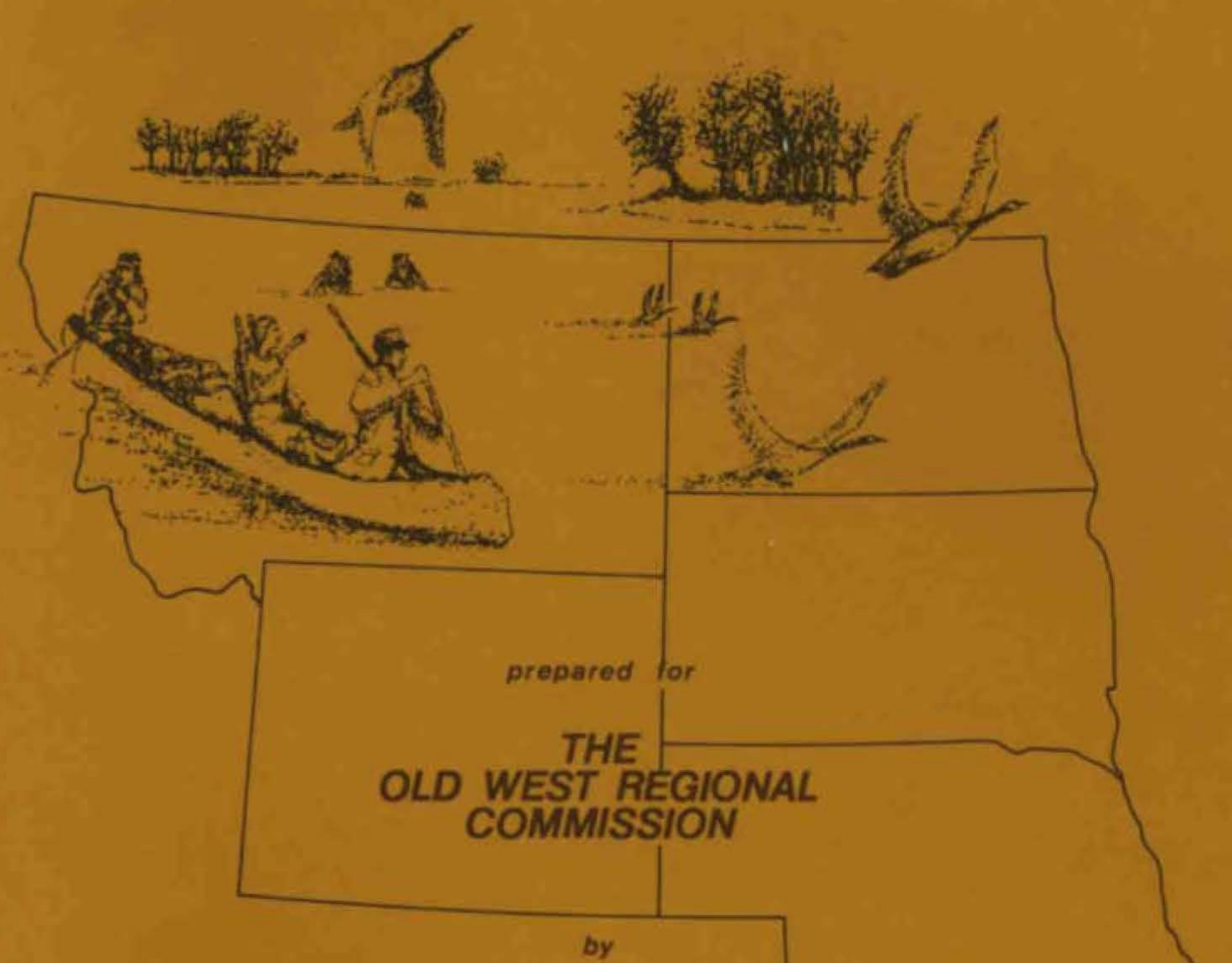
Aquatic invertebrates of the Yellowstone River Basin, Montana

YELLOWSTONE IMPACT STUDY

TECHNICAL REPORT NO. 5



prepared for

THE
OLD WEST REGIONAL
COMMISSION

by

DNRC WATER RESOURCES DIVISION — JULY 1977

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

Aquatic invertebrates of the Yellowstone River Basin, Montana

by

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conducted by the

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The Old West Regional Commission is a Federal-State partnership designed to solve regional economic problems and stimulate orderly economic growth in the states of Montana, Nebraska, North Dakota, South Dakota and Wyoming. Established in 1972 under the Public Works and Economic Development Act of 1965, it is one of seven identical commissions throughout the country engaged in formulating and carrying out coordinated action plans for regional economic development.

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FOREWORD

The Old West Regional Commission wishes to express its appreciation for this report to the Montana Department of Natural Resources and Conservation, and more specifically to those Department staff members who participated directly in the project and in preparation of various reports, to Dr. Kenneth A. Blackburn of the Commission staff who coordinated the project, and to the subcontractors who also participated. The Yellowstone Impact Study was one of the first major projects funded by the Commission that was directed at investigating the potential environmental impacts relating to energy development. The Commission is pleased to have been a part of this important research.

George D. McCarthy
Federal Cochairman

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Abbreviations used in this report

af	acre-feet
cfs	cubic feet per second
CPOM	coarse particulate organic matter
$\bar{d}$	mean diversity
E_m	equitability
FPOM	fine particulate organic matter
ft	feet
ft/sec	feet per second
in^2	square inches
J'	evenness
km	kilometers
km^2	square kilometers
m	meter
m^2	square meters
m/sec	meters per second
max.	maximum
min.	minimum
mm	millimeter
mmaf/y	million acre-feet per year
msl	mean sea level
mw	megawatts (10^6 watts)
N	total number of individuals
N_i	number of individuals in the i^{th} taxon
P/R	production/respiration ratio
R	redundancy
s	number of taxa in sample
s^1	tabulated value
SR	species richness
WSP	Water Surface Profile

Preface

THE RIVER

The Yellowstone River Basin of southeastern Montana, northern Wyoming, and western North Dakota encompasses approximately 180,000 km^2 (71,000 square miles), 92,200 (35,600) of them in Montana. Montana's portion of the basin comprises 24 percent of the state's land; where the river crosses the border into North Dakota, it carries about 8.8 million acre-feet of water per year, 21 percent of the state's average annual outflow. The mainstem of the Yellowstone rises in northwestern Wyoming and flows generally northeast to its confluence with the Missouri River just east of the Montana-North Dakota border; the river flows through Montana for about 550 of its 680 miles. The major tributaries, the Boulder, Stillwater, Clarks Fork, Bighorn, Tongue, and Powder rivers, all flow in a northerly direction. The western part of the basin is part of the middle Rocky Mountains physiographic province; the eastern section is located in the northern Great Plains (Rocky Mountain Association of Geologists 1972).

THE CONFLICT

Historically, agriculture has been Montana's most important industry. In 1975, over 40 percent of the primary employment in Montana was provided by agriculture (Montana Department of Community Affairs 1976). In 1973, a good year for agriculture, the earnings of labor and proprietors involved in agricultural production in the fourteen counties that approximate the Yellowstone Basin were over $141 million, as opposed to $13 million for mining and $55 million for manufacturing. Cash receipts for Montana's agricultural products more than doubled from 1968 to 1973. Since that year, receipts have declined because of unfavorable market conditions; some improvement may be in sight, however. In 1970, over 75 percent of the Yellowstone Basin's land was in agricultural use (State Conservation Needs Committee 1970). Irrigated agriculture is the basin's largest water use, consuming annually about 1.5 million acre-feet (af) of water (Montana DNRC 1977).

There is another industry in the Yellowstone Basin which, though it consumes little water now, may require more in the future, and that is the coal development industry. In 1971, the North Central Power Study (North Central Power Study Coordinating Committee 1971) identified 42 potential power plant sites in the five-state (Montana, North and South Dakota, Wyoming, and Colorado) northern Great Plains region, 21 of them in Montana. These plants, all to be fired by northern Great Plains coal, would generate 200,000 megawatts (mw) of electricity, consume 3.4 million acre-feet per year (mmaf/y) of water, and result in a large population increase. Administrative, economic, legal, and technological considerations have kept most of these conversion facilities, identified in the North Central Power Study as necessary for 1980, on the drawing board or in the courtroom. There is now no chance of their being completed by that date or even soon after, which will delay and diminish the economic benefits some basin residents had expected as a result of coal development. On the other hand, contracts have been signed for the mining of large amounts of Montana coal, and applications have been approved not only for new and expanded coal mines but also for Colstrip Units 3 and 4, twin 700-mw, coal-fired, electric generating plants.

In 1975, over 22 million tons of coal were mined in the state, up from 14 million in 1974, 11 million in 1973, and 1 million in 1969. By 1980, even if no new contracts are entered, Montana's annual coal production will exceed 40 million tons. Coal reserves, estimated at over 50 billion economically strippable tons (Montana Energy Advisory Council 1976), pose no serious constraint to the levels of development projected by this study, which range from 186.7 to 462.8 million tons stripped in the basin annually by the year 2000. Strip mining itself involves little use of water. How important the energy industry becomes as a water user in the basin will depend on: 1) how much of the coal mined in Montana is exported, and by what means, and 2) by what process and to what end product the remainder is converted within the state. If conversion follows the patterns projected in this study, the energy industry will use from 48,350 to 326,740 af of water annually by the year 2000.

A third consumptive use of water, municipal use, is also bound to increase as the basin population increases in response to increased employment opportunities in agriculture and the energy industry.

Can the Yellowstone River satisfy all of these demands for her water? Perhaps in the mainstem. But the tributary basins, especially the Bighorn, Tongue, and Powder, have much smaller flows, and it is in those basins that much of the increased agricultural and industrial water demand is expected.

Some impacts could occur even in the mainstem. What would happen to water quality after massive depletions? How would a change in water quality affect existing and future agricultural,industrial, and municipal users? What would happen to fish, furbearers, and migratory waterfowl that are dependent on a certain level of instream flow? Would the river be as attractive a place for recreation after dewatering?

One of the first manifestations of Montana's growing concern for water in the Yellowstone Basin and elsewhere in the state was the passage of significant legislation. The Water Use Act of 1973, which, among other things, mandates the adjudication of all existing water rights and makes possible the reservation of water for future beneficial use, was followed by the Water Moratorium Act of 1974, which delayed action on major applications for Yellowstone Basin water for three years. The moratorium, by any standard a bold action, was prompted by a steadily increasing rush of applications and filings for water (mostly for industrial use) which, in two tributary basins to the Yellowstone, exceeded supply. The DNRC's intention during the moratorium was to study the basin's water and related land resources, as well as existing and future need for the basin's water, so that the state would be able to proceed wisely with the allocation of that water. The study which resulted in this series of reports was one of the fruits of that intention. Several other Yellowstone water studies were undertaken during the moratorium at the state and federal levels. Early in 1977, the 45th Montana Legislature extended the moratorium to allow more time to consider reservations of water for future use in the basin.

THE STUDY

The Yellowstone Impact Study, conducted by the Water Resources Division of the Montana Department of Natural Resources and Conservation and financed by the Old West Regional Commission, was designed to evaluate the potential physical, biological, and water use impacts of water withdrawals and water development on the middle and lower reaches of the Yellowstone River Basin in Montana. The study's plan of operation was to project three possible levels of future agricultural, industrial, and muncipal development in the Yellowstone Basin and the streamflow depletions associated with that development. Impacts on river morphology and water quality were then assessed, and, finally, the impacts of altered streamflow, morphology, and water quality on such factors as migratory birds, furbearers, recreation, and existing water users were analyzed.

The study began in the fall of 1974. By its conclusion in December of 1976, the information generated by the study had already been used for a number of moratorium-related projects--the EIS on reservations of water in the Yellowstone Basin, for example (Montana DNRC 1976). The study resulted in a final report summarizing all aspects of the study and in eleven specialized technical reports:

Report No. 1	Future Development Projections and Hydrologic Modeling in the Yellowstone River Basin, Montana.
Report No. 2	The Effect of Altered Streamflow on the Hydrology and Geomorphology of the Yellowstone River Basin, Montana.
Report No. 3	The Effect of Altered Streamflow on the Water Quality of the Yellowstone River Basin, Montana.
Report No. 4	The Adequacy of Montana's Regulatory Framework for Water Quality Control
Report No. 5	Aquatic Invertebrates of the Yellowstone River Basin, Montana.
Report No. 6	The Effect of Altered Streamflow on Furbearing Mammals of the Yellowstone River Basin, Montana.
Report No. 7	The Effect of Altered Streamflow on Migratory Birds of the Yellowstone River Basin, Montana.

Report No. 8 The Effect of Altered Streamflow on Fish of the Yellowstone and Tongue Rivers, Montana.

Report No. 9 The Effect of Altered Streamflow on Existing Municipal and Agricultural Users of the Yellowstone River Basin, Montana.

Report No. 10 The Effect of Altered Streamflow on Water-Based Recreation in the Yellowstone River Basin, Montana.

Report No. 11 The Economics of Altered Streamflow in the Yellowstone River Basin, Montana.

ACKNOWLEDGMENTS

The author would like to thank all biologists and friends who contributed time, effort, and specimens for this study. He would also like to thank the Intake Water Company and the Old West Regional Commission for contributing research funds.

The author also thanks the following experts who helped identify organisms: Trichoptera (D.G. Denning);Plecoptera (R.W. Bauman, B. Stark); Coleoptera-Elmidae (H.P. Brown); Diptera-Chironomidae (L. Curry); Oligochaeta and Mollusca (D. Klemm); Odonata and Hemiptera (G. Roemhild).

A special thanks is given to R. Berg, D. Workman, and D. Schwehr of the Montana Department of Fish and Game for taking bottom samples on the middle and upper Yellowstone River and to A. Elser and R. McFarland for taking samples on the Tongue River. Mr. Burwell Gooch of the Systems Development Bureau, Data Processing Division, Montana State Department of Administration was very helpful in constructing computer programs for species diversity analyses and regression analysis.

Carole Massman, Jim Bond, and Pam Tennis of the Montana Department of Natural Resources and Conservation provided editorial assistance. Graphics were coordinated and performed by Gary Wolf, with the assistance of June Virag and Dan Nelson and of D. C. Howard, who also designed and executed the cover.

Introduction

PURPOSE

Objectives of this research task were to gain insight into the environmental requirements of the dominant macroinvertebrate genera and species of the Yellowstone River and to describe the distribution of macroinvertebrates in the Yellowstone and Tongue rivers.

SCOPE

Water velocity and depth were chosen as the independent variables that would be examined. Since current affects invertebrate distribution in several ways, e.g., distribution of food and size of substratum, and because current and discharge are closely interrelated, studies of the effects of current on invertebrate distribution are meaningful and permit predictions about changes in invertebrate communities occurring because of altered flows. Because of the gently sloping morphology of the river channel, depth is also important; both current velocity and depth are functions of discharge.

Species diversity and river zonation analyses were made in an attempt to understand distributional patterns of invertebrates, provide baseline data, and record differences and similarities among populations at different sampling stations.

STUDY AREA

Almost all of the length of the Yellowstone River outside of Yellowstone Park was included in the study. Of the 20 invertebrate sampling stations employed in the study (figure 1), the uppermost, at Corwin Springs, is only about seven river miles (11 km) below the park boundary, and the lowest, at Cartwright, N.D., only about nine river miles (14 km) above the mouth of the river. These stations are shown on a longitudinal profile of the river in figure 2.

The Tongue River also was extensively studied since the macroinvertebrate fauna there influence the fauna of the lower Yellowstone River. Figures 3 and 4 show sampling stations employed on the Tongue River.

Figures 5 through 14 illustrate selected sampling station locations and characteristic views of the upper and lower Yellowstone River.

No.	Location	County	Elevation (msl) in ft	River Mile[a]
1	Corwin Springs	Park	5110	549
2	Mallard Rest Access	Park	4620	515
3	above Livingston	Park	4490	501
4	above Shields River	Park	4380	497
5	Grey Bear Access	Sweetgrass	4100	468
6	below Greycliff	Sweetgrass	3880	444
7	Columbus	Stillwater	3566	411
8	Laurel	Yellowstone	3294	391
9	Duck Creek Bridge	Yellowstone	3140	360
10	Huntley	Yellowstone	3110	349
11	Custer	Yellowstone	2720	300
12	Bighorn River	Treasure	2700	296
13	Myers	Treasure	2640	279
14	Forsyth	Rosebud	2490	234
15	Miles City	Custer	2335	184
16	Terry	Prairie	2190	138
17	Glendive	Dawson	2045	93
18	Intake	Dawson	1998	71
19	Sidney	Richland	1892	30
20	Cartwright, N.D.	McKenzie	1850	9

CONVERSIONS: 1 ft = .305 m
1 mile = 1.609 km

[a]Mouth of the Yellowstone River is river mile 0.

Yellowstone River Basin

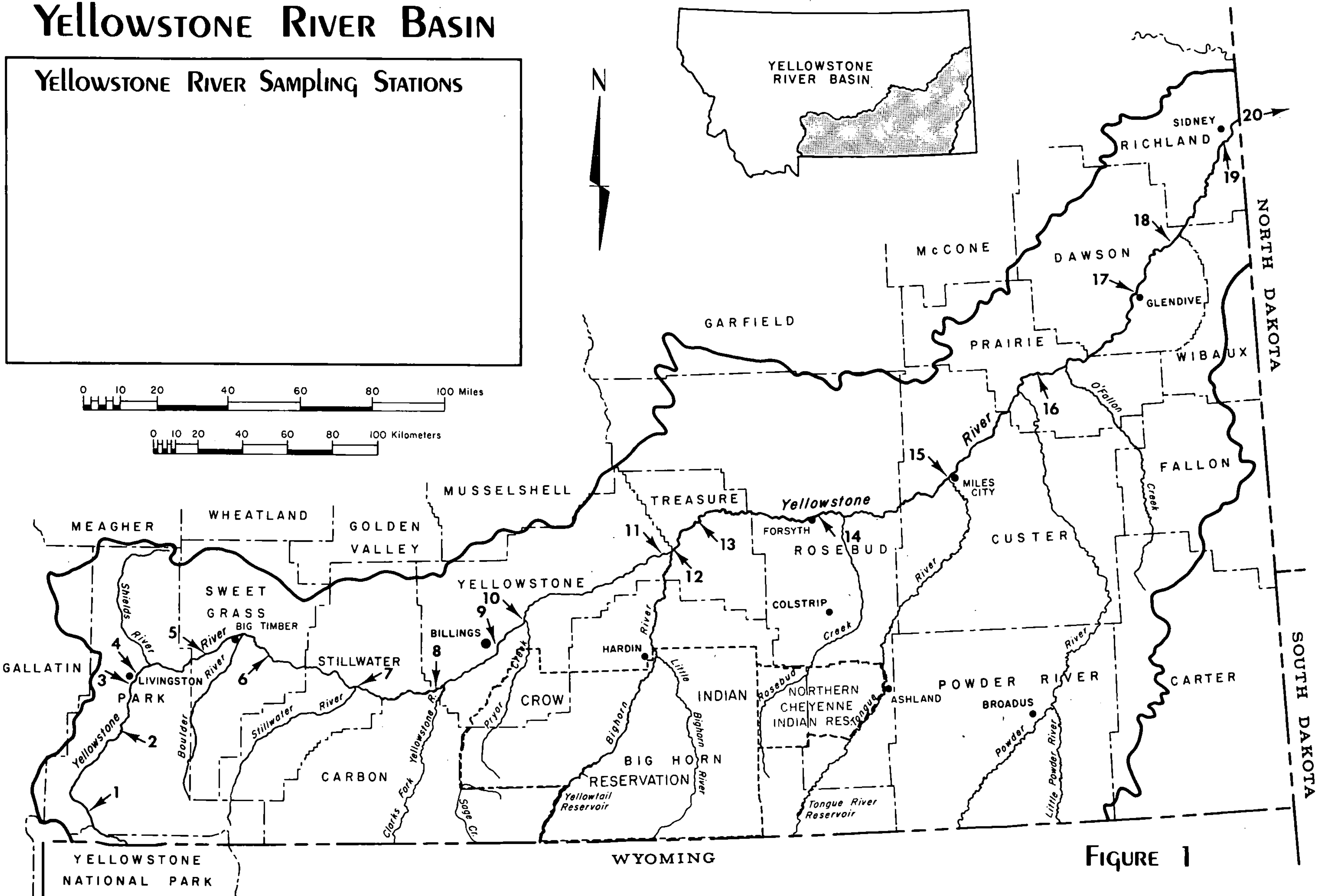


FIGURE 1

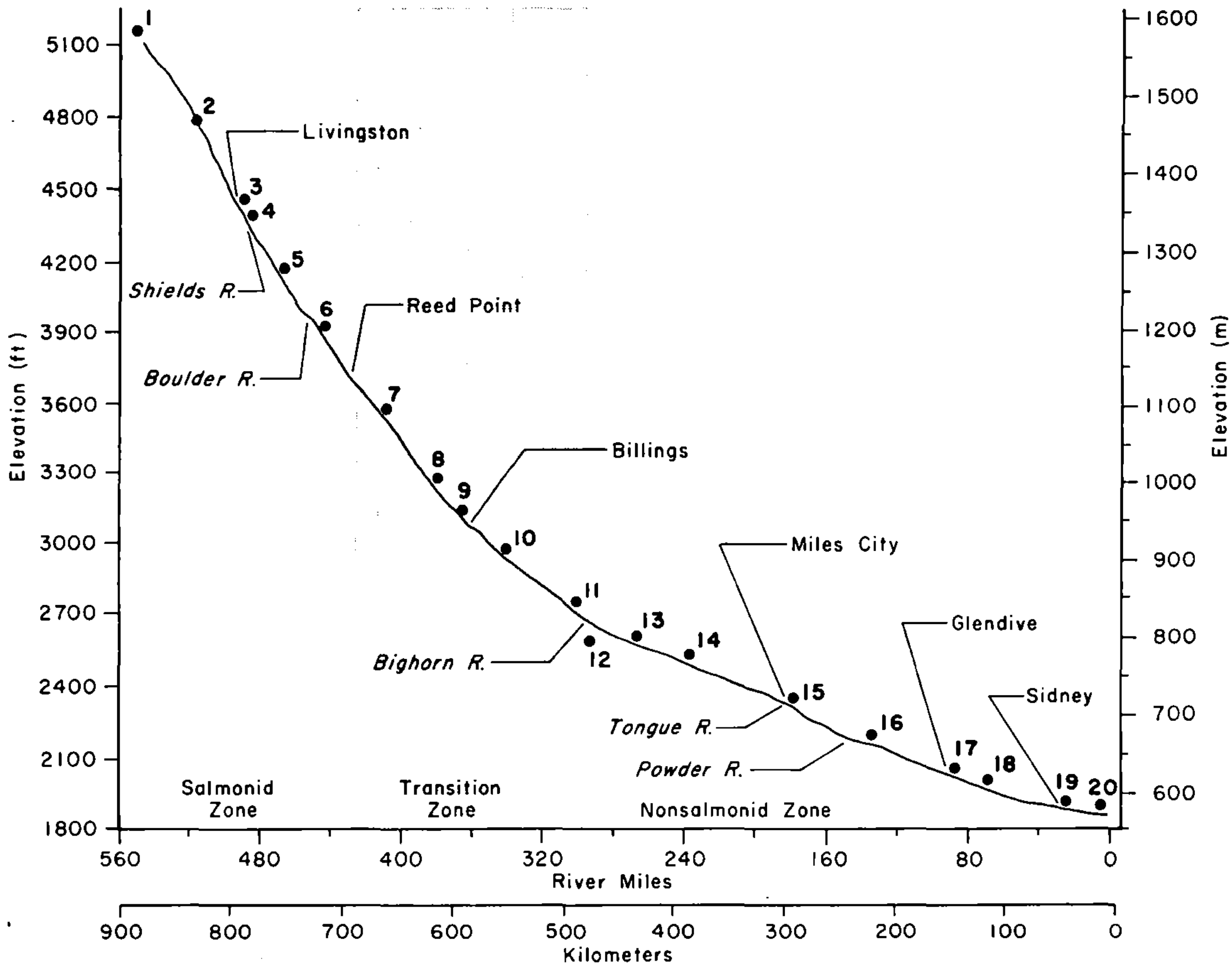


Figure 2. Longitudinal profile of the Yellowstone River, showing invertebrate sampling stations and probable fish distribution zones.

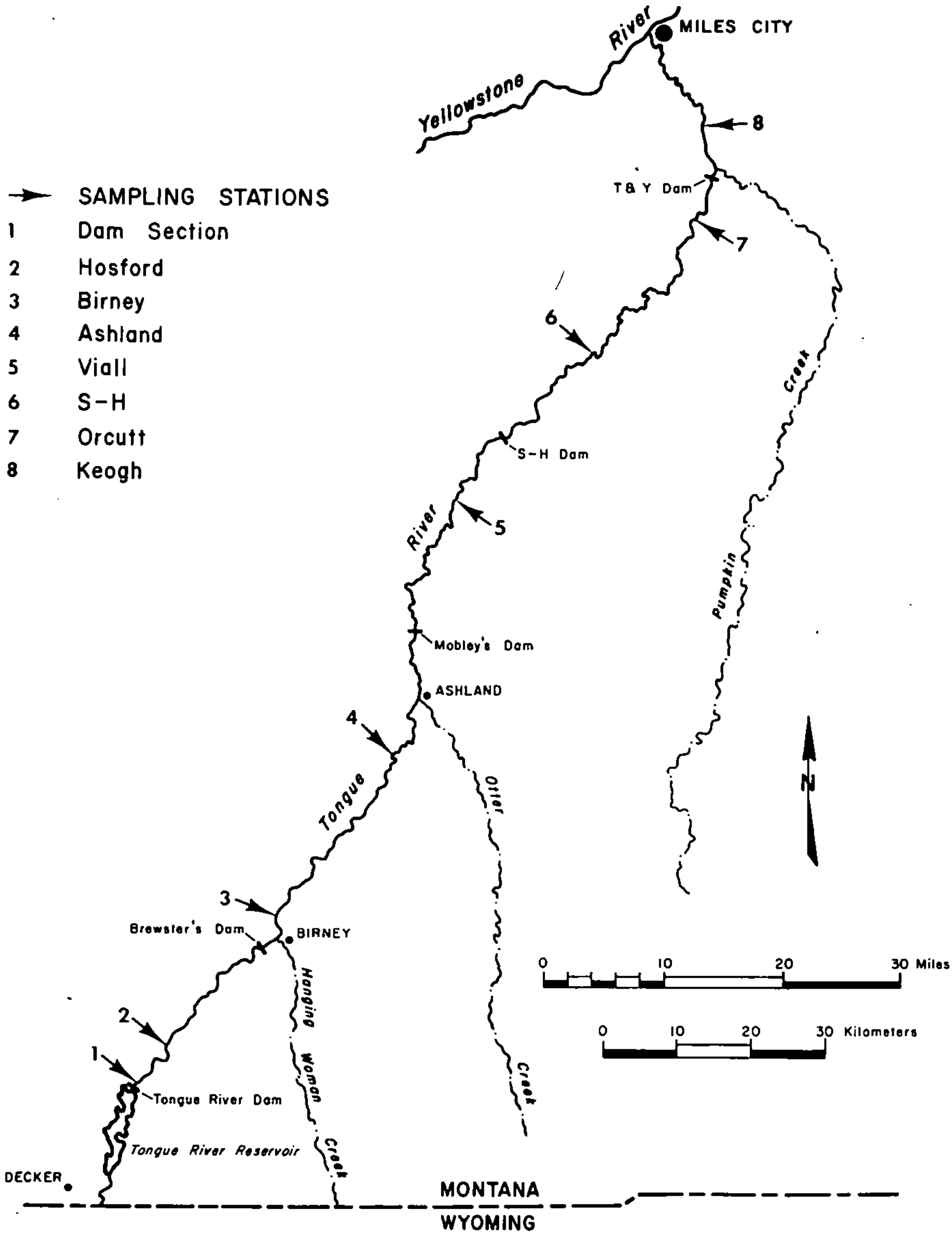


Figure 3. Tongue River sampling stations.

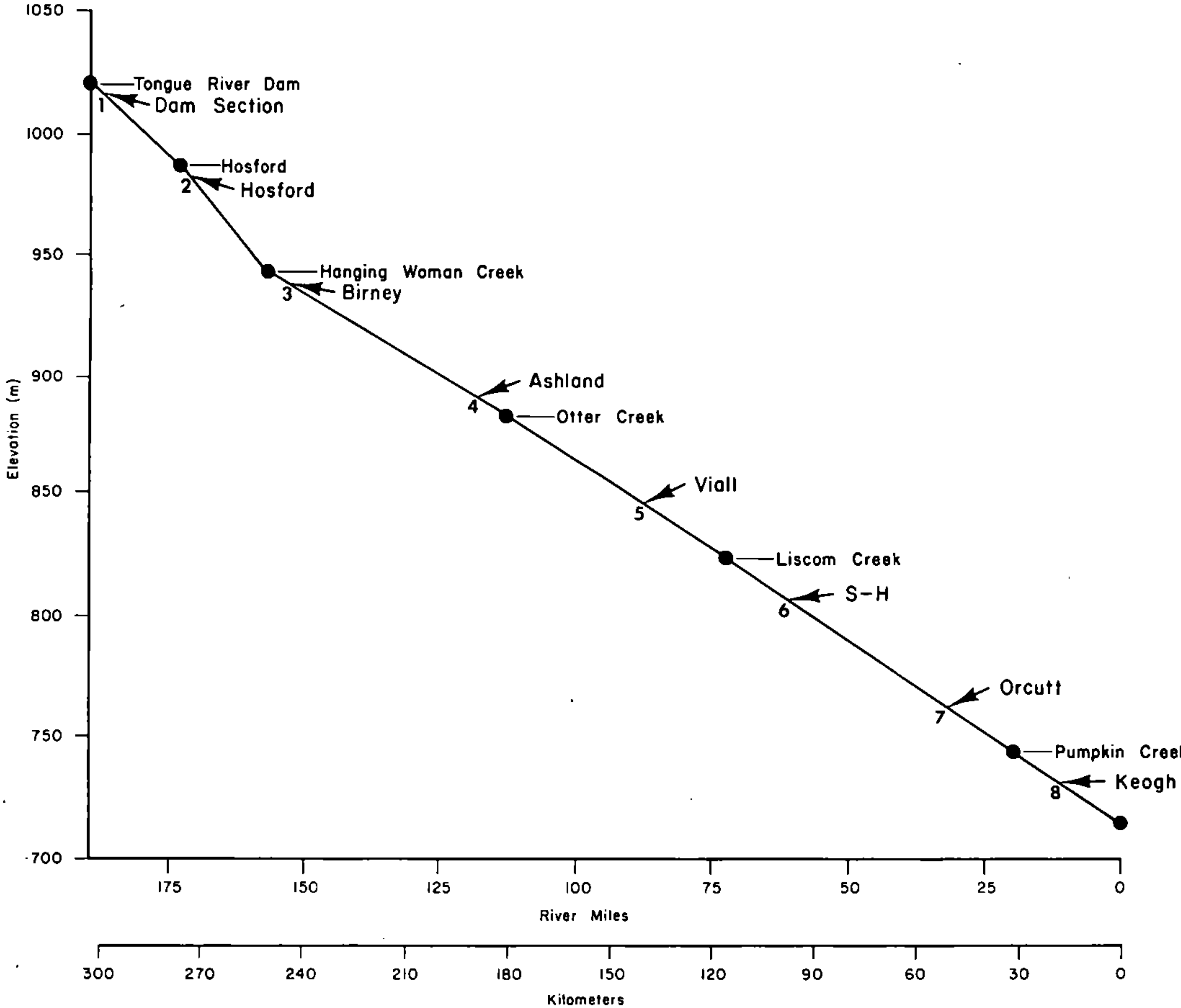


Figure 4. Longitudinal profile of the Tongue River in Montana, showing invertebrate sampling stations.

Figure 5. Sampling Station 1, Corwin Springs.

Figure 6. Yankee Jim Canyon between stations 1 and 2.

Figure 7. Near Station 3 above Livingston.

Figure 8. Station 4 at Livingston.

Figure 9. Station 5 at Grey Bear Fishing Access.

Figure 10. Aerial view of Yellowstone River above Miles City.

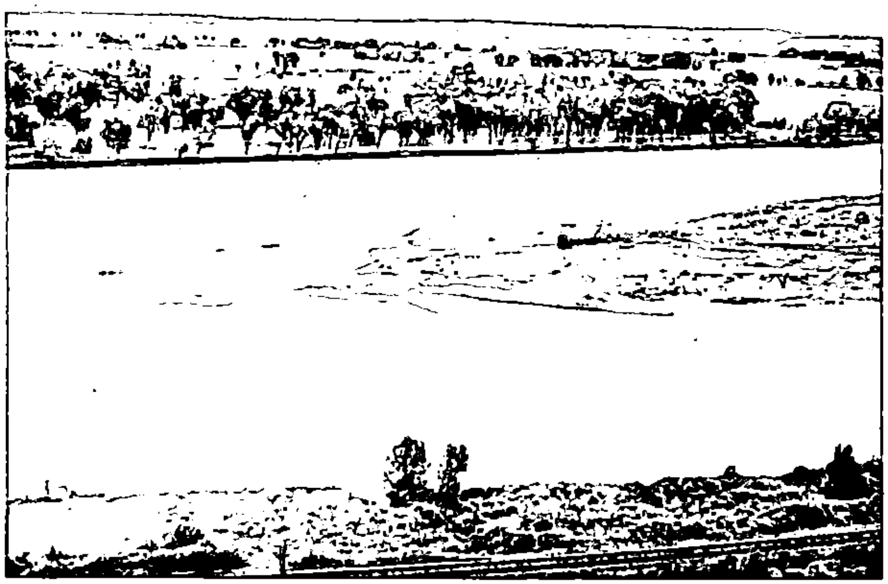


Figure 11. The Yellowstone River about 10 miles upstream from Miles City.

Figure 12. Yellowstone River at Glendive during early winter.

Figure 13. Aerial view of the Intake diversion, sampling station No. 18.

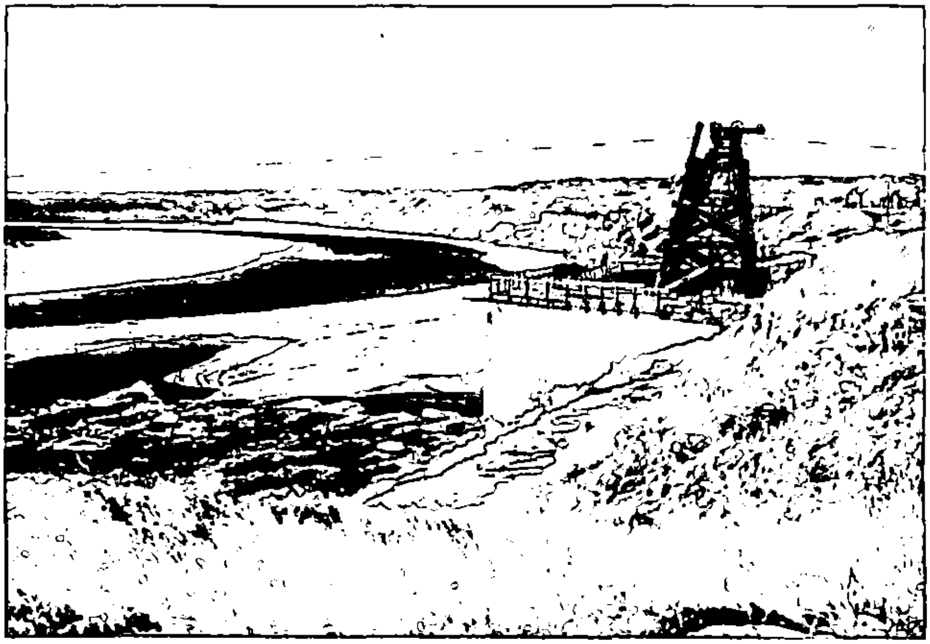


Figure 14. Yellowstone River at Intake diversion.

Methods

SAMPLING METHODS AND MATERIALS

Sampling methods used to collect aquatic macroinvertebrates on the Yellowstone River included kick nets (figure 15), Water's round samplers (figure 16), and Hester-Dendy multiple plate artifical substrates.

The kick net, essentially a Surber Sampler on a pole, consisted of a modified Turtox bottom net 10" deep with dimensions of 8" x 8", a six-foot wooden handle used to hold the net perpendicular to the current, and wire frame 17" x 16" attached to the bottom lip of the net frame perpendicular to the net opening in such a way that the wire frame rested on the stream bottom. The area within the frame was 272 in^2 (0.175 m^2). When the area within the frame was disturbed, bottom organisms were carried into the number 20 (0.70 mm) mesh net. Net material was added to each side of the wire frame to minimize side washout of organisms.

This technique can be used as long as the water is shallow enough to wade. The bottom outlined by the frame is merely stirred with the foot. This sampler was used at the Glendive and Intake sampling stations during 1975 only. Water depth, and current speed at six-tenths total depth, were determined in the center of each sampling site. A timed (2-minute) kick sample without the 17" x 16" frame was taken at many stations during 1974 in the Yellowstone and Tongue rivers to determine relative abundance of organisms.

A Water's round sampler was used to take six samples per month at ten of the 20 sampling stations in the Yellowstone River from August to November 1975. The Water's sampler is 19.5 in (.495 m) in height and encloses an area just slightly less than one ft^2 (143.14 in^2 or 0.093 m^2). The area to be sampled, randomly selected, is approached from downstream. After forcing the sampler into the bottom, the investigator reaches down through the open top and stirs the bottom with his hand. Water current carries the organisms into the trailing, 20-mesh net. All organisms were preserved in the field in 70-percent ethyl alcohol.

Hester-Dendy multiple-plate artificial samplers (Hester and Dendy 1962), Fullner 1971, Parsons and Tatum 1974) were used occasionally during 1974 but their use was discontinued when they proved to be unsatisfactorily colonized.

In the laboratory, all organisms were picked from bottom detritus and gravel under a dissecting microscope. Immature invertebrates were identified to genus and species (and, less commonly, only to family) using appropriate taxonomic keys. Adult insects were used whenever possible to confirm species identifications. Experts (identified on page 4) were consulted when difficulties were encountered.

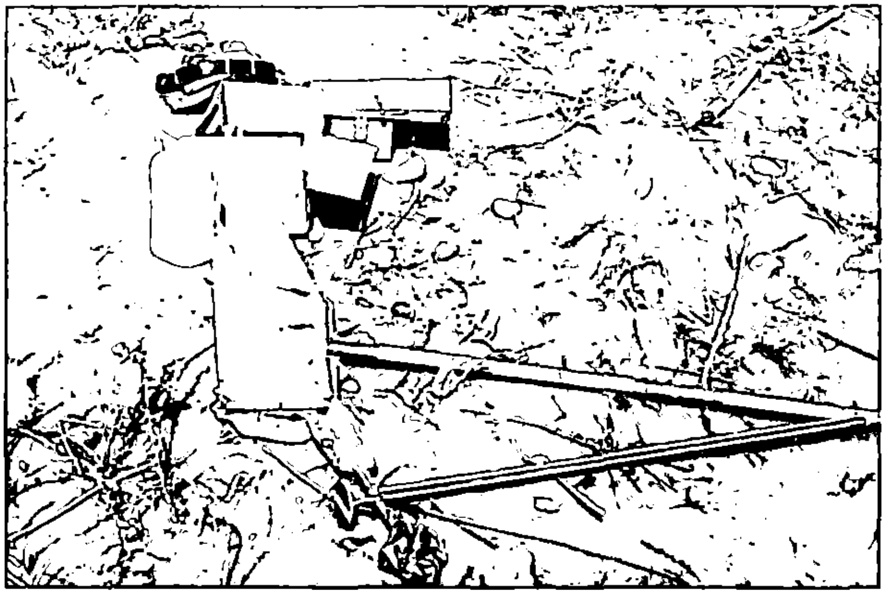


Figure 15. Kick net and other data collecting gear.

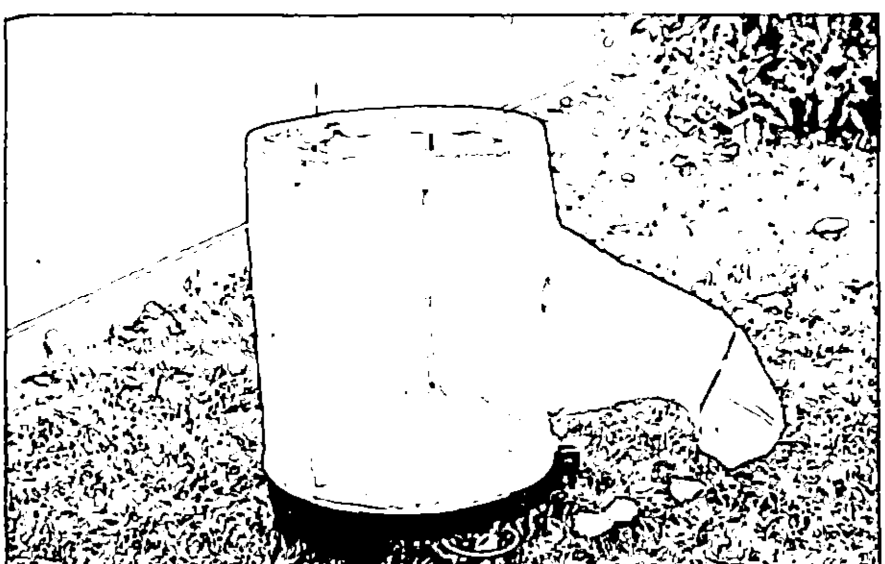


Figure 16. Water's round bottom sampler.

Measurements were made to determine velocity and depth preferences of invertebrates. All velocity measurements were made with a Price model-AA-type current meter at six-tenths total depth.

Discharge at the Miles City and Sidney stations on dates sampling was preformed is shown in Table 1 (USGS 1976).

Table 1. Discharges of the Yellowstone River at Miles City and Sidney during sampling periods (cfs).

Date	Miles City	Sidney
August 6, 1975	20,200	21,200
August 7, 1975	18,500	20,300
September 9, 1975	9,890	10,100
September 17, 1975	8,440	8,980
October 9, 1975	8,000	9,730
October 15, 1975	8,850	10,300
November 7, 1975	8,620	10,400
November 11, 1975	10,300	10,100

CONVERSIONS: 1 cfs = .0283 m^3/sec

SPECIES DIVERSITY CALCULATIONS

Aggregations or communities of aquatic organisms are subjected to almost continual stress due to environmental changes, some natural and others caused by society. It is a generally accepted axiom in ecology that a gross environmental stress exerted upon a diverse biological community (one consisting of a large number of species) results in a simplication of the system through a reduction of species diversity (i.e. number of species) (Cairns 1969). Slobodkin and Sanders (1969) developed the stability-time hypothesis to suggest the kinds of animals that must live in low- and high-diversity places: all places of high diversity would have stable or predictable environments, and all places of low diversity would either be places of unpredictable hazard or would be short-lived. This theory was tested in one widespread, stable environment--the ocean floor. Although this investigation is far from complete, the theory appears to hold.

In low-diversity areas, the dangers of species extinction are great. Populations of opportunistic animals must frequently be decreased by weather to prevent it, and the possibility still exists of breeding failure. The loss of several consecutive year-classes means extinction even for long-lived animals. But such year-class failure is less likely in stable climates, and a series of failures is unlikely. Extinction is thus more probable as environmental stress increases.

The actual number of species present in any place is a product both of the loss of species by extinction and of their replacement with new species. In a few specialized organisms, such as birds, a limit to the number of species that can accumulate is set by a restricted number of possible niches. For most other kinds of animals and plants, the number of possible niches is much larger than the number of existing species. The patterns of diversity presently evident are the products of different environments of the earth (Colinvaux 1973).

The use of species diversity indices to analyze biological communities originates from efforts to apply information theory to complex biological problems. Workers who have explored the theoretical use of diversity indices in biology, suggested refinements, or attempted studies include Brillouin (1960), Lloyd and Ghelardi (1964), Wilhm and Dorris (1966, 1968) Lloyd et al. (1968), Margalef (1968), Pielou (1969), Wilhm (1967, 1970abc, 1972), and Cairns and Dickson (1971). Several indices have been generally accepted: mean diversity ($\bar{d}$), equitability (E_m), redundancy (R), evenness (J'), and richness (SR).

FORTRAN computer programs for calculating species diversity indices are available from the following sources: Wilhm (1970b), Cairns and Dickson (1971), and Orr et al. (1973).

MEAN DIVERSITY ($\bar{d}$)

In general, the fundamental objective of information theory is applied to biology is to provide insight into community structure. The biological information theorist asks how much new knowledge or "information" about the species composition of a community can be obtained by drawing individuals at random. If the community is composed of only one species, then no new composition information is obtained after the first drawing. But if the community is composed of numerous species, possibly with each individual being a different species, then much new information is gained with each drawing. Information theory attempts to quantify the information contained in the community in terms of "bits" of information per individual.

Mathematically stated, "information" equals the uncertainty of correctly predicting the identity of an individual randomly chosen from a community. Where uncertainty is high, information per individual is high. The mean amount of uncertainty of prediction of any individual's identity equals the mean number of bits of information per individual, and this number is referred to as the species diversity index. Mean information per individual is commonly measured using the function developed by and named after Shannon and Weaver (1964). The formula for the Shannon-Weaver function is:

$$d = -\sum_{i=1}^{s} (N_i/N) \log_2(N_i/N)$$

where d = mean number of bits of information per individual, or the species diversity index.

s = number of taxa in the sample

N_i = number of individuals in the taxon

N = total number of individuals

A few of the authors cited earlier in this section and Hurlbert (1971) have criticized the Shannon-Weaver function as improperly used in many studies. However, the U.S. Environmental Protection Agency (1973) has provisionally accepted and recommended the function for aquatic macrobenthos studies.

The index, $\bar{d}$, possesses features that make it a useful method for summarizing community diversity. The index is dimensionless and expresses the relative importance of each species in the community. As sample size is increased, the $\bar{d}$ of the progressively pooled samples increases rapidly at first and then levels off. Since diversity of progressively pooled samples asymptotically approaches the diversity of the population, and since diversity of individual samples are highly variable, it is preferable to report the diversity of the pooled samples. Diversity had leveled off by the fifth pooled sample in most of the areas sampled by Wilhm (1970abc). The range of $\bar{d}$ varies from zero to any positive number. A value of zero is obtained when all individuals belong to the same species. The maximum value of $\bar{d}$ depends on the number of individuals counted and is obtained when all individuals belong to different species. The $\bar{d}$ usually varies between three and four in clean-water stream areas and is usually less than one in polluted stream areas (Wilhm 1970abc).

A low diversity index indicates a largely monotypic community dominated by a few abundant organisms. Often the total number of species is low. In addition, a low diversity index often suggests that degraded environmental conditions exist which favor the proliferation of a few tolerant species and the removal of less tolerant forms. A high diversity index indicates a heterogeneous community in which abundance is distributed more evenly among a number of species. The total number of species is generally high.

EQUITABILITY (E_m)

As measured by Margalef (1957) and Krebs (1972), equitability (E_m) is a retio of the observed $\bar{d}$ to a maximum theoretical diversity ($\bar{d}_{max}$) computed as though all individuals were equally distributed among the species. Maximum diversity here is measured simply as $\log_2$ s; therefore

$$E_m = \bar{d}/\log_2 s$$

As equitability increases, the species become more evenly distributed and their distributions conform more closely to perfect theoretical distributions. Equitability may range from 0 to 1, except that in samples containing only a few specimens with several taxa represented, values of E_m greater than 1 may occur. The estimates of E_m and $\bar{d}$ improve with increased sample size, and samples containing fewer than 100 specimens should be evaluated with caution if at all (U.S. EPA 1973).

An improved equitability formula is presented below and must be used with tables presented in Lloyd and Ghelardi (1964) and U.S. EPA (1973):

$$E_{m2} = s^1/s$$

where s^1 = tabulated value

Because a table is required to calculate E_{m2} it is not easily applied to computer operations.

Equitability has been found to be sensitive to even slight levels of environmental degradation. Equitability levels below 0.5 have not been encountered in southeastern U.S. streams known to be unaffected by oxygen-demanding wastes, and in such streams E_{m2} values are generally between 0.6 and 0.8. Even slight levels of degradation have been found to reduce E_{m2} below 0.5 and generally to a range of 0.0 to 0.3.

REDUNDANCY (R)

Redundancy (R), as measured by Wilhm and Dorris (1968) and Cairns and Dickson (1971), gives the relative position of the observed diversity index ($\overline{d}$) between theoretical maximum and minimum diversities ($\overline{d}_{max}$ and d_{min}). It is calculated as follows:

$$R = \frac{\overline{d}_{max} - \overline{d}}{\overline{d}_{max} - \overline{d}_{min}}$$

Theoretical maximum and minimum diversities are calculated as follows:

$$\overline{d}_{max} = (1/N) \quad [\log_2 N! - s \log_2 (N/s)!]$$

$$\overline{d}_{min} = (1/N) \quad \{\log_2 N! - \log_2 [N-(s-1)]\ !\}$$

Redundancy measures the repetition of information within a community, thereby expressing the dominance of one or more species, and is inversely proportional to the wealth of species. It is maximal when no choice of species exists and minimal when there is a greater choice of species.

EVENNESS (J')

If the numbers of individuals, N_1, N_2, . . . N_s, in each of the s species are portrayed in histogram form, s is the range of data or the width of the histogram. The shape of the histogram is best described in what may be called its "evenness." Thus, the distribution has maximum evenness if all the species abundances are equal; the greater the disparities among the different species abundances, the smaller the evenness. Evenness (J') is calculated as follows: (Pielou 1969):

$$J' = \frac{\overline{d}}{\log_2 s}$$

Egloff and Brakel (1973) calculated evenness for a population of aquatic macroinvertebrates in a stream receiving large inputs of domestic sewage. Above the outfall, evenness values ranged from 0.6 to 0.7 and diversity was 3.0 and greater; below the outfall, evenness dropped to 0.4 and below and diversity decreased to less than one. The number of species and evenness appeared to be inversely related along the stream except at the outfall, where both decrease.

The evenness index has not been widely used in aquatic studies.

SPECIES RICHNESS (SR)

A further component of diversity, richness, was calculated in the computer program furnished by Orr et.al. (1973), but no reference to it could be found in the literature. It was calculated as follows:

$$SR = \bar{d} - \bar{d}/\log_2 N$$

Species richness is more commonly calculated by summing the total number of species present in a sample.

An introduction to faunal zonation

The classification of river zones is helpful in comparing studies of the ecology of different rivers and is useful in fishery and river management. Most attempts at river classification have been instigated by the needs of fishery management. With an increasing need for conservation of water quantity and quality, a system of river-zone classification is invaluable in predicting the likely effect on the ecology of the river of project management policies such as water removal and flow regulation.

River zonation studies began at the end of the last century with German biologists who developed a system of classifying river zones on the basis of the dominant fish species present, after which they named the zones--trout, grayling, barbel, and bream. Similar methods of classification were developed in other regions. Subsequent studies carried out throughout the world to establish whether the German zonation scheme was generally applicable attempted to characterize the different zones more precisely in physiographical, physiochemical, and biotic terms (Whitton 1975).

Carpenter (1928), an early British researcher influenced by the earlier German workers, attempted to classify the mountain streams of North Wales. She described a typical river as arising from several sources at high altitude and forming a stream characterized by swift current, steep gradient, and extensive erosion. Downstream, as the gradient decreases, the current slows, and the stream deepens and widens. With the reduction in current, stones, gravel and sand are successively deposited on the streambed. Still farther downstream, current is further reduced, the river widens and meanders, and the bed is covered with deposited silt. Carpenter's classification of streams included a taxonomic list of the flora and fauna of each zone. High altitude zones included headstreams, trout becks, and minnow reaches. Lowland stream zones included upper and lower reaches.

Huet (1949, 1954), using European stream data, refined the European system which recognized four zones, each identified by key fish species. The trout zone had a steep gradient, fast current, cool temperatures, and oxygenated water. The grayling zone was deeper and had less gradient, a gravel bottom, cool temperatures, and oxygenated water. The barbel zone had moderate gradient with an alternating riffle-pool morphology and few trout still present. The bream zone was characterized by slight current, high temperatures, and deep turbid water. The four zones represent two fish faunistic regions--an upper, cool water region containing salmonid fish, and the lower, warmer waters containing cyprinids. From longitudinal profiles of many European streams, Huet concluded that the fish fauna was directly related to the gradient of the stream, and that, in nearly all rivers of comparable size, streches with similar gradients have similar fish faunas. From these conclusions he formulated his slope rule: in a given biogeographical area, rivers or stretches of rivers of like breadth, depth, and slope have nearly identical biological characteristics and similar fish populations.

It is necessary to realize the limitations of zone classifilcation due to historic, geographic, and climatic influences, however. Generally, the greater the distance from the original streams studied, the more the original scheme of zonation needs to be modified to meet local conditions. Pollution can change zonation in localized areas.

The zonal distribution of fish in North American rivers has been demonstrated by a succession of workers. Shelford (1911) studied the distribution of fish in a number of Lake Michigan tributaries and concluded that fish have definite habitat preferences which cause them to be definitely arranged in streams which have a graded series of conditions from source to mouth. Burton and Odum (1945) and Funk and Campbell (1953) all report fish distributed in zones in North American streams.

From these studies in different parts of the world, it is evident that in general there is a longitudinal distribution of fish species in rivers in which a succession of different fish populations occurs from source to mouth. Other generalizations regarding the pattern of this distribution are more difficult to make. Funk and Campbell (1953) report that succession is by gradual transition; other workers report a zonal distribution in which there is a sharp border between zones.

To what extent do fish zones represent different river biocoenoses? Numerous studies have been conducted on the longitudinal distribution of different benthic invertebrates in rivers. Again, the earliest research occurred in Europe, but studies have taken place throughout the world (Beauchamp and Ullyott 1932, Carpenter 1928 , Chandler 1966). The longitudinal distribution of several insect orders has been investigated (Dodds and Hisaw 1925, Ide 1935, Hynes 1941 and 1948, Macan 1957).

Past studies of the longitudinal distribution of aquatic insects have found them be be disturbuted zonally along the length of rivers. It appears that each taxon exhibits a zonal distribution of its different species along the length of a river. Within taxa some species have a restricted distribution, especially those in the upper reaches, while others extend over a long stretch of river: therefore, over some distances, there may be little change in species present. Relative abundance changes along the length of river, reflecting a change in the ecological structure of the community (Hynes 1961).

The conclusion may be drawn that both fish and benthic invertebrates are longitudinally distributed along rivers, with particular species occupying particular sections of the river. One would expect a correlation among the zones of fish species and of benthic invertebrates. Some authors have concluded generally that biocoenoses associated with the fish zones can be recognized. Thorup (1966) is critical of these studies and suggests that pollution is responsible for the observed zonation of invertebrates and fish. Maitland's work (1966) supports the views expressed by Thorup. It appears from available evidence that, although fish zones can be recognized, the association of benthic biocoenoses with them does not always exist.

A theory, known as the river continuum theory in Cummins (1975b), has recently emerged to explain the distribution of groups of invertebrates on the bottom of streams and rivers. This theory makes use of theoretical relationships between stream order (Leopold et. al, 1964, Hynes 1970), size of organic matter, and production-respiration (P/R) ratios. Stream order employs an ordinal scale to describe stream characteristics. Streams of orders 1, 2, or 3, for example, are headwaters streams with few or no tributaries (figure 17).

Headwater streams characteristically receive substantial terrestrial contributions (allochthonous) of organic matter, especially coarse particulate organic matter (CPOM) such as leaf litter, with little or no photosynthetic production of organic matter. The two categories of dominant macroconsumers are detritivores (collectors) feeding on fine particulate organic matter (FPOM) and CPOM-feeding invertebrates (shredders). Thus, a headwaters food chain can be described as: CPOM--fungi--shredders--FPOM--bacteria--collectors (figures 17 and 18).

Food chains in intermediate-sized rivers are less dependent upon allochthonous inputs and more on organic production by producer organisms along with input of FPOM from upstream. The ratio of photosynthetic production to community respiration is often greater than one ($P/R > 1$) in contrast to headwater and large rivers where $P/R < 1$ (figure 17).

Large rivers tend to be turbid with heavy sediment loads, the culmination of all upstream processes. These systems, which possess plankton communities, could be characterized by their food chains: FPOM--bacteria--collectors (figure 17).

Fish populations generally show a downstream transition from cold-water invertivores to warm-water invertivores and from piscivores to planktivores.

A more autecological approach to distribution of aquatic invertebrates in aquatic ecosystems investigates the distribution and abundance of stream-dwelling invertebrates as regulated by such factors as current speed, temperature, substrata, vegetation, and dissolved substances (Hynes 1970); others are competition, zoogeography, and food.

Temperature and water chemistry usually exert the greatest influence on the composition of living communities considered over large areas, but because of feeding and respiratory requirements, it is largely current that determines how local communities actually are composed (Jaag and Ambuhl 1964, Chutter 1969). In fact, some macroinvertebrate species are confined to fairly narrow ranges of current speed. As an example, in the case of the net-building caddisflies (e.g., *Hydropsyche, Cheumatopsyche, Parapsyche*), the nets require a definite current in order for them to function properly (Philipson 1954). Many organisms must function in proximity to a specific current but cannot tolerate being actually in it. There is often great variation in current velocity for an insect living on top of a rock compared with one living under that rock, yet both may have current requirements. Because of the impossibility of taking measurements at most places macroinvertebrates inhabit (such as under rocks), current velocity is usually measured at some reproducible depth, e.g., mid-depth, six-tenths of total depth, or near the bottom (Hynes 1970).

There are unmistakable high-current specialists (e.g., *Baetis, Simulium,* and *Hydropsyche*), while some organisms find optimum habitat at low velocities (e.g., *Gammarus, Hyalella, Tricorythodes*). Each species prefers a certain range of current velocity.

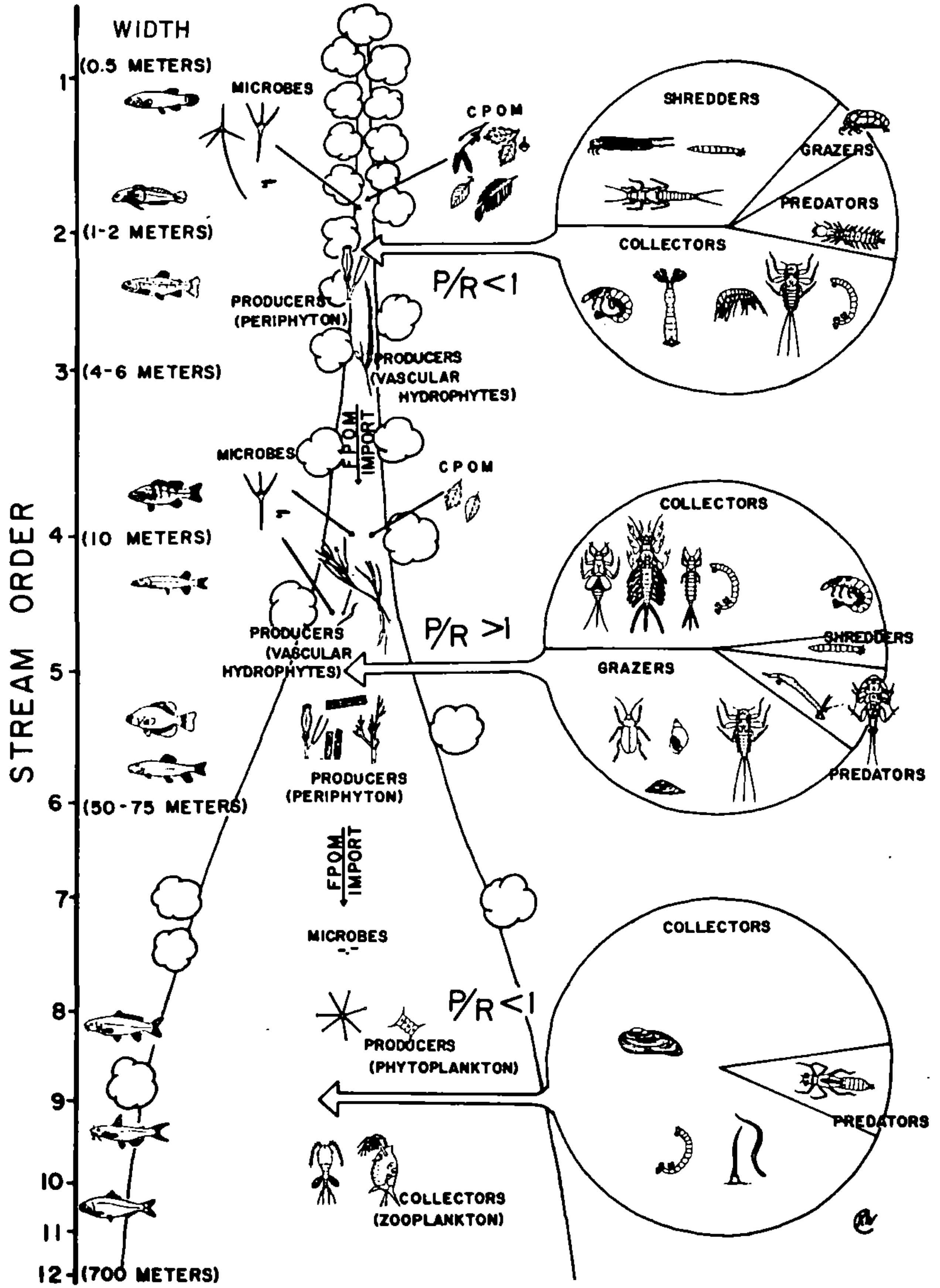


Figure 17. Relationships between detritus, producers, and consumers in different order streams--stream continuum. Reproduced with permission from Cummins 1975b.

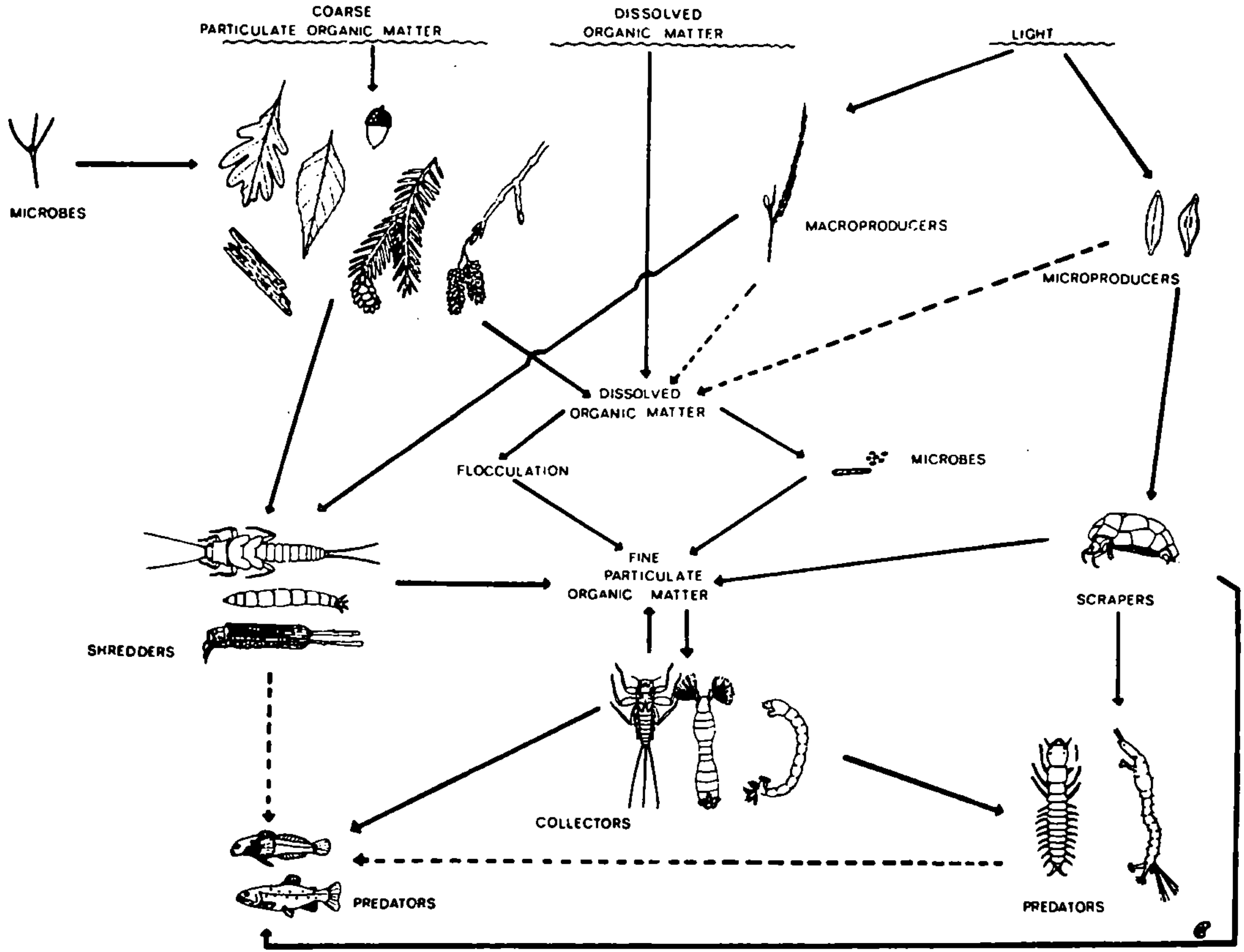


Figure 18. Relationship between detritus and stream consumers. Reproduced with permission from Cummins 1975b.

In every turbulent flowing system, marginal effects develop in the boundary layers. Close to the substratum, movement of the water gradually slows due to friction, and a boundary layer is formed in which the flow is strongly retarded, until, close to the substratum, it is stagnant (Jaag and Ambuhl 1964). The thickness of this boundary layer depends, among other things, on the velocity of the current above and the shape and roughness of the substratum. Extremely flattened organisms (e.g., *Epeorus, Rhithrogena*) make use of the boundary layer to avoid the current.

Many species that live in flowing water (e.g.,most Plecoptera) can be maintained only in such water, since they either possess no ventilating organs or have changed or lost the function of those organs in the course of their evolutionary development. They are extremely sensitive to still water and quickly die in it.

Macrodistribution of aquatic invertebrates can be explained with increasing difficulty as habitat gradually changes moving downstream. Cummins (1975a) described food as the ultimate determinant of macroinvertebrate distribution and abundance in nondisturbed running waters. The current regime, velocity, and turbulence set the limits on the range of sediment particle sizes present as well as controlling such features as the growth of periphyton and macrophytes and accumulation of particulate detritus. The size of particles present decreases in a downstream direction (Macan 1974, Hynes 1970), resulting in community variation in primary producers, macroinvertebrates, and fish. These community changes may be generally placed into three categories or habitat subsystems: (1) erosional zone, (2) intermediate zone, and (3) depositional zone. Each zone has a characteristic physical-chemical makeup and a characteristic fauna.

Existing situation

MACROINVERTEBRATE DISTRIBUTION

A checklist of the macroinvertebrates found in the Tongue and Yellowstone rivers is presented in table 2. This list is as complete as possible and utilizes all published sources available, as well as data gathered during this study. Distributional records were taken from Stadnyk (1971), Gaufin et al. (1972), and Thurston et al. (1975).

For specimens for which a precise species identification was not possible, the most probable species (considering the most recent available distribution data) is listed in parentheses. In the order Diptera, several genera are listed under the family Chironomidae; this is the only place these genera will appear in this report because of unconfirmed identifications. Identifications of this group are difficult both to make and to confirm.

YELLOWSTONE RIVER

Mayflies

The distribution of all mayflies (Ephemeroptera) known to occur in the Yellowstone River (37 species variously distributed) is presented in figure 19. Four species were collected throughout the study area, and a fifth species (*Ephemerella inermis*) was missing only from the lower two sampling stations.

In this figure and in several others, stations 7-12 are shaded and represent the probable location of the transition zone between the salmonid and nonsalmonid zones. This transition zone also corresponds to the intermediate zone between the erosional and depositional habitat subsystems outlined by Cummins (1975b) for large rivers.

The number of mayfly species found at each station is illustrated in figure 20. Station 5 yielded the largest number of species (19) and stations 19 and 20 the fewest with 10 species. No pattern of mayfly distribution is apparent throughout the transition zone. Longitudinally, the community exhibits a gradual shift from mountain fauna to prairie fauna more adapted to slower flow, warmer temperatures, and a silty substratum, but the number of species is reasonably constant along the entire river.

A mature *Heptagenia elegantula* nymph is shown in figure 21.

TABLE 2. Checklist of the aquatic macroinvertebrates of the Tongue River (t) and the Yellowstone River (y).

		Phylum Arthropoda
		Order Ephemeroptera
		Family Siphlonuridae
y		*Ameletus (oregonensis* McD.?)
y		*Isonychia (sicca campestris* McD.?)
		Family Baetidae
y	t	*Baetis insignificans* McD.
y	t	*Baetis parvus* Dodds
y		*Baetis (propinquus* Walsh)
y		*Baetis tricaudatus* Dodds
y		*Centroptilum* sp. A
y	t	*Dactylobaetis cepheus* Traver & Edmunds
y		*Pseudocloeon* sp. A
		Family Oligoneuriidae
y		*Lachlania powelli* Edmunds
		Family Heptageniidae
y		*Epeorus (Iron) albertae* (McD.)
y		*Epeorus (Iron) longimanus* (Eaton)
y	t	*Heptagenia elegantula* (Eaton)
y	t	*Rhithrogena undulata* (Bks.)
y	t	*Stenonema terminatum* (Walsh)
y		*Stenonema* prob n. sp.
		Family Ametropodidae
y		*Ametropus (neavei* McD.)?
		Family Leptophlebiidae
y	t	*Choroterpes albiannulata* McD.
y	t	*Leptophlebia gravastella* Eaton
y		*Paraleptophlebia bicornuta* (McD.)
y		*Paraleptophlebia heteronea* (McD.)
y	t	*Traverella albertana* (McD.)
		Family Ephemerellidae
y		*Ephemerella (Attenuatella) margarita* N.
y		*Ephemerella (Caudatella) h. heterocaudata* McD.
y		*Ephemerella (Caudatella) hystrix* Traver
y		*Ephemerella (Drunella) doddsi* Needham
y		*Ephemerella g. grandis* Eaton
y	t	*Ephemerella (Ephemerella) inermis* Eaton
y		*Ephemerella (Serratella) tibialis* McD.
y		*Ephemerella (Timpanoga) h. hecuba* (Eaton)
		Family Tricorythidae
y	t	*Tricorythodes minutus* Traver
y		*Tricorythodes* sp. A
		Family Ephemeridae
y		*Ephemera* sp. A
		Family Polymitarcidae
y		*Ephoron album* (Say)
		Family Caenidae
y	t	*Brachycercus (prudens* McD.?)
y		*Caenis latipennis*

TABLE 2 (continued).

		Family Baetiscidae
y	t	*Baetisca* sp. A
		Order Trichoptera
		Family Rhyacophilidae
y		*Rhyacophila bifila* Bks.
		Family Helicopsychidae
y		*Helicopsyche borealis* (Hagen)
		Family Glossosomatidae
y	t	*Glossosoma* sp. A
y		*Glossosoma traviatum* Bks.
y		*Glossosoma velona* Ross
		Family Psychomyiidae
y		*Polycentropus cinereus* Hagen
y		*Psychomyia flavida* Hagen
		Family Hydropsychidae
y		*Arctopsyche grandis* Bks
y	t	*Cheumatopsyche* sp. A
y		*Cheumatopsyche analis* (Bks.)
y		*Cheumatopsyche campyla* Ross
y		*Cheumatopsyche lasia* Ross
y		*Cheumatopsyche enonis* Ross
y	t	*Hydropsyche* sp. A
	t	*Hydropsyche* near *alhedra* Ross
y		*Hydropsyche cockerelli* Bks.
y		*Hydropsyche corbeti* Nimmo
y		*Hydropsyche occidentalis* Bks.
y		*Hydropsyche oslari* Bks.
y		*Hydropsyche separata* Bks.
		Family Hydroptilidae
y	t	*Hydroptila* sp. A
y		*Hydroptila waubesiana* Betten
y		*Agraylea multipunctata* Curtis
y		*Ochrotrichia potomas* Denning
y		*Neotrichia* sp. A
		Family Leptoceridae
y		*Athripsodes* sp. A
y		*Leptocella* sp. A
y	t	*Oecetis* sp. A
y		*Oecetis avara* (Bks.)
y		*Oecetis disjuncta* (Bks.)
y		*Triaenodes frontalis* Bks.
		Family Lepidostomatidae
y		*Lepidostoma* n. sp.
y		*Lepidostoma pluvialis* Milne
y		*Lepidostoma veleda* Denning
		Family Brachycentridae
y		*Amiocentrus aspilus* (Ross)
y	t	*Brachycentrus* sp. A.
y		*Brachycentrus americanus* (Bks)
y		*Brachycentrus occidentalis* Bks.

TABLE 2 (continued).

		Order Hemiptera
		Family Corixidae
y		*Callicorixa utahensis* (Hung.)
y		*Cenocorixa audeni* (Hung.)
y		*Sigara alternata* Say
y		*Trichocorixa borealis* Sailer
		Family Naucoridae
y		*Ambrysis mormon* Mont.
		Family Veliidae
y	t	*Rhagovelia distincta* Champion
		Family Gerridae
y		*Gerris remigis* Say
		Family Nepidae
y		*Ranatra fusca* P.B.
		Order Odonata
		Family Gomphidae
y	t	*Gomphus* sp. A
y	t	*Ophiogomphus* sp. A
		Family Agrionidae
	t	*Calopteryx* sp. A
		Family Coenagrionidae
	t	*Argia* sp. A
y	t	*Amphiagrion* sp. A
y		*Enallagma* sp. A
	t	*Enallagma ebrium* (Hagen)
	t	*Ischnura* sp. A
		Order Coleoptera
		Family Dytiscidae
y		*Oreodytes* sp. A
		Family Dryopidae
y		*Helichus* sp. A
		Family Elmidae
y	t	*Dubiraphia* sp. A
y	t	*Microcylloepus pusillus* (LeConte)
y		*Optioservus quadrimaculatus* (Horn)
y	t	*Stenelmis* sp. A
y		*Zaitzevia parvula* (Horn)
		Family Gyrinidae
y		*Cyrinus* sp. A
		Order Diptera
		Family Blepharoceridae
y		*Agathon* sp. A
y		Family Ceratopogonidae
		Family Chironomidae
		Subfamily Tanypodinae
y		*Ablabesmyia* sp. A
y		*Clinotanypus* sp. A
y		*Cryptocladius* sp. A
y		*Procladius* sp. A

TABLE 2 (continued).

		Family Limnephilidae
y		*Hesperophylax incisus* Bks.
y		*Limnephilus taloga* Ross
		Order Plecoptera
		Family Nemouridae
y		*Nemoura (Prostoia) besametsa* Ricker
y		*Nemoura (Zapada) cinctipes* Bks.
y		*Paraleuctra sara* Claassen
y		*Capnia (Capnia) confusa* Claassen
y		*Capnia (Capnia) gracilaria* Claassen
y		*Capnia (Capnia) limata* Frison
y		*Capnia (Utacapnia) distincta* Frison
y		*Capnia (Utacapnia) poda* Nebeker & Gaufin
y		*Eucapnopsis vedderensis* Ricker
y		*Isocapnia missourii* Ricker
y		*Isocapnia vedderensis* (Ricker)
y	t	*Brachyptera (Taenionema) fosketti* Ricker
y		*Brachyptera (Taenionema) nigripennis* Bks.
y		*Brachyptera (Taenionema) pacifica* (Bks)
		Family Pteronarcidae
y		*Pteronarcella badia* (Hagen)
y		*Pteronarcys californica* Newport
		Family Perlodidae
y		*Arcynopteryx (Skwala) parallela* (Frison)
y		*Isogenus (Cultus) aestivalis* (N & C)
y		*Isogenus (Cultus) tostonus* Ricker
y	t	*Isogenus (Isogenoides) frontalis colubrinus* Hagen
y		*Isogenus (Isogenoides) elongatus* Hagen
y		*Isoperla fulva* Claasen
y		*Isoperla mormona* Bks.
y		*Isoperla longiseta* Bks.
y		*Isoperla patricia* Frison
		Family Chloroperlidae
y		*Alloperla (Suwallia) pallidula* (Bks)
y		*Alloperla (Sweltsa) coloradensis* (Bks)
y		*Alloperla (Alloperla) severa* Hagen
y		*Alloperla (Triznaka) signata* (Bks)
		Family Perlidae
y	t	*Acroneuria abnormis*
y		*Acroneuria (Hesperoperla) pacifica* Bks.
y		*Claassenia sabulosa* (Bks)
		Order Isopoda
		Family Asellidae
y		*Asellus racovitzai racovitzai* Williams
		Order Lepidoptera
		Family Pyralidae
y	t	*Cataclysta* sp. A

TABLE 2 (continued).

		Subfamily Chironominae
y		*Chironomus* sp. A
y		*Cryptochironomus* sp. A
y		*Microtendipes* sp. A
y		*Paralauterborniella* sp. A
y	t	*Rheotanytarsus* sp. A
y		*Stictochironomus* sp. A
		Subfamily Diamesinae
y	t	*Diamesa* sp. A
y		*Monodiamesa* sp. A
		Subfamily Orthocladiinae
y		*Brillia* sp. A
y	t	*Cardiocladius* sp. A
y		*Cricotopus* sp. A
y	t	*Eukiefferiella* sp. A
y		*Metriocnemus* sp. A
y	t	*Orthocladius* sp. A
y		*Trichocladius* sp. A
		Family Dolochopodidae
		Family Empididae
y		*Hemerodromia* sp. A
		Family Muscidae
y		*Limnophora* sp. A

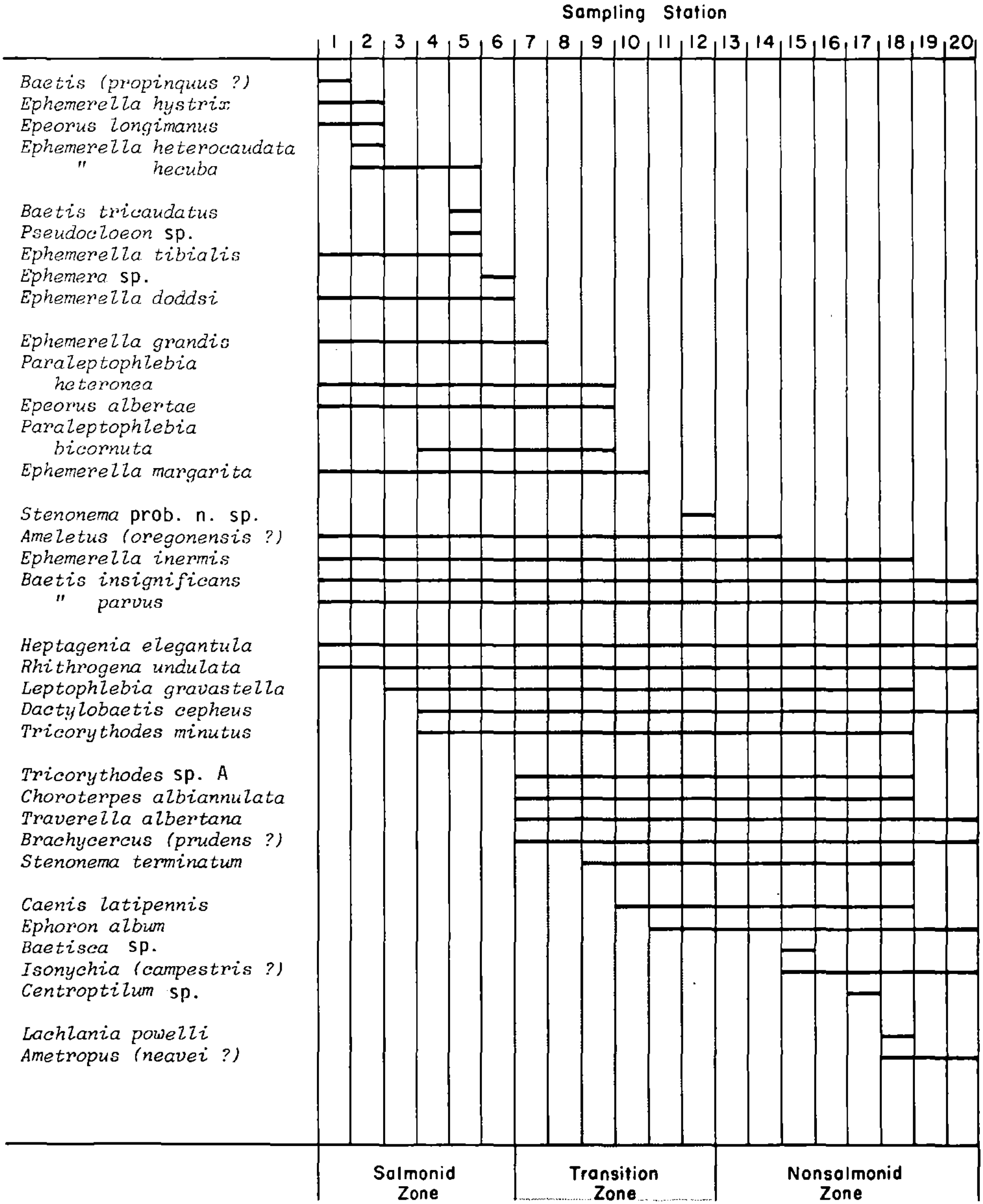


Figure 19. Ephemeroptera of the Yellowstone River.

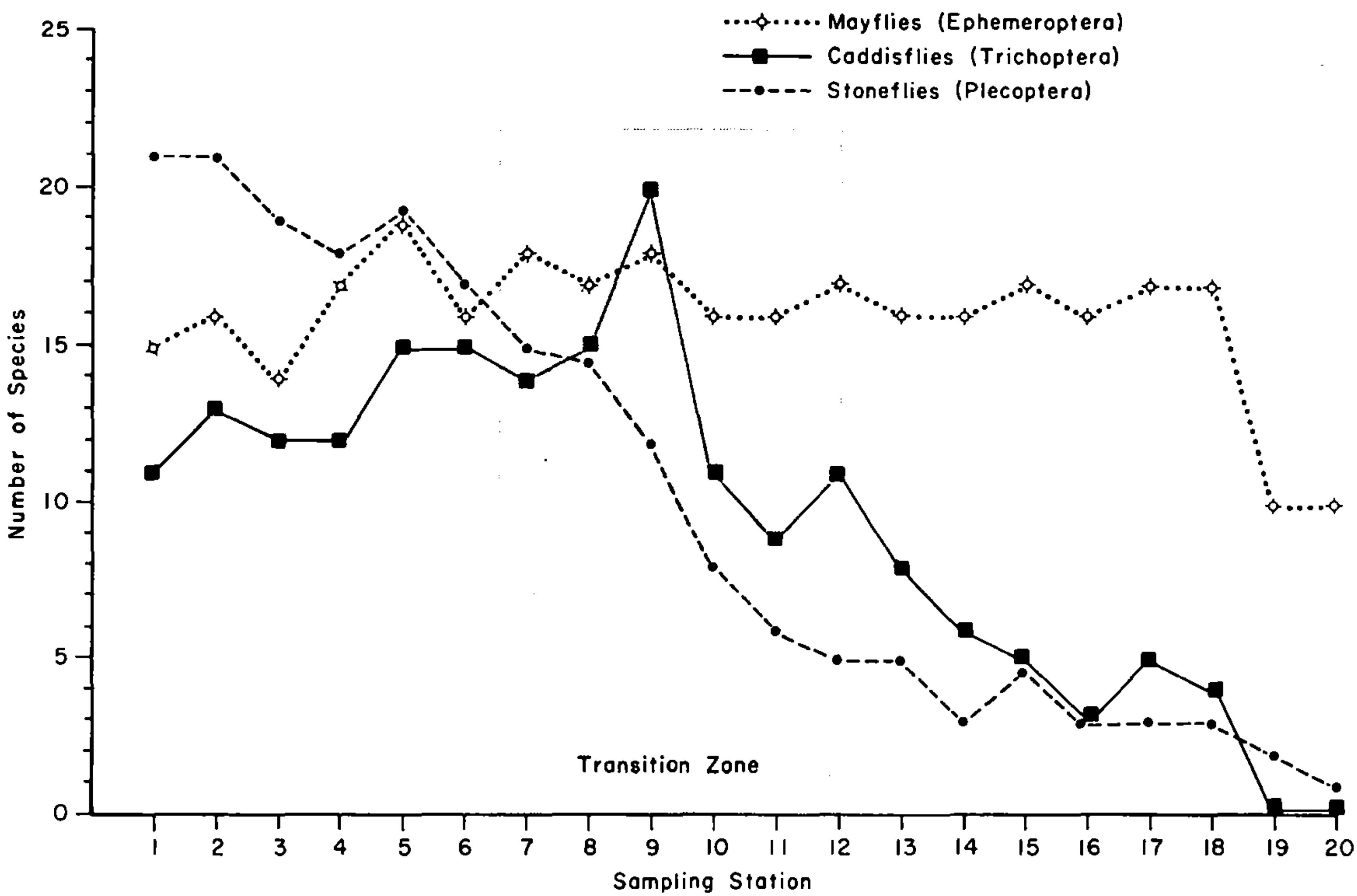


Figure 20. Number of species of the three major orders found at each sampling station in the Yellowstone River.

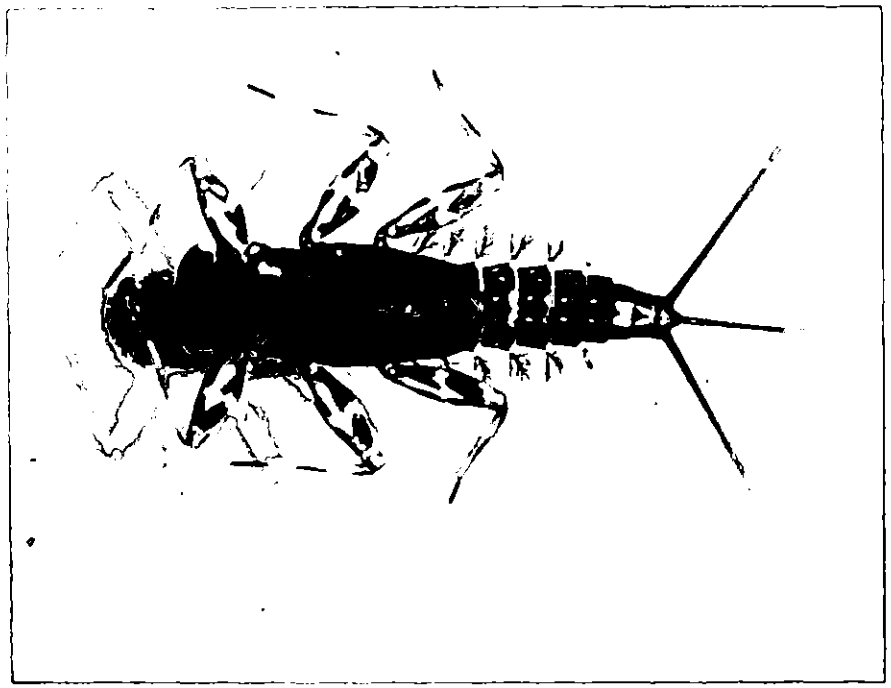


Figure 21. Mature nymph of the mayfly *(Heptagenia elegantula)*.

Stoneflies

The longitudinal distribution of the stoneflies (Plecoptera) in figure 22 differs considerably from that of the Ephemeroptera (figure 19). Thirty-seven species were identified in the study area. Data available for this order are probably the most accurate because of the work of Stadnyk (1971) and Gaufin et al. (1972). Only one species was collected at every station. Most of the fauna are probably adapted to the conditions found in the upper river. Twelve species drop out in the transition zone, and five could be classified as prairie stream forms. *Acroneuria abnormis* probably washed out of the Tongue River, where it is abundant, and was collected only at station 15. The number of Plecoptera species decreases steadily downstream (figure 20). Generally the nonprairie stoneflies appear to have habitat requirements similar to those of the salmonid fishes.

Caddisflies

Caddisfly (Trichoptera) distribution in the Yellowstone River is presented in figure 23. The present list contains 36 species; more will probably be collected if additional studies are performed. Distributional patterns are less distinct than with the Ephemeroptera and Plecoptera. In most cases caddisfly larvae cannot be identified to species; adult males are necessary. The present distribution data are incomplete because all stations were not sampled with equal frequency. For example, station 9, sampled more intensively,

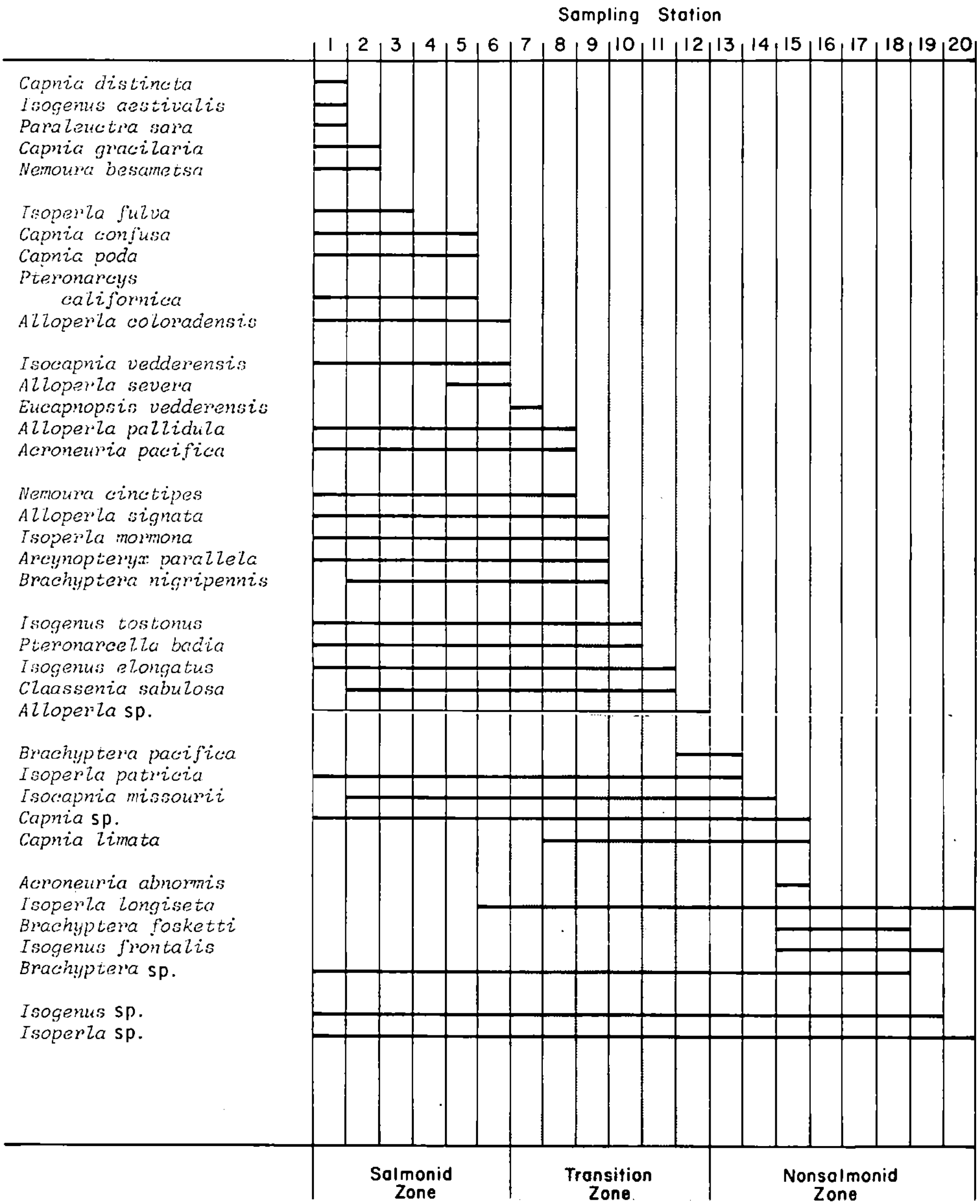


Figure 22. Plecoptera of the Yellowstone River.

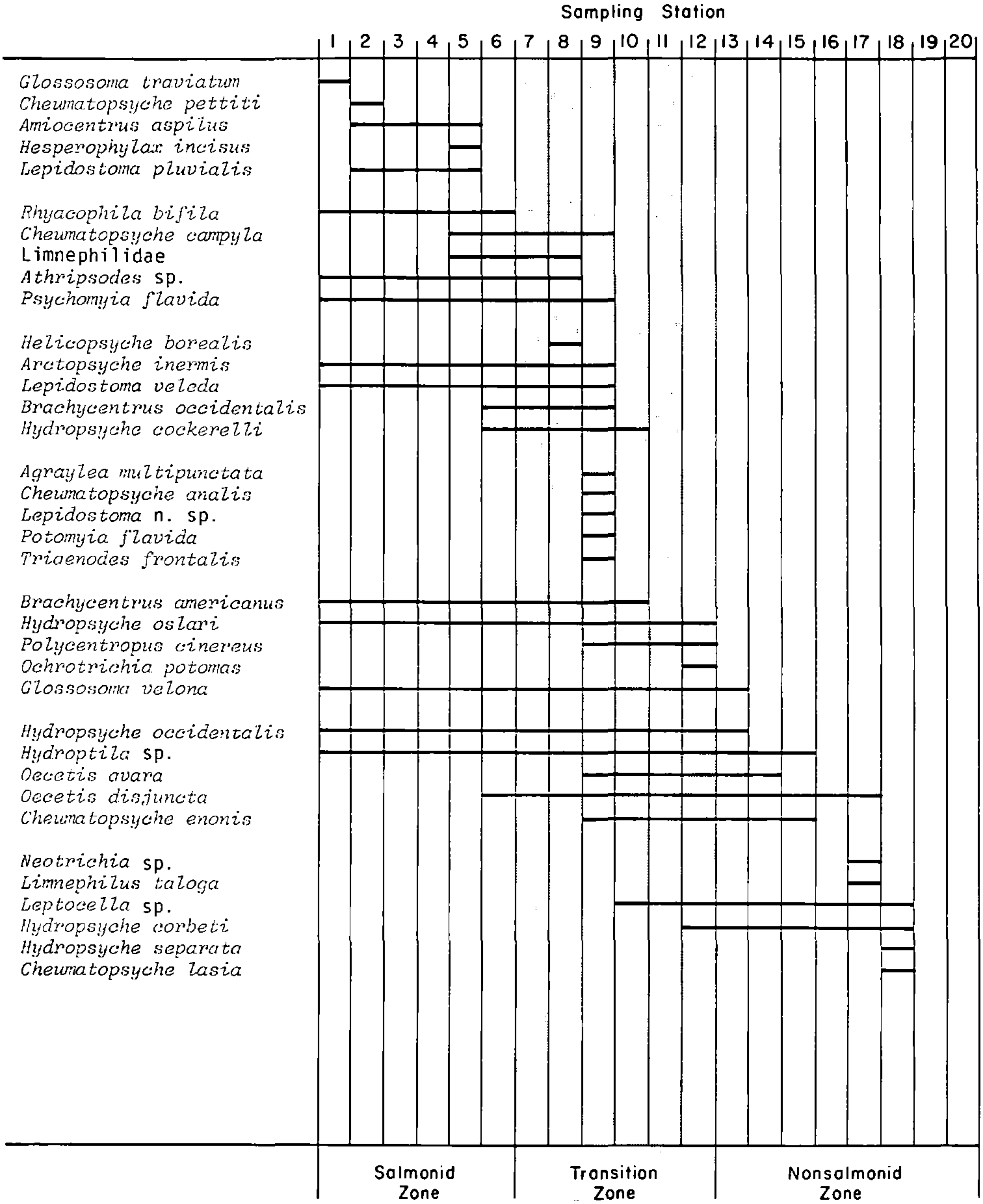


Figure 23. Trichoptera of the Yellowstone River.

had the largest number of species. Generally caddisfly distribution is similar to that of the Plecoptera with a steady downstream decline in species. The genera *Hydropsyche* (figures 24 and 25) and *Cheumatopsyche* are abundant throughout the river, but dominate in the lower 10 stations.

Other Orders

The distribution of the remaining aquatic orders is given in figure 26. The order Diptera is widely distributed throughout the river, with the family Chironomidae being the most abundant and diverse. *Protanyderus margarita,* a Diptera species previously unreported from Montana, was captured at several stations. Representatives of the remaining orders illustrated no distributional trends and, with the exception of the Oligochaeta, were never abundant.

TONGUE RIVER

The distribution of macroinvertebrates found in the Tongue River, shown in table 3,is complex and not easily explained. The fauna is similar to the Yellowstone fauna in many ways, but there are several differences. The stonefly *Acroneuria abnormis,* the elmid beetle *Stenelmis* sp. and the mussel *Lampsilis* sp. are abundant in the Tongue but rare in the Yellowstone. Odonates are more abundant and diverse in the Tongue River.

INSECT EMERGENCE

MAYFLIES

Emergence times were determined for only 13 species of mayflies (figure 27), generally the species common in the lower reaches of the Yellowstone River. Most mayfly adults emerge at dawn or dusk and live from a few hours to a few days. Emergence of mayfly adults in the lower river is concentrated in the June-September period. Adult *Ephoron album* emerged so late in the summer that many adults, influenced by cold morning temperatures, were observed fluttering on the beaches, unable to fly.

One of the largest mayfly emergences observed occurred in late August 1974 at Huntley (station 11), where adult *Traverella albertana* (figure 28) were emerging. The adults were so thick on the water surface (probably hundreds of thousands of insects were involved) that carp were surface feeding on them. It was a wet day, and the adults hovered over the wet highway from Huntley to Miles City. The conspicuous emergences of *Tricorythodes minutus* (figure 29) and *Ephoron album* also involved large numbers of individuals.

STONEFLIES

The emergence of adult stoneflies, occurring from March to August (figure 30), covers a longer time span than does that of mayflies. Three species,

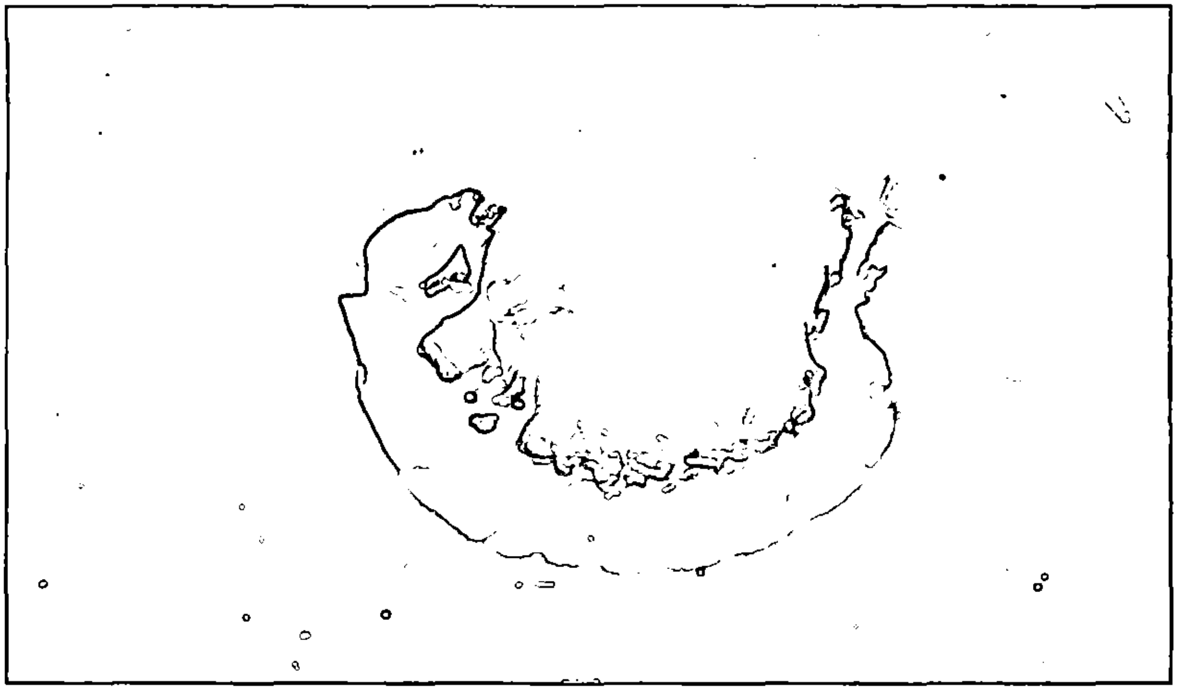


Figure 24. Larvae of the Caddisfly *Hydropsyche*.

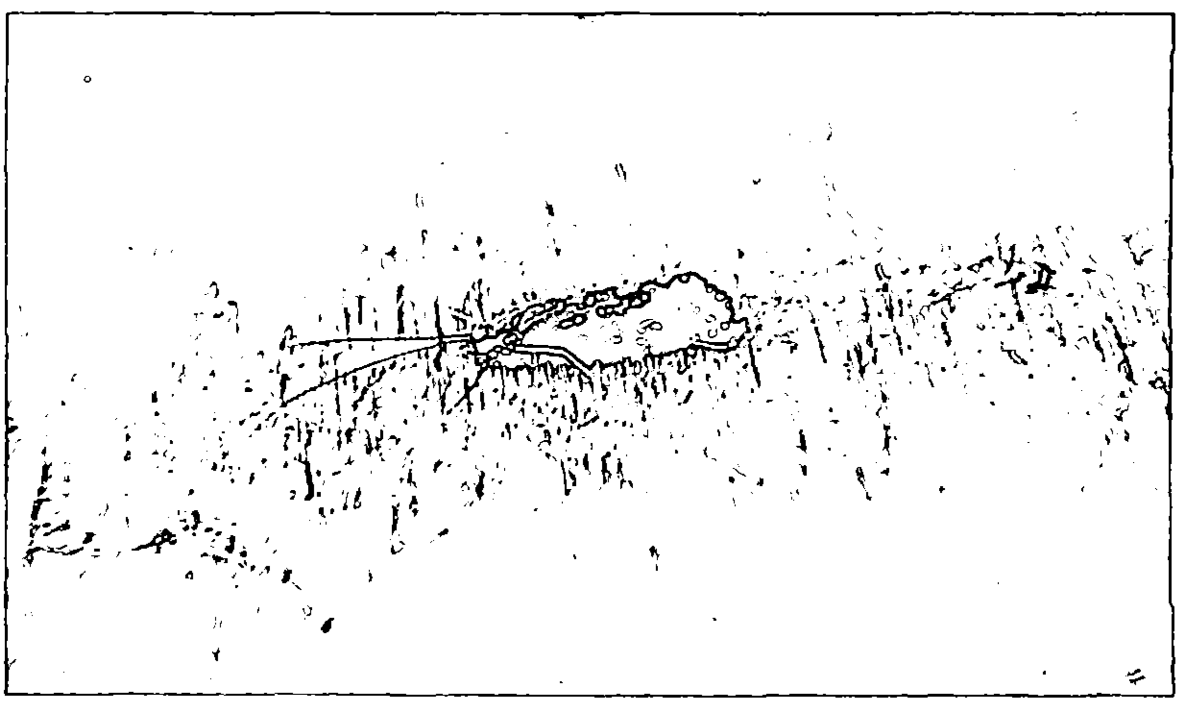


Figure 25. An adult of the genus *Hydropsyche*.

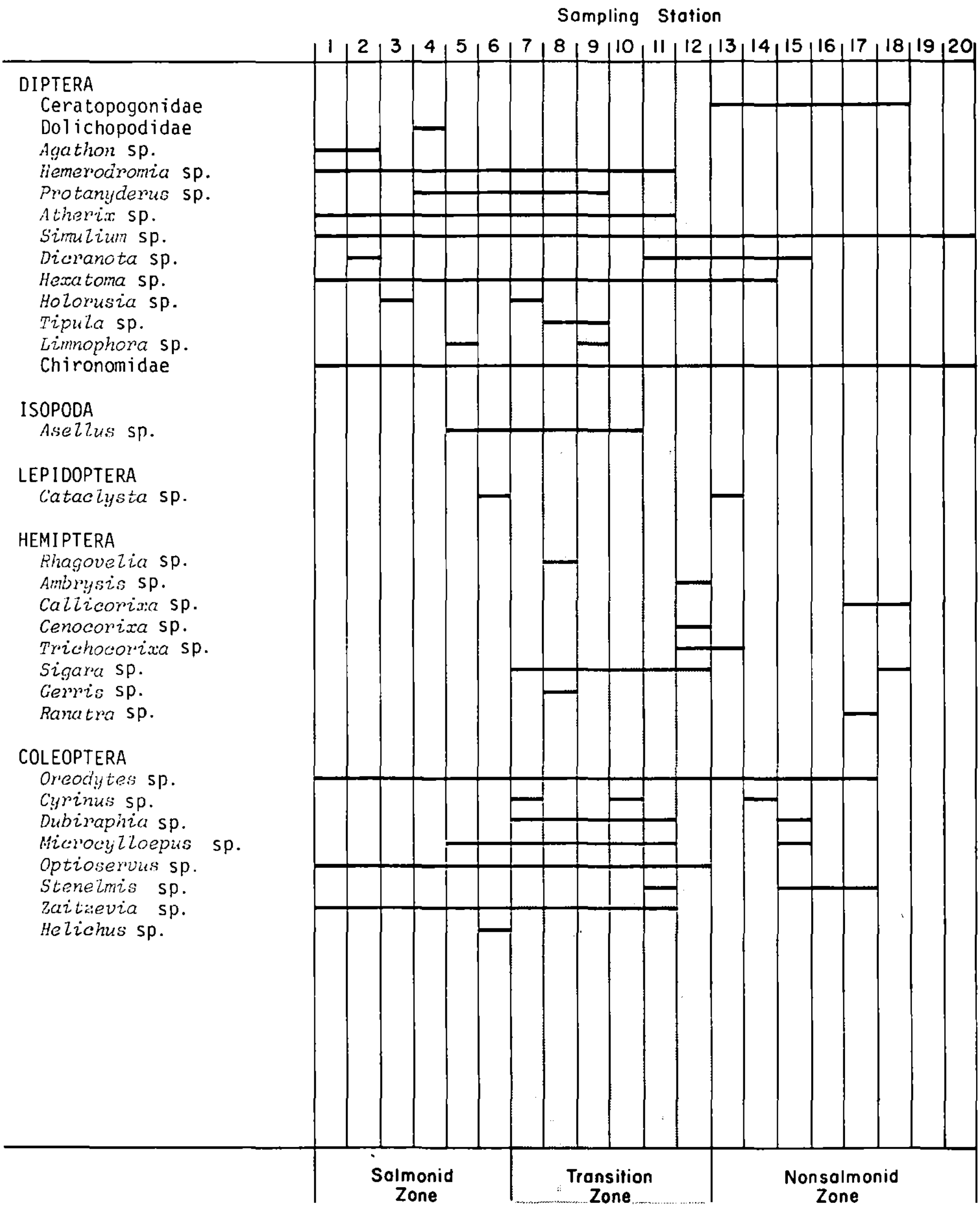


Figure 26. Aquatic invertebrates of the Yellowstone River.

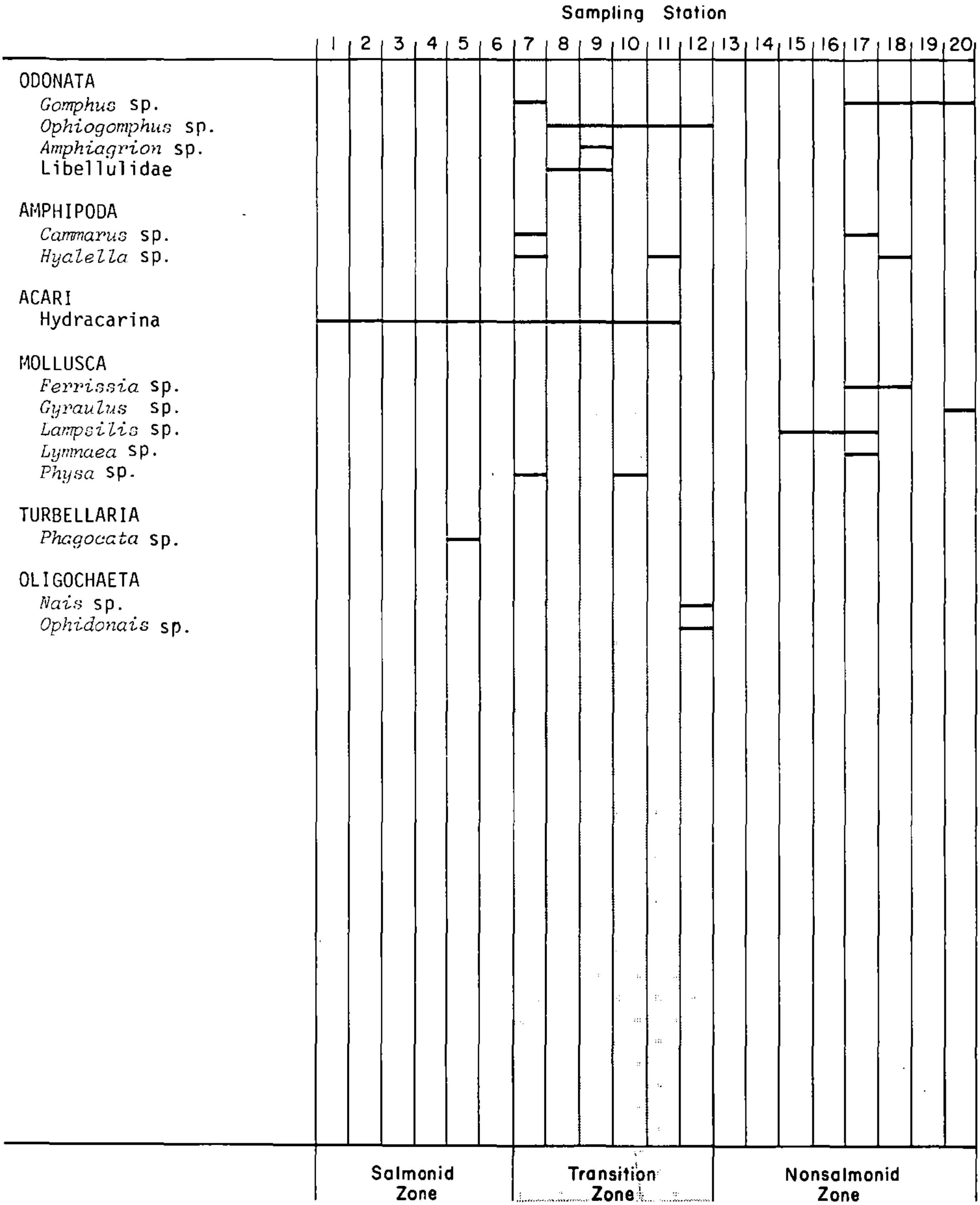


Figure 26. (Continued)

TABLE 3. Macroinvertebrate fauna of the Tongue River, Montana.

Taxa	Station No. 1 Dam Section	2 Hosford	3 Birney	4 Ashland	5 Viall	6 S-H	7 Orcutt	8 Keogh
Ephemeroptera								
Baetis spp.	x	x	x		x	x		
Baetisca sp.						x		
Brachycercus sp.					x			
Choroterpes sp.				x		x		
Dactylobaetis sp.						x		
Ephemerella sp.	x	x	x	x	x	x	x	
Heptagenia sp.			x	x	x	x	x	
Leptophlebia sp.			x	x			x	
Rhithrogena sp.			x	x	x	x	x	x
Stenonema sp.		x				x		
Traverella sp.			x	x	x	x	x	
Tricorythodes sp.	x	x	x	x	x	x	x	
Trichoptera								
Brachycentrus sp.	x		x	x	x	x	x	x
Cheumatopsyche sp.	x	x	x	x	x	x	x	x
Glossosoma sp.		x	x					
Hydropsyche sp.	x	x	x	x	x	x	x	x
Hydroptila sp.	x	x	x				x	x
Mystacides sp.			x	x			x	
Oecetis sp.			x	x		x	x	
Plecoptera								
Acroneuria sp.			x			x	x	x
Brachyptera sp.			x		x	x	x	x
Isogenus sp.			x	x	x	x	x	x
Coleoptera								
Dubiraphia sp.		x	x					
Microcylloepus sp.		x	x	x				
Stenelmis sp.		x	x	x	x	x	x	x
Mollusca								
Ferrissia sp.	x	x	x					
Gyraulus sp.		x						
Lymnaea sp.	x	x						
Lampsilis sp.								x
Physa sp.	x	x	x					
Pisidium sp.		x				x		
Sphaerium sp.		x						

TABLE 3 continued.

Taxa	Station No. 1 Dam Section	2 Hosford	3 Birney	4 Ashland	5 Viall	6 S-H	7 Orcutt	8 Keogh
Odonata								
Argia sp.		x					x	
Calopteryx sp.		x			x	x		
Enallagma sp.								
Ischnura sp.		x						
Gomphus sp.			x					
Ophiogomphus sp.	x	x	x	x	x	x		
Lepidoptera								
Cataclysta sp.	x	x				x	x	
Turbellaria								
Dugesia sp.	x	x	x	x		x	x	
Hemiptera								
Corixidae	x	x	x				x	x
Rhagovelia sp.				x				
Diptera								
Chironomidae	x	x	x	x	x	x	x	x
Cardiocladius sp.	x		x					
Diamesa sp.	x		x					
Eukiefferiella sp.			x					x
Orthocladius sp.	x					x		
Rheolanytarsus sp.			x					
Simuliidae								
Simulium sp.	x	x	x	x	x	x	x	
Tipulidae								
Hexatoma sp.			x	x		x	x	x
Oligochaeta		x	x					

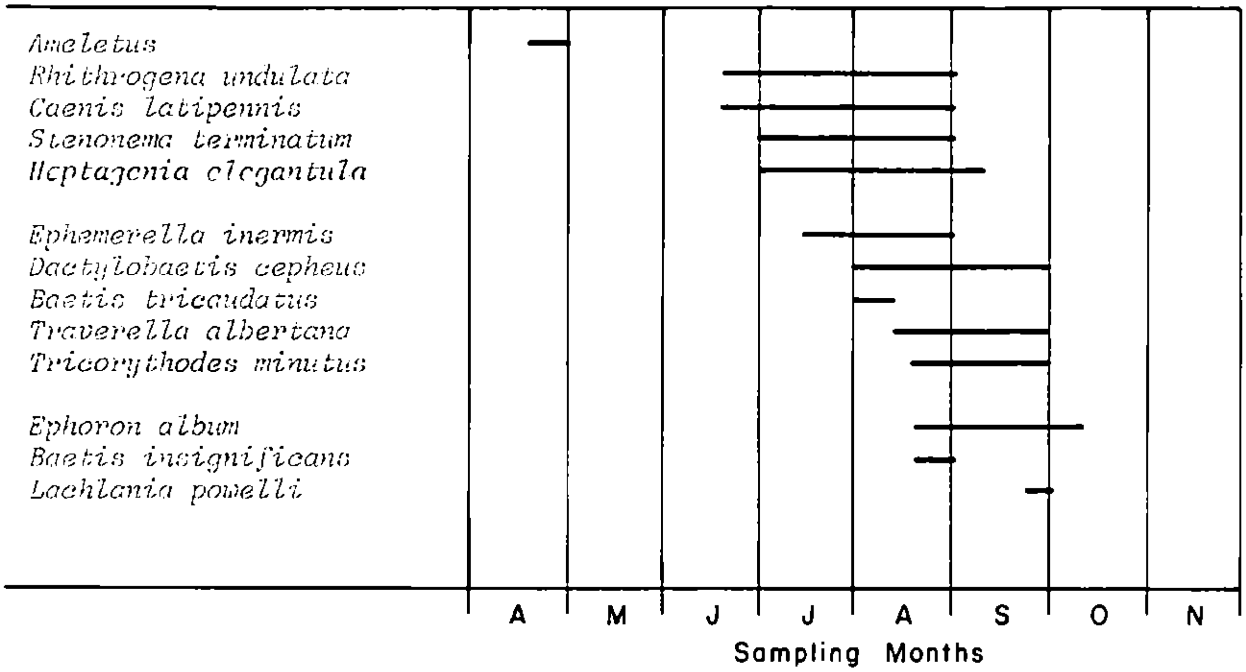


Figure 27. Emergence of mayflies from the Yellowstone River, 1974-76.

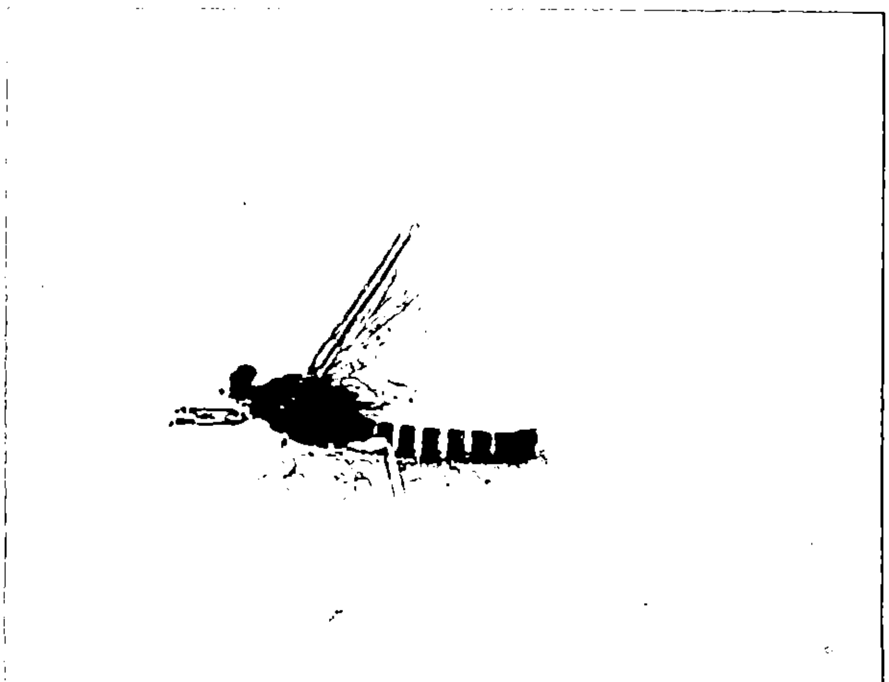


Figure 28. Adult Mayfly *(Traverella albertana)*.

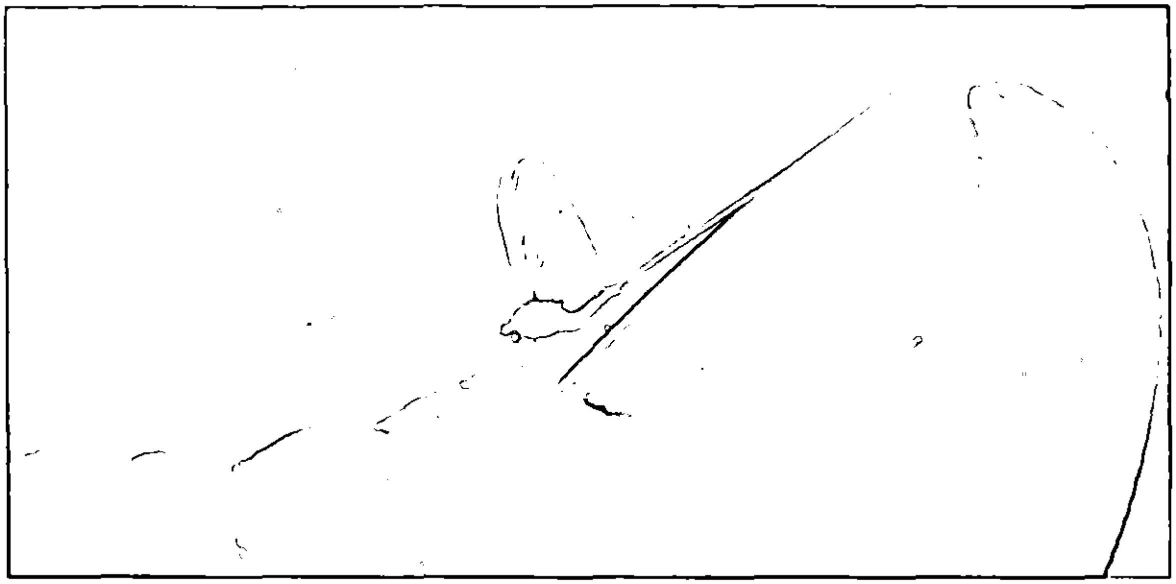


Figure 29. Adult Mayfly *(Tricorythodes minutus)*.

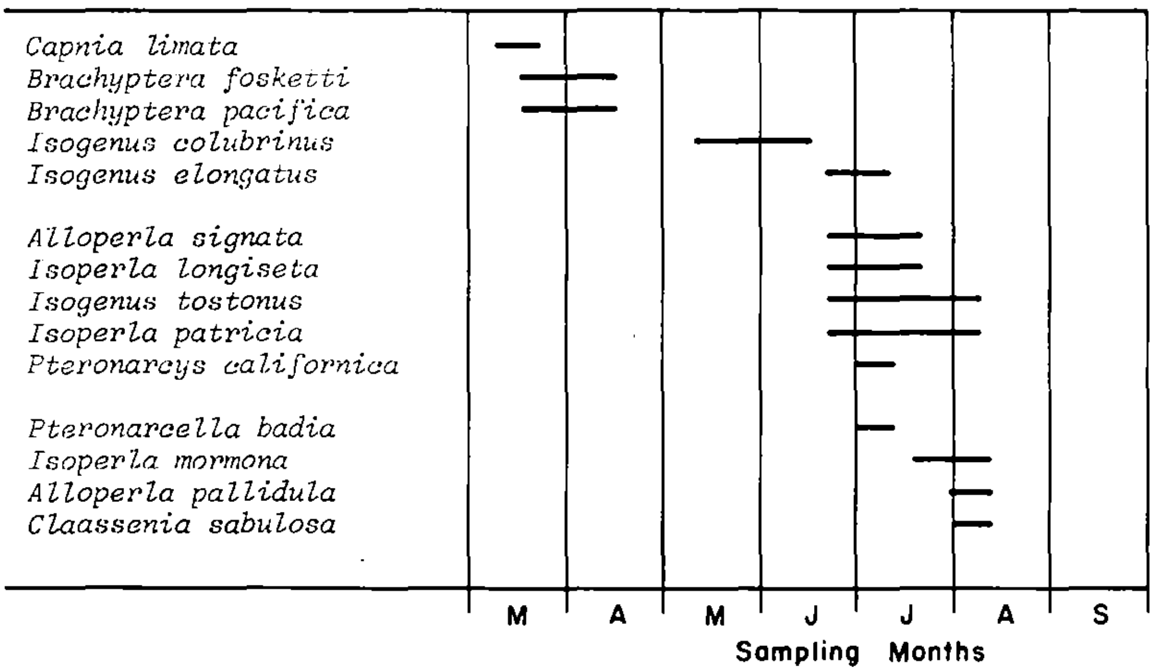


Figure 30. Emergence of stoneflies from the Yellowstone River, 1974-76.

Capnia limata, Brachyptera fosketti, and *B. pacifica,* emerged when the river was still essentially covered with ice. Stoneflies are not as abundant as mayflies and spend less time in flight; they are therefore less conspicuous when emerging. The most spectacular stonefly emergence is that of *Pteronarcys californica,* the giant stonefly or the "salmonfly" of fly fishermen. This species is confined to the upper river where adult insect sampling was less intense. A small yellow stonefly, *Isoperla longiseta* (figure 31) emerges in large numbers in the lower river.

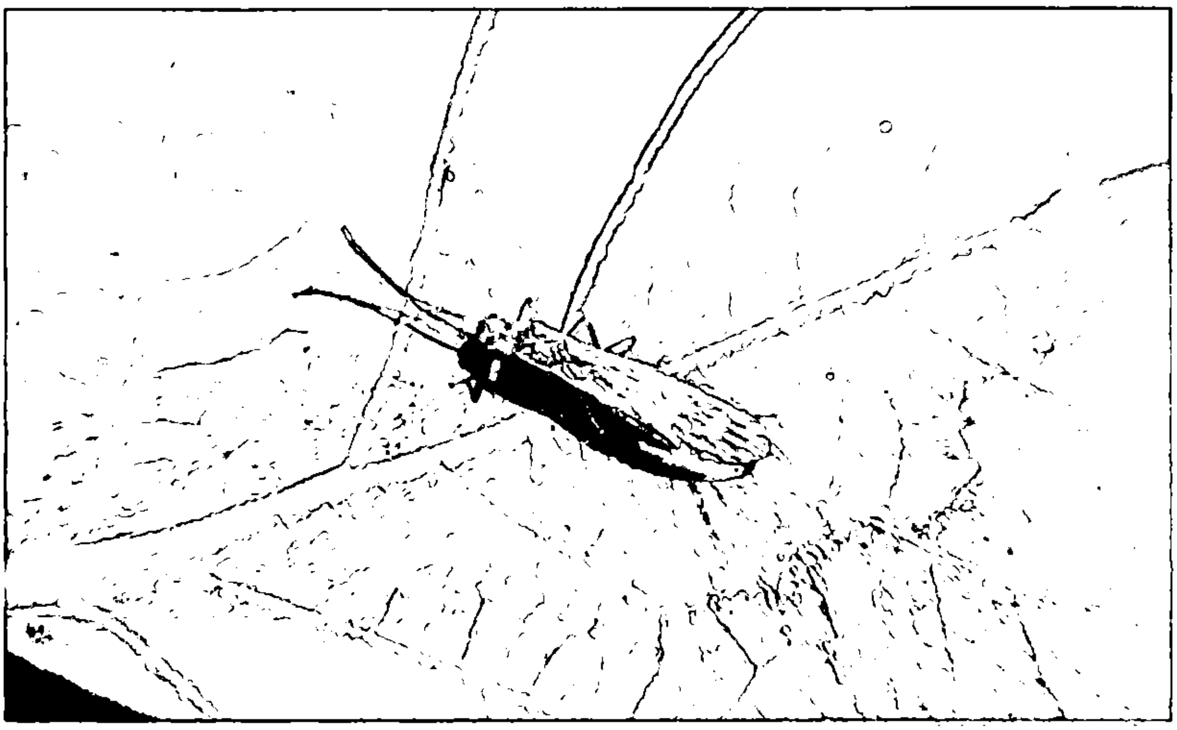


Figure 31. Adult stonefly *(Isoperla longiseta).*

CADDISFLIES

The emergence patterns of caddisflies are presented in figure 32. Emergence and flight times ranged from May to September. Caddisflies and stoneflies can live for several weeks as adults; therefore, the presence of an adult does not necessarily signify recent emergence. The list of species presented in figure 32 is much larger than either the mayfly or stonefly lists (figures 27 and 30) because the fauna is rich and because adult caddisflies, readily attracted to lights, are easily collected.

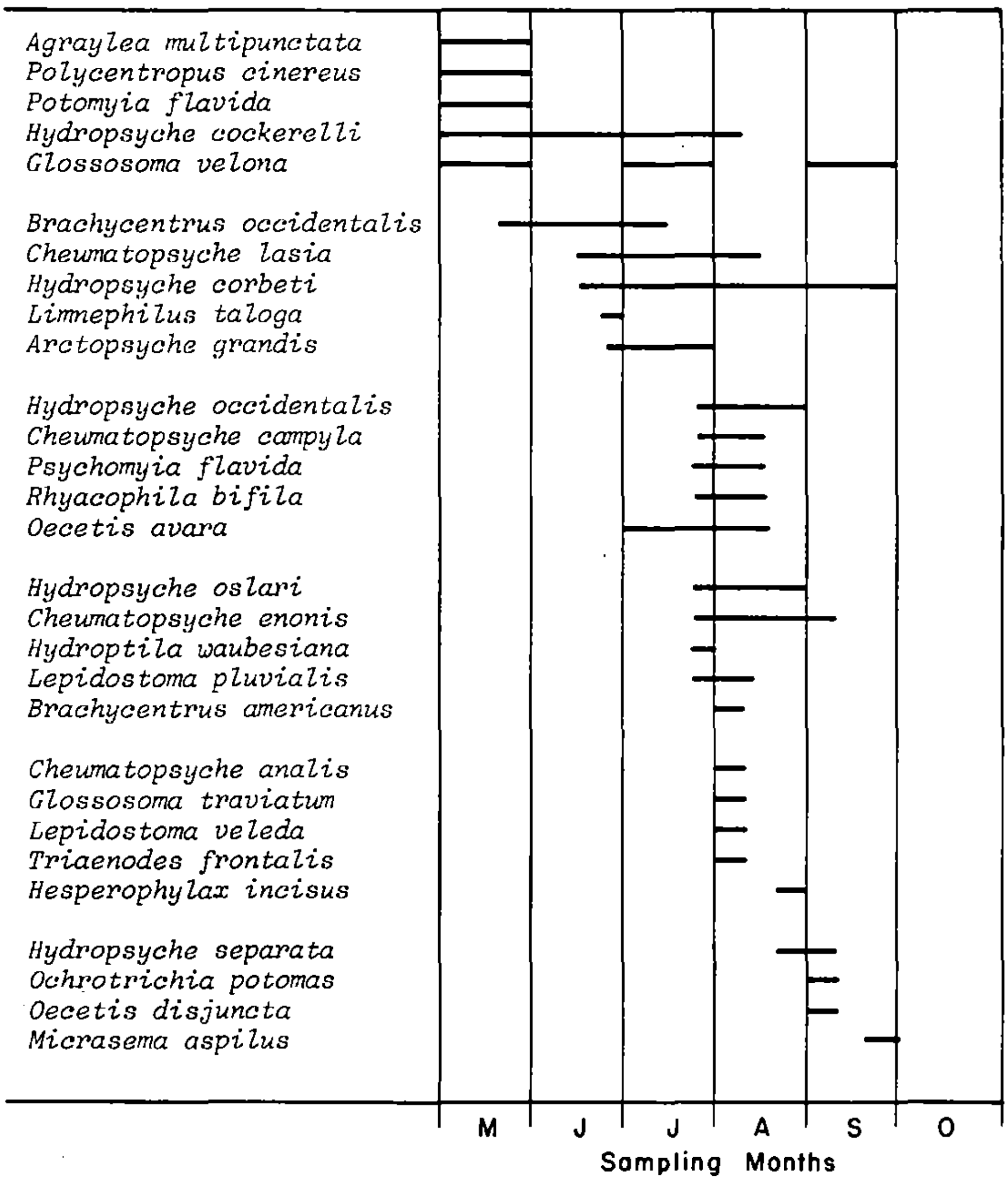


Figure 32. Emergence of caddisflies from the Yellowstone River, 1974-76.

The family Hydropsychidae dominates the caddisfly fauna of the Yellowstone River. Representatives (13 species) of this family are all net spinners and include the genera *Cheumatopsyche*, *Hydropsyche*, and *Arctopsyche*. One species, *Hydropsyche corbeti*, was not known to be present in the United States until collected in the Yellowstone River.

BOTTOM FAUNA POPULATION

Bottom samples taken during the fall of 1974 were designed to survey the bottom fauna and to test equipment. The data (available in Newell 1976 or in the files of the Montana Department of Natural Resources and Conservation, Helena) are, therefore, semiquantitative and difficult to compare with later sampling.

Quantitative bottom fauna sampling began in the summer of 1975. No sampling is possible in the lower river during the winter because of ice cover. Shortly after the ice is removed, spring runoff begins; bottom samples from this period would be of little value. The data gathered by Schwehr (see Report No. 8 in this series) were added here to compare the density of invertebrates of the midriver (stations 5-11) to that of the lower river (stations 12-20). Field data from samples taken at stations 15, 17, and 18 are presented in Newell 1976 and are on file at the Montana DNRC.

In August, bottom fauna population estimates ranged from about 50/m^2 at station 9 to about 2,000/m^2 at station 5 (figure 33). Station 19 exhibited the lowest mean, 250/m^2. Generally, there was a gradual downstream decrease in mean population size.

September population estimates (figure 34) exhibited a greater range, from 20/m^2 at station 19 to 8,500/m^2 (station 5). Estimates from the lower river were much lower than those from upper river stations.

In October, less variation in range was observed (figure 35). The minimum population estimate was 250/m^2 at station 18 and the maximum was 400/m^2 (station 11). The trend again was a gradual downstream decrease in the density of organisms.

In November samples, data from stations 1 and 3 were also available (figure 36). Population estimates at stations 1 and 3 were similar and were much higher than for the remaining sampling stations (range 4,500-12,000/m^2). The trend was a decrease in population downstream.

The percentage composition of all invertebrate orders collected in 1975 is presented in tables 4-7. The mean percentage composition of each order is found in table 8. Ephemeroptera dominate the fauna in August, and Trichoptera begin to dominate in September and October; the Diptera became dominant in November. Plecoptera and others are a minor portion of the fauna. Figure 37 graphically illustrates the longitudinal changes in percentage composition of invertebrate orders.

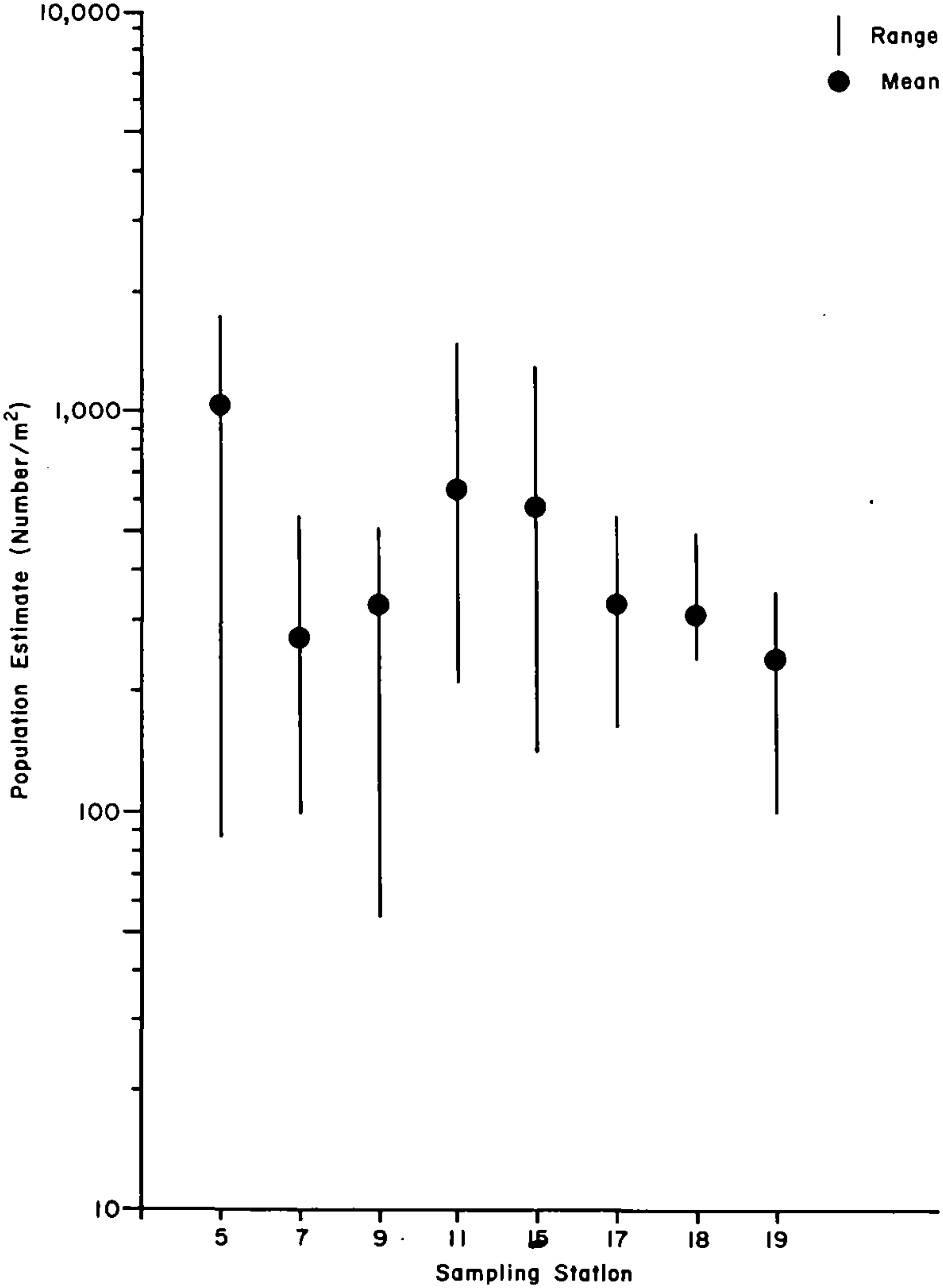


Figure 33. Population estimates for August 1975, mean and range of six Water's samples at each station.

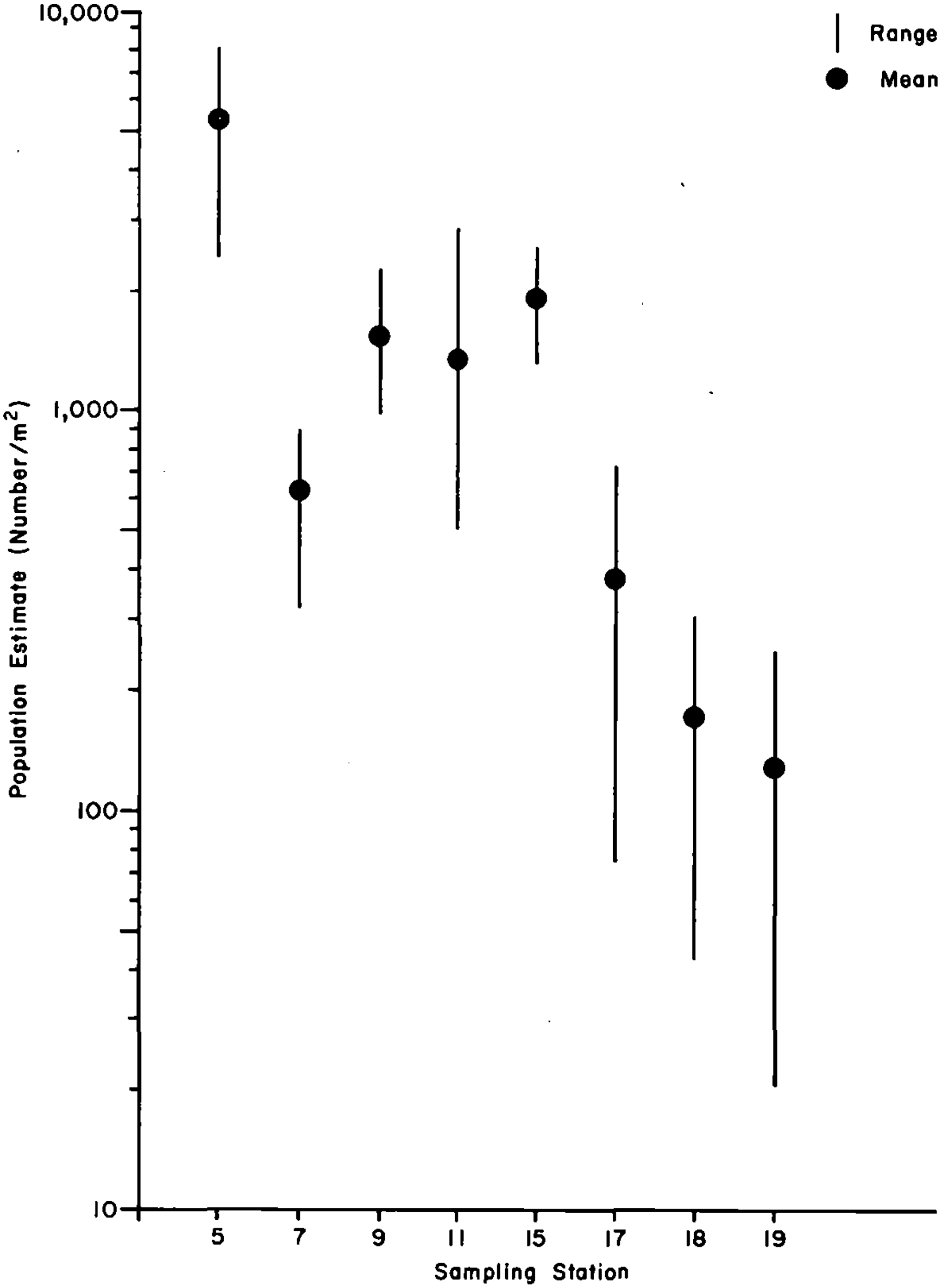


Figure 34. Population estimates for September 1975, mean and range of six Water's samples at each station.

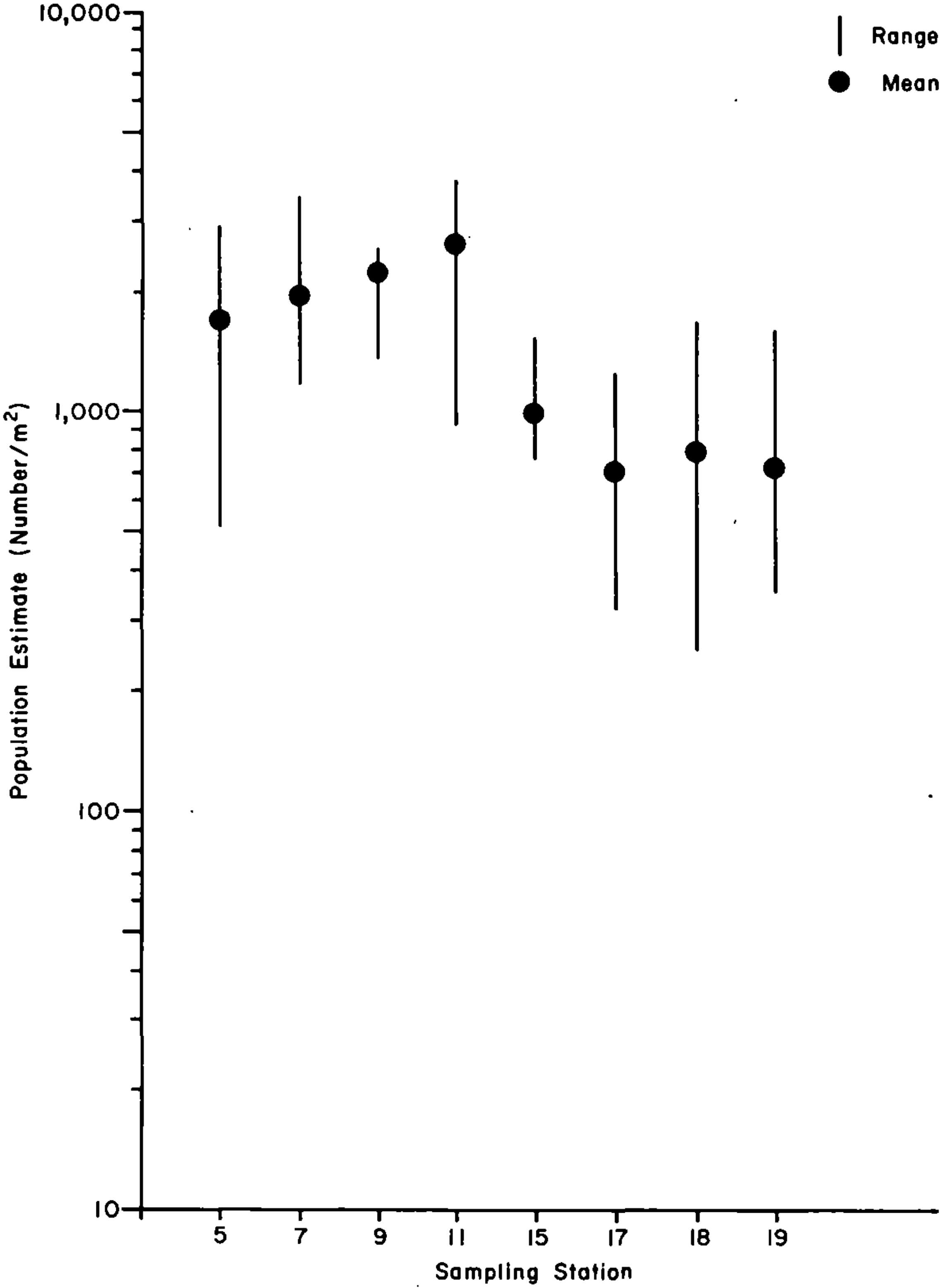


Figure 35. Population estimates for October 1975, mean and range of six Water's samples at each station.

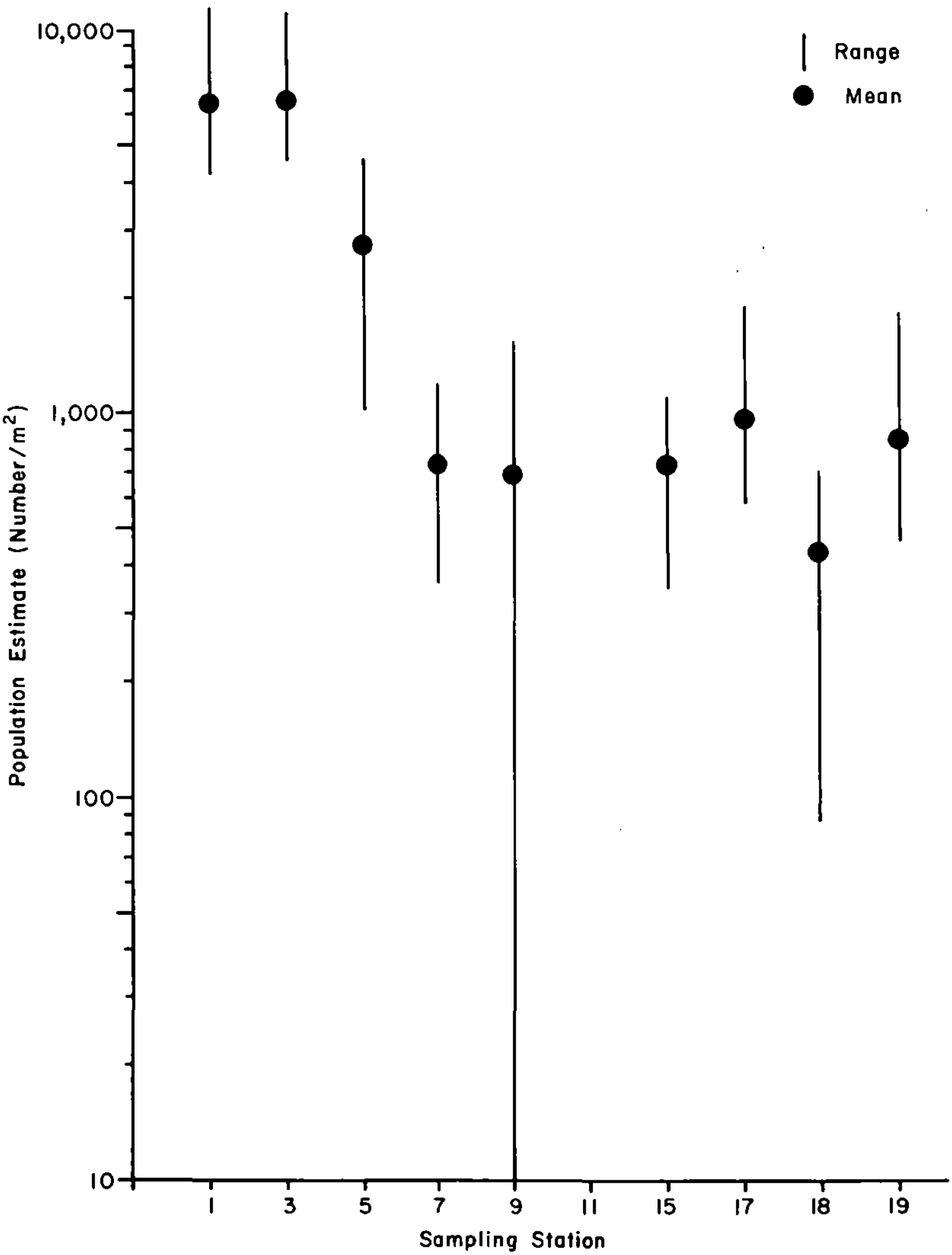


Figure 36. Population estimates for November 1975, mean and range of six Water's samples at each station.

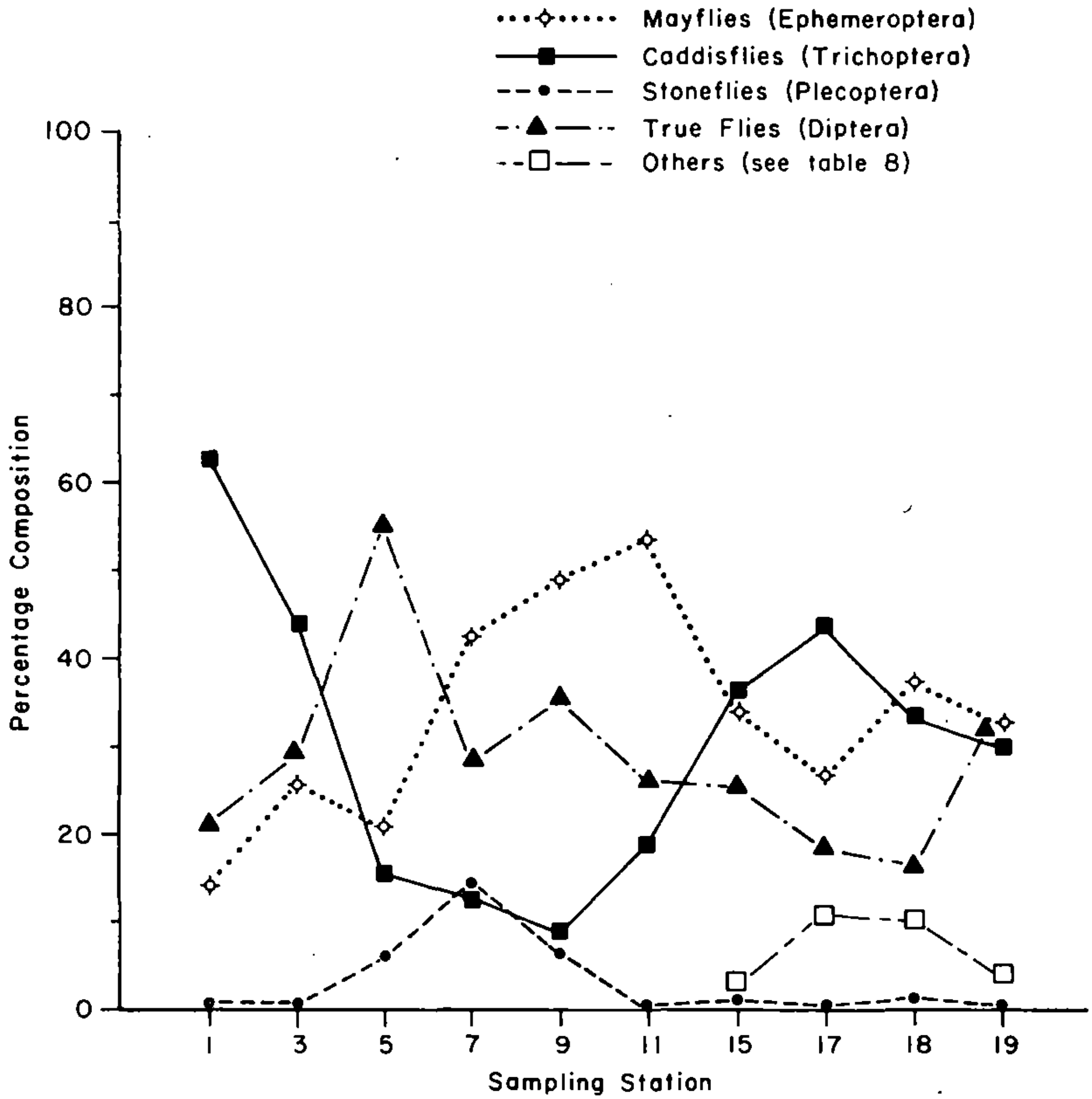


Figure 37. Mean percentage composition of invertebrate orders from Water's samples taken August-November 1975.

TABLE 4. Percentage composition of benthos from the Yellowstone River using Water's samples, August 1975.

Order	Station							
	5	7	9	11	15	17	18	19
Ephemeroptera	24.4	40.1	67.4	84.7	52.3	49.7	68.8	75.2
Plecoptera	6.7	25.7	17.4	0.8	2.8		0.6	
Trichoptera	4.3	22.4	5.8	8.6	31.9	48.7	30.1	19.7
Diptera	63.2	11.8	9.5	5.6	9.9	1.6		5.1
Coleoptera	1.4				3.1			
Odonata				0.5				
Oligochaeta							0.6	

TABLE 5. Percentage composition of benthos from the Yellowstone River using Water's samples, September 1975.

Order	Station							
	5	7	9	11	15	17	18	19
Ephemeroptera	18.2	71.1	50.4	50.7	37.4	30.1	37.8	28.8
Plecoptera	3.1	5.0	1.7	0.1	0.2		2.0	
Trichoptera	21.2	1.7	0.9	18.7	48.1	52.1	57.1	46.6
Diptera	56.5	21.8	47.0	30.3	14.2	14.6	3.0	19.2
Coleoptera	0.9	0.2			0.1			
Hemiptera	0.04							
Turbellaria	0.04							
Odonata								1.4
Oligochaeta						3.2		4.1
Acari				0.1				

TABLE 6. Percentage composition of benthos from the Yellowstone River using Water's samples, October 1975.

Order	Station							
	5	7	9	11	15	17	18	19
Ephemeroptera	8.3	35.6	50.8	26.1	35.0	19.8	22.9	21.8
Plecoptera	7.8	13.4	2.9	0.2	0.2			
Trichoptera	12.2	12.0	14.1	29.9	39.7	47.4	17.9	44.8
Diptera	71.2	38.7	32.0	44.0	23.3	12.9	29.3	27.0
Coleoptera	0.1	0.2		0.1			0.2	0.5
Odonata					0.2			
Oligochaeta					1.6	19.8	29.7	6.0
Acari	0.3	0.1	0.2					

TABLE 7. Percentage composition of benthos from the Yellowstone River using Water's samples, November 1975.

Order	Station 1	3	5	7	9	11	15	17	18	19
Ephemeroptera	14.5	25.4	33.4	22.9	24.8		12.7	7.4	19.6	4.3
Plecoptera	1.4	1.6	8.3	13.8	4.8		1.7	0.4	4.5	1.0
Trichoptera	62.3	43.5	26.3	20.3	16.5		24.7	24.5	29.4	10.8
Diptera	21.1	29.4	29.6	40.6	53.8		54.2	48.4	35.9	75.4
Coleoptera	0.1		0.7	2.4	0.3		0.4			
Oligochaeta	0.1	0.1	0.8				6.2	19.7	10.6	8.6
Acari	0.5		0.1							

TABLE 8. Mean percentage composition of benthos from the Yellowstone River using Water's samples, August-November 1975.

Order	Station 1	3	5	7	9	11	15	17	18	19
Ephemeroptera	14.5	25.4	21.1	42.4	48.4	53.8	34.4	26.8	37.3	32.5
Plecoptera	1.4	1.6	6.5	14.5	6.7	0.4	1.2	0.1	1.8	0.3
Trichoptera	62.3	43.5	16.0	14.1	9.3	19.1	36.1	43.2	33.6	30.5
Diptera	21.1	29.4	55.1	28.2	35.6	26.6	25.4	19.4	17.1	31.7
Coleoptera	0.1		0.8	0.7	0.1		1.0			
Hemiptera			0.01							
Turbellaria			0.01							
Odonata						0.1	0.1			0.4
Oligochaeta	0.1	0.1					2.0	10.7	10.2	3.7
Acari	0.5		0.1							

SPECIES DIVERSITY

Species diversity indices were calculated from Water's samples taken during August-November 1975 in order to begin a monitoring study of the Yellowstone River. Mathematical indices are one way of condensing long species lists to a single mathematical value that can be compared with those from other stations and other time periods. Four diversity indices, based on data collected for this study and presented in raw form in Newell 1976, are graphed and presented in figures 38-41.

The Shannon-Weaver index ($\bar{d}$), apparently the most sensitive to community changes, is presented in figure 42. The Miles City and Sidney stations exhibited the greatest seasonal change. The Glendive and Intake stations were constant and similar (tables 9-12).

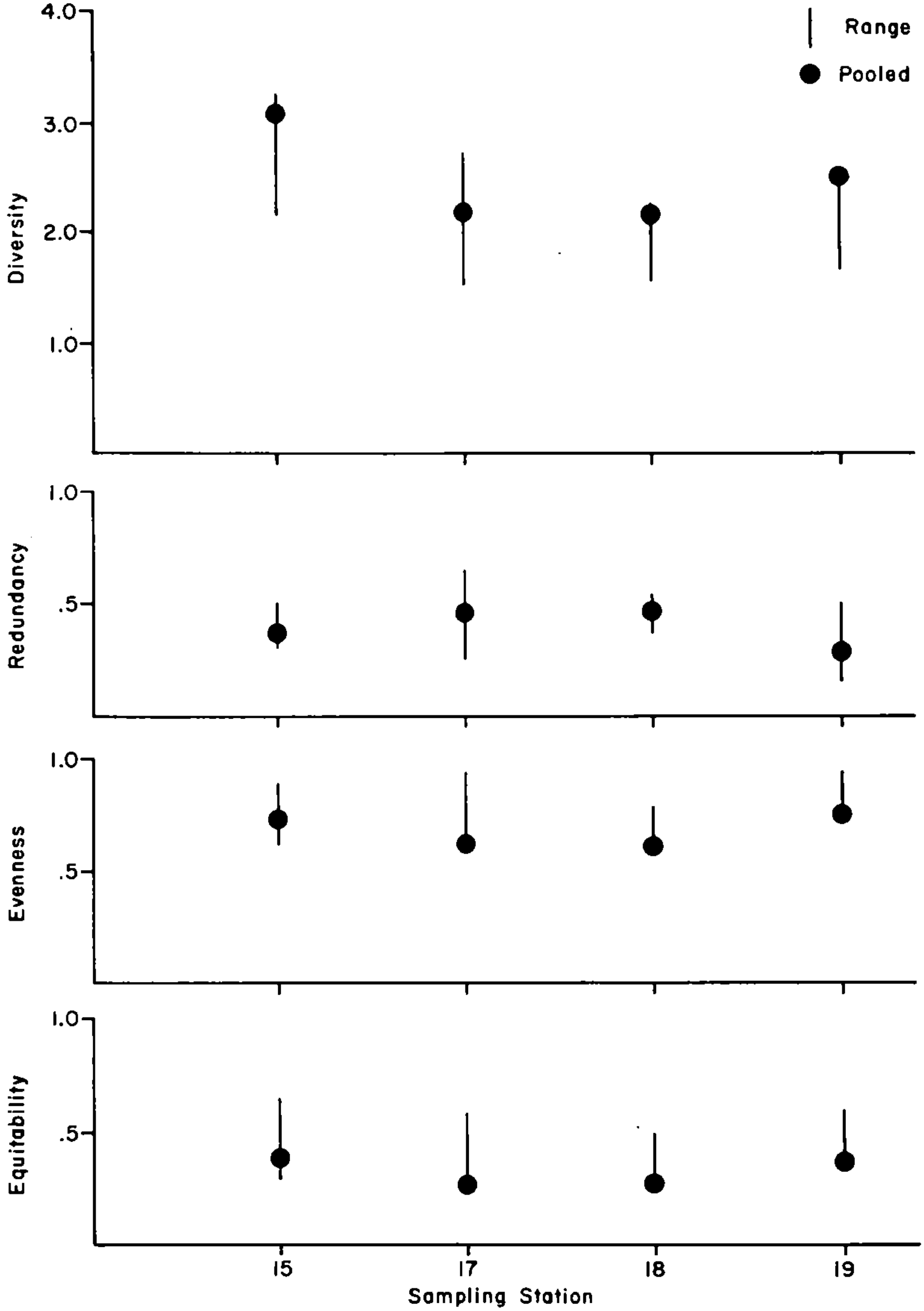


Figure 38. Species diversity: range of six Water's samples and all six pooled, August 1975.

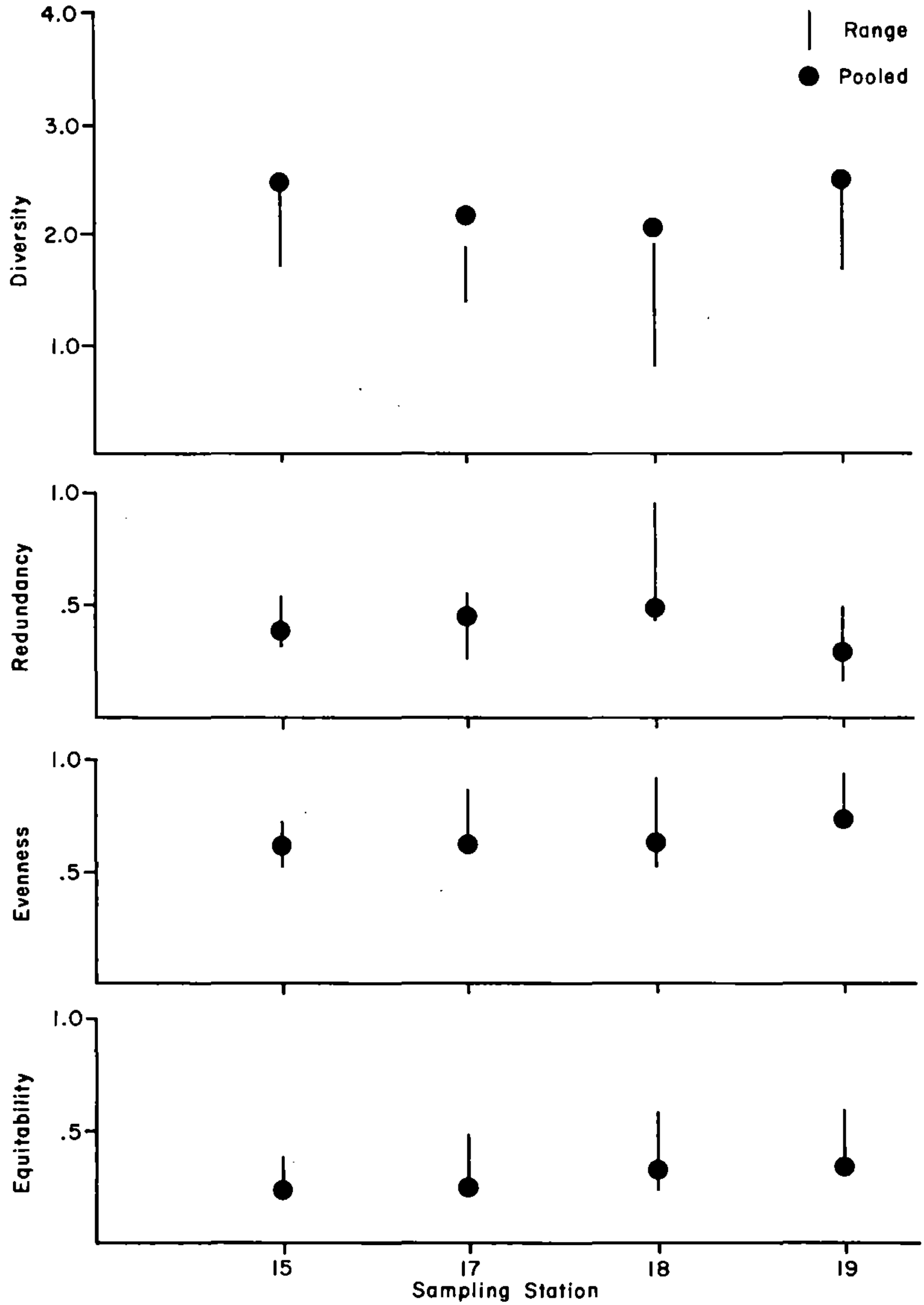


Figure 39. Species diversity: range of six Water's samples and all six pooled, September 1975.

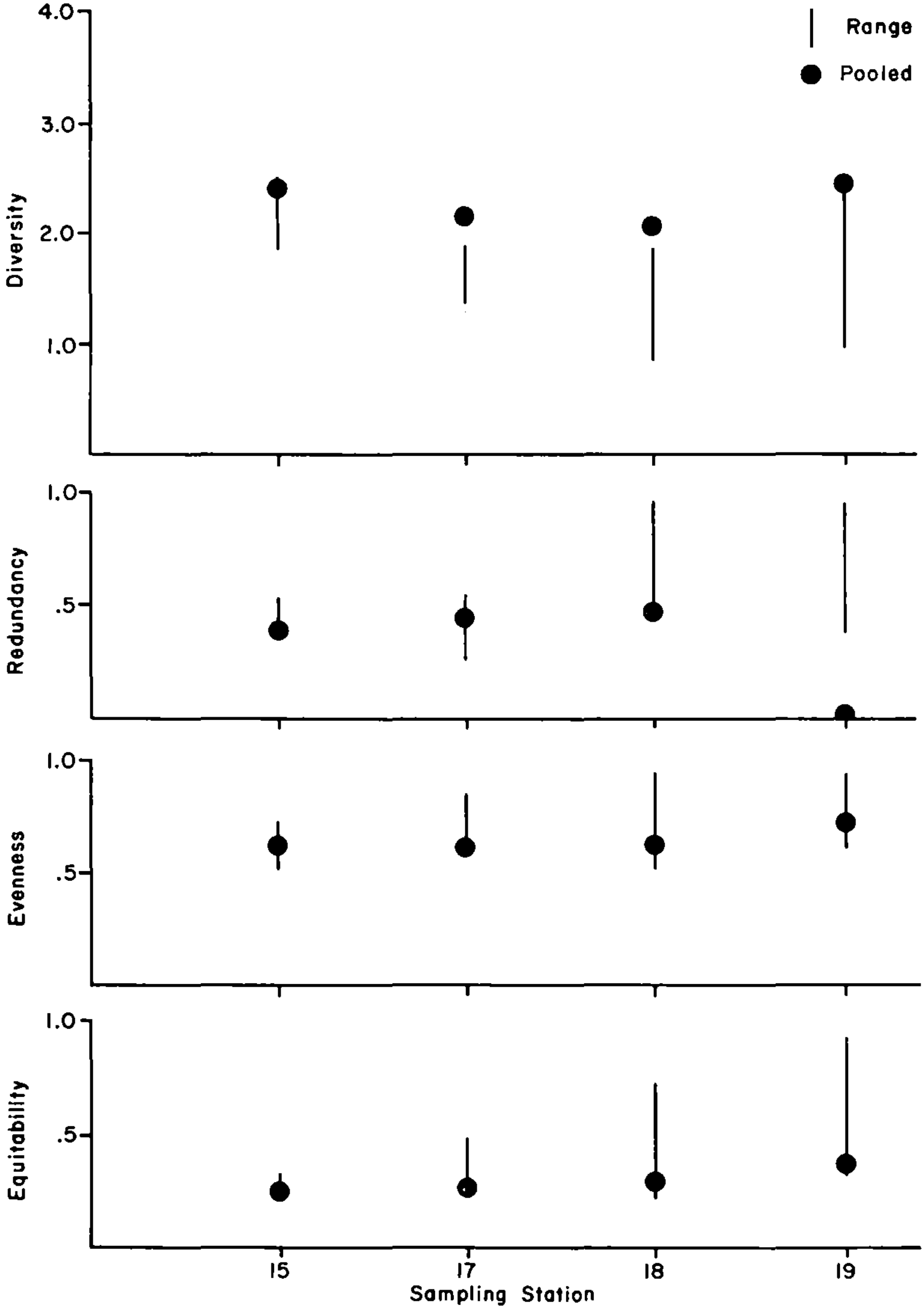


Figure 40. Species diversity: range of six Water's samples and all six pooled, October 1975.

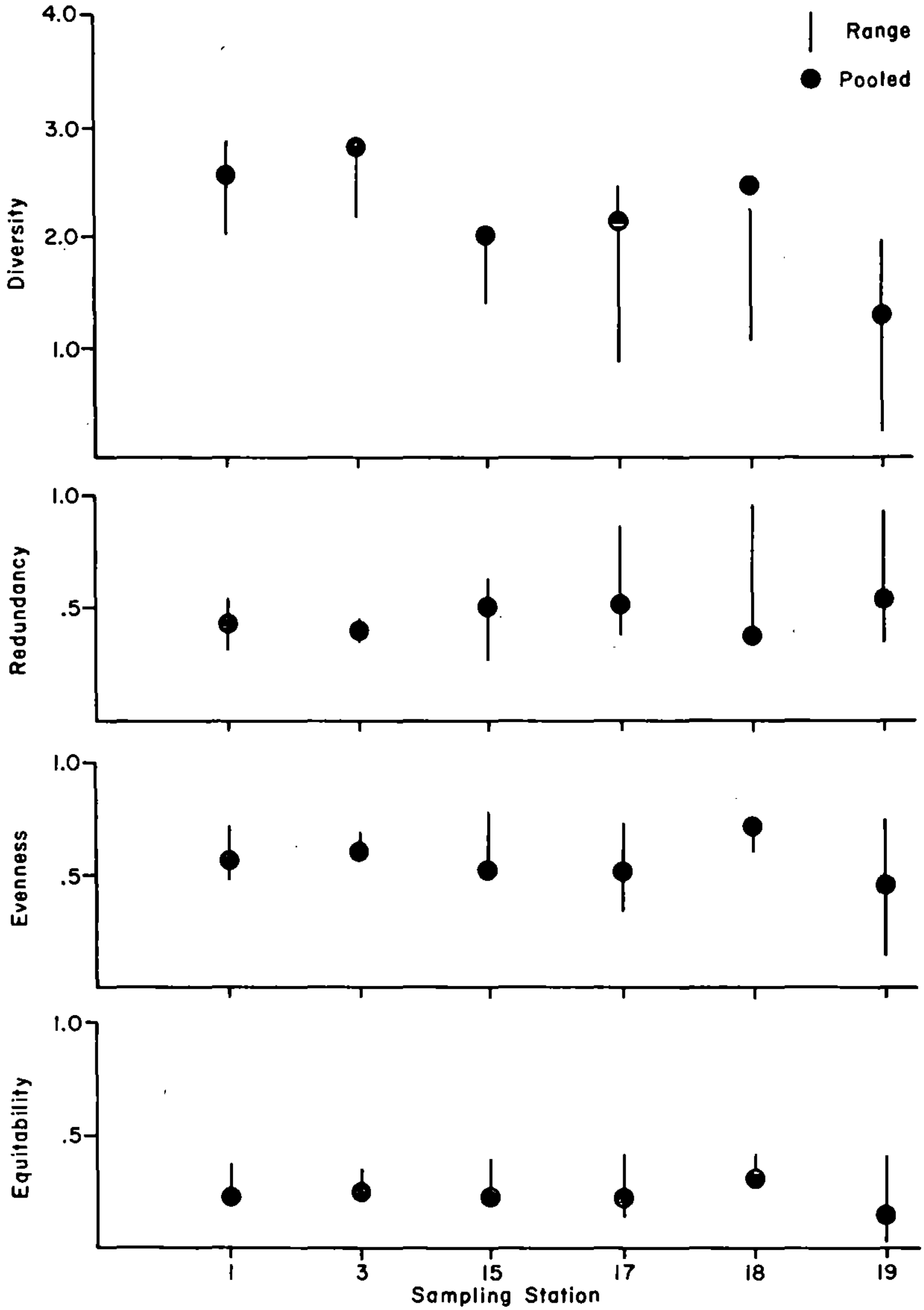


Figure 41. Species diversity: range of six Water's samples and all six pooled, November 1975.

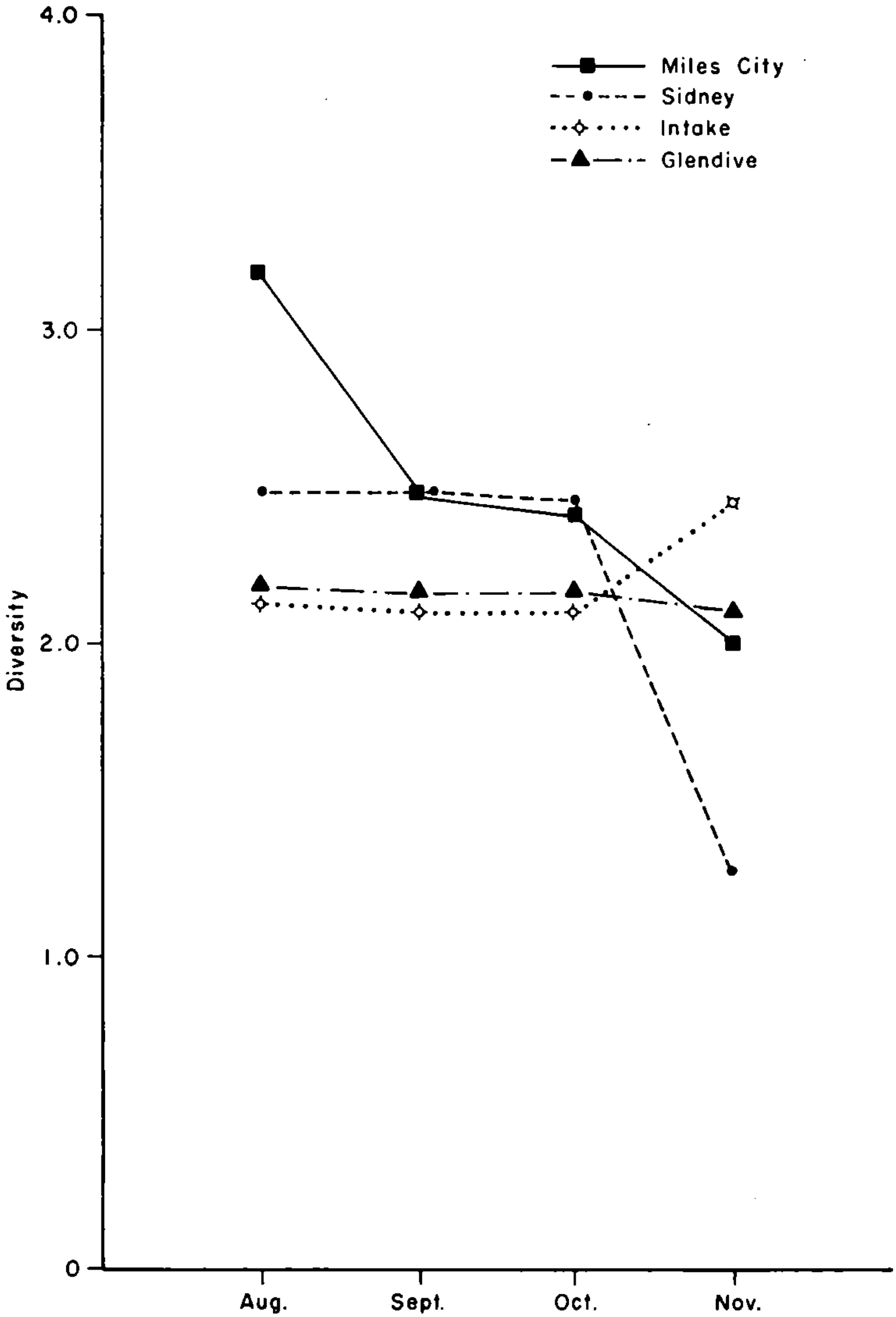


Figure 42. Seasonal changes in Shannon-Weaver diversity indices (the result of pooling six Water's samples each month at each station during 1975).

TABLE 9. Species diversity, range of six Water's samples and all six pooled, August 1975.

Index		Station 5	7	9	11	15	17	18	19
Mean Diversity ($\bar{d}$)	Max	2.79	3.11	2.95	3.17	3.22	2.70	2.27	2.43
	Min	1.24	1.66	2.19	2.58	2.16	1.51	1.59	1.69
	Pooled	2.22	3.43	3.25	3.08	3.19	2.15	2.12	2.49
Redundancy (R)	Max	.72	.22	.94	.36	.50	.65	.52	.49
	Min	.27	.00	.02	.01	.24	.23	.33	.14
	Pooled	.49	.08	.28	.26	.32	.44	.45	.30
Evenness (J')	Max	.78	.96	1.00	.92	.89	.90	.81	.95
	Min	.18	.83	.12	.70	.65	.62	.68	.76
	Pooled	.53	.88	.75	.74	.73	.62	.61	.75
Equitability (E_m)	Max	.52	.72	1.00	.65	.68	.60	.50	.60
	Min	.18	.52	.45	.36	.31	.27	.29	.39
	Pooled	.24	.47	.43	.36	.38	.29	.28	.35

TABLE 10. Species diversity, range of six Water's samples and all six pooled, September 1975.

Index		Station 15	17	18	19
Mean Diversity ($\bar{d}$)	Max	2.50	1.86	1.85	2.33
	Min	1.84	1.38	0.83	1.69
	Pooled	2.49	2.14	2.09	2.49
Redundancy (R)	Max	.55	.59	1.00	.49
	Min	.33	.25	.43	.14
	Pooled	.39	.43	.48	.30
Evenness (J')	Max	.72	.87	.95	.95
	Min	.55	.61	.53	.76
	Pooled	.62	.62	.63	.75
Equitability (E_m)	Max	.33	.49	.58	.60
	Min	.26	.30	.20	.39
	Pooled	.25	.27	.32	.35

TABLE 11. Species diversity, range of six Water's samples and all six pooled, October 1975.

Index		Station 15	17	18	19
Mean Diversity ($\bar{d}$)	Max	2.50	1.86	1.85	2.33
	Min	1.84	1.38	0.83	0.99
	Pooled	2.41	2.14	2.09	2.42
Redundancy (R)	Max	.55	.59	1.00	1.00
	Min	.33	.25	0.43	.38
	Pooled	.39	.43	0.48	0.00
Evenness (J')	Max	.72	.87	.95	1.00
	Min	.55	.61	.53	.62
	Pooled	.62	.62	.63	.73
Equitability (E_m)	Max	.33	.49	.75	1.00
	Min	.26	.30	.20	.31
	Pooled	.25	.29	.32	.39

TABLE 12. Species diversity, range of six Water's samples and all six pooled, November 1975.

Index		Station 1	3	15	17	18	19
Mean Diversity ($\bar{d}$)	Max	2.88	2.82	1.96	2.45	2.24	1.97
	Min	2.01	2.18	1.41	0.84	1.06	0.24
	Pooled	2.64	2.81	2.00	2.11	2.46	1.30
Redundancy (R)	Max	.53	.44	.64	.82	1.00	.91
	Min	.31	.32	.26	.33	.36	.32
	Pooled	.43	.39	.50	.51	.33	.56
Evenness (J')	Max	.72	.70	.80	.74	.75	.76
	Min	.49	.59	.54	.32	.61	.15
	Pooled	.58	.62	.54	.53	.71	.46
Equitability (E_m)	Max	.32	.31	.35	.36	.39	.36
	Min	.28	.25	.29	.13	.28	.03
	Pooled	.23	.25	.23	.23	.33	.14

The Shannon-Weaver index was near or below 3.0 for most stations. Generally an index above 3.0 illustrates a healthy, unstressed community, while an index below 1.0 is indicative of a monospecific community under stress. The index range of 1.0-3.0 seems to illustrate a community under some stress (Wilhm 1970bc). Stresses upon certain Yellowstone communities might be due to large amounts of inorganic sediments and nondiverse, uniform riverbottom substrate types in some areas.

FEEDING MECHANISMS

It is interesting to note that Egglishaw (1964), Macan (1974), and Cummins (1975a) all believe that the microdistribution of a species is determined more by food preferences than by any other factor. Current distributes allochthonous detritus and periphyton which in turn determine invertebrate distribution (figure 43).

In attempting to determine if faunal zonation occurs in the Yellowstone River, aquatic genera found in the Yellowstone River were grouped according to feeding mechanisms (table 13). A grouping of organisms into zones is difficult. It is necessary to go to a lower taxonomic level than family in describing distribution; e.g., the family Chironomidae is listed under all four feeding mechanism categories and is found at all 20 stations. Four genera in the shredder category confined to the upper river represent, at least in part, the erosional habitat of Cummins (1975a). Genera found in the collector and scraper categories are variously distributed along the entire river, thus obscuring the importance of the intermediate and depositional zones for faunal zonation. It may be necessary to graph the abundance of each genus or each species in order to separate the fauna into habitat zones. More information on feeding habits of individual species is necessary before this can be done.

CURRENT AND DEPTH REQUIREMENTS FOR INVERTEBRATES

DATA COLLECTED

Data from the current-depth studies at Glendive and Intake are summarized in table 14. In general, current and depth means are similar for both stations and all sampling times. Taxa and number of individuals varied greatly, however. At Glendive the mean number of taxa increased from 3.9 in August to 9.0 in November; a similar trend was evident in the Intake samples. The mean number of individuals increased from 9.1 to 149 at Glendive and from 37.9 to 65.8 at Intake. More taxa and more individuals were captured in the October and November samples at both stations than during August and September. December samples would have been valuable, but were unavailable because the lower river froze on November 30, 1975.

Population estimates from 24 samples at each station are shown in tables 15-18. In August (table 15) the fauna was dominated by *Traverella* and *Hydropsyche*. There was a large difference in the total number of individuals collected at Glendive (1222) and Intake (5199).

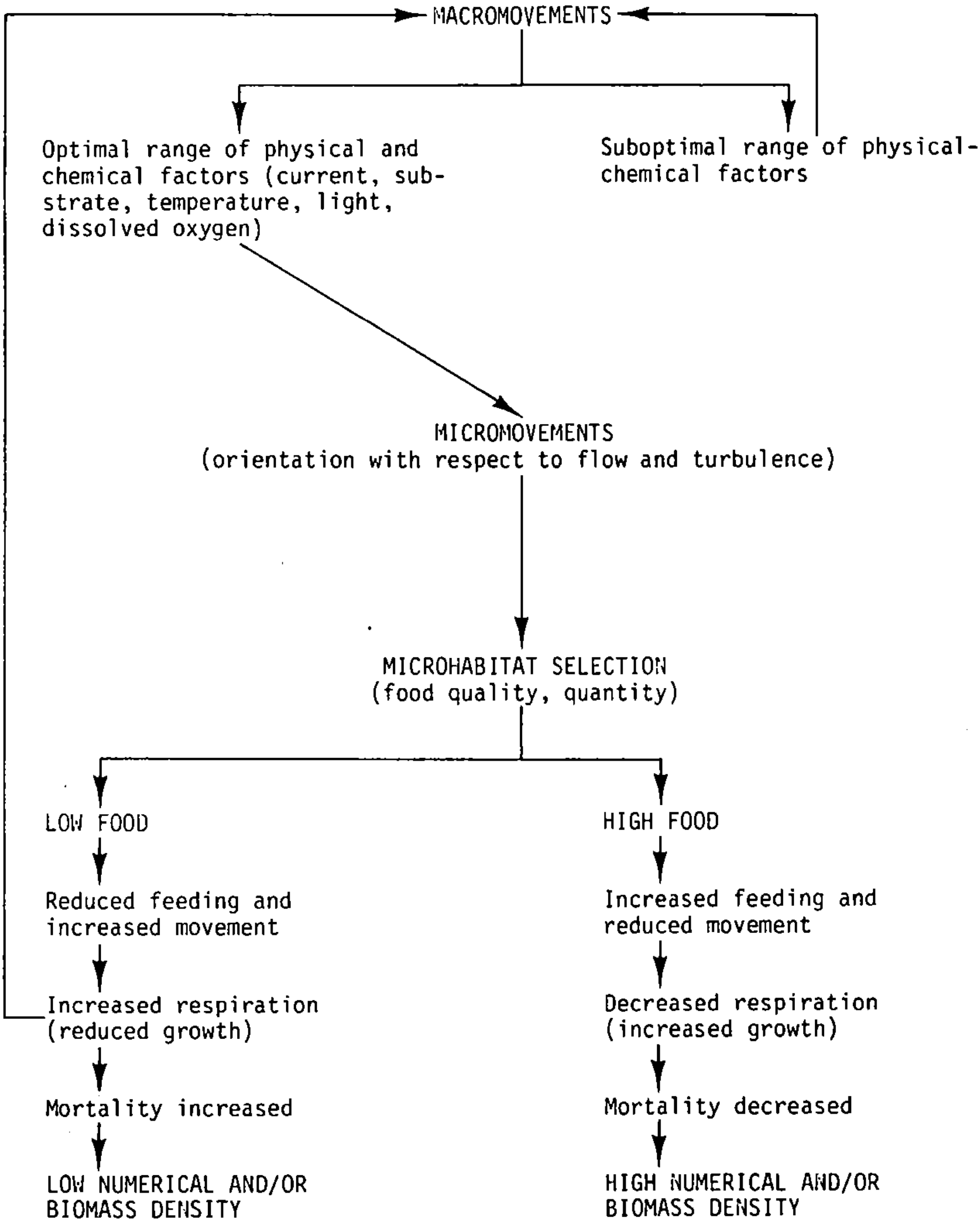


Figure 43. Proposed relationships between invertebrates and the factors that determine their distribution and abundance (from Cummins 1972).

TABLE 13. Yellowstone River aquatic invertebrate distribution based on feeding mechanism.

Feeding Mechanism	Dominant Orders	Family	Genus	Distribution in Yellowstone River Stations
Shredders (large particle detritivores)	Trichoptera	Leptoceridae	*Leptocella*	10-18
			Oecetis	6-17
		Lepidostomatidae	*Lepidostoma*	1- 9
	Plecoptera	(Filipalpia)	*Nemoura*	1- 8
			Capnia	1-15
			Pteronarcella	1-10
			Pteronarcys	1- 5
	Diptera	Chironomidae		1-20
Collectors (fine particle detritivores)	Trichoptera	Hydropsychidae	*Hydropsyche*	1-18
			Cheumatopsyche	2-18
			Arctopsyche	1- 9
	Ephemeroptera	Leptophlebiidae	*Leptophlebia*	3-18
		Baetidae	*Baetis*	1-20
		Ephemerellidae	*Ephemerella*	1-18
		Heptageniidae	*Heptagenia*	1-20
	Diptera	Simuliidae	*Simulium*	1-20
		Chironomidae		1-20
Scrapers (grazers)	Ephemeroptera	Heptageniidae	*Heptagenia*	1-20
		Baetidae	*Baetis*	1-20
		Ephemerellidae	*Ephemerella*	1-18
		Caenidae	*Caenis*	10-20
	Diptera	Chironomidae		1-20
Predators	Odonata	Gomphidae		
	Plecoptera	(Setipalpia)	*Arcynopteryx*	1- 9
			Isogenus	1-19
			Isoperla	1-20
			Alloperla	1-12
	Trichoptera	Rhyacophilidae	*Rhyacophila*	1- 6
		Hydropsychidae	*Hydropsyche*	1-18
	Diptera	Chironomidae		1-20
		Rhagionidae	*Atherix*	1-11

SOURCE: After Cummins 1973, 1975a

TABLE 14. Mean (upper number) and standard deviation (bottom number) for four variables measured in the invertebrate/current investigation in the Yellowstone River

Date	Depth ft	Depth m	Current ft/sec	Current m/sec	Number of Taxa	Number of Individuals
GLENDIVE						
August 7	1.8 0.9	.55 .27	1.202 0.575	.366 .175	3.9 1.6	9.1 8.2
September 17	1.2 0.9	.37 .27	0.744 0.613	.226 .186	6.5 2.4	21.7 11.1
October 9	1.4 1.0	.43 .30	0.786 0.570	.239 .173	10.9 2.2	126.9 86.6
November 7	1.6 0.9	.49 .27	1.029 0.678	.313 .206	9.0 3.8	149.0 133.9
INTAKE						
August 6	1.3 0.6	.4 .18	1.653 0.782	.505 .238	4.8 1.8	37.9 32.4
September 9	1.4 1.0	.43 .3	0.970 0.623	.295 .189	6.0 1.7	28.9 12.2
October 15	0.8 0.6	.24 .18	1.124 1.031	.342 .314	8.5 2.9	84.0 53.1
November 11	1.6 0.9	.49 .27	1.477 0.921	.450 .280	7.0 3.2	65.8 44.8

TABLE 15. Population estimates from the August 6 and 7, 1975, invertebrate-current samples (24 pooled samples from each station).

Taxa	Glendive	Intake
Baetis insignificans	17	6
Baetis parvus	34	74
Brachycercus sp.	80	17
Choroterpes sp.	0	11
Dactylobaetis sp.	11	11
Ephemerella sp.	6	0
Heptagenia sp.	57	28
Isonychia sp.	11	40
Rhithrogena sp.	11	210
Traverella sp.	193	3,111
Tricorythodes minutus	63	734
Hydropsyche spp.	569	751
Leptocella sp.	28	6
Isoperla sp.	6	46
Chironomidae	119	114
Simuliidae	11	23
Dytiscidae	0	6
Oligochaeta	6	11
Totals	1,222	5,199
Means of 24 samples	51	217

TABLE 16. Population estimates from the September 9, 1975, invertebrate-current samples (24 pooled samples from each station).

Taxa	Glendive	Intake
Baetis insignificans	28	102
Baetis parvus	28	108
Brachycercus sp.	34	17
Caenis sp.	6	0
Choroterpes sp.	23	57
Dactylobaetis sp.	28	97
Ephemerella sp.	0	0
Ephoron sp.	28	17
Heptagenia sp.	131	14
Isonychia sp.	0	6
Ametropus sp.	0	6
Traverella sp.	74	682
Tricorythodes minutus	279	347
Tricorythodes sp.	0	57
Stenonema sp.	0	6
Cheumatopsyche sp.	63	23
Hydropsyche sp.	779	1,763
Leptocella sp.	0	6
Acroneuris sp.	0	6
Isoperla sp.	6	6
Microcylleopus sp.	6	0
Ranatra sp.	6	0
Certopogonidae	6	0
Chironomidae	1,314	239
Simuliidae	6	51
Oligochaeta	119	28
Totals	2,964	3,638
Means of 24 samples	124	152

TABLE 17. Population estimates from the October 9 and 15, 1975, invertebrate-current samples (24 pooled samples from each station).

Taxa	Glendive	Intake
Baetis insignificans	1,772	1,490
Baetis parvus	142	182
Brachycercus sp.	28	11
Caenis sp.	0	6
Centroptilum sp.	11	0
Choroterpes sp.	46	11
Dactylobaetis sp.	791	301
Ephemerella sp.	0	6
Heptagenia sp.	1,879	943
Isonychia sp.	0	6
Rhithrogena sp.	0	742
Stenonema sp.	6	0
Traverella sp.	165	642
Tricorythodes minutus	267	91
Tricorythodes sp.	11	0
Unknown	6	0
Gammarus sp.	6	6
Hyalella sp.	0	6
Brachycentrus sp.	11	0
Cheumatopsyche sp.	199	51
Hydropsyche sp.	9,845	4,448
Hydroptila sp.	0	6
Oecetis sp.	11	0
Gomphidae	17	0
Isogenus sp.	6	80
Isoperla sp.	6	23
Corixidae	23	0
Dolochopodidae	0	6
Empididae	11	0
Chironomidae	1,973	2,314
Simuliidae	11	154
Stenelmis sp.	6	0
Ferrissia sp.	23	0
Lymnaca sp.	6	0
Oligochaeta	2,776	1,104
Totals	20,037	12,640
Mean of 24 samples	835	527

TABLE 18. Population estimates from the November 7 and 11, 1975, invertebrate-current samples (24 pooled samples from each station).

Taxa	Glendive	Intake
Baetis insignificans	751	
Baetis parvus	17	
Brachycercus sp.	6	0
Caenis sp.	11	0
Dactylobaetis sp.	63	40
Ephemerella sp.	63	0
Heptagenia sp.	956	427
Leptophlebia sp.	6	6
Rhithrogena sp.	80	330
Stenonema sp.	11	0
Traverella sp.	51	11
Tricorythodes minutus	97	34
Tricorythodes sp.	6	6
Cheumatopsyche sp.	927	114
Hydropsyche sp.	10,608	4,846
Hyalella sp.	6	0
Brachyptera sp.	256	239
Isogenus sp.	6	142
Corixidae	46	0
Chironomidae	1,905	1,758
Empididae	6	0
Ceratopogonidae	0	6
Simuliidae	0	6
Dytiscidae	11	6
Ferrissia sp.	17	11
Lymnaea sp.	11	0
Oligochaeta	4,374	529
Totals	20,245	8,938
Mean of 24 samples	844	375

In September (table 16) *Hydropsyche* were again abundant, as were Chironomidae. Totals were comparable for Glendive (2964)and Intake (3638).

Hydropsyche and Chironomidae again dominated in the October samples (table 17). Number of taxa and total number of individuals greatly increased at both stations.

November samples showed *Hydropsyche* and Chironomidae dominant (table 18). Totals were high at Glendive (20,245) but considerably reduced from October at Intake (8988).

All 48 samples taken each month were pooled to illustrate which orders dominate the fauna (table 19). The fauna was dominated by Trichoptera and Ephemeroptera with Diptera third. Ephemeroptera monthly percentages ranged from 11.7 to 73.6 while Trichoptera percentages varied from 21.1 to 56.3 percent of the total. The October and November samples contained more information than the August-September samples, probably due to summer emergence losses and the presence in August and September of very small larvae and nymphs, most of which passed through the collecting net. Mean population estimates varied from 138/m^2 (August) to 681/m^2 (October). Percentage composition of orders at each station is shown in table 20.

Results obtained with the kick net were compared with results of the Water's sampler (figures 44 and 45). The Water's sampler is 19.5 in high; thus only kick samples taken in depths less than 19.5 in were compared. Results were similar, but the number of organisms obtained with the kick net was always lower than numbers obtained with the Water's sampler. Several kick samples were taken at the water's edge in water too shallow to sample with the Water's sampler, tending to expand the range and reduce the mean. Results from the two samplers followed the same trend over time at both stations, and a line joining the means of both methods is almost parallel.

ENVIRONMENTAL REQUIREMENTS

Multiple regression analyses were performed on the current-depth data with current and depth as independent variables and number of taxa and number of individuals as dependent variables. Three models were applied: 1) untransformed; 2) semilog transformation (of dependent variables); and 3) log-log transformation. The detailed results of these analyses, for all three models, are reported in Newell 1976 and are on file with the Montana DNRC. The general results are given in tables 21 and 22.

Number of taxa and number of individuals yield similar results when regressed against current velocity. Figures 46-48 show how these regression equations can be used to predict the numbers of individuals at any particular current or depth. The deviation of the data from the regression line is demonstrated in figure 48, for example, where the regression coefficients (r) are 0.774 for current and 0.808 for depth.

TABLE 19. Invertebrate population estimates and percentage composition, pooled Glendive and Intake sampling.

ORDER	August Total[a]	August %[b]	September Total[a]	September %[b]	October Total[a]	October %[b]	November Total[a]	November %[b]	Mean %[a]
Ephemeroptera	4,725	73.6	2,175	32.9	9,555	29.2	3,449	11.7	36.9
Trichoptera	1,354	21.1	2,634	39.9	14,571	44.6	16,495	56.3	40.5
Plecoptera	52	0.3	18	0.3	115	0.4	643	2.2	0.8
Diptera	267	4.2	1,616	24.5	4,469	13.7	3,681	12.6	13.8
Oligochaeta	17	0.3	147	2.2	3,880	11.9	4,903	16.7	8.0
Others	6	0.1	12	0.2	87	0.2	108	0.4	0.2
Totals	6,421		6,602		32,677		29,279		
Means	138		138		681		610		

[a]Totals of 48 pooled samples, 24 from each station.

[b]Percentage of monthly pooled totals.

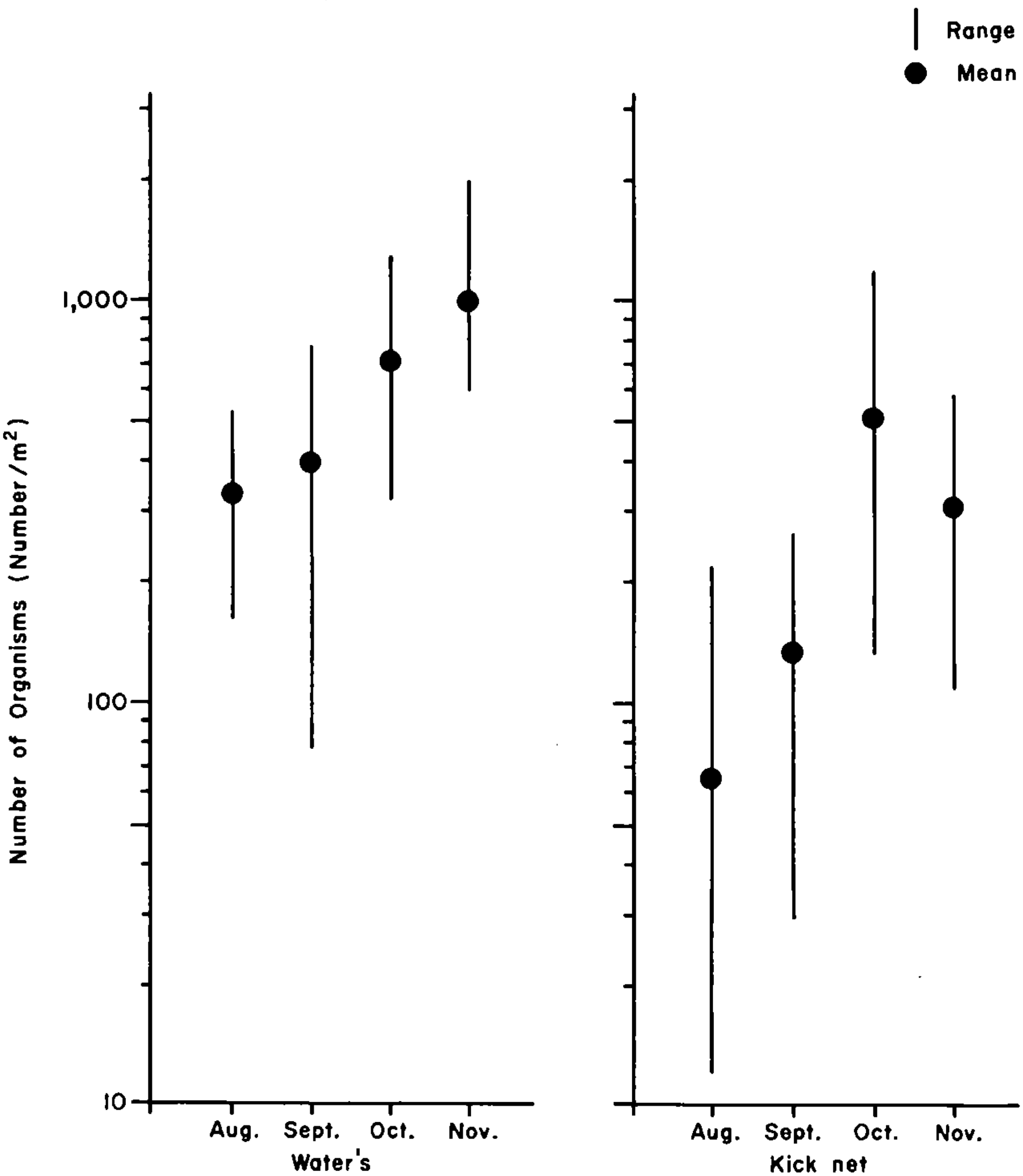


Figure 44. Comparison of sampling methods, Water's and kick net at Glendive using kick samples taken in depths less than 19.5 in.

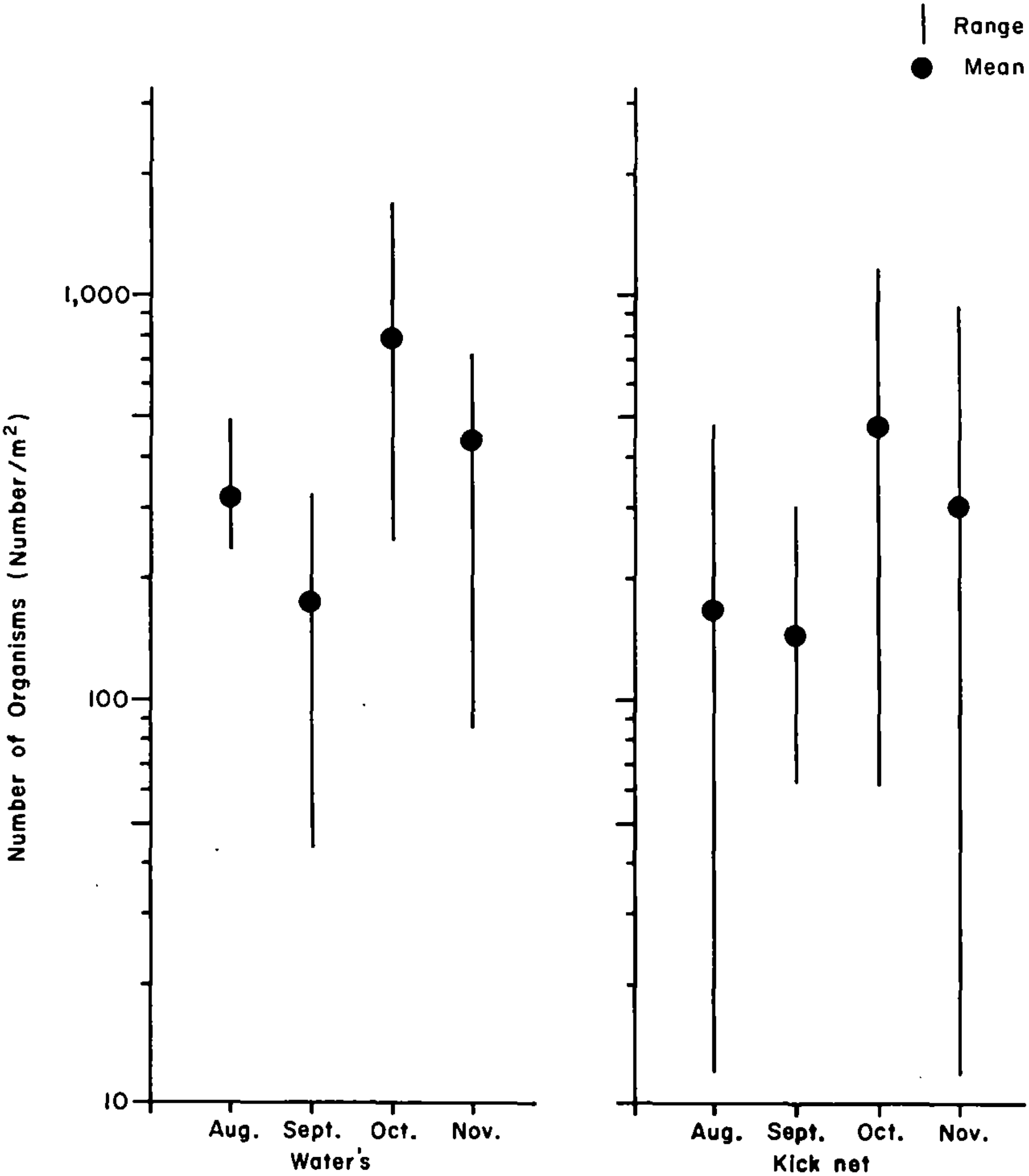


Figure 45. Comparison of sampling methods, Water's and kick net at Intake using kick samples taken in depths less than 19.5 in.

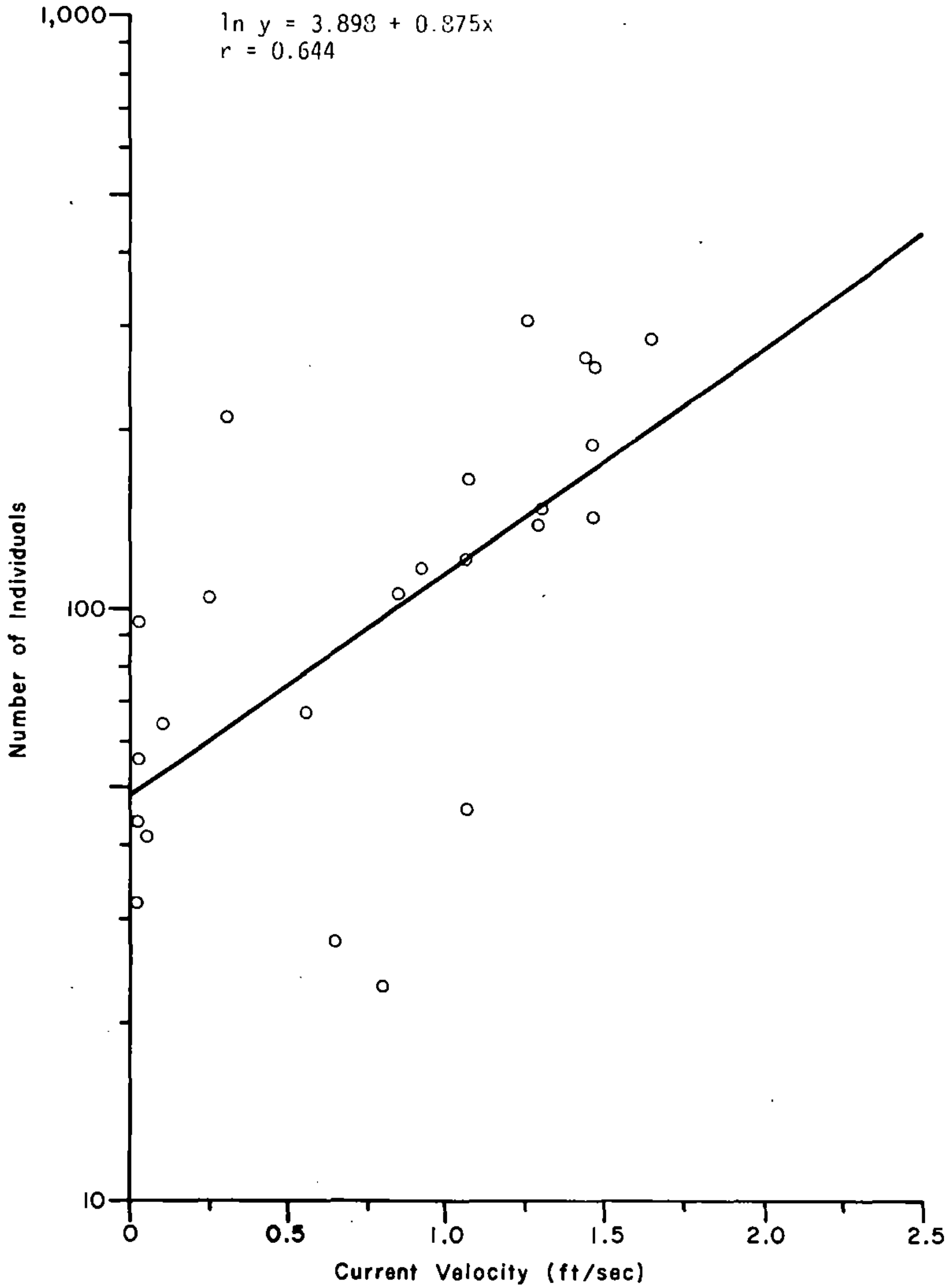


Figure 46. Current/invertebrate relationships, Yellowstone River, Glendive, October 9, 1975.

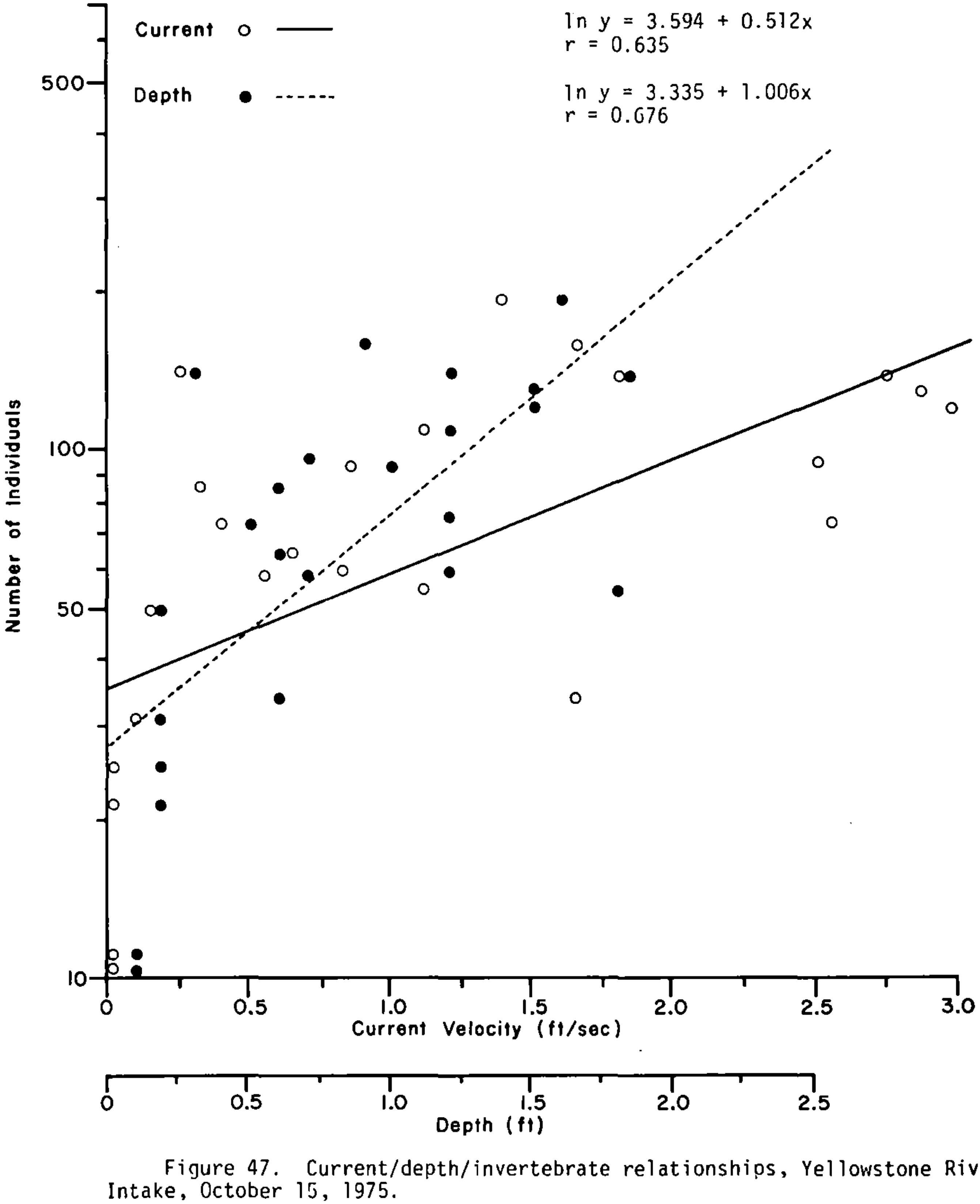


Figure 47. Current/depth/invertebrate relationships, Yellowstone River, Intake, October 15, 1975.

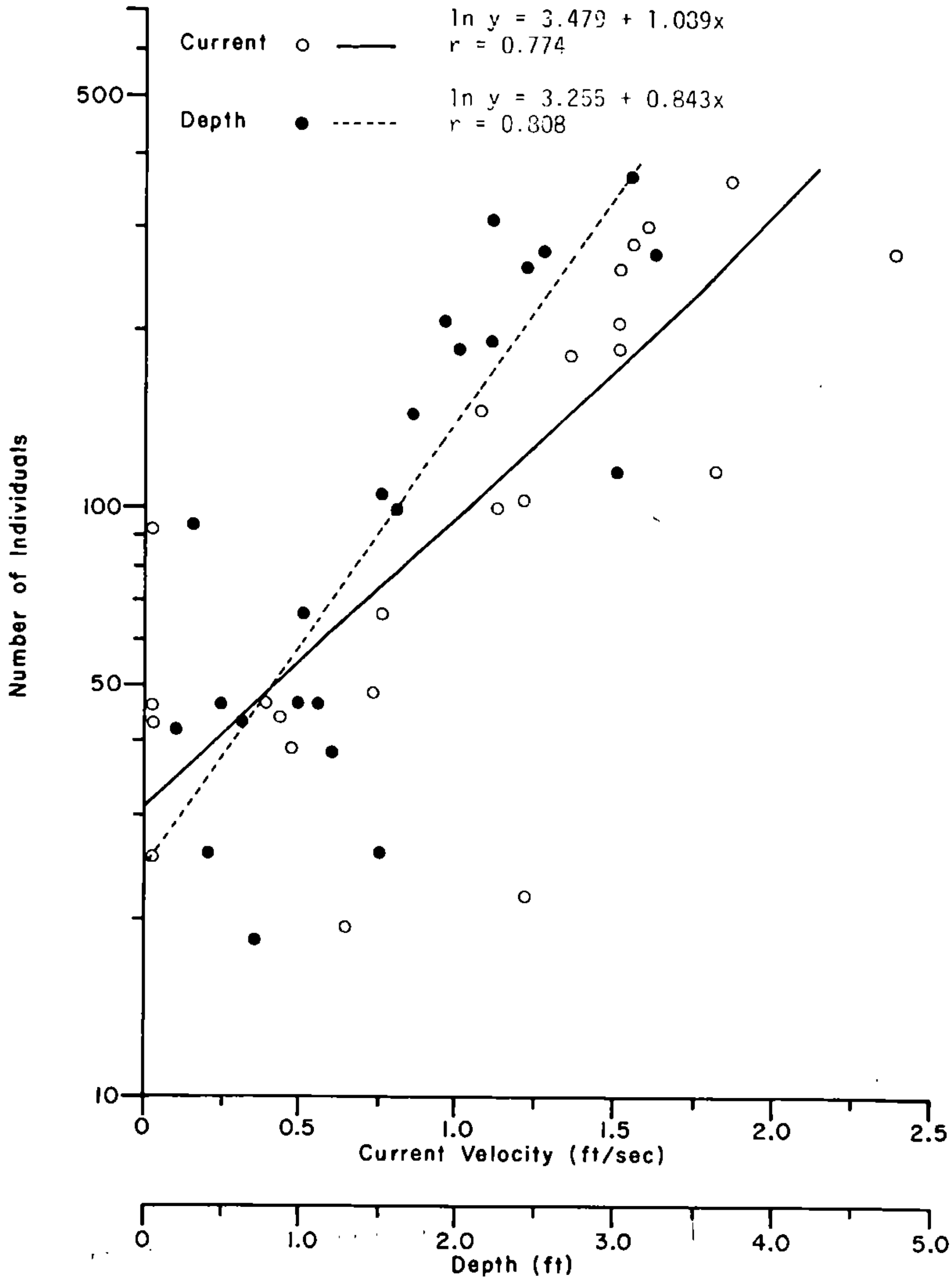


Figure 48. Current/depth/invertebrate relationships, Yellowstone River, Glendive, November 7, 1975.

TABLE 20. Percentage composition of invertebrate orders derived from kick samples taken at Glendive (17) and Intake(18) in 1975.

Order	August		September		October		November	
	17	18	17	18	17	18	17	18
Ephemeroptera	39.8	81.6	22.2	41.7	25.6	35.1	10.5	14.8
Trichoptera	48.9	14.6	28.4	49.3	50.2	35.6	57.0	55.2
Plecoptera	0.5	0.9	0.2	0.2	0.05	0.8	1.3	4.2
Diptera	10.6	2.6	44.7	8.0	10.0	19.6	9.4	19.7
Hempitera	0	0	0.2	0	9.1	0	9.2	-
Coleoptera	0	0.1	0.2	0	0.05	0	0.1	0.1
Odonata	0	0	0	0	0.1	0	0	0
Amphipoda	0	0	0	0	-	0.2	0.1	0
Mollusca	0	0	0	0	0.1	0	0.1	0.1
Oligochaeta	0.5	0.2	4.0	0.8	13.9	8.7	21.6	5.9

Mayflies

Mayfly (Ephemeroptera) species diversity ($\bar{d}$) was great, with as many as 15 species present in some current-depth samples. Because Ephemeroptera nymphs are much easier to identify to the species level, current preferences were obtained for several abundant species. These data provide some insight into niche separation in the mayfly community and how separation and current preference change throughout the life cycle of several species.

Densities of *Traverella albertana* and *Tricorythodes minutus* are presented in figure 49. In this figure and in figures 50-54, the exact nature of the invertebrate/current relationships is not clear from the data; the following conclusions record only how the data were interpreted by the author. Peak densities in August at Intake for *Traverella albertana* occurred at about 2.25 ft/sec. Nymphs of *T. albertana* were more abundant in August than in any other month. This species emerges in September and October, and nymphs do not reappear in any number until November.

At the Intake station during the October samples, peak population densities were determined for several species (figure 50). *Heptagenia elegantula* were more abundant in slower currents and most abundant at 0.5 ft/sec. *Traverella albertana* was abundant near 2.5 ft/sec as in the August samples. *Baetis insignificans* was also most abundant at 2.5-3.0 ft/sec, but there was no way to determine at what velocity this population would reach its peak. A similar situation exists with *Rhithrogena undulata,* although the population seems to reach its greatest density at about 2.75 ft/sec. In November, *H. elegantula* and *B. insignificans* exhibited low densities at Intake, but peak densities appear to have occurred at 1.5 ft/sec and 2.5 ft/sec, respectively (figure 51).

Some current preferences were apparent for mayflies at the Glendive station (figure 52). A population extreme was evident for *H. elegantula* (0.5 ft/sec). In the November samples (figure 53), the highest density of *H. elegantula* occurred at about 1.5 ft/sec.

TABLE 21. Synopsis of regressional analysis on the current-depth[a] data (against number of taxa) showing significance for the three models for both sampling stations.

Model	Depth	Current	Depth & Current	Date	Sta.
I	NS	NS	NS	Aug.	17
II	NS	NS	NS	Aug.	17
III	NS	NS	NS	Aug.	17
I	NS	NS	NS	Sept.	17
II	NS	NS	NS	Sept.	17
III	NS	*	*	Sept.	17
I	NS	NS	*	Oct.	17
II	NS	NS	*	Oct.	17
III	NS	*	**	Oct.	17
I	**	**	**	Nov.	17
II	**	**	**	Nov.	17
III	**	**	**	Nov.	17
I	NS	NS	NS	Aug.	18
II	NS	NS	NS	Aug.	18
III	NS	**	**	Aug.	18
I	NS	NS	NS	Sept.	18
II	NS	NS	NS	Sept.	18
III	NS	NS	NS	Sept.	18
I	**	*	**	Oct.	18
II	**	*	**	Oct.	18
III	**	**	**	Oct.	18
I	*	NS	**	Nov.	18
II	*	NS	**	Nov.	18
III	**	**	**	Nov.	18

NOTE: NS = not significant at p = .05
* = significant at p = .05
** = highly significant at p = .01

[a]Current in ft/sec, depth in ft

TABLE 22. Synopsis of regression analysis on the current-depth[a] data (against number of organisms) showing significance for the three models for both sampling stations.

Model	Depth	Current	Depth & Current	Date	Sta.
I	NS	NS	NS	Aug.	17
II	NS	NS	NS	Aug.	17
III	NS	NS	NS	Aug.	17
I	*	*	*	Sept.	17
II	NS	NS	NS	Sept.	17
III	*	**	**	Sept.	17
I	**	**	**	Oct.	17
II	**	**	**	Oct.	17
III	**	*	**	Oct.	17
I	**	**	**	Nov.	17
II	**	**	**	Nov.	17
III	**	*	**	Nov.	17
I	**	*	**	Aug.	18
II	**	**	**	Aug.	18
III	**	**	**	Aug.	18
I	*	**	**	Sept.	18
II	**	**	**	Sept.	18
III	*	NS	**	Sept.	18
I	**	**	**	Oct.	18
II	**	**	**	Oct.	18
III	**	**	**	Oct.	18
I	**	NS	**	Nov.	18
II	**	**	**	Nov.	18
III	**	**	**	Nov.	18

NOTE: NS = not significant at p = .05
* = significant at p = .05
** = highly significant at p = .01

[a]Current in ft/sec, depth in ft

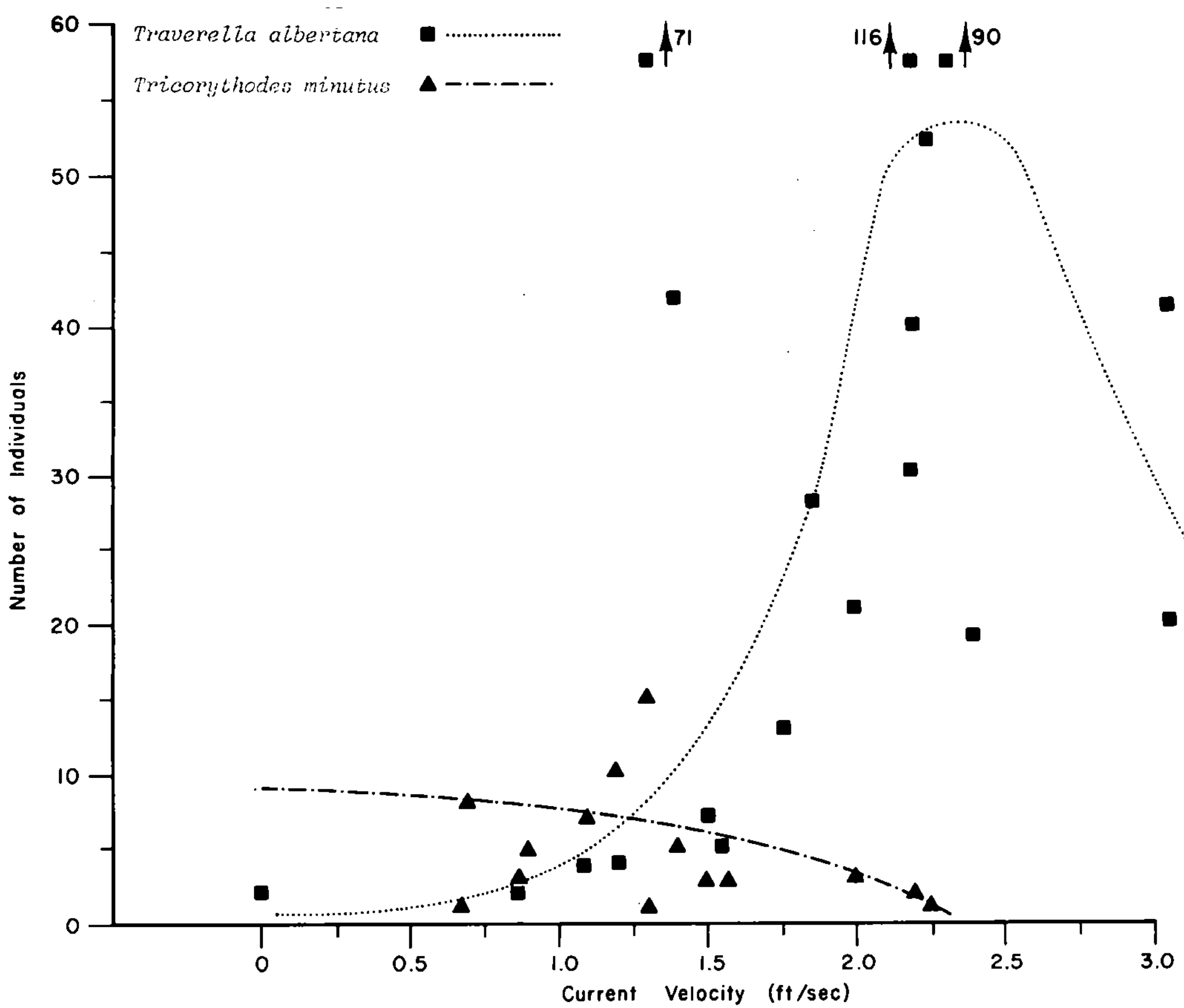


Figure 49. Mayfly (Ephemeroptera) distribution at various currents, Intake, August 1975.

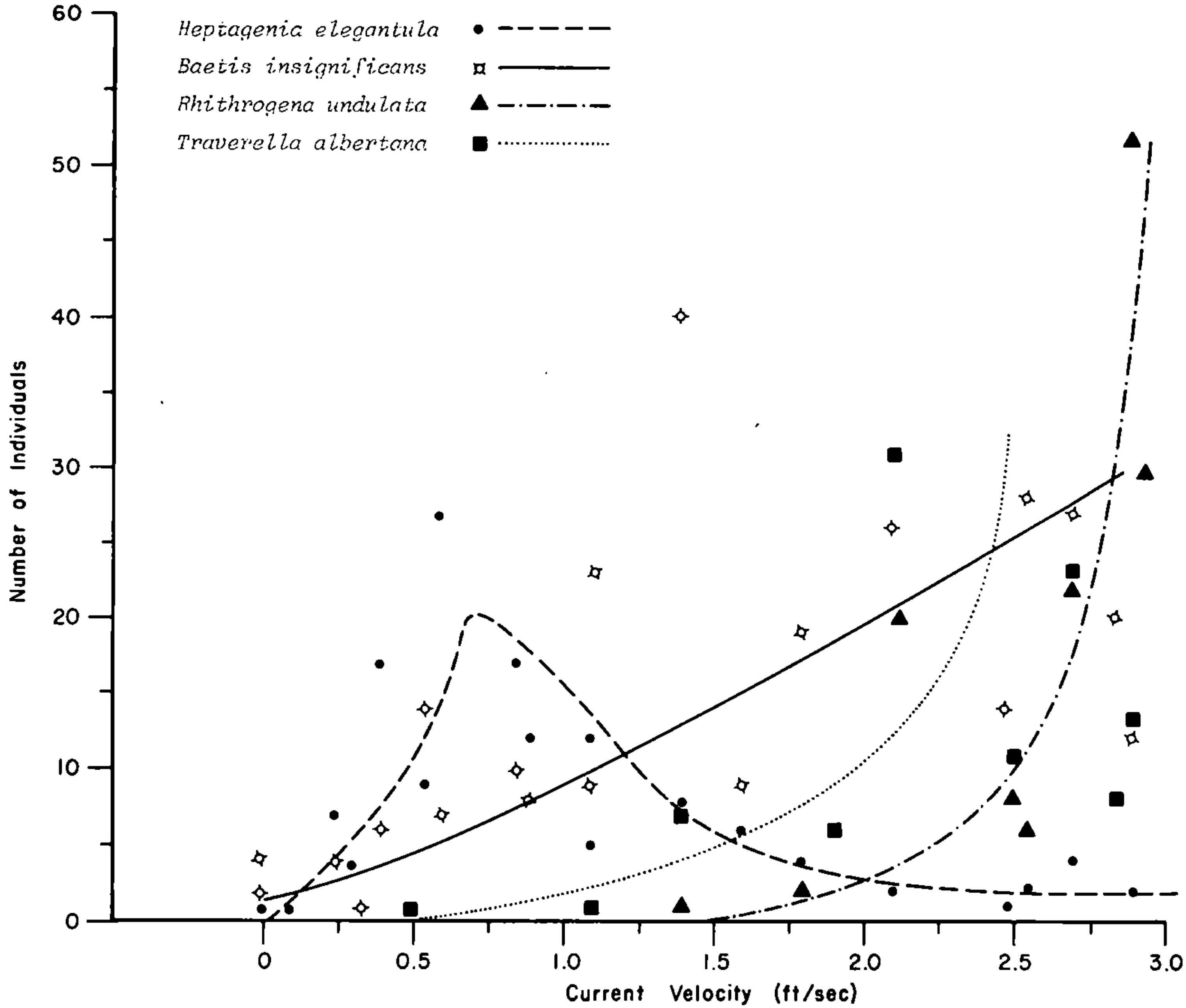
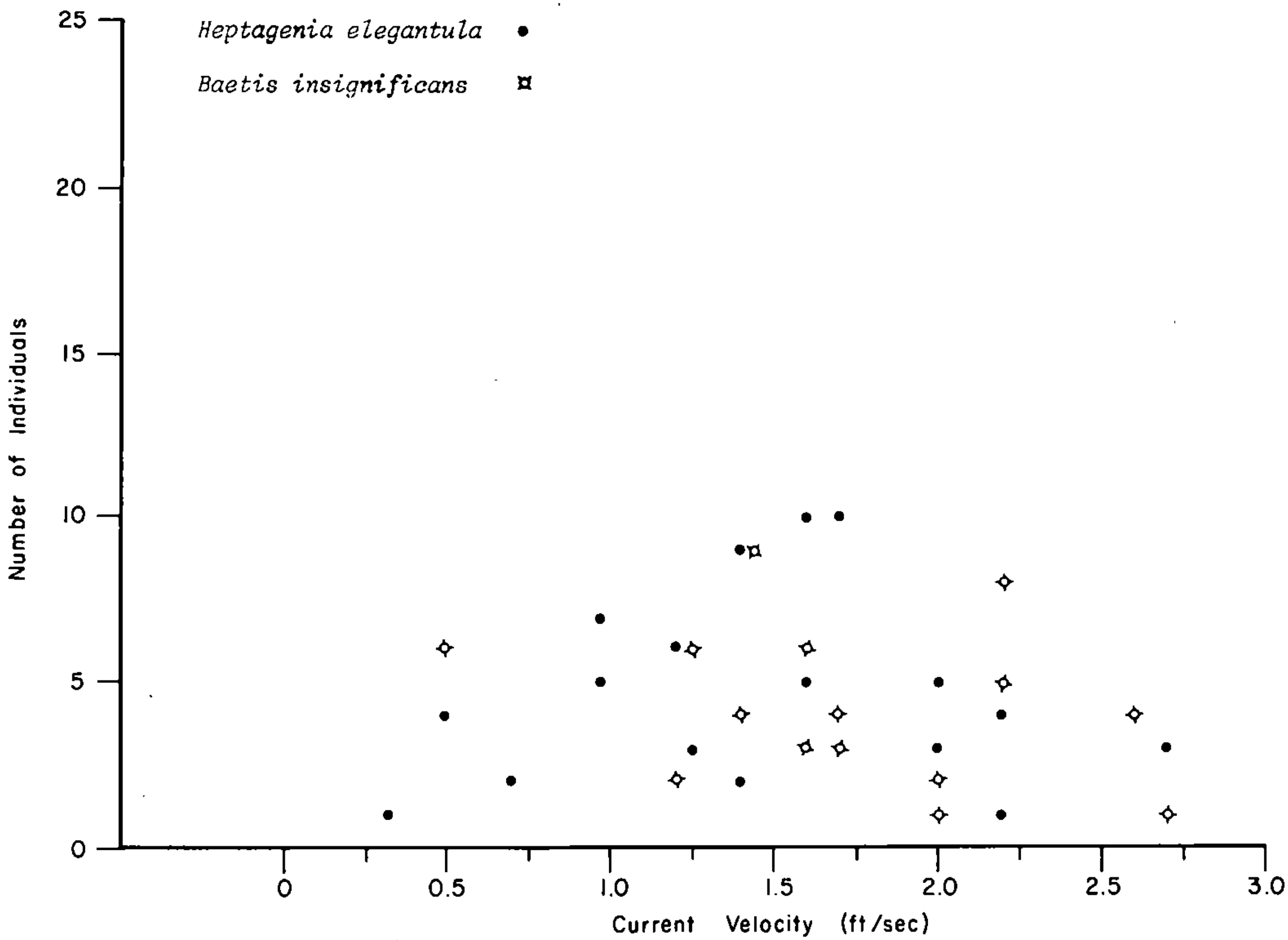


Figure 50. Mayfly (Ephemeroptera) distribution at various currents, Intake, October 1975.



NOTE: Because no apparent trends emerged in the points plotted, no attempt was made to interpret current preference based on the data in this figure.

Figure 51. Mayfly (Ephemeroptera) distribution at various currents, Intake, November 1975.

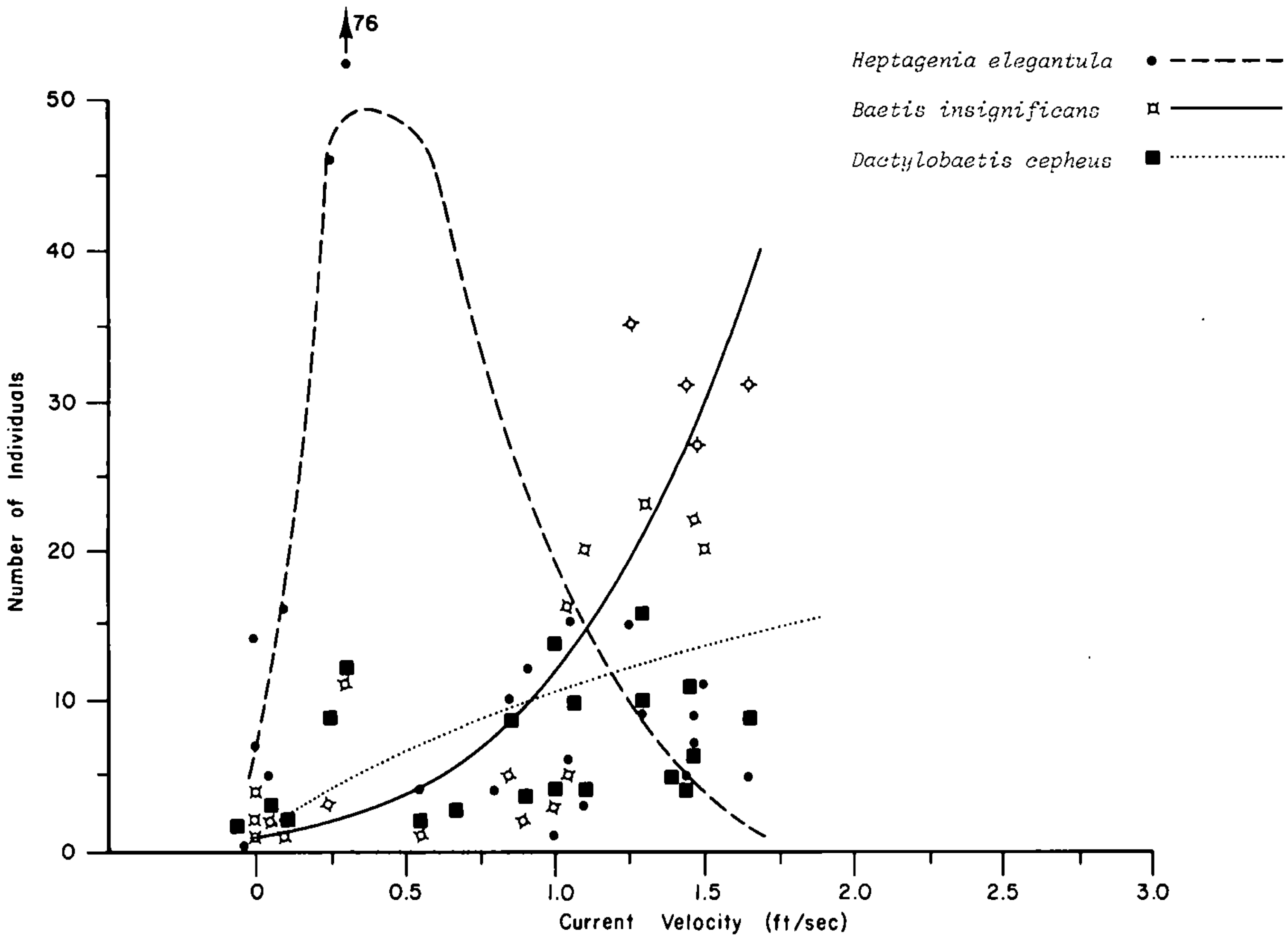


Figure 52. Mayfly (Ephemeroptera) distribution at various currents, Glendive, October 1975.

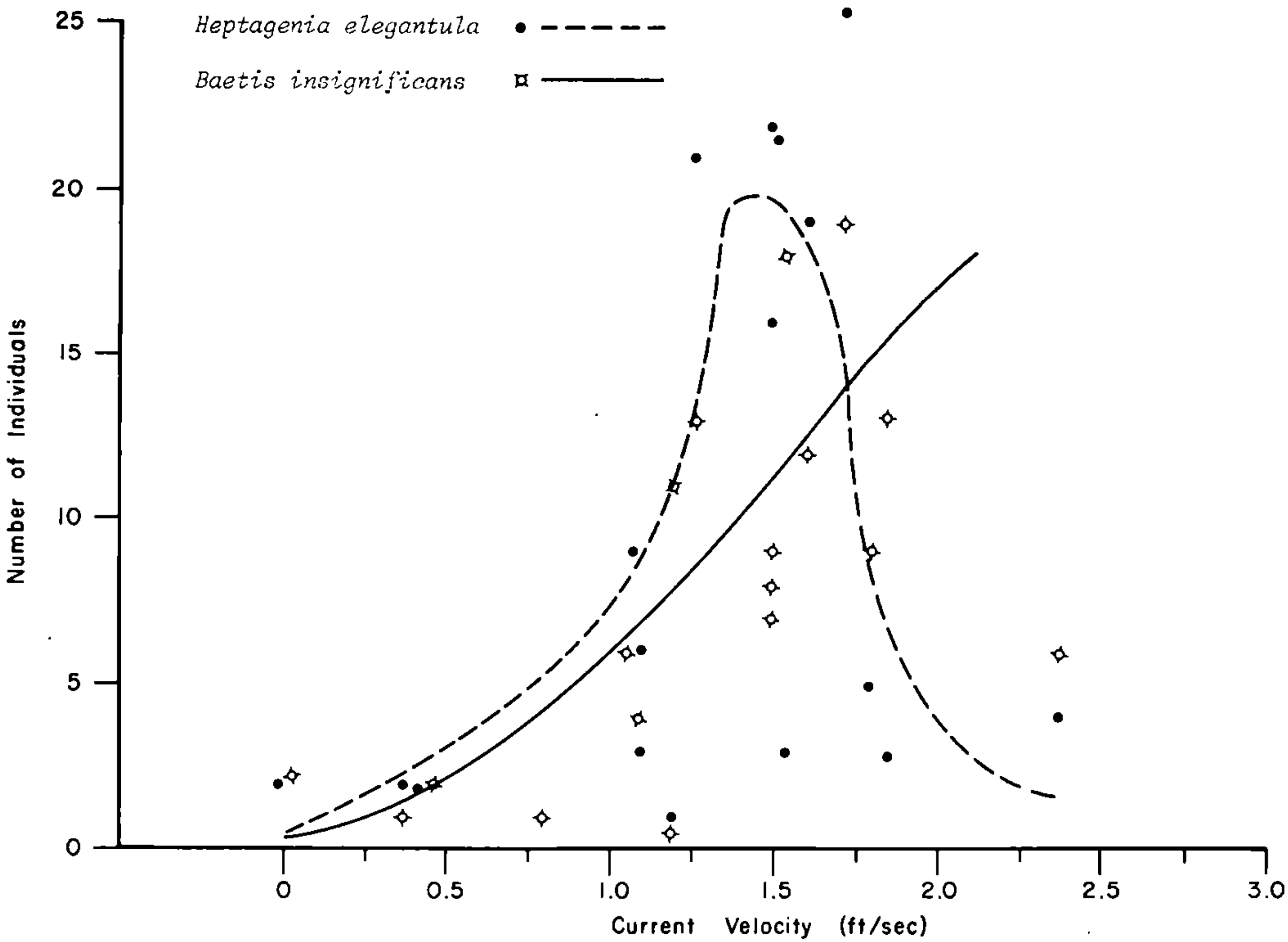


Figure 53. Mayfly (Ephemeroptera) distribution at various currents, Glendive, November 1975.

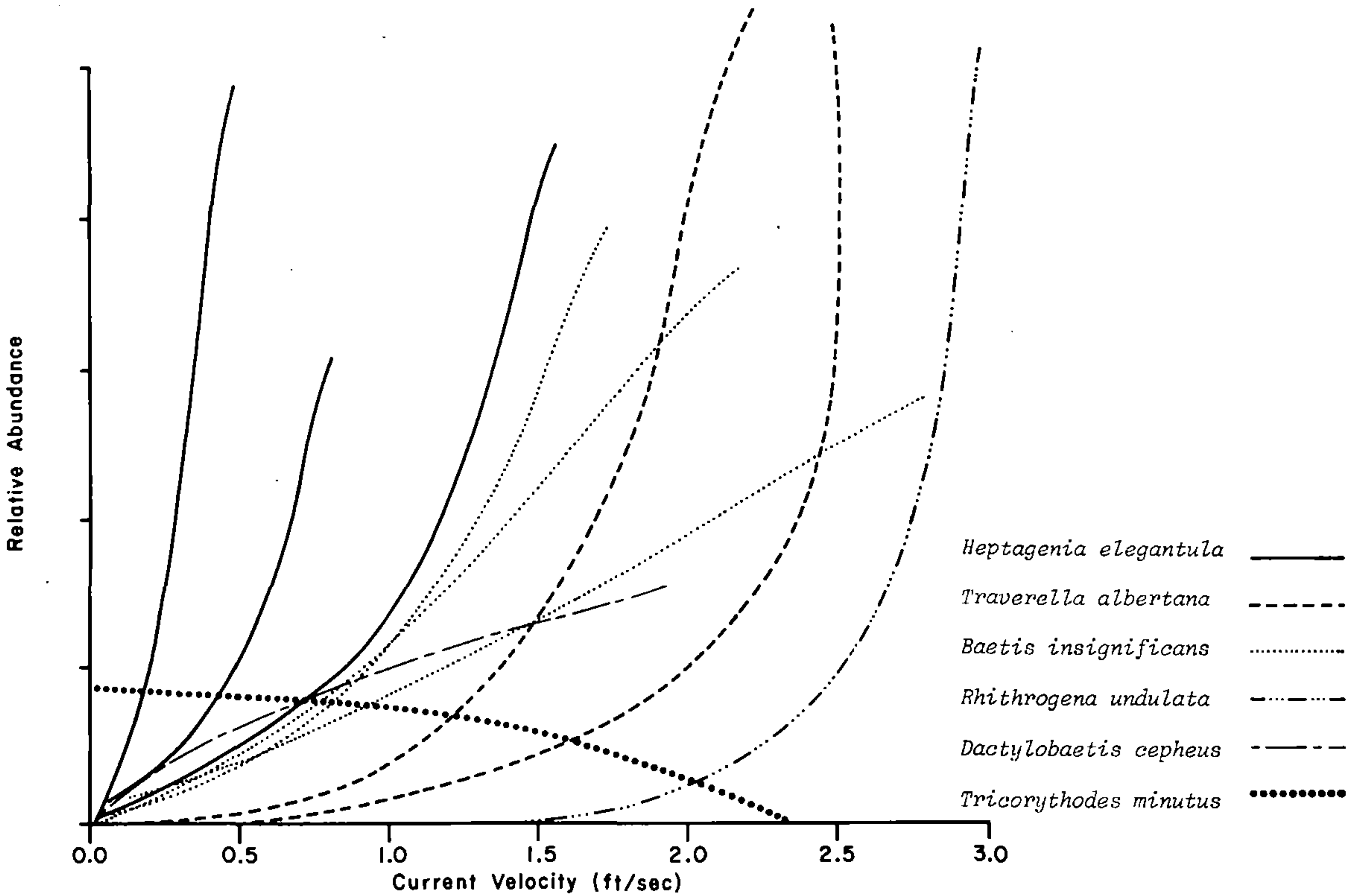


Figure 54. Synopsis of mayfly/current relationships from both stations and for all sampling months.

All of the data on mayfly current preference were pooled and are presented in figure 54. Several characteristics are evident. Current preference seems to change with different periods in the life cycle of a species. Greatest population densities for *Heptagenia elegantula* changed from 0.5 ft/sec in October to 1.5 ft/sec in November. Populations of *Baetis insignificans* exhibited a similar trend but at higher velocities. The two samples of *Traverella albertana*, however, were similar (near 2.5 ft/sec).

Figure 54 gives some insight into niche separation of six species of Ephemeroptera. Each of these species had its highest densities at slightly different current velocities, thus reducing interspecific competition for food and resting areas. The remaining mayfly species were present in numbers too small to illustrate current preference and made up an insignificant part of the fauna in the lower Yellowstone River.

Stoneflies

Stonefly (Plecoptera) nymphs were not common in the lower Yellowstone River, and little information on current preference was obtained. At Intake, however, Plecoptera were found only at the fastest currents.

Caddisflies

Caddisfly (Trichoptera) larvae, *Hydropsyche* in particular, exhibited a distinct current preference, with the greatest number of larvae found at the fastest currents sampled. Larvae could not be identified to species, although at least three species of *Hydropsyche* have been collected at Glendive and Intake. Samples taken in August and September were not significant (p=.05) when relating numbers of individuals to current. Samples taken in October and November at both stations were highly significant. Regression lines varied little from October to November at Glendive and at Intake (figures 55 and 56).

There is some evidence that *Hydropsyche* reached its greatest densities at about 2.5 ft/sec at Intake in October (figure 55) and November (figure 56).

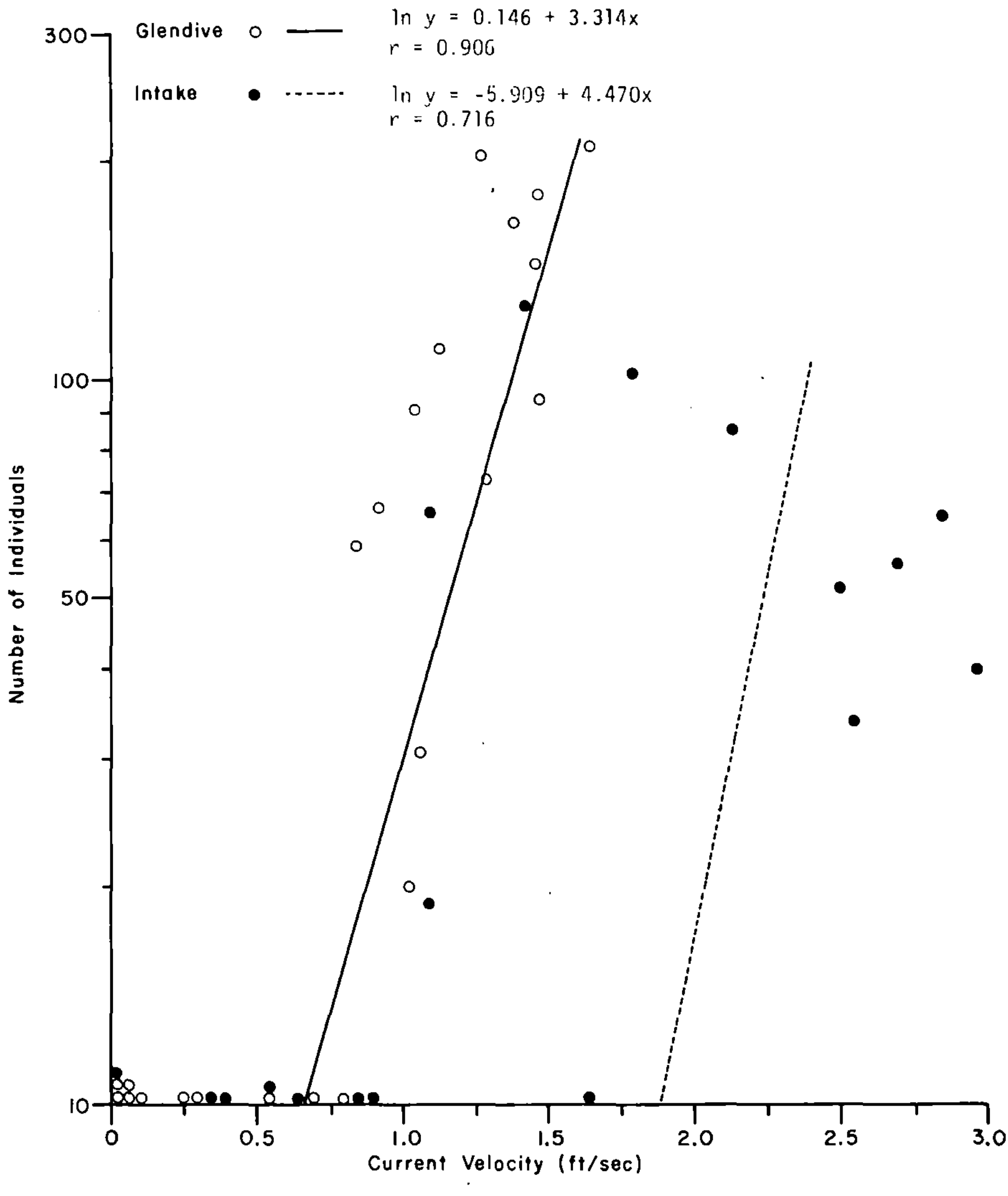


Figure 55. Distribution of *Hydropsyche* larvae at various currents during October 1975.

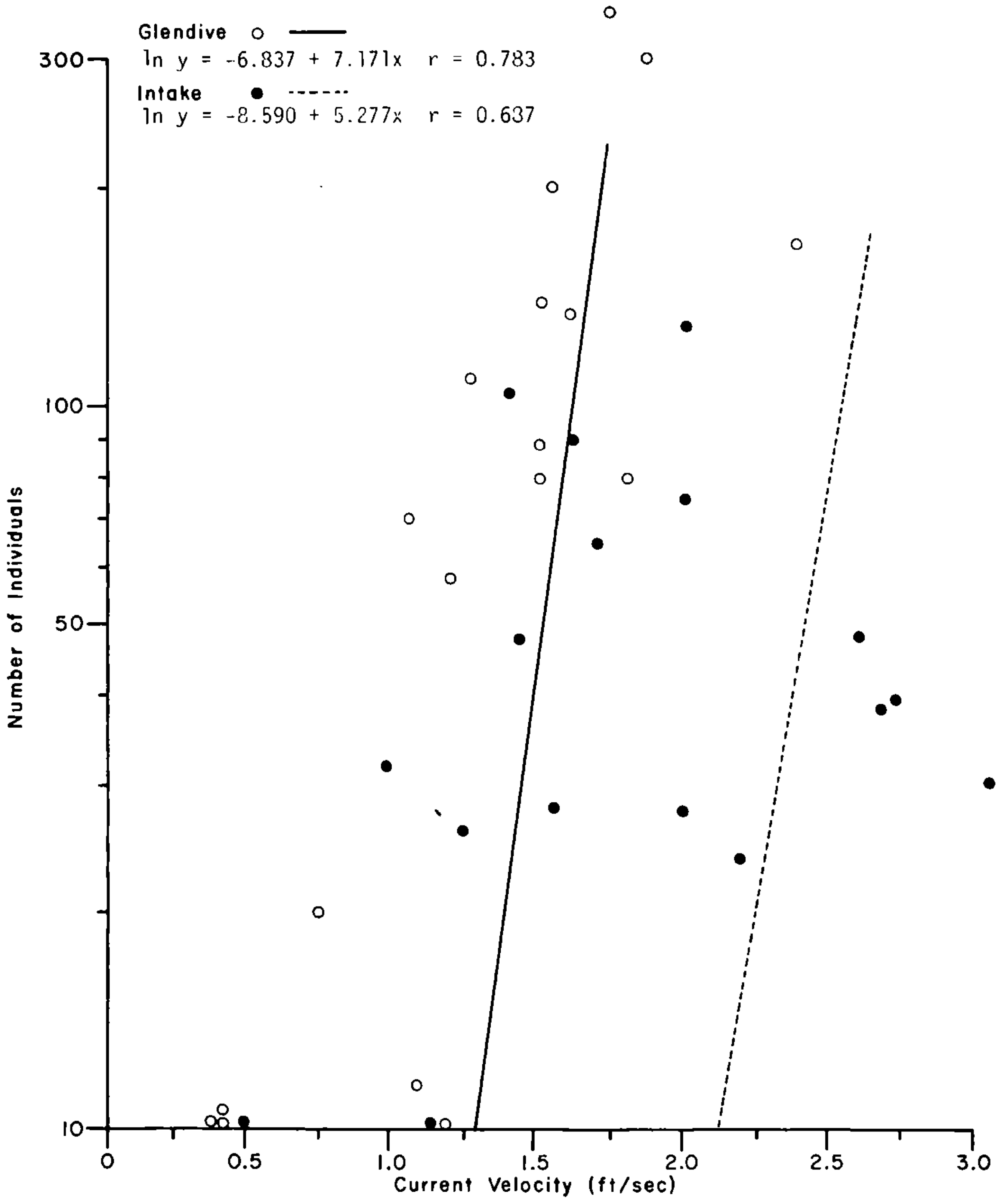


Figure 56. Distribution of *Hydropsyche* larvae at various currents during November 1975.

Impacts of water withdrawals

It is difficult to predict the effects of flow reduction on the invertebrate fauna because of the large number of species involved and the inability to discuss the environmental requirements and tolerances of a group as large as the Ephemeroptera or Trichoptera. Even within genera there are large variations in tolerance. The need to know environmental requirements of a species is complicated in the west because few western species have been intensively examined. Roback (1974) lists the habitat requirements of many aquatic insects in terms of chemical concentrations, but few western species are listed. Because of these problems, the following evaluation of effects of reduced flows will be general.

The three levels of development projected for the Yellowstone Impact Study (see Report No. 1 in this series) were not considered in this impact assessment because of the lack of specific invertebrate data and because this invertebrate study was completed before the final projections were available.

CHEMICAL

Attempts to explain the distribution of species in terms of chemical differences have not had much success except where conditions are extreme (Macan 1974). At present in the Yellowstone River, dissolved oxygen concentrations are sufficiently high to sustain invertebrates and fish. Dissolved oxygen could influence invertebrate communities if reduced flows are so low that the BOD of domestic sewage or decaying organisms taxes the reaeration capacity of the river.

With reduced flows, increased concentrations of nutrients could result in an increase in periphyton growth, especially of the present dominant alga *Cladophora*. A large mat of *Cladophora* would increase the diversity of benthic habitats, probably resulting in a larger standing crop of benthic organisms and a shift in benthic species composition (Percival and Whitehead 1929).

SILT

The Yellowstone River carries large amounts of suspended material, mostly inorganic in nature. There is sufficient current to remove much of this material, and silt deposits are not frequent along the river. The high spring runoff is one factor that keeps the river flushed of inorganic sediment.

The macroinvertebrate fauna of the lower Yellowstone is predominantly silt tolerant. Genera known to be silt tolerant include: *Isonychia, Tricorythodes, Caenis, Traverella, Brachycercus, Stenonema, Dactylobaetis,* and *Ephoron* (Berner 1959, Jensen 1966). It is not known how much silt the benthic fauna of the lower river can tolerate. Sampling station 20 has the lowest gradient, greatest silt concentrations, and lowest benthic diversity of all sampling stations. If station 20 is used as an example of what could happen at other stations if a high level of development is achieved, the result will be a fauna poorer in numbers and species.

TEMPERATURE

Reduced flows, resulting in a shallower river, would probably result in higher summer water temperatures. These increased temperatures, besides affecting dissolved oxygen levels, would affect invertebrate growth, emergence, egg hatching, and metabolism. The net effect would probably be a reduction of the fauna.

Another factor associated with temperature is ice. In the lower Yellowstone River, a solid ice cover lasts for several months (figure 57). Ice cover at Glendive lasted from late December to April during the winter of 1974-75 and from late November to mid-March during 1975-76. Surface ice can act in several ways to kill invertebrates (Brown et al. 1953). Low flows would permit thicker ice conditions, freezing of large areas of shallow water, and increased gouging and molar action during the time of ice break-up (figure 58).

CURRENT AND BOTTOM HABITAT

Bottom samples taken at Glendive and Intake during 1975 revealed that invertebrate densities are directly proportional to current velocity up to velocities of 3.0 ft/sec (no samples were taken at velocities greater than 3.0 ft/sec).

Flow reductions in the Yellowstone would result in reduction in current velocities across the river channel because of its "U" shaped configuration. A general reduction in velocity would result in a faunal reduction because of most species' preference for swift currents. Minshall and Winger (1968) found that a reduction in flow caused a large increase in the percentage of organisms drifting, exposing a greater number of invertebrates to predation by fish which could result in species extinction in a section of stream.

It is possible to relate invertebrate densities to discharge if mean current velocities across the river at several points are known. The Bureau of Reclamation's Water Surface Profile (WSP) Computer Program (U.S. Department of Interior 1968) utilizes current and depth measurements from several transects to compute area and mean current velocity in several subsections of all transects at any desired discharge. At the Intake station, the WSP Program was used to predict mean current velocities in 15 subsections (shown in figure 59) at three discharges (table 23). The mean current velocity was placed in the regression equation obtained from kick samples in November 1975 (sampling

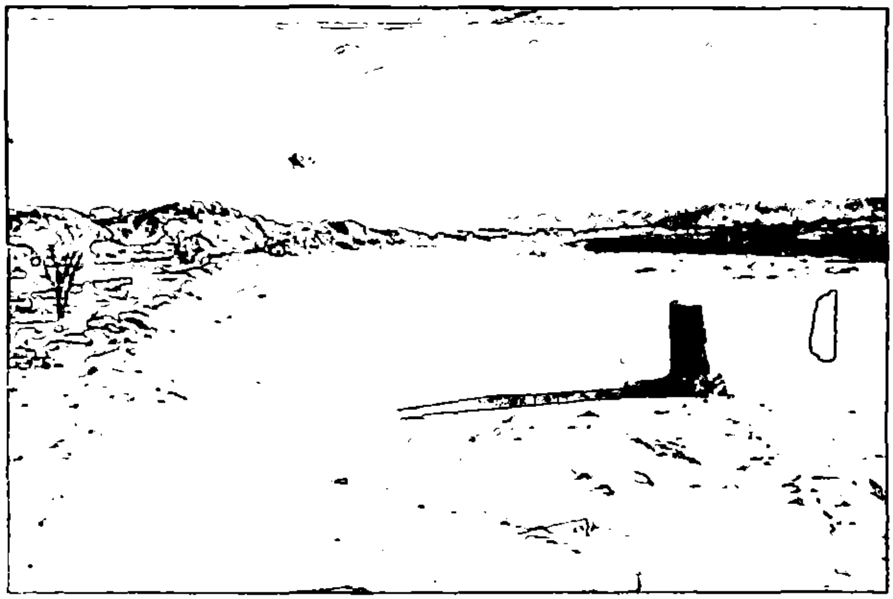


Figure 57. Yellowstone River at Terry during late winter.

Figure 58. Ice jam during late winter at Glendive.

data available in Newell 1976 or in Montana DNRC files), selected because it was the last month bottom samples were obtained.

The population was summed for all subsections. At a discharge of 9000 cfs (about mean low summer discharge), the population estimate is approximately 209,000 for a bank-to-bank, one-meter-wide strip of river bottom at Intake (table 23). This number decreases to about 190,000 at 8,000 cfs and approximately 172,000 at 7,000 cfs, about a ten-percent reduction in population with each 1,000-cfs reduction in discharge.

TABLE 23. Invertebrate population estimates utilizing data from Intake station 18, subsections from WSP (Water Surface Profile), and regression equation from November kick samples.

Sub-Section[a]	at 9000 cfs		at 8000 cfs		at 7000 cfs	
	Mean Current Velocity (ft/sec)	Population Estimate	Mean Current Velocity (ft/sec)	Population Estimate	Mean Current Velocity (ft/sec)	Population Estimate
1	0	0	0	0	0	0
2	1.02	0	0.91	0	0.81	0
3	2.53	20,819	2.32	18,640	2.15	16,704
4	3.42	39,563	3.17	34,306	2.96	30,433
5	2.94	30,156	2.72	26,560	2.54	24,070
6	2.09	25,868	1.90	22,825	1.73	20,923
7	1.88	16,600	1.70	14,940	1.58	14,110
8	2.13	11,931	1.94	10,721	1.77	9,683
9	2.56	15,217	2.35	13,487	2.18	12,277
10	2.39	16,600	2.66	19,297	2.49	17,430
11	2.85	17,983	2.68	16,254	2.45	14,352
12	1.97	10,894	1.79	9,856	1.62	8,819
13	0.72	3,216	0.62	3,009	0.50	2,801
14	0	0	0	0	0	0
15	0	0	0	0	0	0
TOTALS		208,847		189,895		171,602

[a]Shown in figure 59

Population estimates at 7,000, 8,000, and 9,000 cfs are graphed in figure 60; a diagramatic representation of loss of habitat due to water withdrawal is shown in figure 59. Stage at 9,000 cfs is 1985.30 ft at cross-section 5 (opposite the boat launch at Intake). Stage decreased to 1985.15 ft at 8,000 cfs and 1984.90 ft at 7,000 cfs. Thus the river drops only a few inches as discharges decrease by 1000 cfs, and only a small percentage of the river bottom is exposed. All of these calculations apply to transect 5 at Intake; the river bottom figuration changes at other locations, as do current and population.

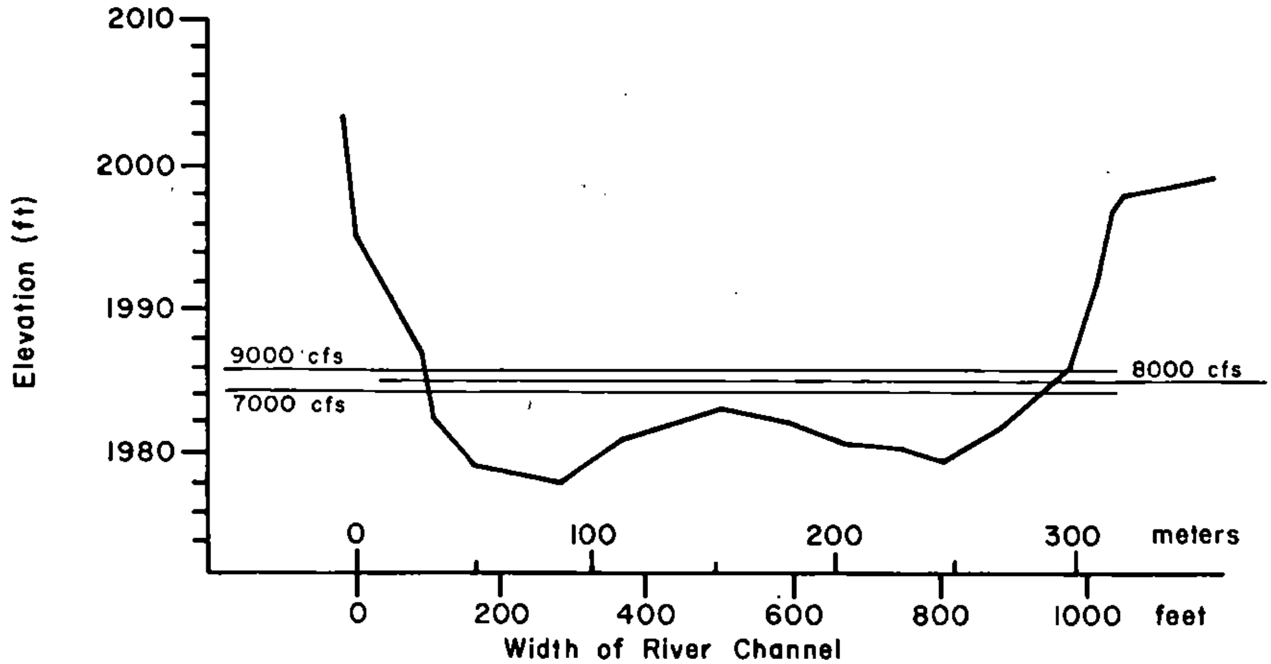


Figure 59. Cross section No. 5 at Intake, showing water depth at various flows and the 15 subsections used in WSP calculations.

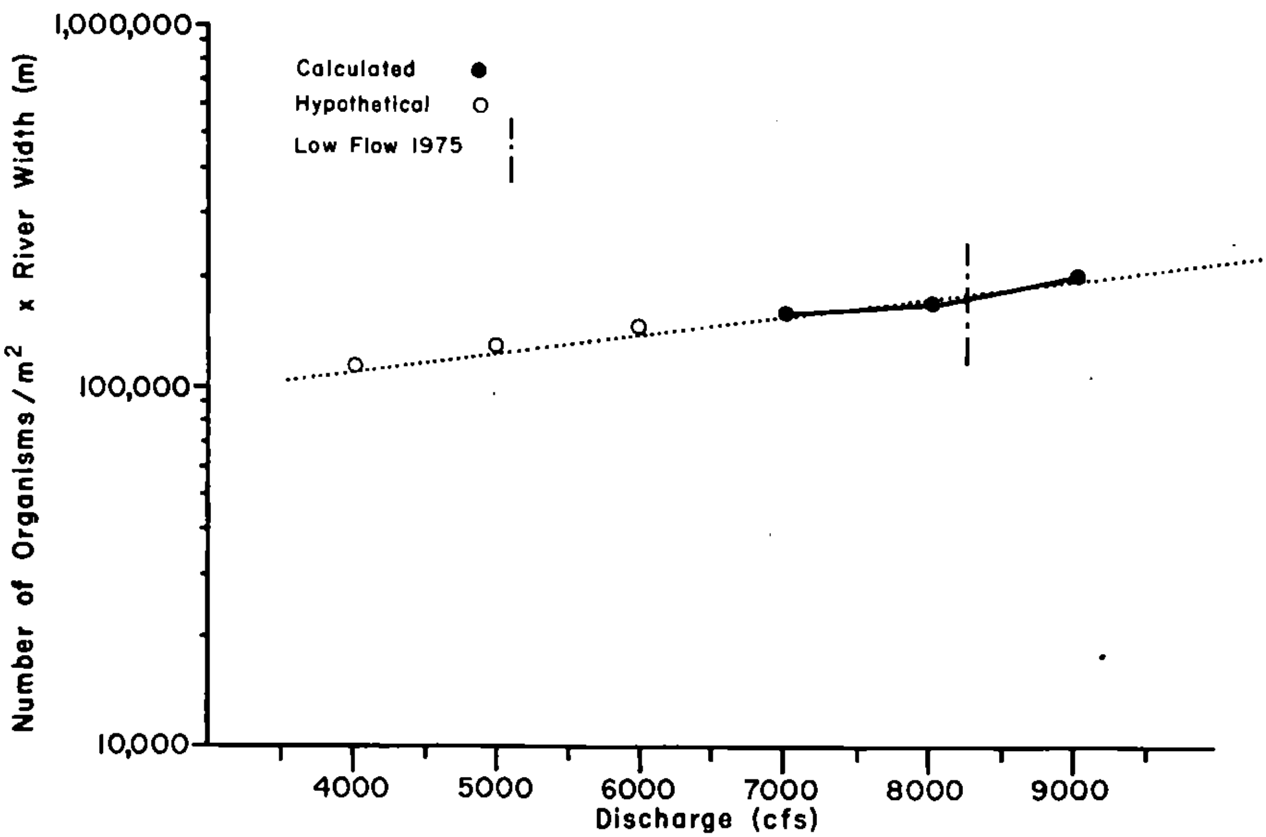


Figure 60. Invertebrate population estimates at various discharges, cross-section No. 5 at Intake.

When population estimates derived at 7,000, 8,000, and 9,000 cfs are plotted against discharge, the following regression equation results (figure 60):

log population = 4.9384 + 0.000042 discharge (cfs)

This equation permits a prediction of population of invertebrates at any discharge. One should remember that a regression equation is a mathematical tool that may or may not predict a future biological event. Population estimates may continue decreasing linearly as the regression equation indicates. In this case the regression line is probably roughly accurate. Because of the channel morphology in the Intake area, decreases in discharge result in decreasing currents across the entire channel, and little bottom habitat is exposed in the process. However, at some low discharge, large amounts of river bottom would be exposed with resultant loss of habitat and a dramatic decrease in fauna. The effects of reduced current velocity and of loss of bottom habitat are separable in their effect on fauna. Reduced current velocities (due to lowered streamflow) could adversely affect bottom fauna even before a significant loss in bottom habitat occurred.

Using the regression equation (figure 60), population estimates in a one-meter-wide strip at Intake can be calculated for lower discharges:

6000 cfs	156,000 organisms
5000 cfs	141,000 organisms
4000 cfs	128,000 organisms
3000 cfs	116,000 organisms
2000 cfs	105,000 organisms
1000 cfs	96,000 organisms

These estimates, based on data gathered in November, are higher than estimates would be based on data gathered later in the winter or in the spring, because of natural mortality and drift out of the study area.

As flows decrease, other factors--ice and silt--would undoubtedly result in a higher-than-normal mortality of invertebrates. With decreased discharges, ice cover would tend to be thicker than normal, thus freezing larger-than-normal areas of river bottom and resulting in a greater amount of molar action during spring ice break up. Low discharges and reduced currents during the spring would permit greater amounts of silt to accumulate, resulting in a detrimental effect to bottom-dwelling organisms.

Evidence confirming the "stream continuum" theory is apparent, although not in large quantities. One major problem with implementing this theory in the west involves stream order. With the multitude of tributaries to every stream a large creek might be of order 10 to 15 by the time it reaches a larger river. The Yellowstone River could conceivably be of order 20 or more, although this has never been calculated. Some of the basic tenets of the theory are evident. The invertebrate fauna in stations 1-8 is dominated by shredder-type organisms. The fauna in the middle and lower river is dominated by collector organisms, e.g., the Trichoptera family Hydropsychidae, which build small nets to collect small food particles and organisms carried along by the current. Scraper or grazing organisms are found throughout the river, and silt-tolerant organisms become abundant in the low-gradient portions.

Faunal zones, both for fish and bottom-dwelling organisms, are broad and not distinctly defined. Throughout the upper half of the river, the salmonid community gradually decreases, as does the Plecoptera fauna. Ephemeroptera, however, exhibit a gradual shift in species composition from one community to another with the exception of several adaptable species that are present throughout the entire river.

Summary

The invertebrate fauna of the Yellowstone River is rich in numbers and species. The number of species and the population are greatest in the upper river (stations 1-5), and both decrease downstream.

The invertebrate fauna is dominated by mayflies (Ephemeroptera), caddisflies (Trichoptera), and true flies (Diptera). The stonefly (Plecoptera) fauna is diverse but not abundant, and there is a steady decrease in number of species downstream. The mayfly fauna is composed of a mountain fauna and a prairie fauna, although several species are found throughout the river. In the lower five sampling stations, mayflies are the most diverse order. Caddisflies are abundant and diverse throughout the Yellowstone River. The caddisfly family Hydropsychidae dominates the invertebrate fauna in the lower half of the river. True flies, in particular the midge family, Chironomidae, are abundant and diverse throughout the river.

The invertebrate fauna of the Tongue River is similar to but distinct from the fauna of the lower Yellowstone River.

Baseline species diversity calculations showed that the Shannon-Weaver index was near or below 3.0 for most stations. Generally an index above 3.0 illustrates a healthy unstressed community, while an index below 1.0 is indicative of a monospecific community under stress. The index range of 1.0-3.0 seems to illustrate a community under some stress.

The current preferences of many species and genera were examined. For most species, increasing current (up to 3 ft/sec) means a larger population.

At present, dissolved oxygen concentrations in the Yellowstone River are high enough to sustain invertebrates and fish. Lack of dissolved oxygen could influence invertebrate communities if reduced flows are so low that domestic sewage or decaying organisms tax the capacity of the river. With reduced flows, increased concentrations of nutrients could result in an increase in periphyton (alga) growth which probably would result in a larger standing crop of benthic organisms and a shift in benthic species composition.

Increased water temperatures as a result of reduced flows would affect invertebrate growth, emergence, egg hatching, and metabolism. The net effect would probably be a reduction of the fauna.

A reduction in flow which results in a reduction of current velocity will result in a faunal reduction because most species prefer swift currents. Flow reduction also decreases the river stage, exposing large amounts of river bottom with a resultant loss of habitat and a dramatic decrease in fauna.

The effects of reduced current velocity and of loss of bottom habitat are separable in their effect of fauna. Reduced current velocities (due to lowered streamflow) could adversely affect bottom fauna even before a significant loss in bottom habitat occurred. Because of the shape of the Yellowstone River channel, flow reductions would result in corresponding reductions in water velocity. For each 1,000-cfs reduction in mean low summer discharge in the lower Yellowstone, the aquatic invertebrate population would be reduced by approximately ten percent because of reduced velocity. Further reduction in invertebrate populations could result from other factors related to reduced flow, such as exposure of bottom habitat, increased freezing of the river bottom, and silt accumulation.

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DEPARTMENT OF NATURAL RESOURCES

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Helena, Montana

YELLOWSTONE IMPACT STUDY

Aquatic Invertebrates

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