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 DOCTOR OF PHILOSOPHY in Zoology
Montana State University

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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ABSTRACT

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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 *aufwuchs*[1] 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

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[1] Underlining 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

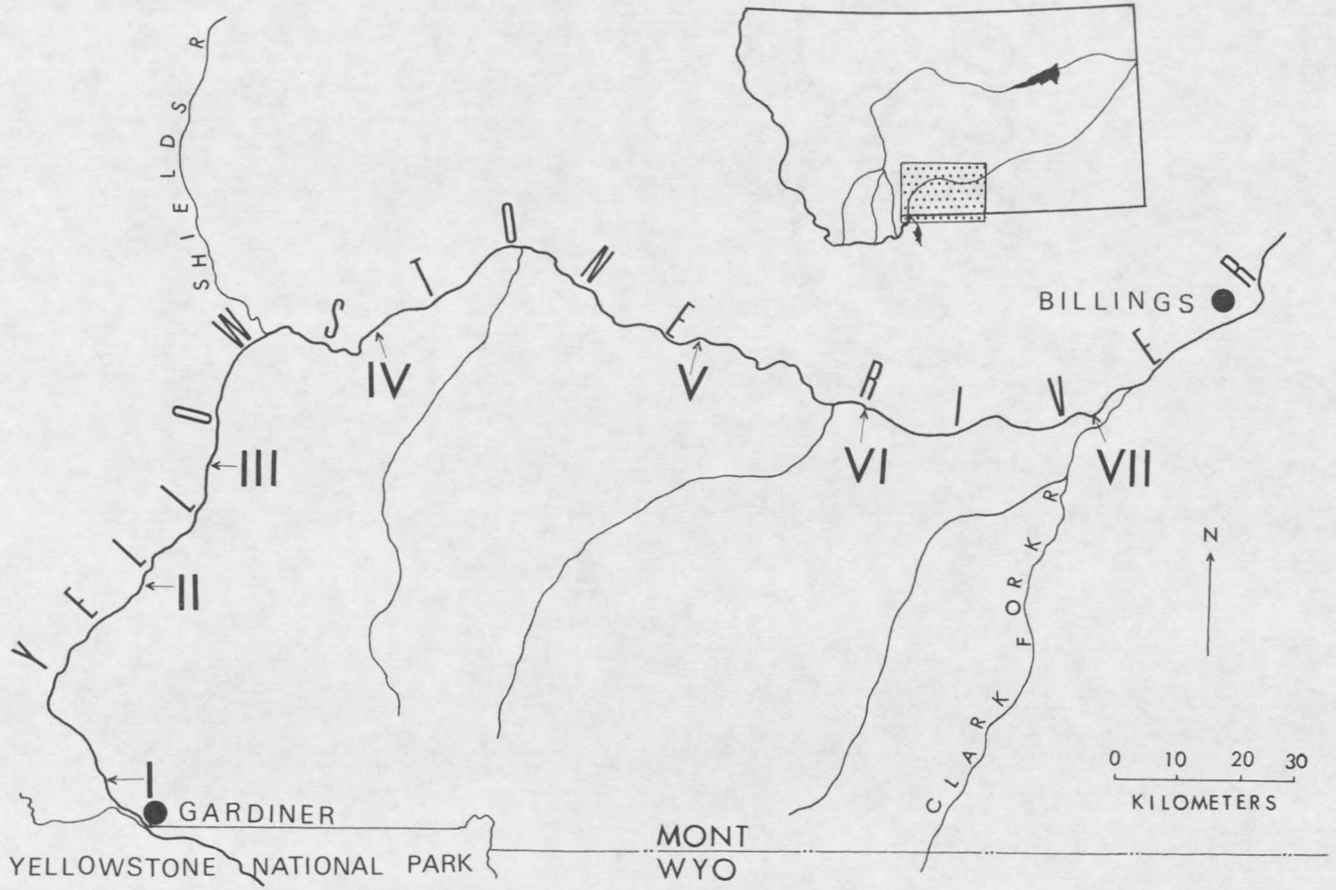

Figure 1. Yellowstone River Study Section.

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

[1] Approximate 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.

[1] Approximate mileage above mouth of the river.

[2] Approximate 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 Gumtow (1955). A rubber ring having an internal area of 50 cm^2 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:

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

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 mμ.

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±2 C for 12 hr. It was then cooled in a desiccator and weighed on an analytical balance accurate to 100 μgm. The sample was then ashed at 600 C for 20 min, cooled and weighed again. By this method, the gm/m^2 of chlorophyll and gm/m^2 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 Gaufin
          8) *Capnia limata* Frison
      Genus *Isocapnia* Banks
          9) *Isocapnia vedderensis* Ricker
          10) *Isocapnia missourii* 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 *Suwallia* 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 YELLOWSTONE RIVER (July, 1969 - June, 1971).

Species	Station						
	I	II	III	IV	V	VI	VII
Nemoura besametsa	X		X				
Nemoura cinctipes	X	X					X
Paraleuctra sara	X						
Capnia confusa	X			X			
C. gracilaria	X	X	X				
C. distincta	X						
C. poda	X	X	X	X			
C. limata							X
Isocapnia vedderensis	X	X			X		
I. missourii		X		X	X		X
Brachyptera nigripennis			X	X		X	X
*Pteronarcella badia**	X	X	X	X	X	X	X
*Pteronarcys californica**	X	X	X	X			
Arcynopteryx parallela	X	X	X	X	X		X
Isogenus aestivalis	X						
*I. tostonus**	X	X	X	X	X	X	X
*I. elongatus**		X	X	X	X	X	X
Isoperla longiseta						X	
I. mormona			X	X	X	X	
*I. patricia**	X	X	X	X	X	X	X
*Alloperla pallidula**	X	X	X	X	X	X	X
A. coloradensis					X		
*A. signata**	X	X	X	X			
*Acroneuria pacifica**	X	X	X	X			X
*Claassenia sabulosa**			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 missourii,* 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/m^2), *Isogenus* spp. (7.4/m^2), *Isoperla* spp. (8.3/m^2) and *Acroneuria pacifica* (28.9/m^2), while the most abundant species at station IV were *Pteronarcella badia* (46.0/m^2), *Isogenus* spp. (39.9/m^2), *Isogenus elongatus* (13.8/m^2), *Isoperla* spp. (70.8/m^2) and *Alloperla* spp. (36.9/m^2). At station VII *P. badia* (29.5/m^2), *Isoperla* spp. (20.7/m^2), *Isogenus elongatus* (21.1/m^2) and *Claassenia sabulosa* (35.2/m^2) 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
Nemoura besametsa	0.5	0.4	absent
N. cinctipes	0.1	0.2	absent
Paraleuctra sara	0.3	absent	absent
Pteronarcella badia	absent	46.0	29.5
Pteronarcys californica	35.2	0.4	absent
Arcynopteryx parallela	0.2	0.1	0.4
Isogenus spp.	7.4	39.9	4.0
I. elongatus	absent	13.8	21.1
Isoperla spp.	8.3	70.8	20.7
Alloperla spp.	2.3	36.9	6.2
Acroneuria pacifica	28.9	0.2	0.2
Claassenia sabulosa	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	Station IV	Station VII
Pteronarcella badia	absent	13.6	7.2
Pteronarcys californica	58.3	1.1	absent
Isogenus elongatus	absent	6.3	7.3
Acroneuria pacifica	6.8	0.1	0.2
Claassenia sabulosa	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

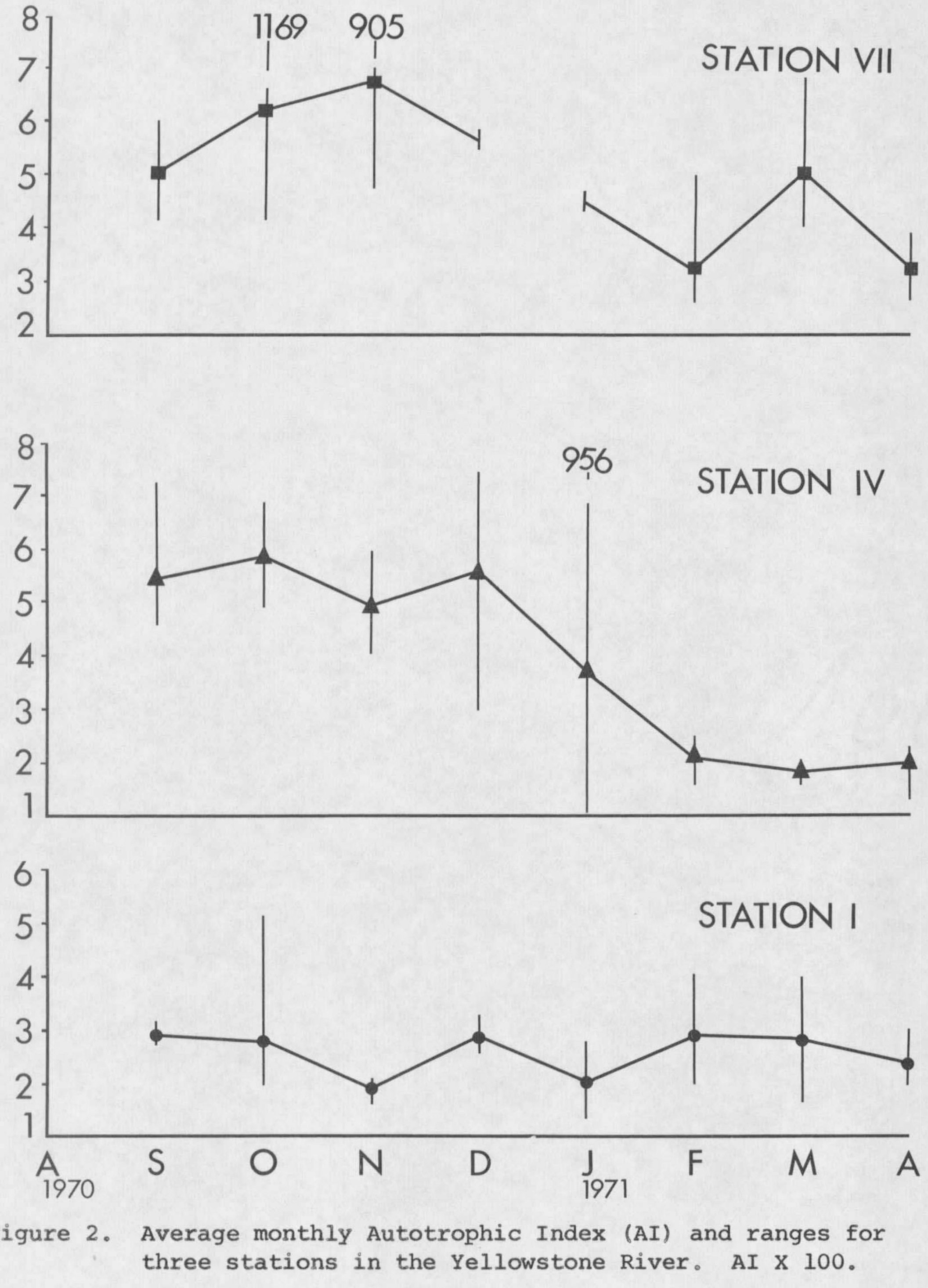

Figure 2. Average monthly Autotrophic Index (AI) and ranges for three stations in the Yellowstone River. AI X 100.

this portion of the river. Large blocks of ice break loose and scour the aufwuchs community from the rock surfaces resulting in marked shifts in the AI. These shifts occurred since observations showed the recolonizing organisms were initially only diatoms. As heterotrophic organisms again establish themselves, the AI probably approaches levels found in the fall of 1970.

Both total biomass of the aufwuchs community and the AI markedly reflect the differences in winter conditions between the upper and lower stations. Estimates of biomass during November, 1970 were as follows: station I - 59.7 g/m^2; station IV - 51.4 g/m^2; and station VII - 38.9 g/m^2. However, by February, 1971 biomass estimates were: station I - 31.8 g/m^2; station IV - 7.6 g/m^2; and station VII - 20.8 g/m^2. Although total biomass is reduced at all three stations, the greatest reductions occurred at station IV and to a slightly lesser degree at station VII. The percentage of organic and inorganic material associated with the aufwuchs community was determined. Increases in the percentage of inorganic material at the lower stations was believed to result from siltation. Diatoms made up the vast majority of the autotrophic fauna at all stations. Approximately 50% of the total weight of diatoms is inorganic material (Strickland, 1960) and changes in the quantity of diatoms in relation to other algae could account for differences in the percentage of inorganic material not associated with changes in siltation. However, no such gross changes in algal species were observed.

Although differences were not pronounced, station I appears to have less inorganic material in the aufwuchs mat than either station IV or station VII (Fig. 3). At stations IV and VII there was an apparent increase in the percentage of organic material during late winter due to the molar action of ice blocks removing the existing aufwuchs mat containing inorganic material.

Physical Factors

A number of physical parameters were measured at the three stations. Current velocity was not significantly different ($\alpha<0.05$; $n=20$) at the three selected locations. The average velocities were: station I - 0.95 m/sec; station IV - 1.29 m/sec; and station VII - 1.07 m/sec. Although the means were different, enough overlap occurred between measurements to show no significant differences. Preference for any particular velocity could probably be satisfied at either of the three stations.

Discharge measurements were obtained from the USGS for three areas within the study section (Table VI). Peak discharge occurred both years (1968-69 and 1969-70 water years) during the month of June as follows: Corwin Springs - 287.8 m^3/sec and 413.2 m^3/sec; Livingston - 337.3 m^3/sec and 519.9 m^3/sec; and Billings - 634.2 m^3/sec and 1037.5 m^3/sec. Lowest flows occurred during the middle of the winter at all three stations. Average minimum discharges were about 1/10th the maximum averages. Over the entire year, the lower portion of the study section

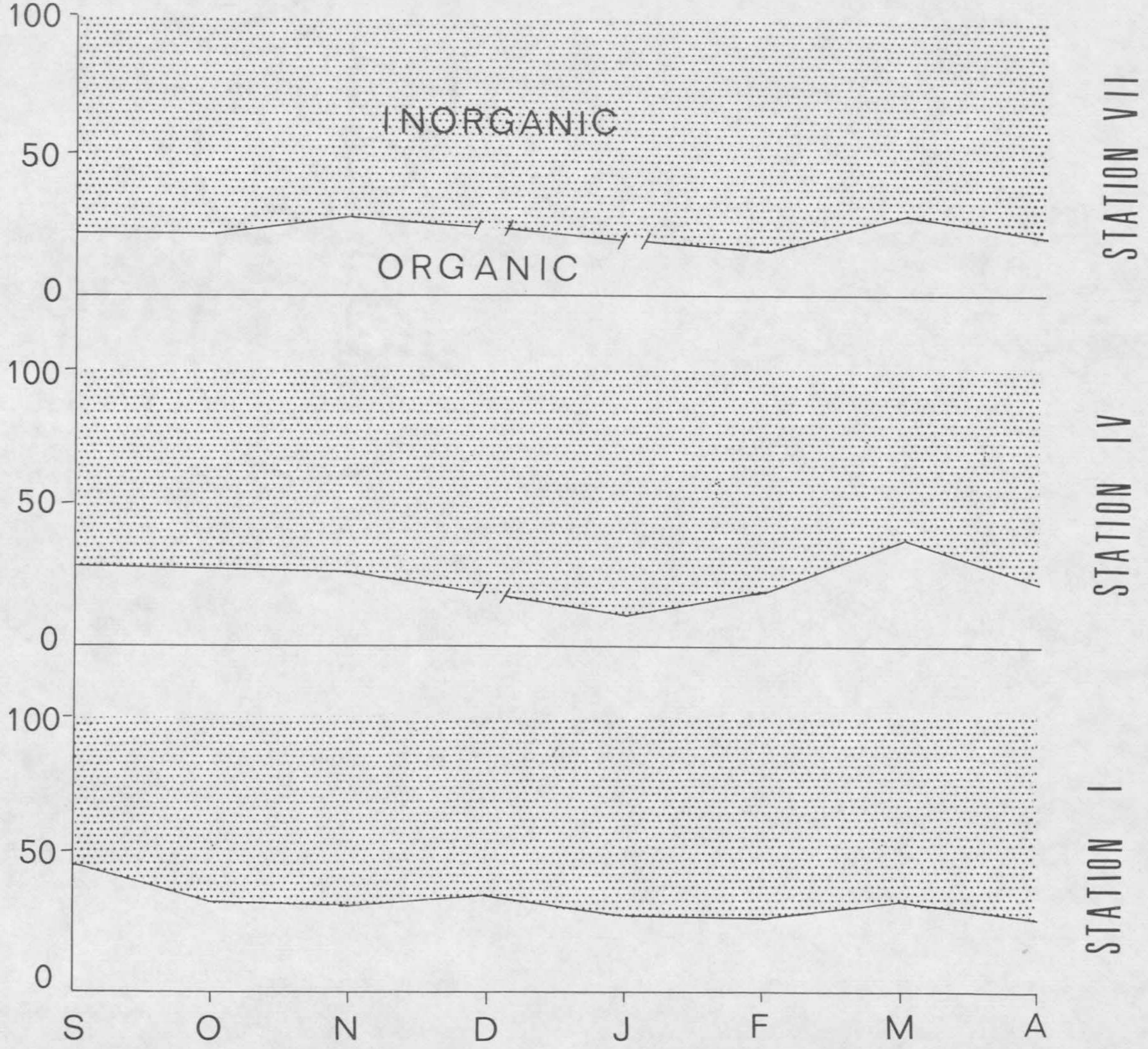

Figure 3. Percentage of inorganic and organic material associated with the aufwuchs community at three stations in the Yellowstone River.

TABLE VI. AVERAGE MONTHLY DISCHARGE (m^3/sec) OF THE YELLOWSTONE RIVER FOR THE 1968-69 AND 1969-70 WATER YEARS.

	Corwin Springs[1]		Livingston[2]		Billings[3]	
Month	68-69	69-70	68-69	69-70	68-69	69-70
October	62.9	38.9	84.1	56.5	157.1	116.3
November	46.8	32.9	64.0	48.9	130.3	106.6
December	34.1	26.7	48.7	41.0	92.1	86.8
January	30.1	23.6	40.2	36.7	82.0	71.7
February	33.3	24.8	46.6	38.1	91.4	81.1
March	33.1	26.8	45.0	38.0	103.5	76.7
April	64.3	28.0	78.6	38.7	172.7	87.3
May	273.3	168.6	311.6	190.1	451.1	470.1
June	287.8	413.2	337.3	519.9	634.2	1037.5
July	192.0	242.8	229.7	281.1	440.1	476.6
August	85.0	100.4	102.6	115.2	135.2	156.5
September	49.7	64.6	63.4	85.2	97.0	166.0

[1] Gaging station approximately 0.2 miles below station I.

[2] Gaging station approximately 26 miles above station IV.

[3] Gaging station approximately 21 miles below station VII.

carried about twice the volume of water as the upper part.

Because of the extended runoff period (May - August) no satisfactory quantitative summer collections of either benthos or aufwuchs could be made.

A gross analysis of the substrate was made using the first three ranks of the Wentworth classification (Fig. 4). The percentage of cobble and pebble was similar at all three stations, however, boulders (>256 mm) were only present at station I. The angular boulders found at station I were recent additions to the river from the steep canyon walls in this area. The gross substrate composition was similar at all stations except for the absence of boulders at the lower two stations.

Long term temperature records were available (Aagaard, 1969) for the upper, middle and lower portions of the Yellowstone River study section (Table VII). Summer temperatures were higher downstream although differences were not as great as might be expected. Maximum water temperatures occurred during July and August. The average and range of water temperatures (C) for the three locations for July were: Corwin Springs - 17.1 (14-19); Livingston - 17.2 (14-20); and Billings 18.9 (13-25). August temperatures were: Corwin Springs - 15.6 (12-19); Livingston - 16.8 (14-22); and Billings - 19.4 (14-23). Slightly higher winter temperatures (January and February) at Corwin Springs reflect the additions of thermal water to the upper Yellowstone River.

Chemical Factors

The concentration of ions increased during the winter months and decreased during the May to August period of runoff (Table VIII). Specific conductance (μmhos) at station I varied from 101 in May to 227

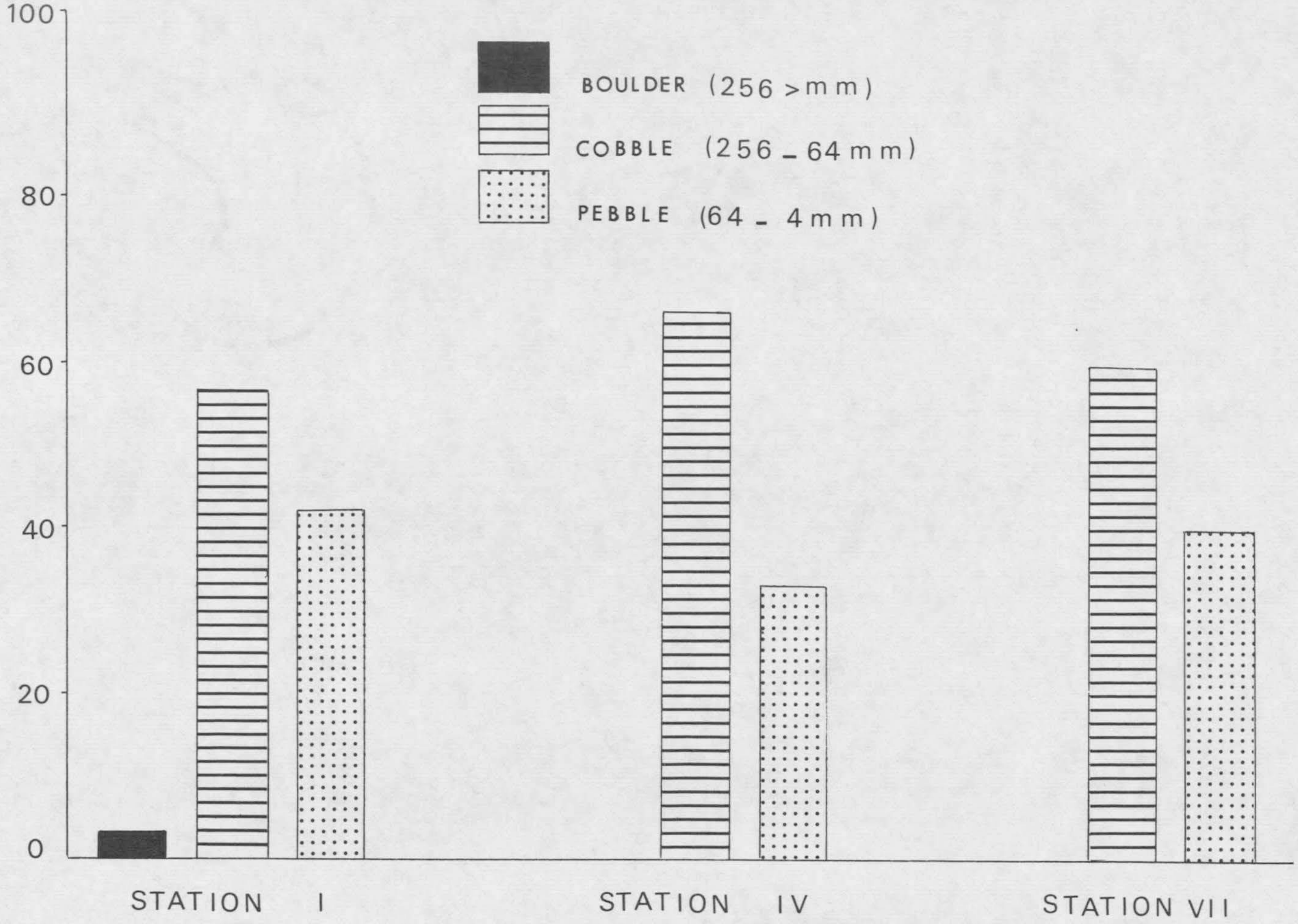

Figure 4. Percentage of larger substrate material at three stations in the Yellowstone River.

TABLE VII. AVERAGE MONTHLY TEMPERATURES (C) AND EXTREMES FOR THREE AREAS OF THE UPPER YELLOWSTONE RIVER. DATA FROM AAGAARD (1969).

	Corwin Springs[1]		Livingston[2]		Billings[3]	
Month	$\overline{X}$	Extremes	$\overline{X}$	Extremes	$\overline{X}$	Extremes
January	1.5	0 - 3	1.2	0 - 3	0.4	0 - 4
February	2.0	0 - 5	2.1	0 - 7	1.1	0 - 3
March	4.0	0 - 8	4.1	0 - 8	4.3	0 - 14
April	7.8	4 - 14	9.0	5 - 17	8.4	1 - 14
May	7.7	6 - 13	9.4	5 - 17	13.0	6 - 18
June	10.7	8 - 17	11.7	8 - 17	13.9	11 - 20
July	17.1	14 - 19	17.2	14 - 20	18.9	13 - 25
August	15.6	12 - 19	16.8	14 - 22	19.4	14 - 23
September	10.8	6 - 17	11.6	4 - 18	14.7	8 - 20
October	6.3	2 - 13	8.0	4 - 13	9.8	2 - 17
November	1.8	0 - 5	2.7	0 - 10	3.6	0 - 8
December	0.8	0 - 4	1.4	0 - 4	0.8	0 - 6

[1] Approximately 0.2 miles below station I. Spot readings April 1949-December 1965.

[2] Approximately 26 miles above station IV. Spot readings September 1949-December 1965.

[3] Approximately 21 miles below station VII. Spot readings April 1949-December 1965.

TABLE VIII. SPECIFIC CONDUCTANCE (µmhos) AT THREE STATIONS ON THE YELLOWSTONE RIVER. DATA FOR THE PERIOD JULY, 1970 TO JUNE, 1971.

Month	Station I	 IV	 VII
July	134	184	221
August	168	230	259
September	195	266	278
October	215	278	298
November	230	327	327
December	260	289	327
January	271	287	355
February	267	314	328
March	277	299	318
April	248	298	309
May	101	150	168
June	123	153	182

in March, at station IV from 150 in May to 327 in November, and at station VII from 168 in May to 355 in January.

The concentration of all major ions increased from station I to station VII except Na, K and Cl (Table IX). This increase was due mainly to additions of Ca, Mg, and HCO_3. Decreases in the concentration of Na, K, and Cl ions were due to alterations of the river water after it left Yellowstone National Park. The predominant rock

TABLE 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.

Ion	Station I	Station IV	Station VII
Calcium	0.787 (0.47-0.98)	1.282 (0.75-1.50)	1.459 (0.95-1.81)
Magnesium	0.403 (0.26-0.49)	0.569 (0.36-0.66)	0.601 (0.30-0.76)
Sodium	0.920 (0.48-1.14)	0.781 (0.34-0.99)	0.818 (0.41-1.01)
Potassium	0.111 (0.06-0.14)	0.093 (0.04-0.11)	0.086 (0.05-0.13)
Carbonate and Bicarbonate	1.181 (0.75-1.44)	1.774 (1.15-2.13)	2.043 (1.42-2.37)
Chloride	0.293 (0.08-0.41)	0.224 (0.08-0.30)	0.183 (0.07-0.27)
Sulfate	0.756 (0.37-1.31)	0.756 (0.39-1.42)	0.892 (0.44-1.58)
pH	8.13 (7.7 - 8.6)	8.35 (7.8 - 9.0)	8.21 (7.6 - 8.5)

type within the park is rhyolite (Boyd, 1961) which along with thermal water from springs and geysers may produce high Na, K, and Cl concentrations (Wright and Mills, 1967). Most feeder streams within the study section flow through granite or limestone formations which may explain chemical differences after the river leaves the park.

Dissolved oxygen was not measured since previous values at or near saturation were shown for all parts of the study section (Montana State Board of Health, 1963).

DISCUSSION

The study section in the Yellowstone River lies in the transition zone between the mountains and the prairie. Differences in the species and abundance of stoneflies exist between the upper and lower stations. There are also differences in certain physical, chemical and other biotic factors but gross substrate composition and velocity are similar.

That macro-substrate differences may influence distribution of riffle invertebrates was shown by Thorup (1966) and Cummings (1966) but was not considered significant in this study. The only major difference was the absence of a few boulders at the lower two stations. Pebble (4-64 mm) and cobble (64-256 mm) percentages were similar. Current velocity was not significantly different at the three stations and is considered to have little influence upon distribution of Plecoptera in this study. Preference for a particular velocity could probably be satisfied within different portions of the same riffle area. However, velocity may be a factor affecting distribution within a limited area (Madsen, 1969). Discharge was different at the three stations but was judged to be of minor importance in directly affecting distribution of stoneflies within the study section. Periods of peak discharge and minimum flow were approximately the same at all three stations with the only difference being the actual amount of water.

Temperature has been implicated as the major factor influencing riffle invertebrate distribution by many authors (Ide, 1935; Minshall, 1969; Dodds and Hisaw, 1925; others). In the Yellowstone River study section, summer water temperature is not the major factor controlling distribution, at least for species such as *Pteronarcys californica* and *Acroneuria pacifica*. These species became deleted from the fauna near station IV. Summer water temperatures in this area averaged no higher than 17.2 C and with a maximum of up to 22 C. Armitage (1961) found populations of *P. californica* and *A. pacifica* in the Firehole River system where summer water temperatures reached 24 C. Nebeker and Lemke (1968) show lethal temperatures to be 29 - 30 C for some stoneflies, while Knight and Gaufin (1966) found 19 - 20 C to be lethal to *A. pacifica*.

That temperature is not an important factor in the distribution of stoneflies in the Yellowstone River study section is also supported by the distribution of *A. pacifica* and *Claassenia sabulosa*. Knight and Gaufin (1966) considered these two species to be eurythermic. However, *A. pacificia* is found in abundance only in the upper part of the study section while *C. sabulosa* was abundant toward the lower portion. Knight and Gaufin also described *Alloperla pallidula* and *Pteronarcella badia* as eurythermic species and these were found at all stations. The upper critical temperature for a stonefly depends upon oxygen levels and rates of flow (Knight and Gaufin, 1963; 1964). In the study section both velocity and dissolved oxygen were high. While temperature in the study section may influence distribution to a small degree, other factors are probably more important.

Downstream alterations in the chemical composition of the river were found. These differences probably do not affect the stonefly fauna directly but may be important through their effect upon the aufwuchs. Minshall and Kuehne (1969) reported that "Differences in nutrients or other water quality factors appear to be the most likely explanation for the observed discontinuity of the fauna". Egglishaw and Morgan (1965) found that variations in the richness of the bottom fauna were associated with differences in chemical composition of the water. There was a downstream increase in the amount of inorganic material incorporated into the aufwuchs community which may have influenced distribution of stoneflies. Chutter (1970) found that the amount of silt and sand influences distribution of riffle invertebrates, however, the actual amount of inorganic material found in this study was not of the same magnitude as found by Chutter.

Increases in the AI show that the Yellowstone River is more eutrophic downstream. The aufwuchs community contains a higher percentage of heterotrophic organisms and is much less stable in the lower portion of the study section. These changes in the aufwuchs may have a marked influence on the distribution of herbivorous stoneflies. Diatoms which are the major algal group in the study section are known to be an important source of food for herbivores (Minshall, 1968). Large changes in the aufwuchs community downstream due to the action of ice blocks may also be a factor influencing those stoneflies that are herbivores. These changes in the aufwuchs could also indirectly affect predacious stoneflies through alterations in prey species.

Allochthonous detritus is known to be important in the distribution of some invertebrates (Egglishaw, 1964; Minshall, 1967). No quantitative estimate of this material was made during the study and it is possible that allochthonous detritus may be a factor in stonefly distribution.

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