic conditions. Ice action caused large changes in the aufwuchs community at the lower stations and the amount of inorganic material in the aufwuchs mat increased downstream. Eutrophic conditions and changes in the aufwuchs community were considered to be major factors influencing stonefly distribution in the upper Yellowstone River.

INTRODUCTION

The distribution of stoneflies (Plecoptera) in relation to certain physical, chemical and biotic factors was investigated in the upper Yellowstone River. Samples were collected from July, 1969 to June, 1971.

Stoneflies were selected because there are numerous species and large populations in this stream and because they are sensitive to variations in the habitat (Gaufin, 1965). In addition, the taxonomy of this group is comparatively well known.

The stream factors studied in relation to stonefly distribution were substrate size, discharge, temperature, velocity, major cations and anions, pH and conductivity, and characteristics of the aufwuchs¹ community.

Many investigations have been made on the distribution of aquatic invertebrates in stream systems. Hynes (1941) outlined some factors controlling distribution of stoneflies in English streams. Armitage (1961) studied the distribution of riffle insects in the Firehole River, Yellowstone National Park, Wyoming. Ulfstrand (1968) analyzed the benthic fauna in Lapland rivers, including distribution patterns in relation to various physical and chemical factors. Knight and Gaufin (1966, 1967) studied the Plecoptera populations in the Gunnison

¹Underlining is omitted in the remainder of the paper.

River Drainage in Colorado, while Minshall (1969) and Minshall and Kuehne (1969) described the distribution of Plecoptera in English mountain streams.

DESCRIPTION OF THE STUDY SECTION

The Yellowstone River originates on the Continental Divide south of Yellowstone National Park in Wyoming. It traverses the park from south to north, passing through Yellowstone Lake and the "Grand Canyon" to reach the Montana border at Gardiner. From this point it runs first north to Livingston and then easterly across Montana to join the Missouri River in North Dakota. Major tributaries include the Lamar and Gardiner rivers inside Yellowstone National Park and the Shields, Boulder, Stillwater, Clarks Fork, Big Horn, Tongue and Powder rivers in Montana.

The study section extended from Gardiner (elevation 1637 meters mean sea level) to Laurel (944 meters mean sea level). A marked transition exists in the study section; i.e., the river changes from a mountain stream with steep-sided canyons to one with an ever widening flood plain (Fig. 1).

The Yellowstone River within the park is relatively free of pollution but a number of domestic pollution sources are present in the Montana portion of the drainage (Table I). No major industrial pollution exists in the study section, although there is considerable entering the river at and below Billings, Montana. There are approximately 350,000 acres (141,600 hectares) of irrigated ranch land above Billings (USGS, 1969) and irrigation returns add silt and ions to the river at various points along the study section. These returns may

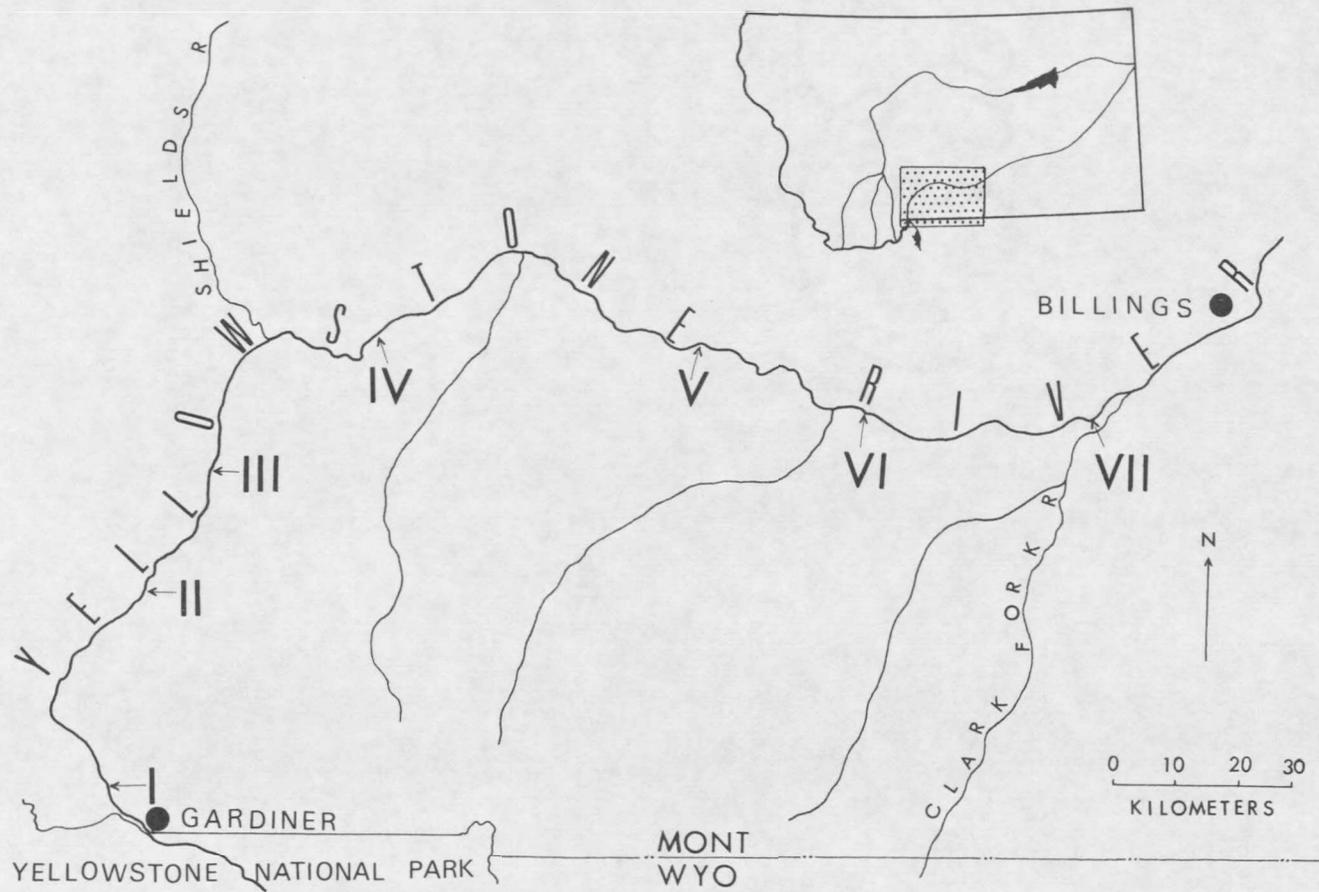


Figure 1. Yellowstone River Study Section.

TABLE I. SOURCES OF DOMESTIC POLLUTION IN THE STUDY SECTION OF THE YELLOWSTONE RIVER.

Municipality	Mileage ¹	Population	Treatment
Gardiner	537	650	Septic Tanks
Livingston	476	8,229	Primary with Chlorination
Big Timber	436	1,660	Lagoon
Columbus	394	1,281	Lagoon
Laurel	363	4,601	Primary with Chlorination
Billings	345	55,000	Primary

¹Approximate mileage above mouth of the river

also increase the temperature slightly. A few feedlots may contribute wastes to the portion of the study section below Livingston.

Historically, the study section was polluted with mining wastes near the park boundary in Montana but, with the exception of small sand and gravel operations, there is no mining at present. During 1955-1957, DDT was sprayed over surrounding forest areas to control the spruce budworm. Sufficient pesticide entered the river to cause mortality of aquatic invertebrates (Cope, 1961).

During this investigation stoneflies of various species were abundant throughout the study section. Adult stoneflies were collected at regular intervals from seven stations (Fig. 1). Stations I, IV, and

VII were chosen for detailed study. The location and description of each station is presented in Table II.

TABLE II. SAMPLING STATIONS IN THE STUDY SECTION OF THE YELLOWSTONE RIVER.

Station No.	Mileage ¹	Elevation ²	Location and Description
I	530	1,563	Near Corwin Springs, Montana; in a very narrow valley.
II	505	1,485	Near Emigrant, Montana; in Paradise Valley.
III	491	1,427	18 kilometers above Livingston, Montana; Mallard's Rest access area.
IV	454	1,284	Near Springdale, Montana; surrounded by rolling ranch land.
V	412	1,141	Near Reed Point, Montana; surrounded by rolling pine hills.
VI	394	1,086	Near Columbus, Montana; surrounded by rolling pine hills and ranch land.
VII	367	944	Near Laurel, Montana; surrounded by flat agricultural land.

¹Approximate mileage above mouth of the river.

²Approximate elevation above mean sea level in meters.

METHODS AND MATERIALS

Adult stoneflies were collected from July, 1969 to June, 1971 at all seven stations (Fig. 1). Methods of capture included sweeps of stream side vegetation with a hand net and examination of rocks and debris along the stream bank. All adults were preserved in a modified Hoods solution (Harden and Mickel, 1952). Collections were made monthly except during periods of peak emergence when they were taken biweekly.

Collections of stream benthos were also made monthly when river conditions permitted. A Surber-type sampler having an area of 0.5 m^2 was employed for this purpose. This sampler was 1.0 m long and 0.5 m wide and had a cod of nylon netting 1 m long. The netting had 9 meshes/cm and a pore size of approximately 1 mm^2 . A device of these dimensions is more appropriate for a large river such as the Yellowstone because of high current velocity and the presence of large rubble. Needham and Usinger (1956) demonstrated the difficulty of obtaining a good estimate using the Surber sampler. Various methods of sampling the benthic fauna are described by Cummins (1962). Recently Coleman and Hynes (1970) investigated the substrate depth (approximately 70 cm) occupied by certain benthic forms.

Two hauls of the 0.5 m^2 sampler were taken at stations I, IV, and VII monthly when river conditions permitted. The samples were promptly preserved with 10% formalin. In the laboratory most of the detritus

was separated from the organisms by the sugar flotation method (Anderson, 1959). The resulting mass of invertebrates and some detritus was sorted under a dissecting scope (10X) to find all the stonefly nymphs. Wet weights were estimated from alcohol preserved material on an analytical balance.

The aufwuchs community of the Yellowstone River was analyzed following a procedure modified from King and Ball (1966) and Weber and McFarland (unpublished). Five samples were collected at each of the three intensively studied areas (I, IV, and VII). Each sample was taken from one of five randomly chosen rocks removed from the same general area where the quantitative benthos samples were taken. This technique is similar to that used by Guntow (1955). A rubber ring having an internal area of 50 cm² was placed on the upper surface of the rock and all the material adhering to the rock surface was scraped into a vial. Any material remaining on the funnel or scalpel was washed into the vial with distilled water. The vials were capped, placed in a dark container and transported to the laboratory. The water was removed from the aufwuchs material by centrifugation and chlorophyll was extracted in a flask with acetone (90%). Extraction was carried out in the dark at 2-3 C for 24 hr. The chlorophyll "a" content was determined using a Baush and Lomb Spectronic 20 at 665 mμ as follows:

$$\text{gm/m}^2 \text{ chlorophyll} = \frac{11.6 \times \text{OD} \times v}{L \times A} \times 10^6$$

where:

11.6 = Factor for converting optical density to weight of chlorophyll "a" assuming diatoms are the dominant forms

(Bahls, 1971).

OD = Optical density of the acetone extract at 665 m μ .

v = Volume of 90% acetone used in extraction(ml).

L = Length of the light path in cm (1.27 cm).

A = Area of the sample in square meters.

After the chlorophyll content was determined, the entire sample was transferred to a pre-weighed porcelain dish, the acetone was evaporated and the sample was dried at 102 \pm 2 C for 12 hr. It was then cooled in a desiccator and weighed on an analytical balance accurate to 100 μ gm. The sample was then ashed at 600 C for 20 min, cooled and weighed again. By this method, the gm/m² of chlorophyll and gm/m² of total biomass was determined and the Autotrophic Index (AI) was computed by dividing biomass by chlorophyll. The amount of inorganic material to total biomass was also determined.

Current velocity was secured with a Gurley current meter. Twenty readings were taken along 5 transects at stations I, IV, and VII during minimum discharge.

A gross analysis of the substrate at station I, IV, and VII was made using the photographic method (Cummins, 1962). A number of 35 mm photographs were taken of the bottom using a polarizing filter. A

scale was included in the picture and the transparency was enlarged with a slide projector to natural size in the laboratory. The actual diameter of the rocks was determined using the Wentworth classification of coarser sediments (boulder, cobble and pebble).

Temperature and discharge data were secured from USGS records (U. S. Geological Survey, 1969 and preliminary data for 1970; Aagaard, 1969).

Water analyses were made at stations I, IV, and VII monthly from July, 1970 to June, 1971. The major cations (Ca, Mg, Na, and K) and anions (CO_3 - HCO_3 , SO_4 , and Cl) plus pH and conductivity were determined according to Standard Methods (1965).

RESULTS

Stoneflies

Initial work involved determination of which stoneflies were present in the upper Yellowstone River. The following list of 25 species of Plecoptera is based upon both adult and nymph collections and represents the entire species complex found in the study section.

Suborder Filipalpia

I. Family Nemouridae

Subfamily Nemourinae

Genus *Nemoura*

Subgenus *Prostoia* Ricker

- 1) *Nemoura besametsa* Ricker

Subgenus *Zapada* Ricker

- 2) *Nemoura cinctipes* Banks

Subfamily Leuctrinae

Genus *Paraleuctra* Hanson

- 3) *Paraleuctra sara* (Claassen)

Subfamily Capniinae

Genus *Capnia*

- 4) *Capnia confusa* Claassen
- 5) *Capnia gracilaria* Claassen
- 6) *Capnia distincta* Frison
- 7) *Capnia poda* Nebeker and Gäufin
- 8) *Capnia limata* Frison

Genus *Isocapnia* Banks

- 9) *Isocapnia vedderensis* Ricker
- 10) *Isocapnia missouri* Ricker

Subfamily Taeniopteryginae

Genus *Brachyptera* Newport

Subgenus *Taenionema* Banks

- 11) *Brachyptera nigripennis* (Banks)

II. Family Pteronarcidae

Genus *Pteronarcella* Banks

- 12) *Pteronarcella badia* (Hagen)

Genus *Pteronarcys* Newman

- 13) *Pteronarcys californica* Newport

Suborder Setipalpia

III. Family Perlodidae

Subfamily Isogeninae

Genus *Arcynopteryx* Klapalek

Subgenus *Skwala* Ricker

14) *Arcynopteryx parallela* Frison

Genus *Isogenus* Newman

Subgenus *Cultus* Ricker

15) *Isogenus aestivalis* (Needham and Claassen)

16) *Isogenus tostonus* Ricker

Subgenus *Isogenoides*

17) *Isogenus elongatus* Hagen

Subfamily Isoperlinae

Genus *Isoperla* Banks

18) *Isoperla longiseta* Banks

19) *Isoperla mormona* Banks

20) *Isoperla patricia* Frison

IV. Family Chloroperlidae

Subfamily Chloroperlinae

Genus *Alloperla* Banks

Subgenus *Swallia* Ricker

21) *Alloperla pallidula* Banks

Subgenus *Sweltsa* Ricker

22) *Alloperla coloradensis* (Banks)

Subgenus *Triznaka* Ricker

23) *Alloperla signata* Banks

V. Family Perlidae

Subfamily Acroneurinae

Genus *Acroneuria* Pictet

Subgenus *Hesperoperla* Banks

24) *Acroneuria pacifica* Banks

Genus *Claassenia* Wu

25) *Claassenia sabulosa* (Banks)

Adults were collected at all seven stations. Table III presents the distribution of adult Plecoptera taken in the study section.

TABLE III. DISTRIBUTION OF ADULT STONEFLIES COLLECTED ON THE YELLOW-STONE RIVER (July, 1969 - June, 1971).

Species	Station						
	I	II	III	IV	V	VI	VII
<i>Nemoura besametsa</i>	X		X				
<i>Nemoura cinctipes</i>	X	X					X
<i>Paraleuctra sara</i>	X						
<i>Capnia confusa</i>	X			X			
<i>C. gracilaria</i>	X	X	X				
<i>C. distincta</i>	X						
<i>C. poda</i>	X	X	X	X			
<i>C. limata</i>							X
<i>Isocapnia vedderensis</i>	X	X			X		
<i>I. missouri</i>		X		X	X		X
<i>Brachyptera nigripennis</i>			X	X		X	X
<i>Pteronarcella badia*</i>	X	X	X	X	X	X	X
<i>Pteronarcys californica*</i>	X	X	X	X			
<i>Arcynopteryx parallela</i>	X	X	X	X	X		X
<i>Isogenus aestivalis</i>	X						
<i>I. tostonus*</i>	X	X	X	X	X	X	X
<i>I. elongatus*</i>		X	X	X	X	X	X
<i>Isoperla longiseta</i>						X	
<i>I. mormona</i>			X	X	X	X	
<i>I. patricia*</i>	X	X	X	X	X	X	X
<i>Alloperla pallidula*</i>	X	X	X	X	X	X	X
<i>A. coloradensis</i>					X		
<i>A. signata*</i>	X	X	X	X			
<i>Acroneuria pacifica*</i>	X	X	X	X			X
<i>Claassenia sabulosa*</i>			X	X	X	X	X
Total Species	17	14	15	15	11	9	12

*Most numerous species.

There were fewer species of stoneflies as one proceeded downstream. Seventeen species were collected at station I while only 12 were found at station VII. With the exception of *Capnia limata*, *Nemoura cinctipes* and *Isocapnia missouri*, all of the winter and early spring emerging

species of stoneflies were restricted to the upper part of the study section (stations I - IV). The abundant stoneflies *Pteronarcys californica* and *Acroneuria pacifica* were confined to the upper part of the study section with the exception of *A. pacifica*, which was taken once at station VII. *Claassenia sabulosa* and *Isogenus elongatus* were abundant only at the lower stations (IV - VII) and *Alloperla pallidula*, *Isoperla patricia* and *Isogenus tostonus* were present at all stations.

These differences in species distribution probably reflect changes in the ecology of the river over the study section. Minshall and Kuehne (1969) found that three taxa of Plecoptera were restricted primarily to the upper reaches of the River Duddon, England. These differences were associated with changes in the chemistry and amount of allochthonous detritus. Knight and Gaufin (1966) reported marked differences in stonefly populations with decreasing altitude along the Gunnison River, Colorado. A difference in Plecoptera species with decreasing altitude was also reported by Dodds and Hisaw (1925).

Preliminary observations showed that stations I, IV and VII were generally representative of conditions at the upper, middle and lower parts of the study section and these were more intensively sampled.

Quantitative collections of stonefly nymphs were made from November, 1969 to March, 1971 except for the period May to August, 1970 when water levels prohibited sampling. Since populations of

stoneflies probably change little between the end of the recruitment period and emergence (Minshall, 1969) the data for these two periods of peak abundance were averaged (Table IV).

The most numerous nymphs at station I were *Pteronarcys californica* (35.2/m²), *Isogenus* spp. (7.4/m²), *Isoperla* spp. (8.3/m²) and *Acro-neuria pacifica* (28.9/m²), while the most abundant species at station IV were *Pteronarcella badia* (46.0/m²), *Isogenus* spp. (39.9/m²), *Isogenus elongatus* (13.8/m²), *Isoperla* spp. (70.8/m²) and *Alloperla* spp. (36.9/m²). At station VII *P. badia* (29.5/m²), *Isoperla* spp. (20.7/m²), *Isogenus elongatus* (21.1/m²) and *Claassenia sabulosa* (35.2/m²) were the most numerous.

TABLE IV. AVERAGE NUMBER OF STONEFLY NYMPHS/SQUARE METER OF BOTTOM AT THREE STATIONS IN THE YELLOWSTONE RIVER.

Species	Stations		
	I	IV	VII
<i>Nemoura besametsa</i>	0.5	0.4	absent
<i>N. cinctipes</i>	0.1	0.2	absent
<i>Paraleuctra sara</i>	0.3	absent	absent
<i>Pteronarcella badia</i>	absent	46.0	29.5
<i>Pteronarcys californica</i>	35.2	0.4	absent
<i>Arcynopteryx parallela</i>	0.2	0.1	0.4
<i>Isogenus</i> spp.	7.4	39.9	4.0
<i>I. elongatus</i>	absent	13.8	21.1
<i>Isoperla</i> spp.	8.3	70.8	20.7
<i>Alloperla</i> spp.	2.3	36.9	6.2
<i>Acro-neuria pacifica</i>	28.9	0.2	0.2
<i>Claassenia sabulosa</i>	absent	4.9	35.2
Total	83.2	213.6	117.3

Some species captured as adults were never collected in the benthic samples but quantitative benthos collections were made in only one riffle and did not represent all possible habitats. Also, certain stoneflies (Capniinae and Chloroperlidae) may be found at depths in the substrate not usually taken with the type of sampler used (Radford and Hartland-Rowe, 1971).

At station I, *Pteronarcys californica* made up more than 50% of the biomass while *Acroneuria pacifica* composed about 7% (Table V).

TABLE V. PERCENTAGE (WET WEIGHT) OF STONEFLIES IN RELATION TO THE TOTAL BENTHIC FAUNA OF THE YELLOWSTONE RIVER.

Species	Station		
	I	IV	VII
<i>Pteronarcella badia</i>	absent	13.6	7.2
<i>Pteronarcys californica</i>	58.3	1.1	absent
<i>Isogenus elongatus</i>	absent	6.3	7.3
<i>Acroneuria pacifica</i>	6.8	0.1	0.2
<i>Claassenia sabulosa</i>	absent	0.7	7.3
Other species	0.6	4.1	0.3
Total	65.7	25.9	22.3

At this station stoneflies totaled 62.9% of the biomass of invertebrates. At station IV, *Pteronarcella badia* and *Isogenus elongatus* were the most important species by weight and all stoneflies comprised only 25.9% of the wet-weight biomass of invertebrates. At station VII, *P. badia*, *I. elongatus*, and *Claassenia sabulosa* contributed the greatest biomass and the total weight of stoneflies comprised only 22.3% of the

benthic fauna.

Characteristics of the Aufwuchs

The autotrophic index (AI) was employed as an indicator of eutrophication in the study section. The characteristics of the aufwuchs community may directly influence herbivores such as *Pteronarcys californica* and *Pteronarcella badia* and probably indirectly influences all other riffle invertebrates. Average monthly AI determinations were made at the three selected stations for the period September, 1970 to April, 1971 (Fig. 2). The average AI ranged as follows: station I - 296 (September, 1970) to 193 (November, 1970); station IV - 586 (October, 1970) to 174 (April, 1971); station VII - 676 (November, 1970) to 324 (February, 1971).

These data show increased eutrophication in the downstream portion of the study section, particularly during the fall months. Individual readings of the AI ranged as high as 956 at station IV and 1169 at station VII, while at station I, the highest individual reading was only 402.

The aufwuchs community was apparently much more stable throughout the season at station I, where ice cover was most restricted than at either station IV or VII. Thermal water entering the upper Yellowstone and Gardiner Rivers is responsible for the more temperate conditions found at the upper station. At the lower two stations, large amounts of ice were observed during both winters and is probably typical for

