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Temperature Related Zonation of Aquatic Insects in the Yellowstone River

Research Conducted by:

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Prepared by:

Dennis J. Schwehr
Aquatic Ecologist

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INTRODUCTION

The geographic distribution of all organisms is determined by a species' tolerance to environmental conditions. A major controlling parameter is climate. Optimum climatic conditions exist for all organisms, including aquatic animals. Aquatic life is exposed to a narrower range of temperatures than terrestrial, but, nevertheless, each species inhabits a select range along the temperature gradient such as in a river.

This paper investigates the zonation of aquatic insects relative to temperature in the Yellowstone River. The river provides a unique study situation because it possesses a natural temperature gradient. It is not exposed to external influences that could alter the temperature regime such as water impoundments or significant heated effluents. Although only temperature is addressed, it is recognized that other environmental factors such as turbidity and nutrients may influence the distribution of insects.

The major objective of this study is to locate the transition zone or zones, if any, for aquatic insects. Peterman and Haddix (1975) describe a transition zone for fish of the Yellowstone dividing the cold water salmonids of the upper river and warm water fishes of the lower river. The middle river or transition zone contains individuals common to cold and warm waters, although the numbers in some populations may be relatively low because temperatures of the middle river are outside the optimum range for some species.

Zonation of aquatic insects has received little attention to date because the climatic limitations for most species have not been determined. Ide (1935) emphasizes the importance of temperature as the controlling factor of mayfly distribution in Ontario streams. He found that species of the Ephemeroptera increase in number downstream. Noting that temperature is the prime factor in determining altitudinal zonation, Dodds and Hisaw (1925) found more insect species in the Colorado Rockies above the 8,000 foot elevation than below. Knight and Gaufin (1966), who studies distribution of Plecoptera in mountain streams, found the greatest number of species between elevations of 7,000 and 9,000 feet.

STUDY AREA

The Yellowstone River originates south of Yellowstone National Park in Wyoming, flows north into Montana and northeasterly from Livingston to the Missouri River in North Dakota (Fig. 1). The average annual discharge ranges from 106 cubic meters per second at Livingston to 370 cubic meters per second at Sidney (USGS 1974). The mainstem is free flowing along its entire length of 1094 kilometers.

Recent investigations by Newell (1976) and Schwehr (1976) have noted that a diverse community of aquatic macroinvertebrates exists in the river. The distribution of the organisms was determined during sampling of the bottom fauna at 20 stations. (Refer to their reports for descriptions of sampling sites and insect distribution.)

Temperature data were available from four locations on the river. Thermographs were located at Billings, Miles City, and Sidney. USGS calculated the mean daily temperatures for all but a few months of 1975 for these sites (G. Pike, USGS, personal communication). At Livingston water temperature was recorded once daily. Mean monthly temperatures at the four stations are shown in Fig. 2. As expected, summer temperatures increased downstream but it is also important to note that the increase from low winter temperatures occurs gradually at Livingston while the change takes place rapidly at downstream stations, especially at Sidney.

Temperature characteristics are summarized in Table 1. The temperature range at Livingston is relatively narrow with few days of 0 C or 18 C temperatures. At the other extreme, Sidney has a wide temperature variance with 126 days or 4 months of temperatures that do not exceed 0 C. The river at Livingston possesses the most stable conditions while at Sidney the climate is quite extreme.

Data from bottom samples were taken from 8 of 20 sampling sites. Four stations are on the middle river and four more on the lower river. Mean temperatures from the coldest and warmest months of 1975 were plotted in Figure 3 showing the relation between sampling stations and temperature recording sites.

Table 1. Temperature data for the Yellowstone River in 1975 (courtesy of George Pike, USGS, Helena, Montana).

City	Ave. annual temperature (C)	Annual range	Ave. maximum temperature	No. days of 0 C maximum	No. days of 18 C minimum
Livingston	8.02	0-19.0	16.5 (Aug.)	5	10
Billings	7.98	0-23.5	19.4 (Aug.)	96	32
Miles City	8.98	0-25.0	20.9 (Aug.)	70	63
Sidney	8.59	0-26.0	22.2 (July)	126	58

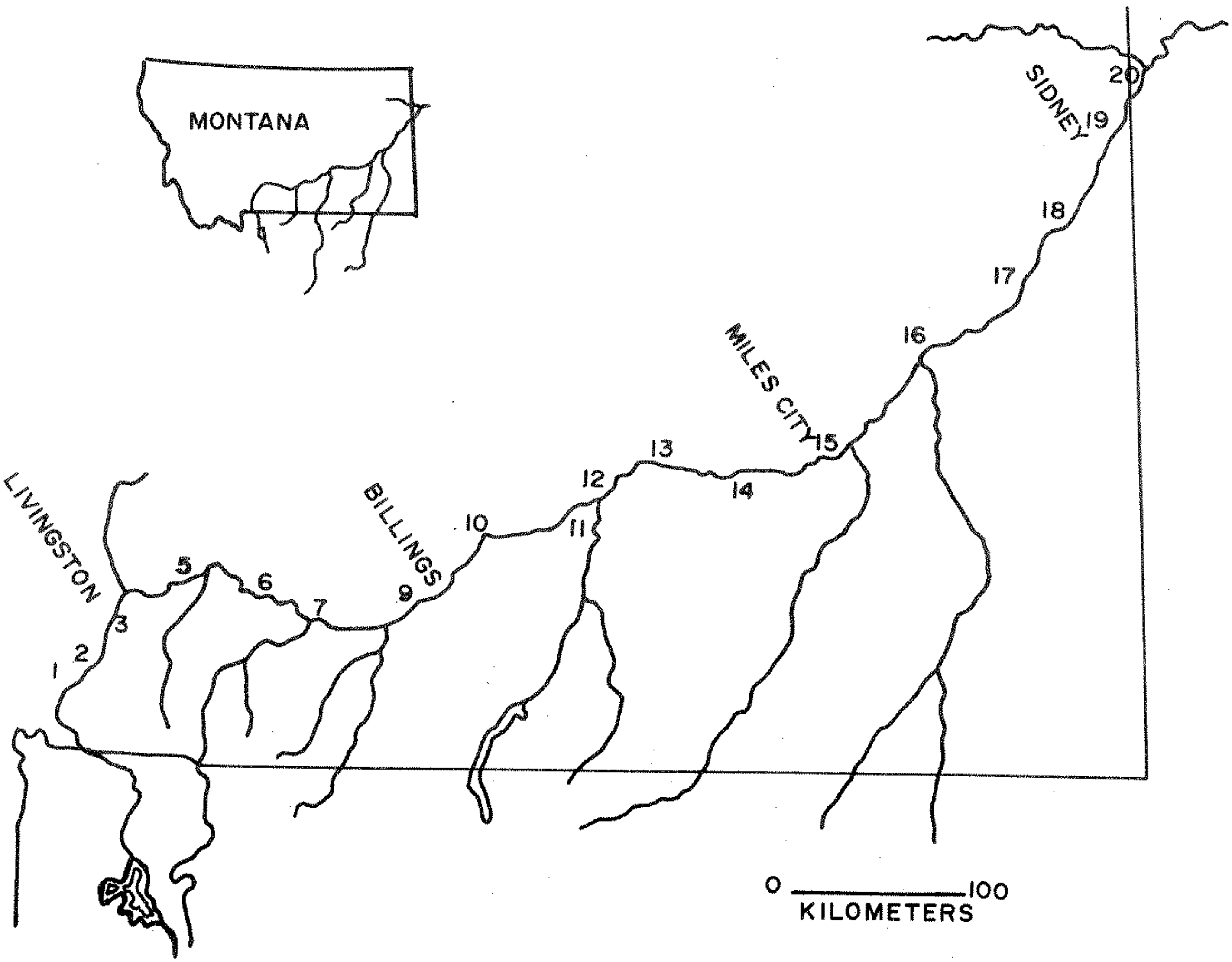

Figure 1. Map of Yellowstone River and major tributaries.

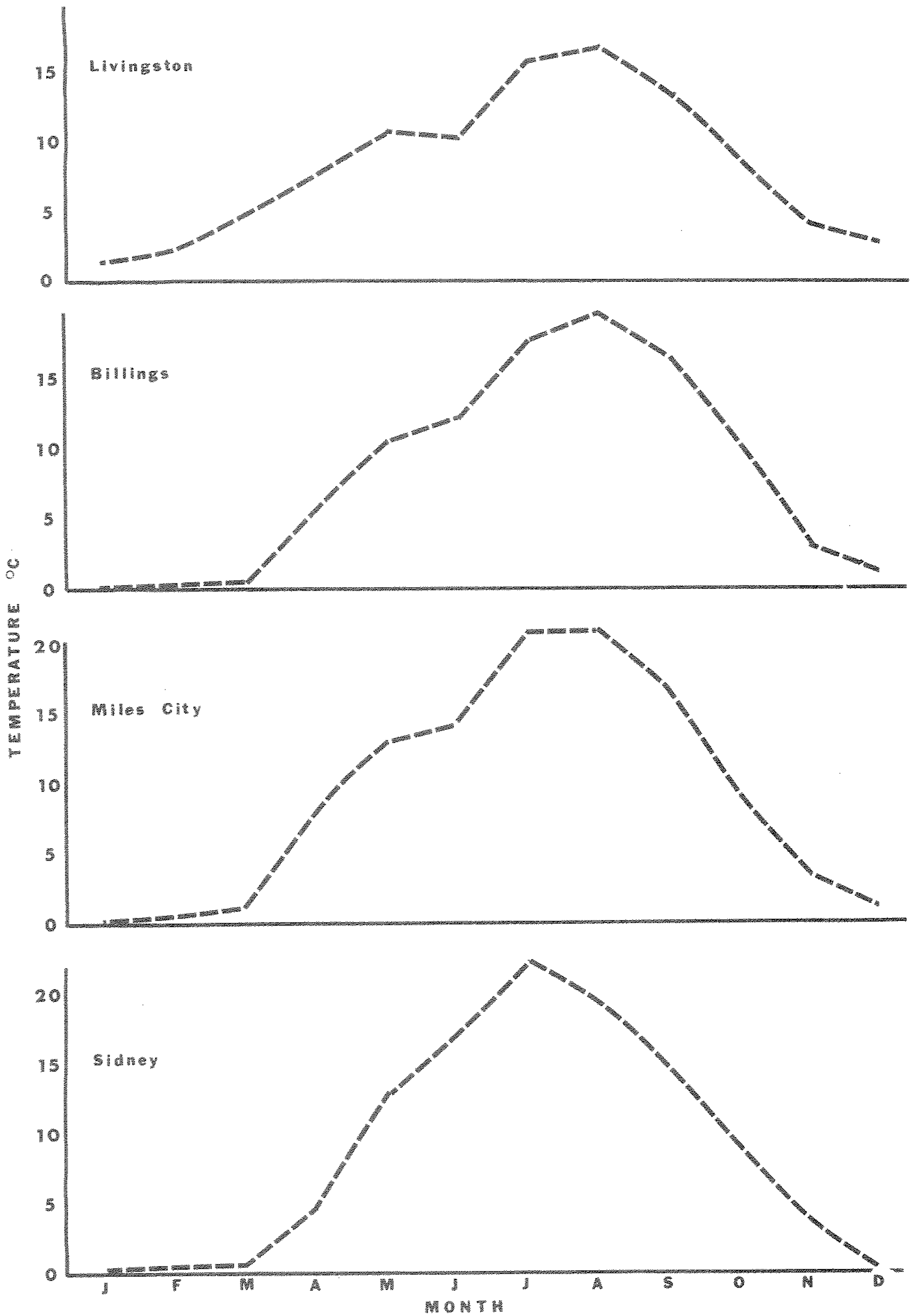

Figure 2. Mean monthly water temperatures for 1975.

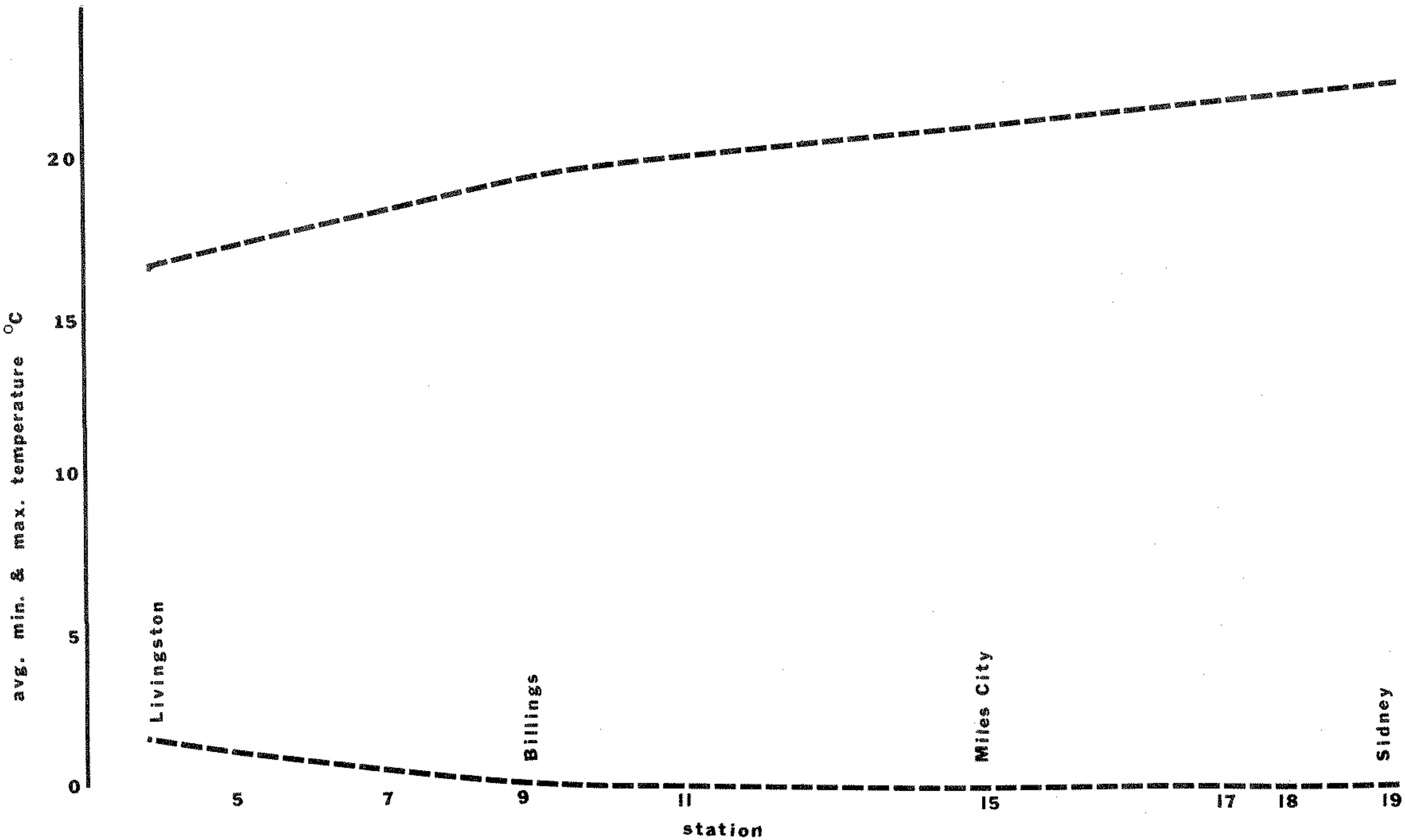

Figure 3. Average maximum and minimum water temperatures of the Yellowstone River in 1975.

METHODS

The insect data used in this paper were taken from bottom samples collected by Newell (1976) and Schwehr (1976) from eight sites on the river (Fig. 1). Sampling was accomplished with a Hess or Water's round bottom sampler which sampled an area of .093 square meters. Six samples were taken at each location at monthly intervals from August through November 1975. These were the only quantitative samples available.

The results from the 24 samples at each station were pooled and abundances and distribution of major species were determined. To eliminate the bias created by rare species, only the dominant taxa were used.

The location of greatest concentration for major taxa was determined. Due to the broad taxonomy of aquatic insects, a transition zone or zone of greatest abundance was determined for each order based on the presence of dominant species at each station. A dominant species at a given station is defined for purposes of this study as one which contributes at least 5% of the total number of individuals of that species in the river. This was necessary to prevent bias created by the presence of organisms at the fringes of their preferred range of temperatures.

RESULTS

Figure 4 reflects the relative abundance of each order. Diptera, which includes mostly chironomids, and Ephemeroptera comprise the majority of the insect groups. Individuals of all orders decrease in abundance downstream. This type of graph is typical in the literature which depicts the abundance of each order relative to the total number of organisms collected in the river.

Figure 5 is a more descriptive representation of abundance which considers the importance of each order relative to the others and weight is added to stations which contain a high diversity of species. This was done by adding the natural log of the abundance of each species at each station. Ephemeroptera is clearly the dominant insect group of the river reaching a peak abundance and diversity at Station 11, Custer. Trichoptera, Plecoptera, and Diptera are most abundant and diverse at Station 5, but their importance decreases considerably downstream. The Figure is a clear indication that environmental conditions for aquatic insects are optimum above Station 11.

The abundance and fall distribution of major species are shown in Figures 6-9. The presence of less common taxa are represented by a straight line. Only the generic name appears in some places because more than one species was contained in a genus or because species identification was not possible for immature nymphs. A complete taxonomic list is found in Newell (1976).

Plecoptera (Fig. 6) show a definite decrease in species numbers downstream from Station 9. All major stonefly species disappear downstream and no new major taxa are encountered. Major stonefly taxa are: *Alloperla*, *Pteronarcella badia*, *Claassenia sabulosa*, *Isogenus* and *Isoperla*.

Trichoptera (Fig. 7) are more diverse and abundant than Plecoptera but show a similar reduction downstream. *Hydropsyche* and *Cheumatopsyche* include several species but individual identifications were not possible. These are the only two major caddisfly groups below Station 15 at Miles City. Dominant caddisflys are: *Lepidostoma*, *Arctopsyche*, *Glossosoma*, *Brachycentrus*, *Hydropsyche* and *Cheumatopsyche*.

Ephemeroptera (Fig. 8) are abundant and diverse. It is the only order that appears to be adapted to all river environments. Unlike the other orders, new species of mayflies are encountered downstream as other species disappear. This is the only group that has a noticeable species turnover along the river. Major mayflies are: *Ameletus*, *Rhithrogena undulata*, *Heptagenia elegantula*, *Ephemerella*, *Baetis*, *Tricorythodes minutus*, *Choroterpes albiannulata*, *Dactylobaetis cepheus*, and *Traverella albertana*.

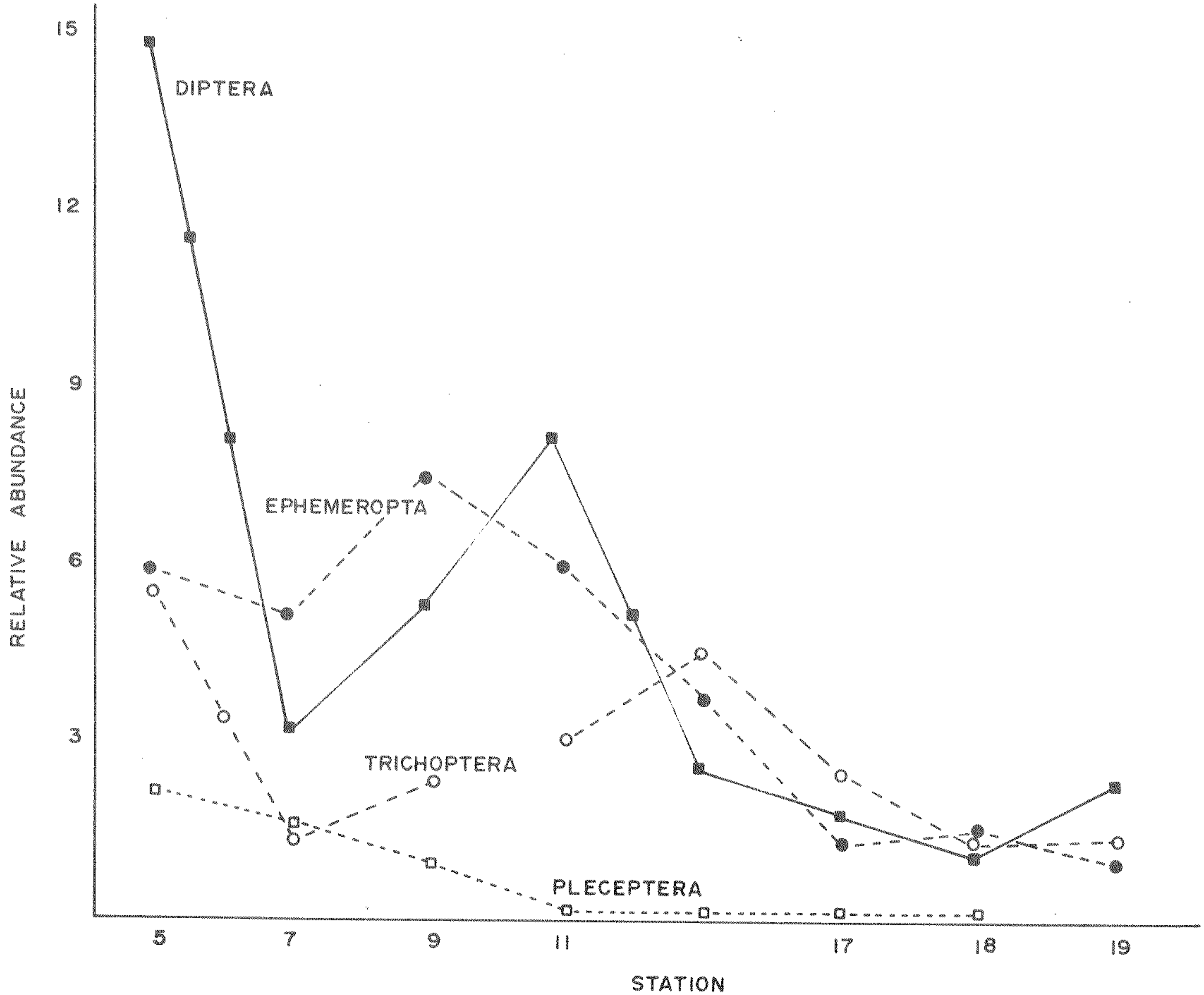

Figure 4. Relative abundance of major insect orders by station from Hess samples, Aug.-Nov. 1975.

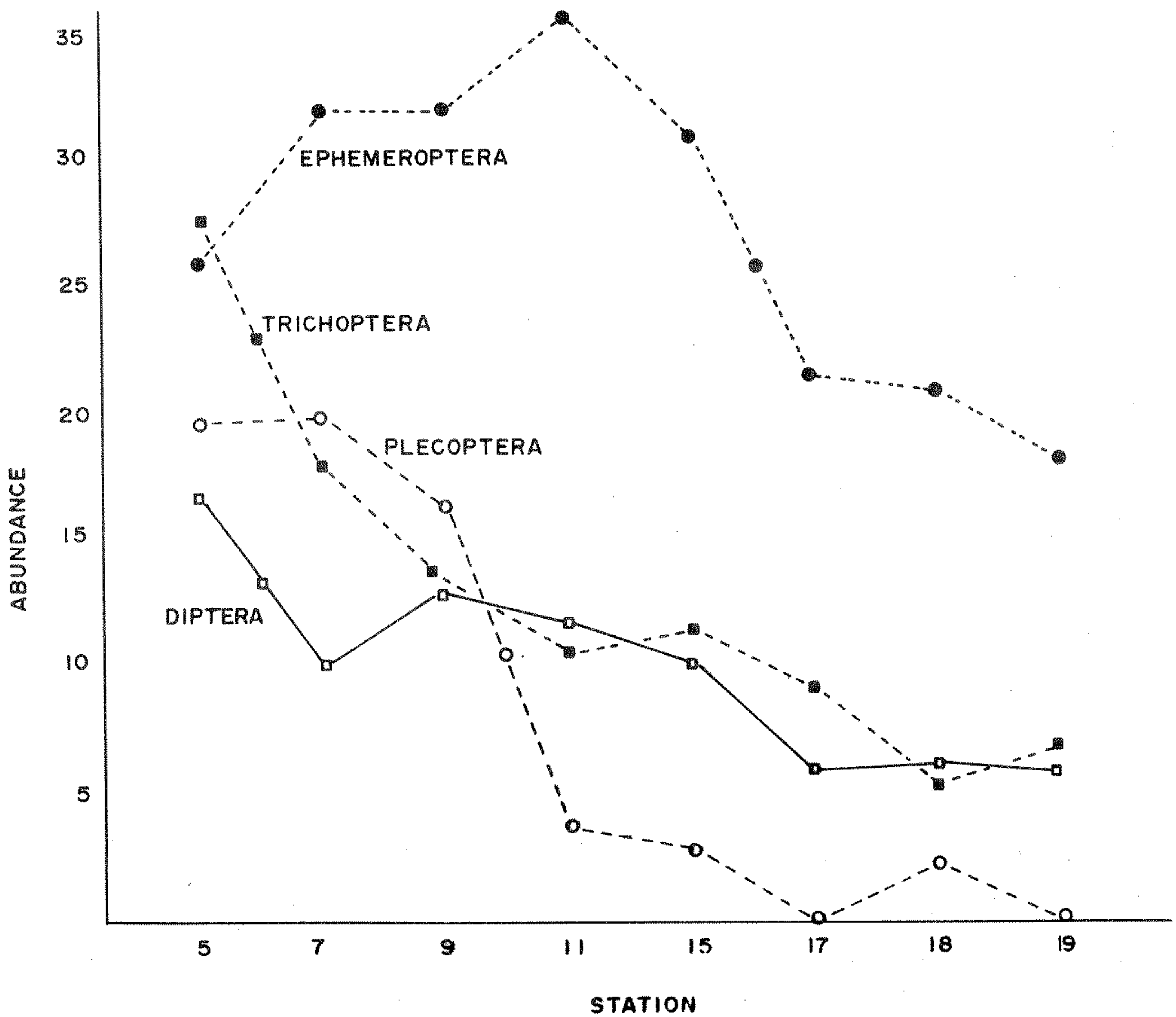

Figure 5. Abundance (sum of $\log_e$ abundance of each species) of major insect orders.

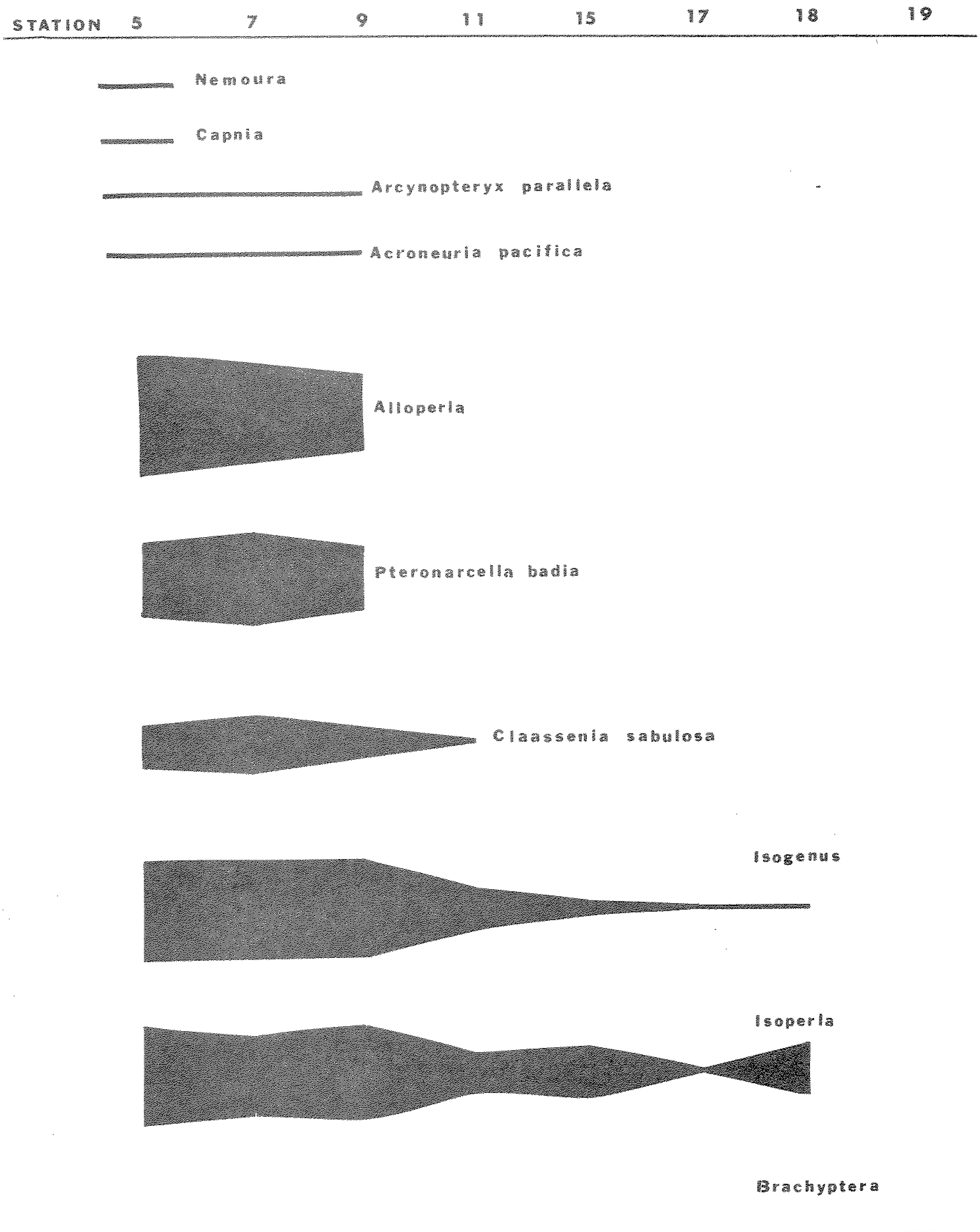

Figure 6. Fall distribution and abundance of Plecoptera.

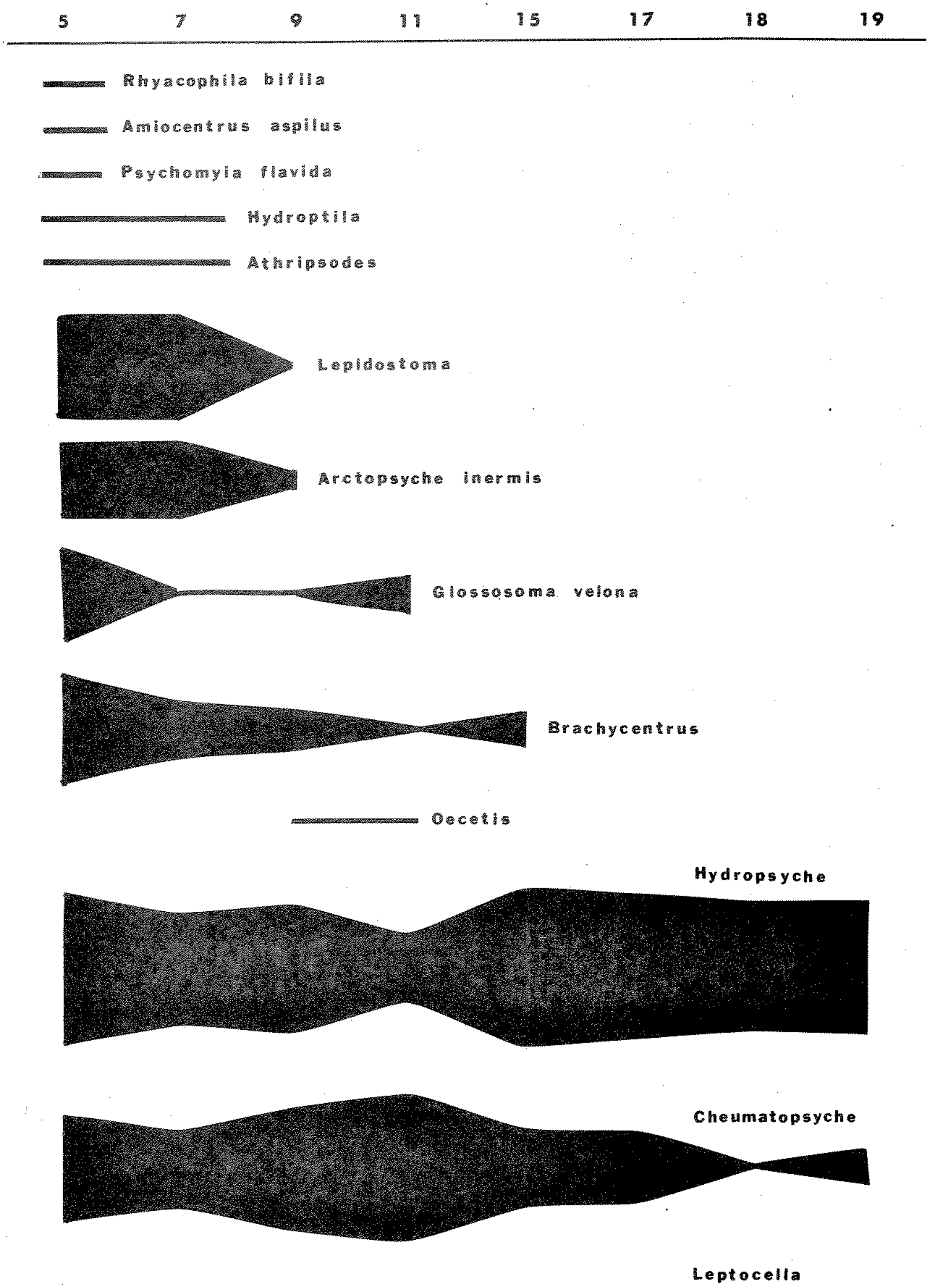

Figure 7. Fall distribution and abundance of Trichoptera.

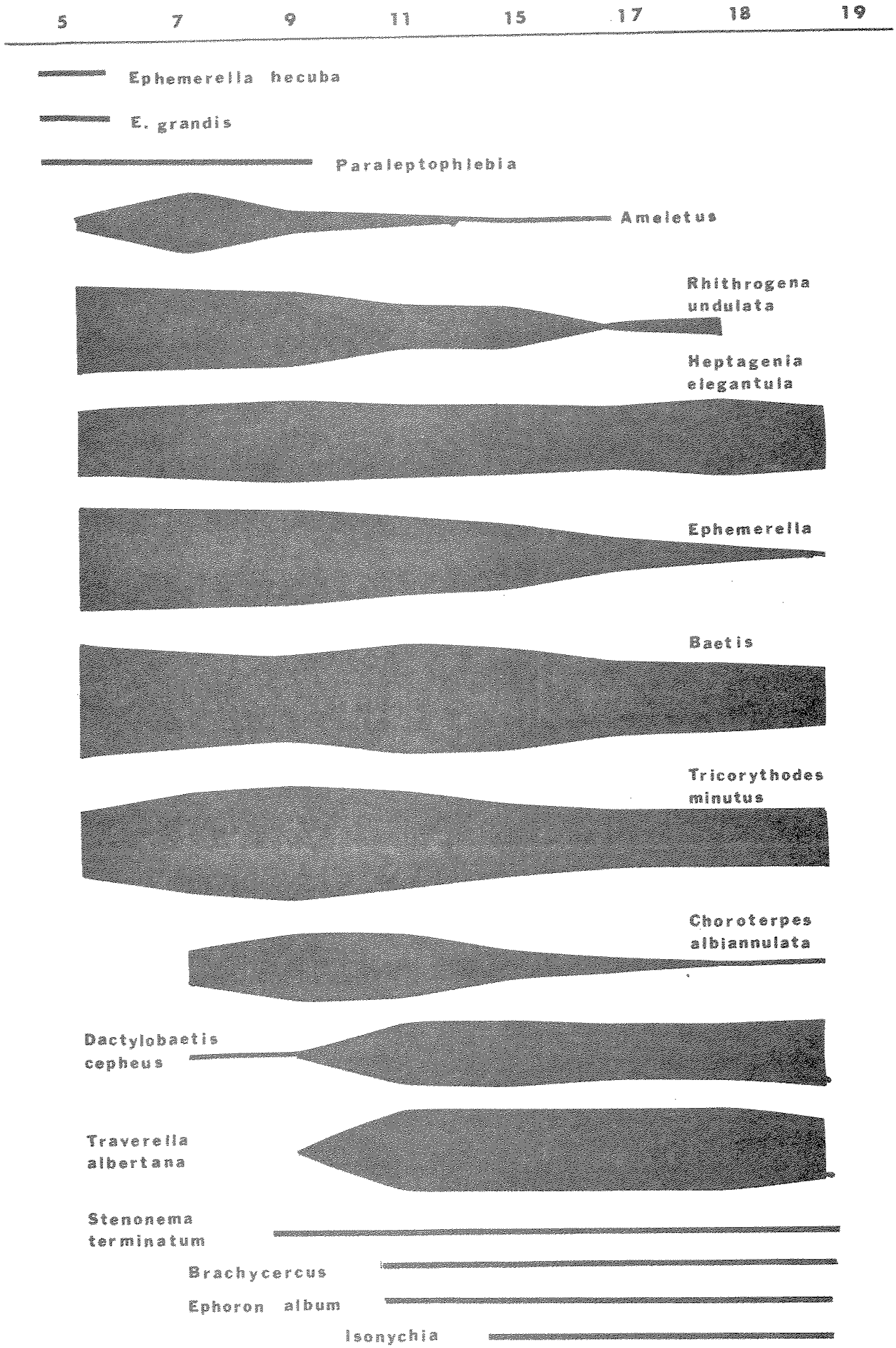

Figure 8. Fall distribution and abundance of Ephemeroptera.

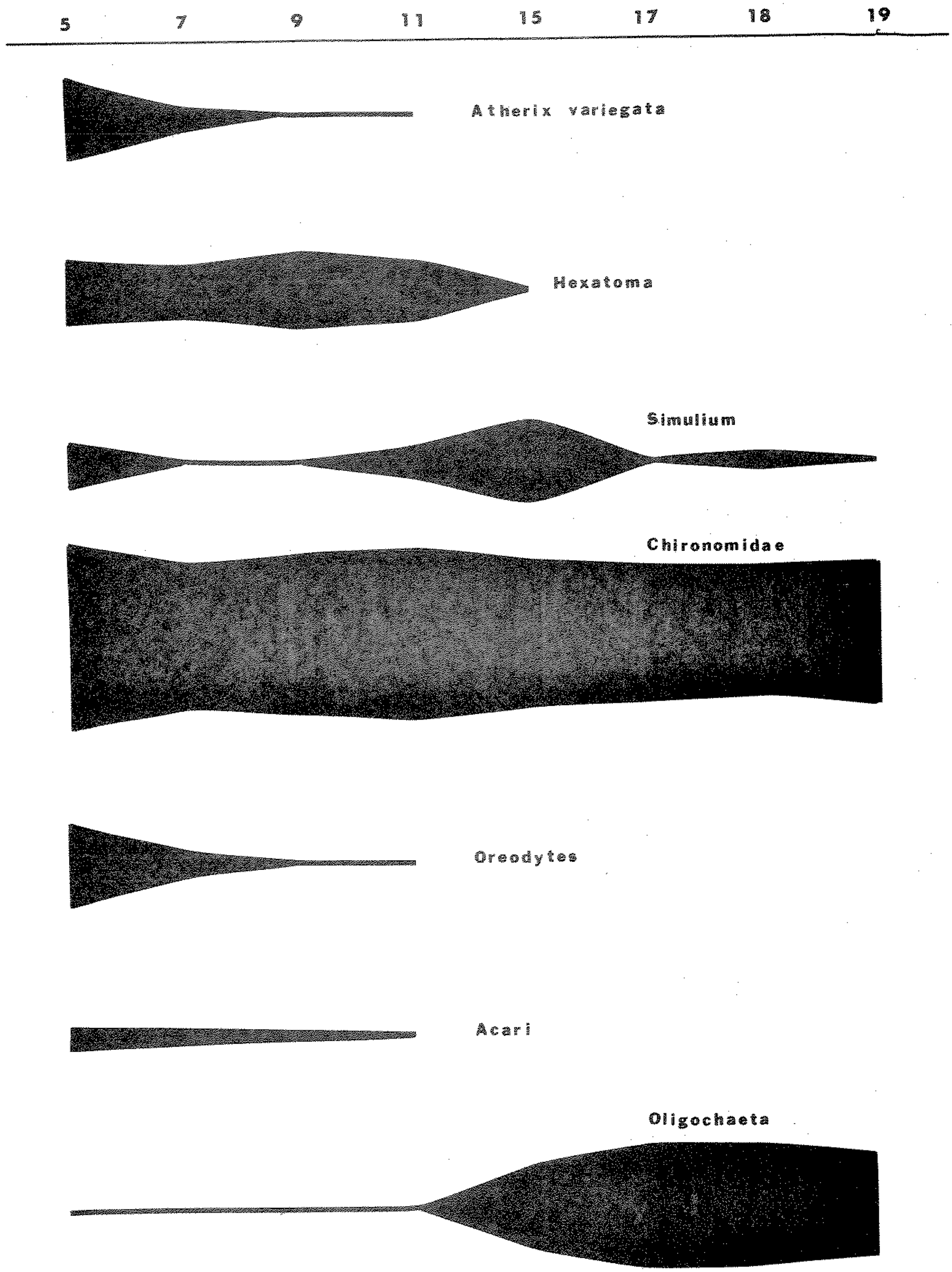

Figure 9. Fall distribution and abundance of major dipterans and miscellaneous taxa.

Diptera (Fig. 9) account for 39% of the organisms collected with the Hess sampler. Of the dipterans, 97% are chironomids. Newell (1976) reports 19 genera of Chironomidae from the Yellowstone. The abundance of each genus was not available at the time of this writing. The dominant dipterans are: *Atherix variegata*, *Hexatoma*, *Simulium*, and Chironomidae.

Figure 9 shows the distribution of *Oreodytes*, a beetle, Acari, and Oligochaeta. Miscellaneous taxa comprise less than 3% of the river invertebrates.

It was not possible to represent the upper Yellowstone in the above figures. Only four Hess samples were taken at each of the two sites, Station 1 at Corwin Springs and Station 3 at Livingston. These samples were taken in November 1975 and included only two species, *Ephemerella doddsi*, and *Pteronarcys californica* that have been collected at Station 5 but not with the Hess sampler. However, the two species account for only 0.5% of the organisms collected in the eight samples at Stations 1 and 3. In addition, of 152 species collected from the entire river over a 1-year period, 136 of them were found in the middle river at Stations 5-11 (Newell 1976, Schwehr 1976).

Shannon diversity values from Newell (1976) and Schwehr (1976) for all Hess samples taken in November 1975 including Hess samples from Stations 1 and 3 are shown in Table 2:

Table 2. Shannon diversity values for Hess samples of November 1975.

Station Number									
1	3	5	7	9	11	15	17	18	19
2.64	2.81	3.31	3.61	3.65	1.81	2.00	2.11	2.46	1.30

Only at Stations 5, 7 and 9 does the species diversity exceed 3.00. This suggests that the middle river contains the optimum environmental conditions for insect diversity. Of the environmental parameters in the upper and middle river, the temperature regime exhibits a measurable change. Therefore, temperature is expected to be the major influence of changes in the insect distribution.

The information presented thus far strongly suggests that the middle river contains the transition zone. A closer look at changes in distribution is obtained by examining the transition of each insect order. Figure 10 reflects the number of major Ephemeroptera taxa at each Station. Stations 7 through 11 contain the highest number of taxa including some which are found throughout the river or only upstream or downstream from these stations. The mayflies are most abundant in this portion of the river (Fig. 5). The transition zone for Ephemeroptera extends from Columbus to Custer, Stations 7 to 11.

The transition of Plecoptera (Fig. 10) is unlike the overlapping distribution of Ephemeroptera. Most of the stoneflies are adapted to relatively cold water. Five major stonefly genera are found at Stations 5 through 9 equal to the number in the upper river. Stonefly diversity and abundance drops rapidly below Station 9 where temperatures are presumably too high for most taxa. Temperatures of 19 C to 20 C are near the upper limit of tolerance for *Pteronarcella*, *Claassenia*, and some species of *Isogenus*, *Isoperla*, and *Alloperla*. The transition zone for *Plecoptera* is centered at Station 9. The greatest change in distribution for this group occurs from Station 7 through 11.

Six dominant taxa of Trichoptera are present at Stations 5 and 7 (Fig. 11). Diversity decreases below this point. Temperatures exceeding 18 C for long periods may be intolerable for *Lepidostoma*, *Arctopsyche*, *Glossosoma*, *Brachycentrus*, and possibly some species of *Hydropsyche* and *Cheumatopsyche*. The transition zone for *Tricoptera* is centered at Stations 7 through 9.

Four major taxa of Diptera were found at Stations 5 through 9 (Fig. 11). Although fewer major taxa are present in the lower river, the transition of this group is difficult to assess because the family Chironomidae contains at least 19 genera and an unknown number of species. The chironomids are the single most abundant insect family in the river. Taxonomic identifications are extremely difficult and data on generic composition for all stations were not available for this report. The transition zone of chironomid species may be quite different from that shown in Figure 11. For the stations of the middle river, diversity of dipterans including the genera of Chironomidae was highest at Station 7 and 9 (Schwehr 1976). Based on the diversity of dipterans and the distribution of major taxa shown in Figure 11, the transition zone for this order probably occurs from Stations 7 to 11.

The previous examination of transitions at the ordinal level indicates that the transition of aquatic macroinvertebrates of the Yellowstone lies between Stations 7 and 11, which is Columbus to Custer.

Summary of Results

Only the mayflies (Ephemeroptera) exhibit a broad tolerance to climatic conditions. Species' distributions overlap at Stations 7 through 11 to form a transition zone for this order.

The majority of the stoneflies (Plecoptera) are adapted to a cold water environment which extends downstream to Station 9, the point of transition to a warmer habitat where minimum temperatures exceed 18 C for as much as 30 consecutive days.

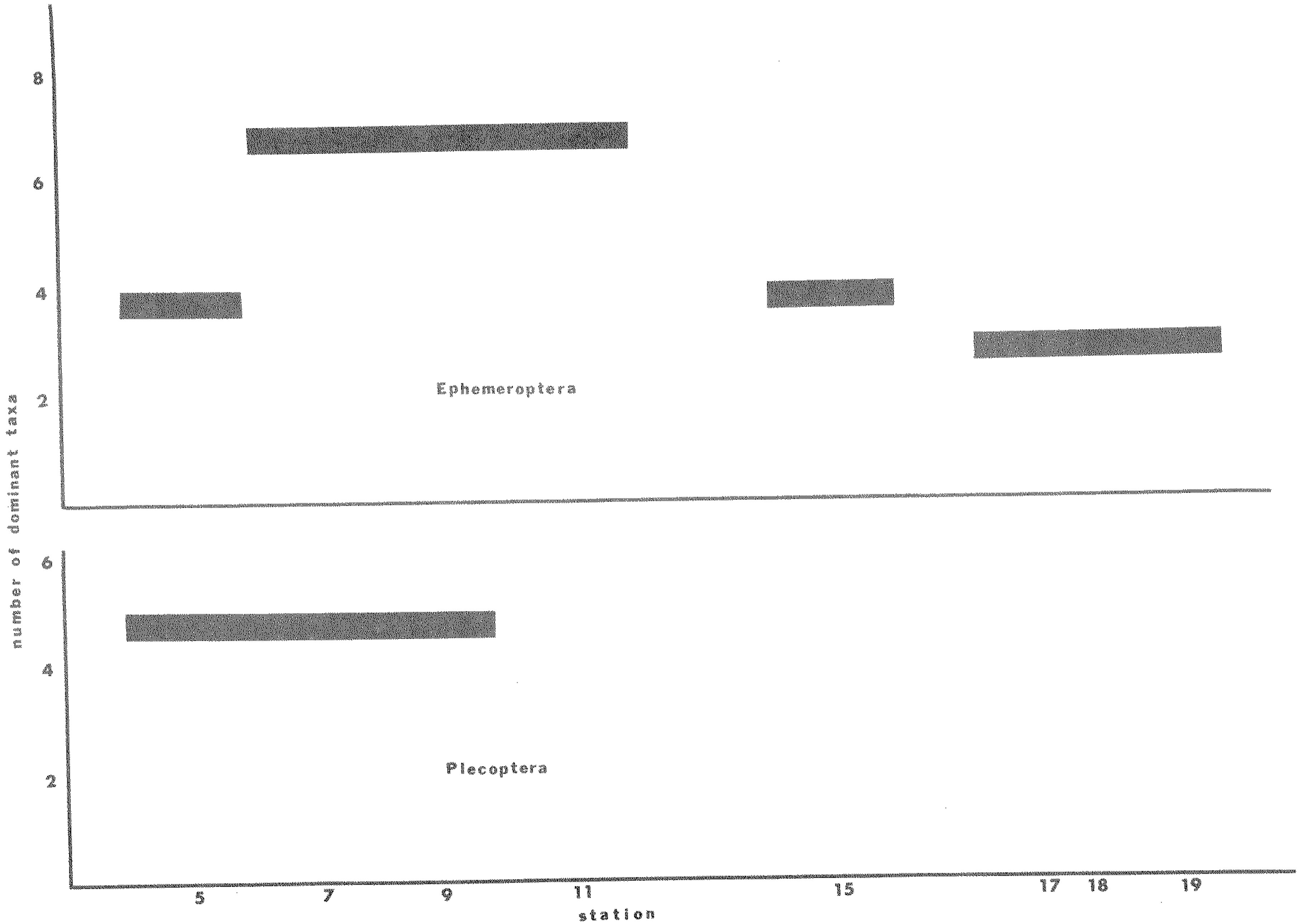

Figure 10. Number of dominant Ephemeroptera and Plecoptera taxa in the fall distribution.

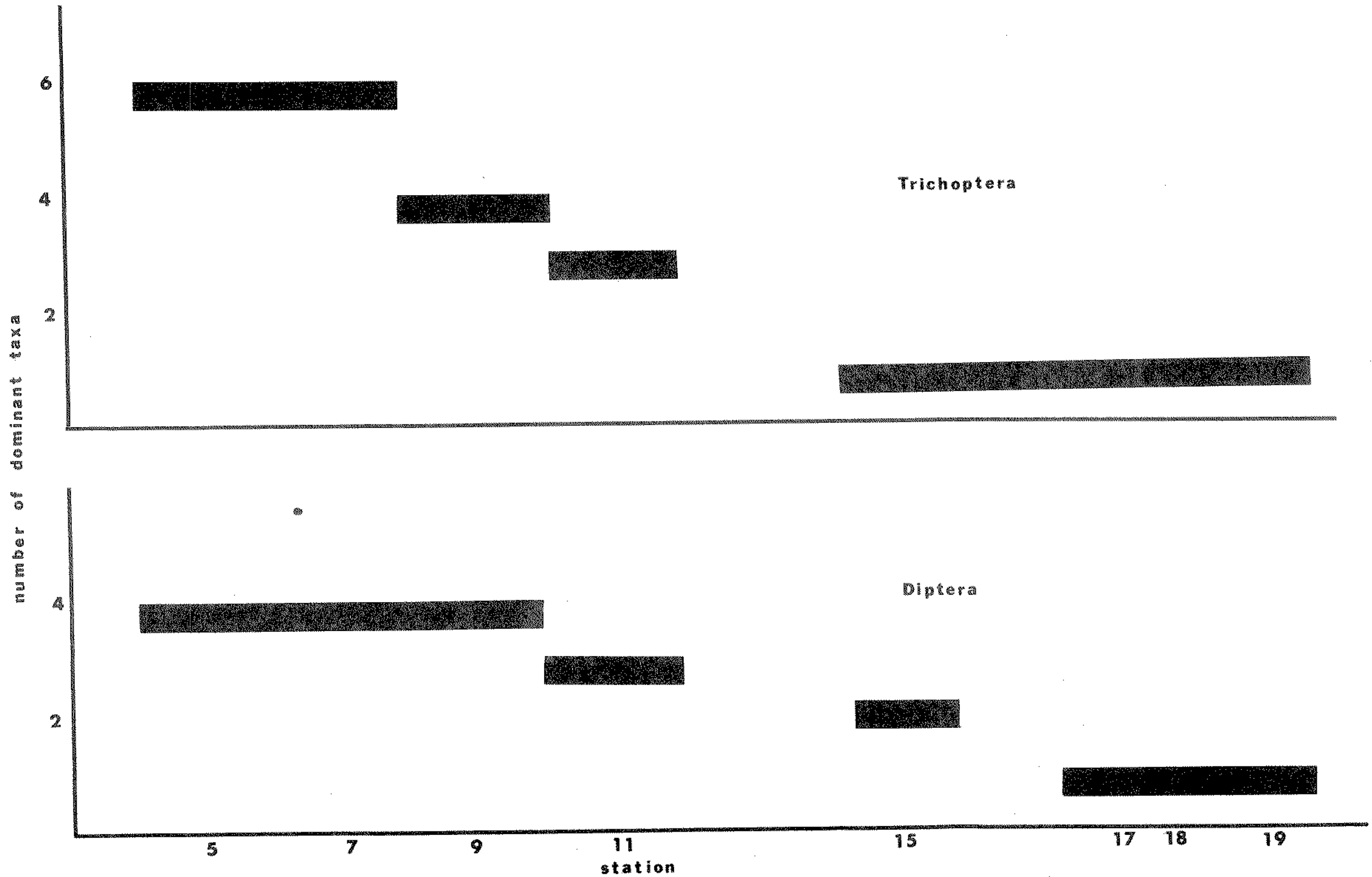

Figure 11. Number of dominant Trichoptera and Diptera taxa in the fall distribution.

Trichoptera and Diptera are more abundant and diverse in cool waters where temperatures rarely exceed 20 C. The major exceptions are *Hydropsyche*, *Cheumatopsyche* and Chironomidae, which are abundant throughout the river.

The transition zone for aquatic insects occurs from Columbus to Custer. Ephemeroptera diversity and abundance are favored by the climatic conditions of this zone, while optimum conditions for most species of Plecoptera, Trichoptera and Diptera occur upstream from the transition zone.

DISCUSSION

Although the transition zone for fishes and insects occurs in the middle river, there are some interesting comparisons and contrasts between the two communities. Distribution of Ephemeroptera somewhat resembles that of the fishes. Populations of both communities are well distributed throughout the river with an overlap of cold and warm water species. Both the fish and the mayflies include a few species that occur throughout the river, but the greatest mayfly diversity occurs in the middle river whereas fish diversity is highest in the lower river.

The distribution of Plecoptera is very similar to that of the salmonid fish species. Both are adapted to the cold water of the upper river and diminish in the middle river near Billings.

Many of the species of Trichoptera and Diptera are present in the cold waters occupied by salmonid fishes, although a few taxa are very abundant in the lower river as well.

Unfortunately, species determinations of many insect larvae and nymphs was difficult or impossible. Analysis of transition zones could be improved by identifying all organisms to the species level. Many insect genera contained only one species. Other closely related species may share similar preferences for temperatures. Therefore, it is not expected that reanalysis of transition zones based on species level determinations would greatly alter the results of this study. But more definite information on temperature requirements could be obtained from investigations at the species level.

Another consideration to note is that the insect data gathered for this study cover only the late summer and fall distribution and specifically the distribution for 1975. Climatic factors may vary from year to year causing a slight shift in organism distribution. Distribution is not expected to change seasonally to any significant degree because most insects have a life-cycle of at least 1 year and have developed the ability to survive seasonal changes in temperature. In fact, many species are able to extend their range of habitation by such means as diapause to escape abnormally high or low temperatures or by emerging from the water as an adult before water temperatures become intolerable for continued nymphal survival.

The importance of temperature as a controlling factor in the distribution of aquatic organisms can not be underemphasized. Two major influences on river temperatures are severe dewatering and on-stream impoundments. Higher temperatures from very low flows or surface drained reservoirs could cause a shift of warm water species to points upstream from their normal occurrence. At the same time cold water species could be eliminated from the downstream points of their normal range. Flows from the hypolimnial drain of a large onstream reservoir could have a significant effect on the temperature regime of the Yellowstone River. Lehmkuhl (1972) found that production of benthic fauna was greatly reduced in an area 70 miles below a reservoir on the Saskatchewan River because water released from the reservoir was warmer than normal in the winter and colder in summer. Effects may have been evident for more than 70 miles but he did not investigate beyond that point. A similar condition could be produced on the Yellowstone River if a dam is constructed above Livingston. This could conceivably shift the transition zone to a point much farther downstream. The seasonal difference in water temperatures below the dam would be small and could eliminate species that require a broad range of water temperatures.

Minor changes to the river ecosystem may have negligible effects on water temperature and such effects would likely be limited to a small area. But to predict the changes that may result from major impacts in terms of temperature, more information is needed concerning temperature regimes and requirements of aquatic insects. The temperature requirements of a specific population are known for very few species. Laboratory investigations have been conducted by Nebeker and Lemke (1968), Gaufin and Hern (1971), and Branham, Gaufin and Traver (1975) to determine the lethal temperature for some insect species. Unfortunately, the results may be quite different from those that could be obtained from field studies. In all three laboratory studies the researchers failed to create normal diurnal changes in water temperatures or subject the organisms to rapid changes in temperature which sometimes occur in nature.

Further knowledge of the temperature regime of the Yellowstone River may be a key to many questions concerning the aspects of the river ecosystem. How are the various communities dependent on one another? How do the characteristics of the upper river affect the lower river? How much of the total river ecosystem will be affected by a single point impact? The upper segment of the river possesses productive and diverse communities of algae and insects. These communities support a fish community of relatively low diversity. The lower river contains a diverse fish community at the upper trophic level, but fish populations in the lower river are dependent on benthic populations that are less diverse than those found upstream. The loss of one major insect species in the lower river could have a greater impact on fish food habits than the loss of that same species or a closely related species upstream where the benthos is diverse enough to sustain such a loss. The algae feeders, including many insects and some fishes, are dependent on the productivity of the upper river to supply them with the algae which is washed downstream (Bahls 1976). The diverse fish community of the lower river may be in a somewhat precarious position because it is dependent on a food base of low diversity. The food chain of the river ecosystem is a complex structure because the upper river is the primary algae producer, the middle river contains the most diverse insect community, and the lower river has the most diverse fish community. Management decisions must not be applied to segments of the river as though each segment were independent of the remainder, but the entire river must be treated as a whole. Decisions that alter one portion of the river may cause impacts throughout the food web at all locations below the point of influence.

LITERATURE CITED

Bahls, L. 1977. Ground floor information. In Montana Outdoors, Vol. 8, No. 2.

Branham, J. M., A. R. Gaufin and R. L. Traver. 1975. Growth of Plecoptera (stoneflies) nymphs at constant, abnormally high temperatures. Great Basin Nat. 35(1):51-61.

Dodds, G. S. and F. L. Hisaw. 1925. Ecological studies on aquatic insects IV. Altitudinal range and zonation of mayflies in the Colorado Rockies. Ecology 6:380-390.

Gaufin, A. R. and S. Hern. 1971. Laboratory studies on tolerance of aquatic insects to heated waters. J. Kans. Entomol. Soc. 44:240-245.

Ide, F. P. 1935. The effect of temperature on the distribution of the mayfly fauna of a stream. Publs. Ont. Fish. Res. Lab. 50:1-76.

Knight, A. W. and A. R. Gaufin. 1966. Altitudinal distribution of stoneflies (Plecoptera) in a Rocky Mountain drainage system. J. Kans. Entomol. Soc. 39:668-675.

Lehmkuhl, D. M. 1972. Changes in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Bd. Can. 29:1329-1332.

Nebeker, A. V. and A. E. Lemke. 1968. Preliminary studies on the tolerance of aquatic insects to heated waters. J. Kans. Entomol. Soc. 41(3):413-418.

Newell, R. L. 1976. Yellowstone River study final report. Mont. Dept. of Fish & Game.

Peterman, L. G. and M. H. Haddix. 1975. Lower Yellowstone River fishery study. Mont. Dept. of Fish & Game.

Schwehr, D. J. 1976. Distribution and diversity of aquatic macroinvertebrates at the middle Yellowstone River. Unpubl. M. S. thesis, Univ. of Montana, Missoula.

U. S. Geological Survey. 1974. Water resources data for Montana, Part I. Surface water records, U. S. Dept. of Int.