SPACIAL AND TEMPORAL DISTRIBUTIONS OF SELECTED IMMATURE AQUATIC INSECT SPECIES COLLECTED IN SINKING CREEK, VIRGINIA

by

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INTRODUCTION

Populations and communities of immature aquatic insects exhibit spacial and temporal change in response to the numerous and complex interactions of a stream environment. These spacial and temporal variations are not necessarily restricted to long stretches of stream length nor prolonged periods of time. The width of a single riffle is sufficient for the establishment of a series of intergrading communities (Armitage, 1958) and a relatively short stretch of stream may contain ever changing species ranges along it (Barber and Kevern, 1973). Within a short period of time some species appear and others disappear as each species completes the aquatic portion of its life cycle. Aquatic insect occurrence and distribution can be defined as a continuum of seasonally changing species distributed along many environmental gradients (Armitage, 1961). Presently there is controversy about the possibility of defining distinct zonal communities in terms of their aquatic invertebrate faunas. A zonal community classification, according to Hynes (1970 a), is justifiable only when applied in a most general way, because too little is known about the specific changes that occur at various points along a continuum.

An analysis of the occurrence and detailed distribution of portions of insect populations often gives information about the dynamics of the intergrading communities present in a stream. It is desirable that such an analysis contain not only information on the relative abundance of each species present, but also a synthesis which describes species interactions and functions in relation to the dynamics of their environment.

The purpose of this investigation is (1) to establish physical-chemical baseline data useful to possible future investigations of Sinking Creek, and (2) to analyze the occurrence and distribution of portions of insect communities present in selected riffles along the longitudinal gradient of the stream, with emphasis on longitudinal distributions, seasonal variations, and community composition, over a twelve month period.

METHODS

DESCRIPTION OF STUDY AREA

Sinking Creek, a tributary of the New River, is located in the southwest portion of Craig County and in part of southeastern Giles County, in the Ridge and Valley Province of Virginia. The stream originates from a series of springs and flows approximately southwest to Newport, Virginia, where it flows west to its confluence with the New River. Numerous tributaries enter Sinking Creek throughout its length and much of its drainage area is used for agriculture. There is continuous flow in the stream throughout the year except in the extreme downstream portion, below the state Route 625 bridge, where the stream sinks underground during periods of summer drought.

In describing the geology of the Sinking Creek area, Hobbs (1953) reported that the strata in the area is approximately 5,400 feet of sedimentary beds, ranging in age from Upper Cambrian to Lower Devonian. The lower two-thirds consists of dolomites and limestone, while sandstone, shales, and siltstone comprise the upper third. All the sedimentary rock is of marine origin.

STATION LOCATIONS

Eight stations, numbered sequentially downstream, were established in riffle areas that appeared to have similar substrates. Stations 1, 2, 5, and 8 were selected for collection of macrobenthos. Fig. 1 is a map of Sinking Creek showing the location of all Stations. The confluence of Sinking Creek with the New River (omitted for clarity of Fig. 1) occurs 4.8 miles downstream of Station 8. Station descriptions are included in the appendix.

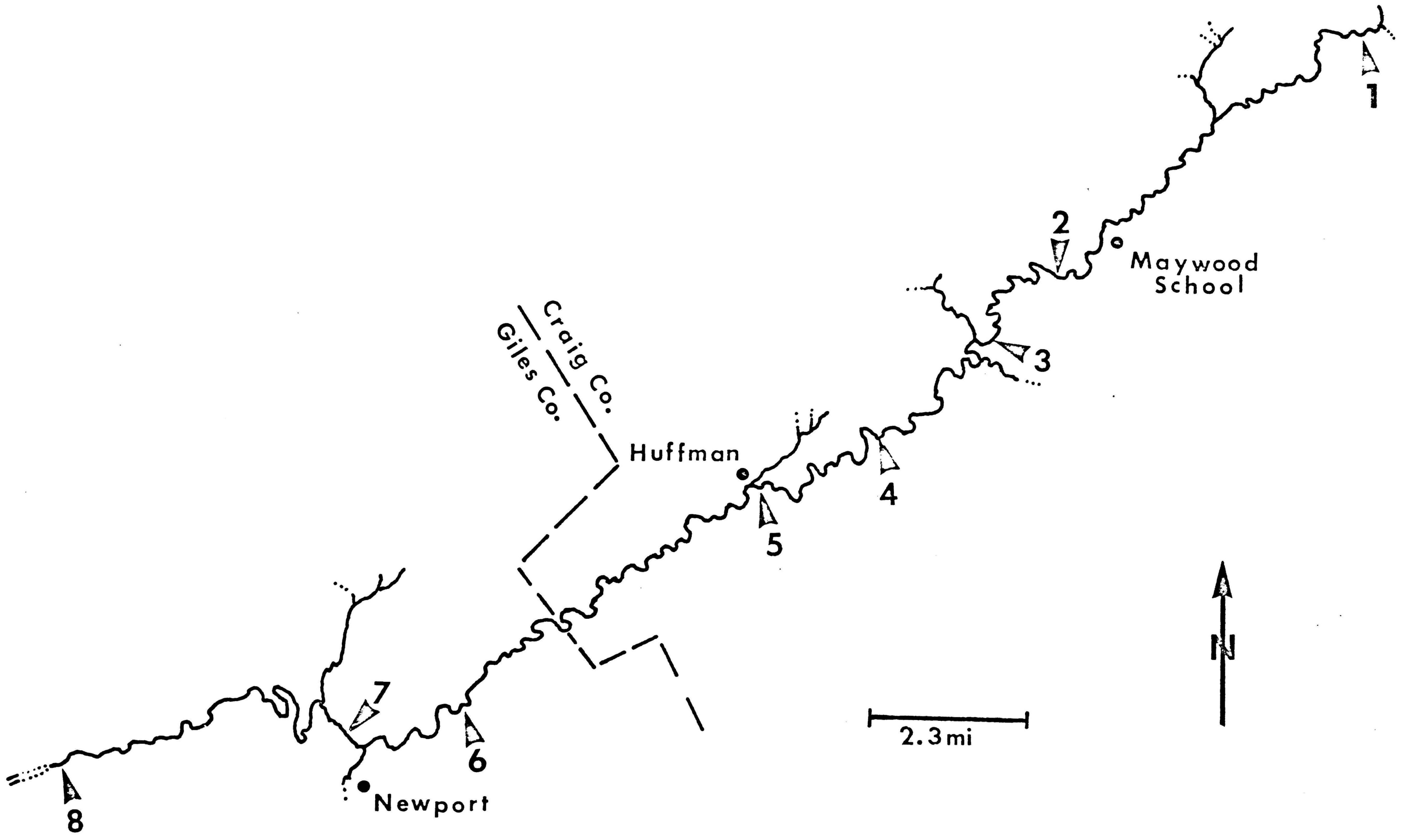
LONGITUDINAL PROFILE OF STUDY AREA

The longitudinal profile of the study area is presented in Fig. 2. There is a change in altitude of approximately 620 feet throughout the area with Station 1 at an altitude of 2360 feet and Station 8 at an altitude of 1740 feet. The change in gradient throughout the study area averaged 23 feet per mile. The steepest altitude gradient was between Stations 3 and 4 with an equivalent change of 50 feet per mile. The smallest change occurred between Stations 1 and 2 and between Stations 7 and 8 with equivalent changes of 16.6 and 18.3 feet per mile respectively.

PHYSICAL AND CHEMICAL SAMPLING METHODS

Monthly physico-chemical measurements were made at all eight stations from June, 1972 through July, 1973. The physical parameters measured included: temperature (Celsius), conductivity, color, and turbidity. Temperature and conductivity were measured in the field. The chemical parameters measured included: dissolved oxygen, pH, alkalinity, total hardness, nitrate, total phosphate, iron, manganese, silica, and sulfate.

Fig. 1 Map of Sinking Creek with station locations.


1
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Maywood School
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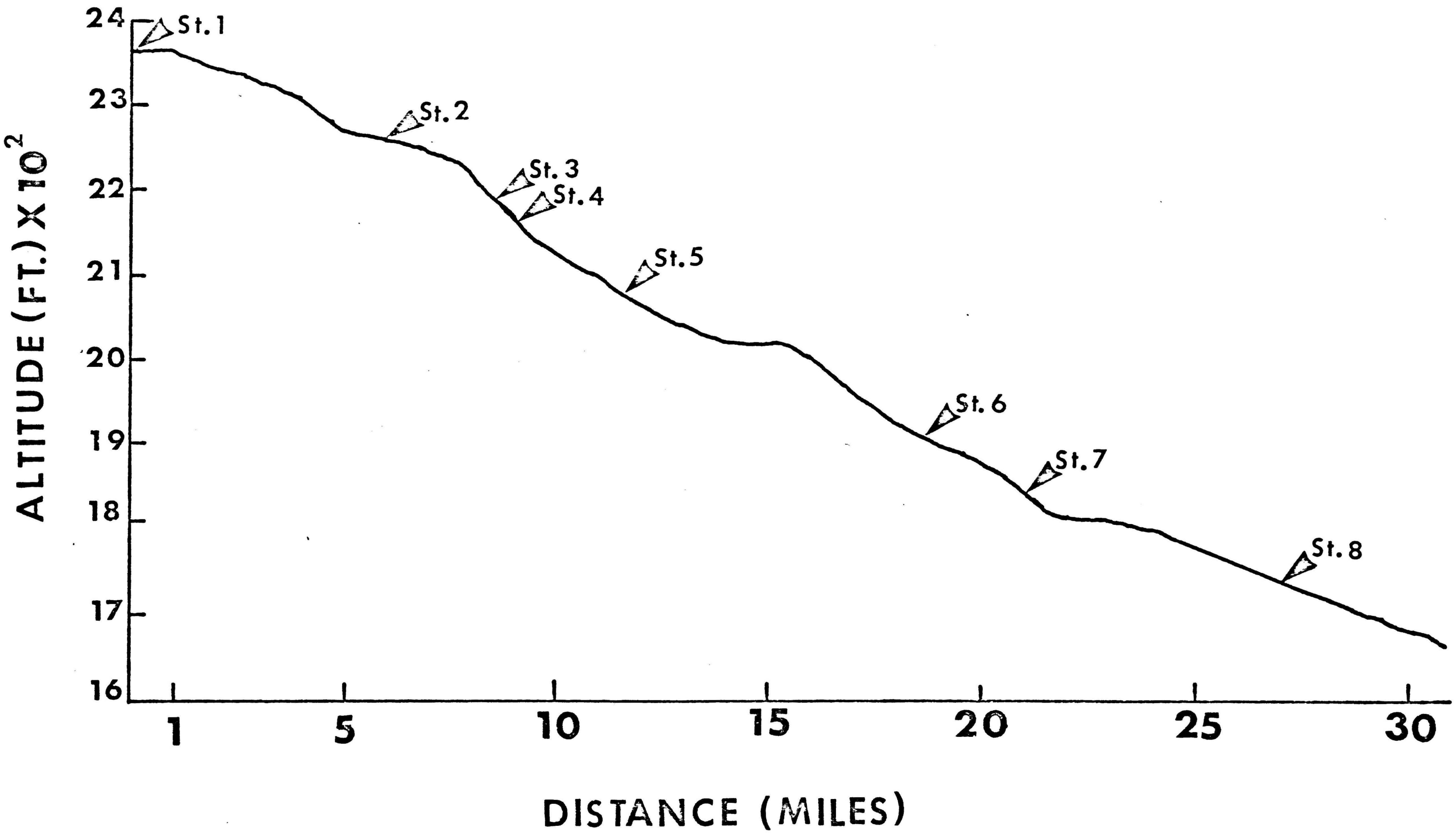
Fig. 2 Longitudinal profile of study area, illustrating the change in altitude and the distance in miles between stations.


ALTITUDE (FT.) X 10^2
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St. 6
St. 7
St. 8
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25
30
DISTANCE (MILES)

Acid cleaned glass containers rinsed with distilled water were used for the collection of water samples. Samples were packed in ice and returned to the laboratory where they were stored at 4°C until analyzed. Analysis of physicochemical samples was completed within three days of collection. Dissolved oxygen (azide modification of the Winkler method), pH, alkalinity, total hardness, nitrate, and phosphate were analyzed by American Public Health Association, *et al.*, (1971). Color, turbidity, iron, manganese, silica, and sulfate were analyzed with the Hach Water Chemistry Kit (Model DR-EL, Hach Chemical Co., Ames, Iowa). In addition to the supplemental conductivity and temperature determinations mentioned above, both parameters were measured at approximately weekly intervals from July, 1972 through August, 1973. Two maximum-minimum thermometers were placed at each of the mainstream stations, one thermometer was placed on the stream bank 1 to 2 meters above the surface of the water. The other thermometer was placed inside a piece of 0.1 m diameter black plastic pipe buried under rocks in the streambed. Tables 1-11 illustrate physical-chemical data collected during this study.

BIOLOGICAL SAMPLING

Samples for immature aquatic insects were collected monthly from July, 1972 through June, 1973 at Stations 1, 2, 5, and 8. Collections were made using a D-frame aquatic net (Wards Natural Science Establishment, Rochester, N.Y.). The

Ward's net was modified by replacing the standard net with a cylindrical net made of #0 silk bolting cloth (pore size ca. 540μ). From its point of attachment to the frame the net sharply increased to a maximum diameter of 0.46 m ; this diameter was maintained for most of the length of the net (0.97 m), excluding the slightly tapered distal end.

Collecting was performed by placing the D-frame vertically against the streambed with the net floating downstream. Each sample was collected by vigorously kicking the area immediately upstream of the net for three one-minute periods. The net was emptied of all material after each one-minute kick and then placed approximately in its original location for subsequent one-minute periods (Frost, Huni, and Kershaw 1971). On a transect, three three-minute samples were collected at each station. All samples were labeled, preserved in either 70% alcohol or 10% formalin, and returned to the laboratory for analysis.

According to Morgan and Egglishaw (1965) this "equal effort" method of sampling can be used on a wide variety of substrates from sand up to stones 60 cm in diameter. Longford (1971), after trying several collecting techniques, stated that most techniques could not be used consistently because of large variations in current velocity and depth throughout the year. He believes, however, that a hand-held net used in a standardized manner is the most effective and adaptable technique for sample collection. It is because of such versatility that the dip-net was used in this study. The method is also rapid, with the whole process of collecting, bottling, and labeling the samples taking 15 to 20 minutes. The method allows large areas of substrate (0.2 to 0.4) square meters to be sampled. Frost, <u>et</u>. <u>al</u>., (1971) believe that when the benthos is in a clumped distribution, as found in streams, large samples supplement the information obtained by small samples from a particular habitat. Although the method is not quantitative in that it does not sample animals living deep in the substrate nor a known substrate area, it is sufficient for qualitative and rough quantitative comparisons between stations (Spence and Hynes, 1971). Furthermore, the method can be employed to determine the percentage composition of various stream taxa and to collect large numbers of specimens for life history studies (Zelt and Clifford, 1972).

In the laboratory, specimens were separated from the substrate using the sugar flotation method of Anderson (1959). Samples were then separated into taxonomically similar groups and stored in 70% alcohol for further enumeration and identification. Identification was carried to the species level where possible. Taxonomic keys for Plecoptera, (Smrchek, 1973), Trichoptera (Ross, 1944), Ephemeroptera, (Needham, Traver and Hsu, 1935), Coleoptera, (Leech and Chandler, 1956) and Diptera (Wirth and Stone, 1956), facilitated identification. For efficient use of time, Diptera, especially Chironimadae and Simulidae, were only identified to family. The total number of individuals and the relative abundance per taxa was calculated for each month and for the entire year.

PHYSICO-CHEMICAL RESULTS AND DISCUSSION

PHYSICO-CHEMICAL PARAMETERS

The characteristics of the groundwater and surface runoff of a watershed largely determine the physical and chemical characteristics of a stream. Since the physico-chemical features of a stream influence the number and kinds of organisms present, it was desirable in this study to establish ranges for these parameters as well as their seasonal and longitudinal variations. Ideally, physico-chemical changes should be continuously monitored to detect diurnal variation; however, this is often difficult because of technical and practical limitations. Although periodic determinations indicate the physical or chemical nature of the stream for the brief period of sample collection, general trends may become evident if the periodic sampling is conducted over extended periods of time (Krumholz and Neff, 1970).

Monthly air temperature maxima and minima are presented in Figure 3 and 4 (weekly fluctuation in temperature were omitted for clarity of figures). The data indicate yearly air temperature maxima and generally smaller ranges between maximum and minimum values were recorded during July and August. Minimum air temperatures and larger ranges characterized January and February, while the fall and spring were transition periods with air temperatures decreasing in October and increasing in March. Although I was able to read and reset air and water thermometers only once a week, I

Fig. 3 Maximum and minimum monthly air temperatures for Stations 1 through 4 on Sinking Creek From July, 1972 through June, 1973.

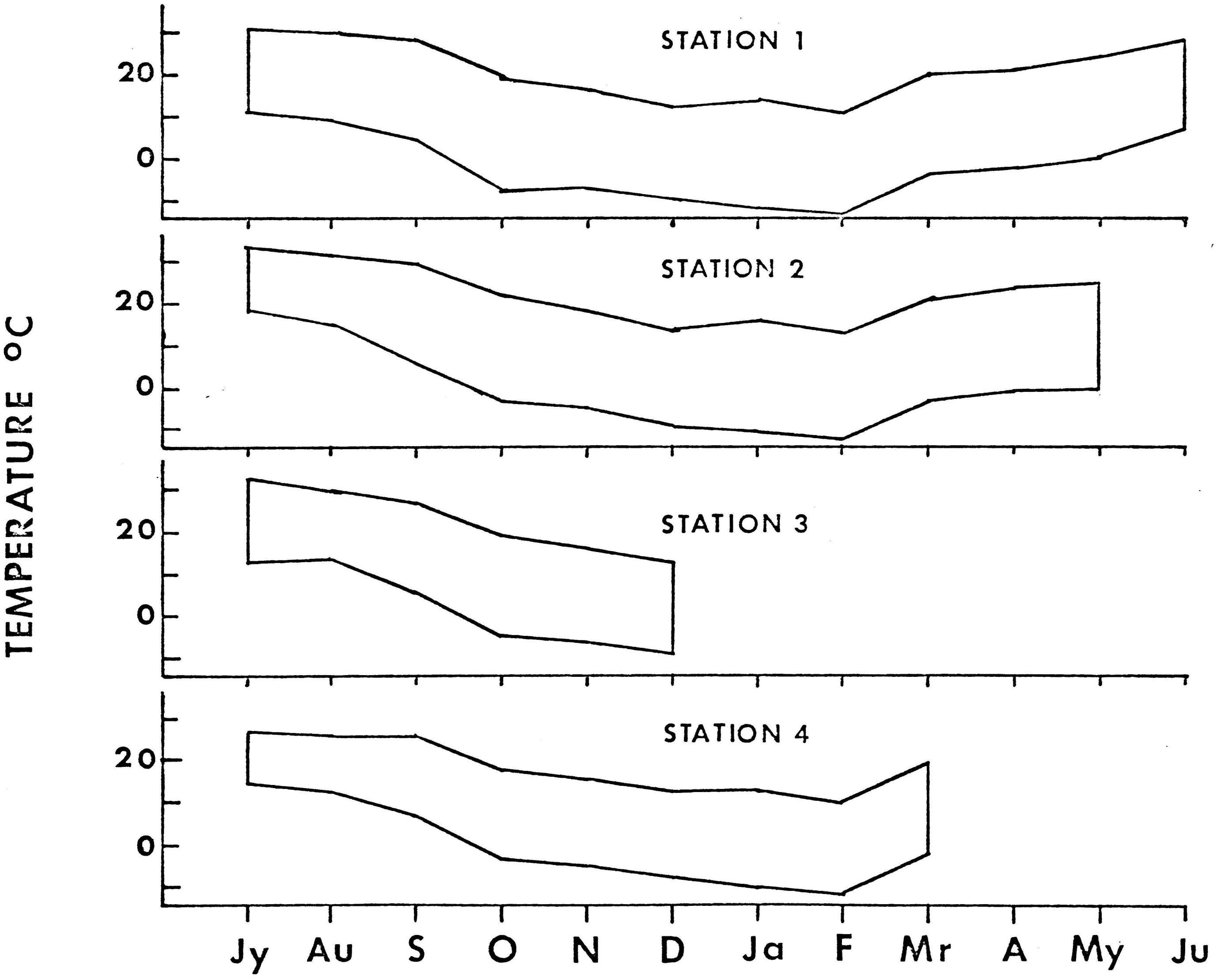
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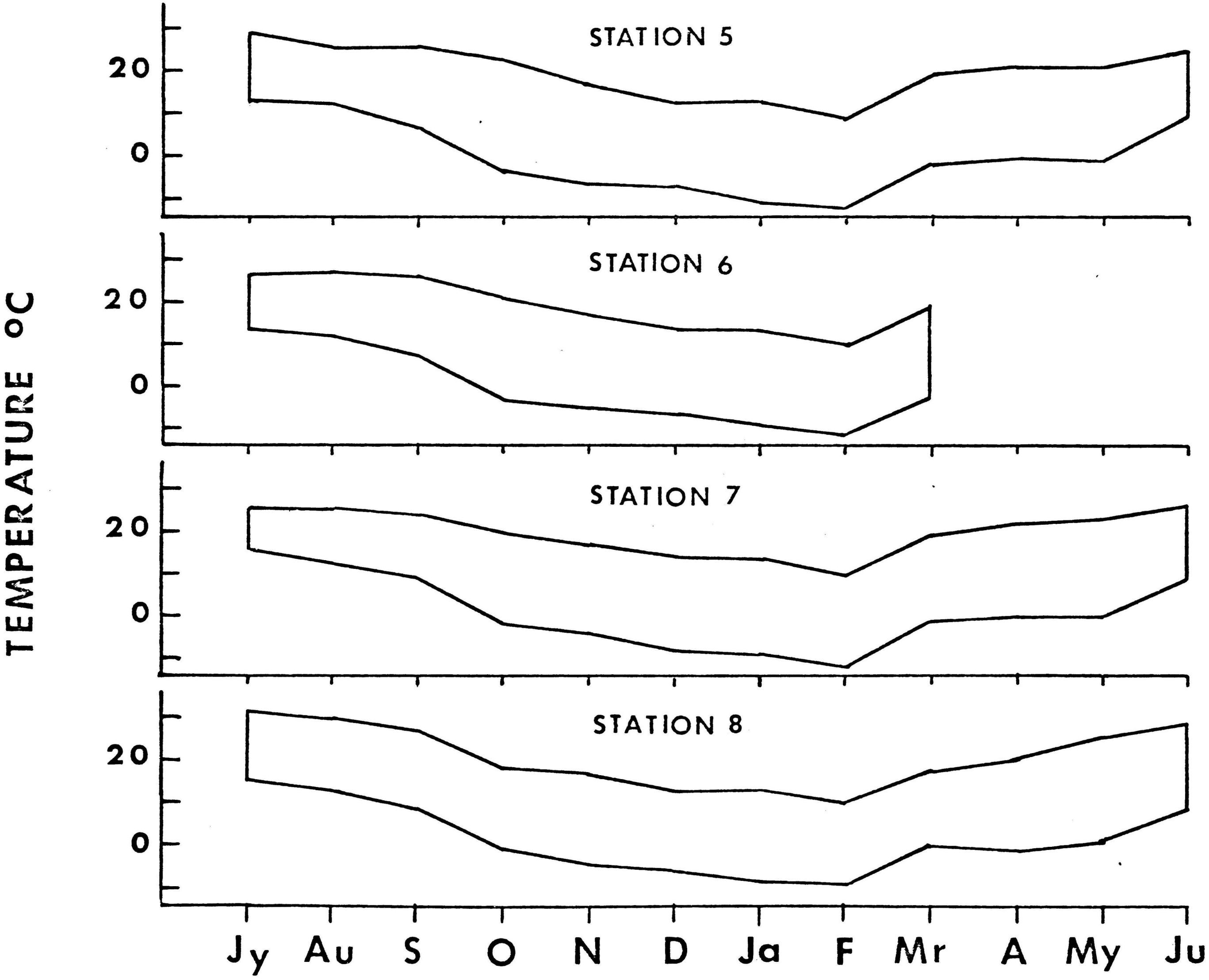
Fig. 4 Maximum and Minimum monthly air temperatures for Stations 5 through 8 on Sinking Creek From July, 1972 through June, 1973.


STATION 5
STATION 6
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observed that seasonal trends were evident from these weekly temperature readings. When compared to a continuously recording thermograph, average temperatures for weekly recordings tend to be higher during periods of warming, and lower during periods of cooling; but, over a long period the averages do not differ greatly (Edington, 1965). Water temperatures (Fig. 5 and 6) followed air temperatures at all stations reaching maximum values in the summer, minimum values in winter, and exhibiting rapidly changing values in the spring and fall. During the summer the maximum water temperature (23°C) at Stations 1 and 3 were generally lower than at other stations; while generally higher maximum water temperatures (25.5°C) were recorded at Station 2. Station 1 also had lower minimum temperatures during summer than the other stations. The presence of springs and/or increased shading of upstream waters by overhanging trees and brush may explain the lower maximum and minimum temperatures of Station 1 and possibly of Station 3. However, a small millpond, maximum depth approximately 4 meters, located upstream of Station 3 may have influenced water temperatures at this station. Since the pond would have a smaller surface to volume ratio than the shallow stream, it would require relatively longer periods of time for solar insolation to heat the water which in turn would loose proportionately less heat to the air by convection. The outfall of the pond, consequently, might be expected to have lower maximum

Fig. 5 Maximum and minimum monthly water temperatures for Stations 1 through 4 on Sinking Creek From July, 1972 through June, 1973.

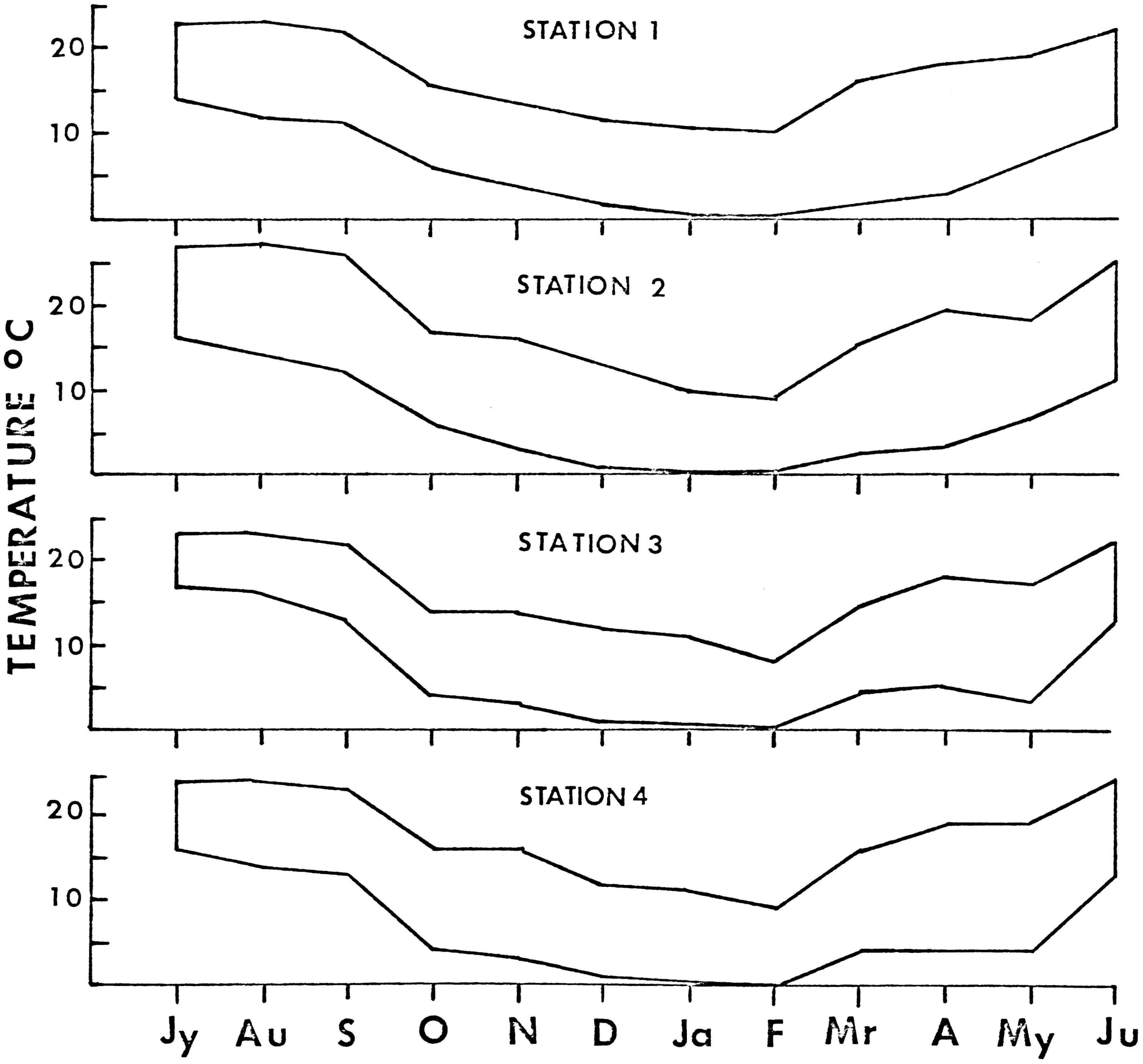
STATION 1
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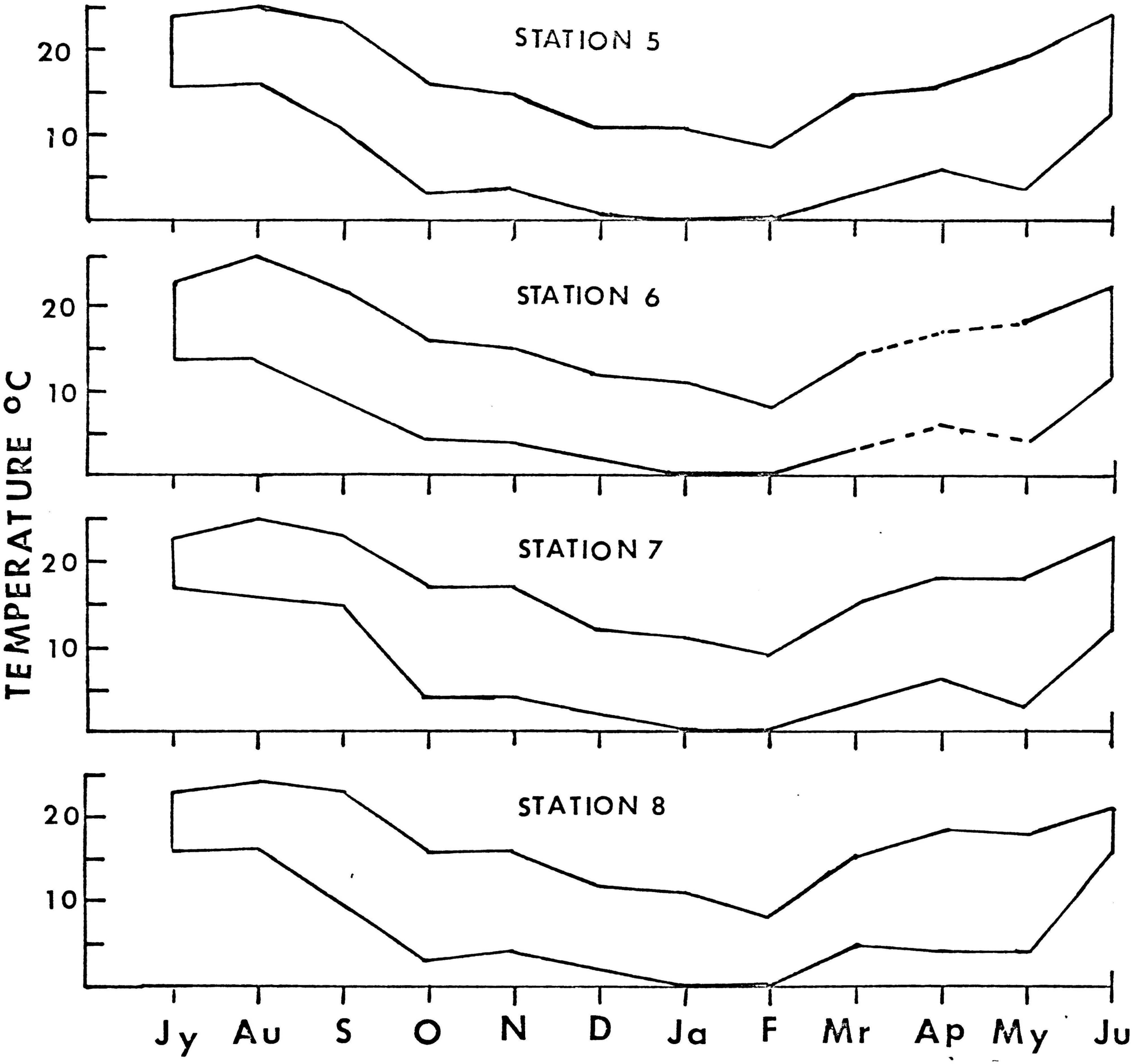
Fig. 6 Maximum and minimum monthly water temperatures for Stations 5 through 8 on Sinking Creek From July, 1972 through June, 1973.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temperatures and smaller temperature ranges than other sections of the stream. This appears to have been the case at Station 3 where the maximum temperatures and the ranges between maximum and minimum water temperatures were less than the values measured at downstream stations. This apparent decrease in temperature range existed only during the summer and fall. Corresponding to the decreases in solar insolation and the increases in flow associated with winter and spring, the ranges at all stations were comparable and closely followed changing air temperatures. Stream morphology and lack of overhanging vegetation upstream of Station 2 may explain the higher maximum water temperature observed at this station. Long stretches of the stream at this station were relatively shallow and flowed through predominately cleared agricultural land, thus exposing the water to relatively longer periods of solar insolation than possible if the banks were treelined. This increased solar insolation upstream of Station 2 possibly explains the higher maximum water temperature measured at this station. At the others, Stations 4 through 8, yearly water temperature profiles were comparable being intermediate between the lower maximum temperatures at Stations 1 and 3 and the higher maximum temperatures at Station 2. One slight exception was observed at Station 7 which was located downstream of a second millpond. The minimum water temperature at this station remained relatively constant during August and September while the minimum temperatures at stations above and below Station 7 were declining. This may have been an artifact due to thermometer error, or it may be that the greater water depths of the millpond required slightly longer periods to cool. Since thermometers were periodically checked for accuracy, I believe a longer cooling period explains the observations made at Station 7.

Specific conductance measurements performed at approximately weekly intervals during the study period furnished an indication of ion concentration of Sinking Creek water. Table 1 illustrates the yearly range and mean for specific conductance at each station. The mean specific conductance at Station 1 was 131 micromhos; the mean increased to 151.4 micromhos at Station 2 and fluctuated between 151 and 158 micromhos from Station 2 through 7. At Station 8 a slight increase to 168 micromhos was observed. Harrell and Doris (1968) speculated that increased conductance may be due to increased leaching of soluble minerals with greater length of flow. Thus the increases in conductance observed in Sinking Creek may be due to increased leaching along the stream gradient. This appears likely since other solutes, alkalinity and total hardness, also increased with greater length of flow. These changes in solute concentrations may indicate changes in the amounts of soluble minerals at various points along the stream. Since all determinations were made in the field, standardization of measurements at 25°C

Table 1

Yearly Mean and Range of Specific Conductance (µ mhos). For Sinking Creek From July, 1972 Through June, 1973

Station	Mean	Range
1	131	40.0 - 215.5
2	151	64.0 - 241.0
3	152	62.0 - 245.0
4	158	94.0 - 300.0
5	157	76.0 - 310.0
6	152	82.5 - 325.0
7	157	82.5 - 338.5
8	168	100.0 - 305.0

was not possible; consequently, seasonal variations were not apparent. Conductivity is known to vary widely from stream to stream, making comparisons between streams difficult; however, the specific conductances measured in Sinking Creek are reasonable when compared to values of greater than 100 micromhos reported in several rainstorms (Whitehead and Feth, 1964).

The true or specific color of natural waters results from the interplay of light on dissolved or colloidal substances while apparent color results from the interplay of light on dissolved and colloidal substances as well as suspended particulate material (Reid, 1961). Apparent color measurements indicate that the values observed at Station 1 had a lower range and a smaller mean than the values observed at the remaining stations (Table 2). On the other hand, values observed for samples collected at Stations 3, and 5, had greater ranges and larger means than those for Stations 2, 4, 6, 7, and 8. The highest readings for color were measured during the spring and summer samples. Fall and winter measurements were usually low (10 to 20), with a color of 10 being barely noticeable to the casual observer (Hem, 1970). The color of natural waters usually results from leaching of organic debris and differences in the amounts of debris may explain color variations observed at successive stations. Although no attempt was made to quantify amounts of debris present in Sinking Creek, it appears that higher readings were observed during the summer when flow is

Table 2

Yearly Mean and Range of Apparent Color For Sinking Creek from July, 1972 Through June, 1973

Station	Mean	Range
1	28	15 - 55
2	33	15 - 110
3	38	15 - 150
4	31	15 - 110
5	38	10 - 170
6	30	7 - 80
7	32	15 - 85
8	35	8 - 80

usually lower than at other seasons. The higher summer readings could be due to increased amounts of debris which possibly accumulated during periods of low flow. Yearly means for turbidity (Formazin Turbidity Units which are comparable to Jackson Turbidity Units) were lowest at Station 1, greatest at Station 2, and of intermediate values at the remaining stations (Table 3). Turbidity describes the degree of opaqueness of the water and is associated with suspended particulate matter. Subtle changes in the types of vegetation or amounts of erosion occurring in the study area may influence the amount of suspended particulate matter present at various points in the stream. These changes in suspended solids may account for differences in turbidity along the longitudinal gradient of Sinking Creek.

Dissolved oxygen for all eight stations, was near or above saturation throughout the year (Table 4); the lowest observed saturation value was 87% (7.6 mg/l) at Station 1. Measurements indicating oxygen super saturation were not uncommon with some values ranging as high as 125% (9.5 mg/l) saturation. The ultimate source of dissolved oxygen in water is from the atmosphere; some oxygen, however, may be contributed by photosynthesis. When the rate of photosynthetic oxygen production is greater than the rate of community respiration, supersaturation of the water may occur. In a study of selected streams in southwestern Virginia, Neel (1973) found oxygen supersaturation present only in

Table 3

Yearly Mean and Range of Turbidity (Formazin Turbidity Units) for Sinking Creek from July, 1972 through June, 1973

Station	Mean	Range
1	9	4 - 23
2	15	2 - 38
3	13	2 - 55
4	12	2 - 29
5	11	2 - 58
6	10	3 - 29
7	10	3 - 28
8	12	4 - 28

Table 4

Yearly Mean and Range of Dissolved Oxygen (percent saturation and mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean (mg/l)	Mean (%)	Range (mg/l)	Range (%)
1	10.4	106	7.6 - 13.2	87 - 123
2	10.6	110	8.7 - 12.7	104 - 125
3	10.5	107	8.4 - 13.6	99 - 119
4	10.4	110	8.6 - 13.3	103 - 124
5	10.6	111	9.0 - 13.2	100 - 119
6	10.7	111	8.8 - 12.6	102 - 122
7	10.5	107	8.6 - 13.2	99 - 114
8	10.5	107	8.8 - 12.2	94 - 125

samples containing carbonate alkalinity. Thus some measurements of Sinking Creek samples indicating super saturation, but not associated with bicarbonate alkalinity, may be artifacts of sampling error or improper chemical analysis. Although significant changes in the relative percent of saturation occur diurnally in many streams, no attempt was made to measure such change in Sinking Creek; consequently, it is not known if the high dissolved oxygen values measured during daylight persist throughout the night.

Hydrogen ion concentrations (pH) ranged from a low of 6.75 to a high of 8.85; higher values (above 8.5) had accompanying carbonate alkalinity (Table 5). Seasonal and longitudinal variations in pH were not conspicuously evident, and therefore will not be considered in detail. However, seasonal variations in pH have been reported for small streams during periods of high leaf fall when large leaf packs often cause marked decreases in pH. Leached constituents and decomposition products of leaves as well as increased bacterial production of carbon dioxide explain such decreases (Slak and Feltz, 1968). Although large leaf packs were observed in Sinking Creek, increased flow during the fall may have removed them from the study area before any significant change in pH could occur. Furthermore, changes caused by remaining leaf packs could have been masked by dilution or pH change could have occurred between two successive sampling periods in which case it would have gone undetected.

Table 5

Yearly Mean and Range of Hydrogen Ion Concentration (pH) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	7.9	6.80 - 8.40
2	8.0	6.75 - 8.85
3	8.0	6.80 - 8.35
4	8.1	6.80 - 8.75
5	8.1	6.70 - 8.70
6	8.1	6.90 - 8.80
7	8.1	6.90 - 8.80
8	8.1	6.80 - 8.80

Table 6 shows the yearly means and ranges for total alkalinity and total hardness at all eight stations. Total alkalinity ranged from a low of 59 mg/l at Station 1 to a high of 125 mg/l at Station 8. Carbonate alkalinity (present in natural waters only when pH exceeds 8.5) was observed in September (at Stations 3, 6, 7 and 8) October (at Stations 2, 4 and 5) and January (at Stations 2, 4, 5 and 6). Total hardness ranged from a low of 68 mg/l (as $CaCo_3$) at Station 1, to 142 mg/l at Station 8. Both alkalinity and hardness increased in the downstream direction with the greatest change in mean values occurring between Stations 1 and 2. The mean values of these parameters increased slightly from Station 2 through 8. Higher solute concentrations were usually observed during periods of low flow. Apparent increases in solute concentrations during low flow have been generalized by Slak and Feltz (1968), who state that the annual chemical quality cycle of small streams are low solute concentrations during relatively high stream flows when run-off predominates over groundwater inflow and high solute concentrations during low flow when ground water predominates over run-off. This generalization may be applicable to Sinking Creek.

Total phosphate and nitrate measurements, using unfiltered water samples, are summarized in Table 7. Yearly means for total phosphate varied from a low of 0.196 mg/l at Station 1 to a high of 0.217 mg/l at Station 8. Although

Table 6

Yearly Mean Concentration and Ranges of Alkalinity (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	81	59 - 114
2	93	72 - 119
3	97	78 - 118
4	99	78 - 124
5	97	79 - 120
6	95	68 - 121
7	100	80 - 123
8	106	87 - 125

Yearly Mean Concentration and Ranges of Hardness (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	95	68 - 122
2	107	83 - 138
3	110	86 - 140
4	112	85 - 138
5	113	90 - 138
6	108	75 - 135
7	113	84 - 135
8	120	100 - 142

Table 7

Yearly Mean Concentration and Range of Total Phosphate (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	.196	.080 - .330
2	.192	.063 - .320
3	.199	.080 - .323
4	.206	.070 - .340
5	.204	.054 - .385
6	.201	.070 - .322
7	.215	.063 - .320
8	.217	.070 - .394

Yearly Mean Concentration and Range of Nitrate (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	1.55	0.45 - 4.40
2	2.10	0.90 - 3.70
3	2.45	1.20 - 4.65
4	2.55	1.15 - 5.10
5	2.25	0.75 - 4.65
6	2.20	0.90 - 3.40
7	2.10	1.10 - 3.35
8	2.60	0.90 - 5.65

yearly means for total phosphate are similar at all Stations, a wide variation in range of phosphate values was observed throughout the study. This range (for total phosphate) extended from a low of 0.054 mg/l to a high of 0.394 mg/l. Nitrate measurements indicated a low concentration of 0.56 mg/l at Station 1 and a high concentration of 5.56 mg/l at Station 8. The mean concentration of nitrate increased from Station 1 to Station 2 by approximately 0.5 mg/l and then fluctuated by less than 0.5 mg/l from Station 2 through 8. One collection, made September 30, 1972, contained elevated nitrate concentrations, however, stream flow was very high and the water appeared muddy, possibly indicating increased erosion and suspended sediments containing additional nitrates. Slight increases in nitrate and phosphate concentrations were measured in September, October and November and again in March, April, and May (all samples collected during "normal" flow). The principal sources of nitrate and phosphate in streams are rainfall and land surface runoff (Hynes, 1970a). Although no attempt was made to quantify amounts of phosphate and nitrate present in rainfall or surface runoff, seasonal variations in precipitation and runoff may explain, in part, observed increases in phosphate and nitrate concentrations during the Fall and Spring. However, these increases in concentration may also be explained by changes in amounts of detritus, rates of decomposition, or ratios of ground water to surface runoff.

Furthermore, phosphate and nitrate concentrations measured in Sinking Creek appear to be slightly higher than those reported by Hayles (1973) for Tom's Creek (a nearby sister tributary in the New River Drainage). Since no two watersheds are identical, variations in solute concentrations between streams are to be expected. Differences in land use, vegetation, and possibly many other interrelated environmental factors, help explain differences in nitrate and phosphate concentrations when comparing values from two or more streams.

Occurring either as particulate ferric hydroxide or as some organic complex form, small amounts of iron were measured in Sinking Creek (Table 8). Comparing all stations, the highest yearly mean value 0.19 mg/l and the greatest range 0.02 to 0.43 mg/l was measured at Station 1. Both the mean and the range decreased at Station 2 and they remained approximately comparable for all remaining stations. Several springs, water from which eventually flowed into Sinking Creek, were discovered upstream of Station 1. Flow near the springs was rust colored, possibly due to precipitating ferric hydroxide, as was much of the vegetation and substrate for a few meters downstream from the mouth of the spring. A possible source of ferric hydroxide is iron found in groundwater. According to Hem (1970) ground water can be sufficiently reduced to carry ferrous iron, and in many areas concentrations of 1.0 to 10 mg/l of iron are common. In the presence of oxygen the water becomes cloudy and then brown

Table 8

Yearly Mean Concentration and Range of Iron (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	.190	.02 - .43
2	.145	.02 - .22
3	.138	.02 - .30
4	.110	.01 - .20
5	.120	.01 - .22
6	.105	.01 - .30
7	.098	.01 - .20
8	.110	.01 - .24

as ferrous iron oxidizes to form precipitating ferric hydroxide. Particles of colloidal organic material, however, can absorb metal oxides or hydroxides including ferric hydroxide. These particles, transported by flow, may have been responsible for the higher iron concentrations observed at Station 1.

The mean concentrations of manganese (Table 9) were similar for all stations and while there was some variation in observed ranges, especially at Station 1, 3, and 8, the study did not indicate seasonal or longitudinal change. Similarly, the means for sulfate as $SO_4^=$ (Table 10) and for silica as SiO_2 (Table 11) demonstrated some variations between stations; however, neither seasonal nor longitudinal trends appeared evident. Exhibiting no evident trend the observed ranges for sulfate were greater at Station 5 and 6 than at the other stations, while Station 2 and 7 had smaller ranges than the others. In a like manner, ranges for silica were greater at Station 1, 5, and 8 than at the other stations. The means observed for silica exhibited no evident longitudinal trends and appeared reasonable when compared to a median value of 14 mg/l silica commonly observed in natural waters (Davis, 1964).

Table 9

Yearly Mean Concentration and Range of Manganese (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	.32	.10 - .80
2	.28	.10 - .55
3	.35	.10 - .75
4	.28	.15 - .50
5	.30	.10 - .50
6	.30	.15 - .50
7	.27	.20 - .50
8	.40	.15 - .80

Table 10

Yearly Mean Concentration and Range of Sulfate (mg/l) For Sinking Creek From July, 1972 through June, 1973

Station	Mean	Range
1	7.2	4 - 16
2	7.1	5 - 10
3	8.7	5 - 18
4	7.1	4 - 12
5	8.3	5 - 20
6	7.9	5 - 20
7	7.2	5 - 12
8	7.7	5 - 15

Table 11

Yearly Mean Concentration and Range of Silica (mg/l) For Sinking Creek From July, 1972 Through June, 1973

Station	Mean	Range
1	8.7	5.1 - 12.1
2	8.6	6.2 - 10.5
3	9.4	7.2 - 11.7
4	9.0	7.1 - 11.0
5	9.0	5.5 - 12.9
6	8.6	6.9 - 10.9
7	8.3	7.0 - 11.5
8	9.0	6.0 - 12.6

BIOLOGICAL RESULTS AND DISCUSSION

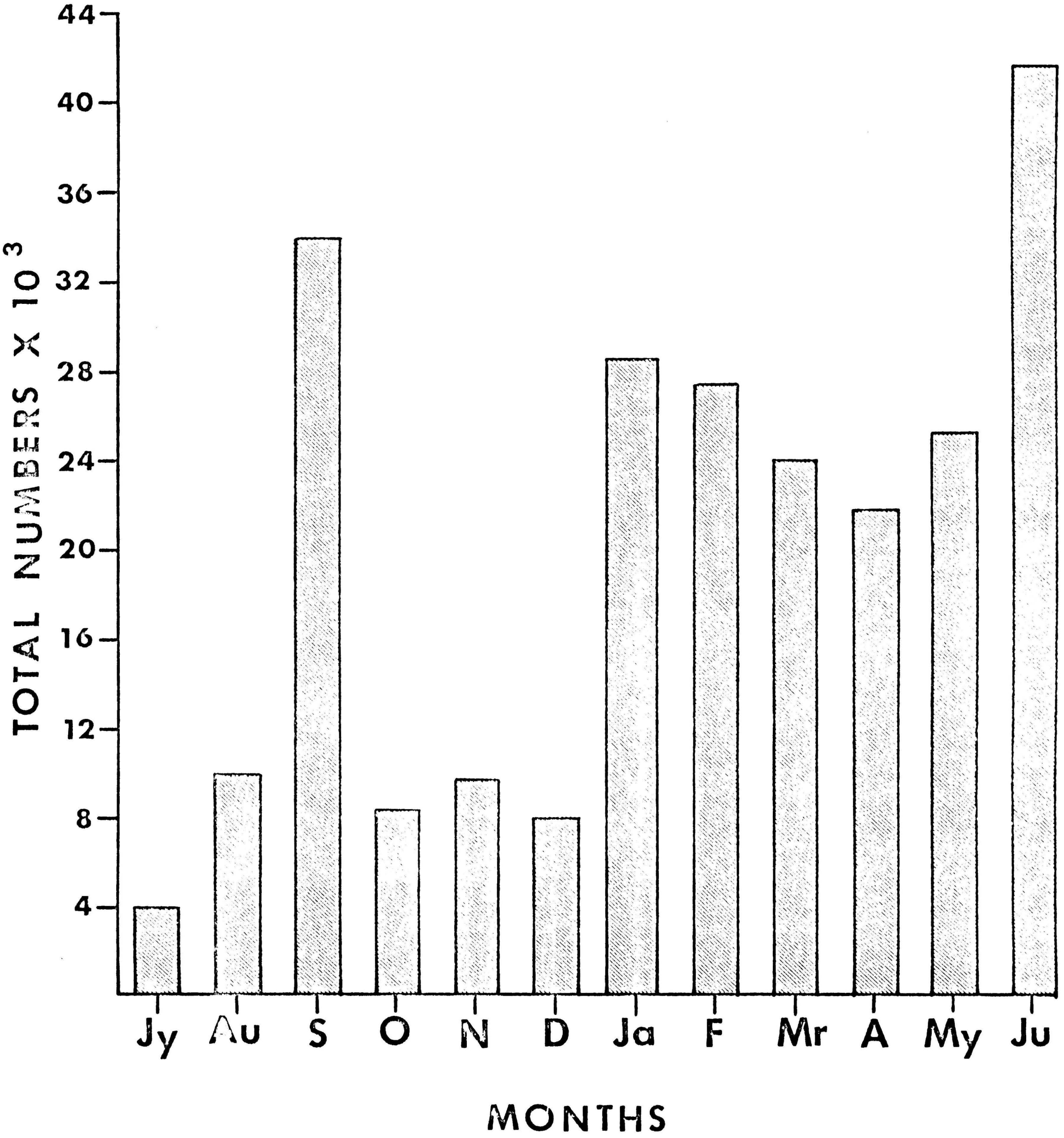
To understand the continuum of change characteristic of aquatic insect communities, seasonal and longitudinal variations of individual taxa must be analyzed. In an attempt to evaluate these changes in Sinking Creek, the following aspects were examined: monthly fluctuations in occurrence, longitudinal patterns of distribution, and the influence of relevant environmental factors on community structure.

SEASONAL CHANGE IN TOTAL NUMBERS OF INDIVIDUALS COLLECTED

In temperate latitudes, several investigators report definite seasonal trends in aquatic insect numbers. Usually faunal numbers decline in the spring and early summer, primarily due to emergence. Numbers rise again during the late summer and early autumn as new individuals are recruited from hatching eggs. In the winter, numbers may decline because this is a time of little or no recruitment and of continued mortality and predation. Faunal numbers may, however, rise quite rapidly during this period if many winter growing Plecoptera and Ephemeroptera are present. Emergence of early stoneflies (Plecoptera) may cause a decrease in total numbers of specimens in the early spring, however, such losses in numbers may be offset by the hatching of eggs from early flying species, especially *Ephemerella* (Ephemeroptera) (Hynes, 1970b).

The generalized seasonal trends for insect numbers recounted above were not apparent in Sinking Creek during the study period. Fig. 7 shows that insect numbers increased from July to September and then decreased in October. Total numbers collected by the standardized technique remained relatively constant during the autumn (October through December) ranging from 7911 to 9802 organisms, but during the winter (January through March) there was an approximate three-fold increase in total numbers of insects collected. Numbers ranged from 28,628 in January to 24,145 in March. Since the winter is a time of little or no recruitment, hatching of eggs does not appear adequate to explain the observed increase. Furthermore, winter growing stonefly species, e.g., Isogenus, Isoperla, and Taeniopterix, were not collected in sufficient numbers to account for this increase. The increase in number of organisms collected in January and February may be explained, in-part, by more favorable collecting conditions, i.e. lower water levels, than experienced during December. Hynes (1961), using several sampling methods, reported that collections at times of high water contain fewer organisms than collections at normal flow. Field observations indicate that flow in Sinking Creek was above normal levels during sampling in December, but at approximately normal flow when samples were collected in January. Favorable collecting conditions do not, however, entirely explain the winter increase in numbers. This is evident from a comparison of faunal numbers collected in

Fig. 7 Generalized trend for total numbers of specimens collected at Stations 1, 2, 5, and 8 on Sinking Creek.


TOTAL NUMBERS X 10^3
44
40
36
32
28
24
20
16
12
8
4
Jy
Au
S
O
N
D
Ja
F
Mr
A
My
Ju
MONTHS

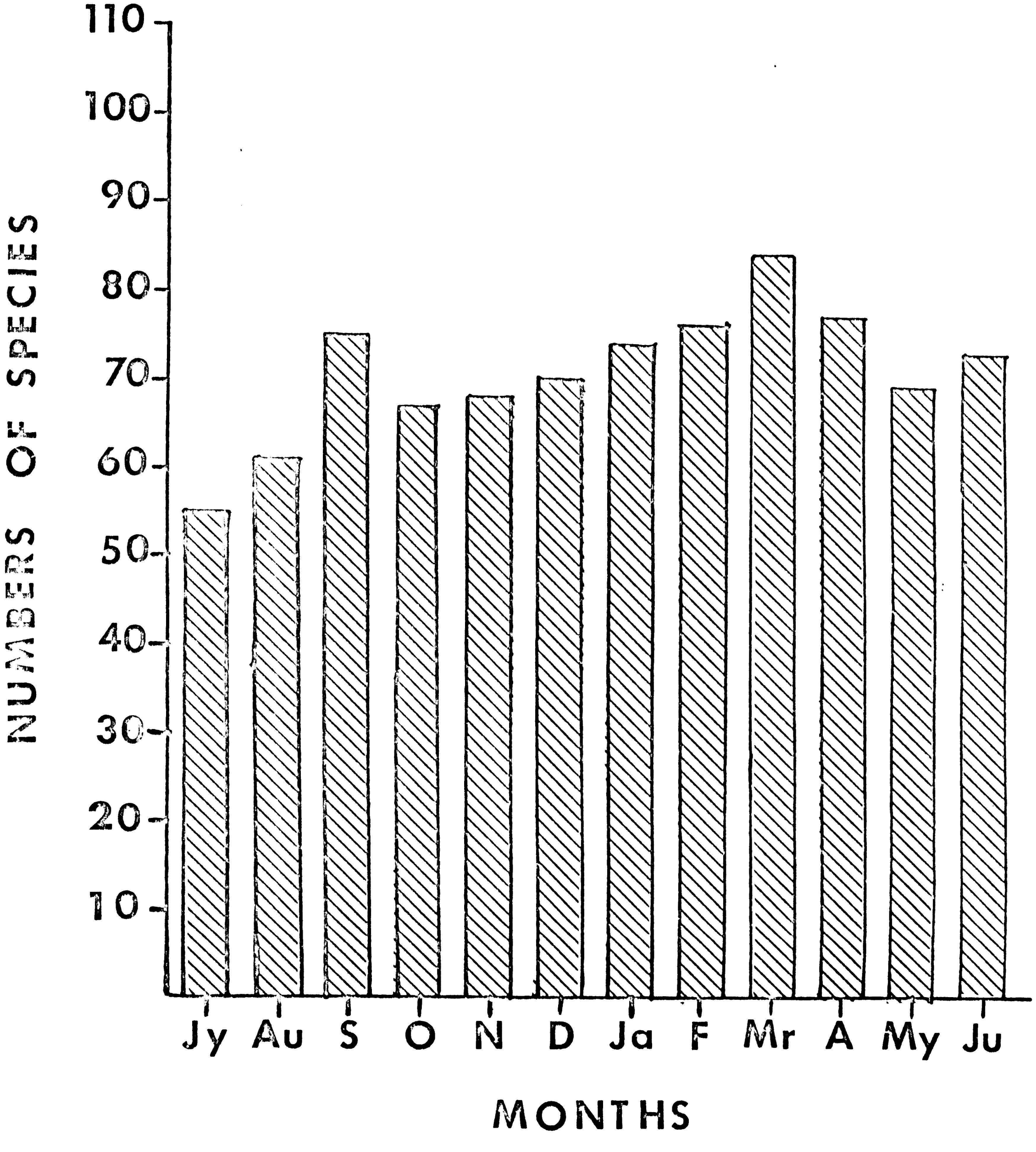
December and March. Samples obtained in December contained less than one-half the number of organisms collected in March yet flows were nearly the same. The January and February increases may also be partially attributed to a large, five-fold, rise in the numbers of Chironomidae and Simulidae collected. The total number of Chironomidae and Simulidae increased from 1806 in December to 10,742 in January. These larvae, when young, are very small and cylindrical. Their size and shape allows many of them to pass through a net with a pore size of 300µ (Zelt and Clifford, 1972). Since the pore size (540µ) used in this study was larger than 300µ many specimens probably escaped collection in the late summer and fall of 1972. Immature insects apparently grew slowly in the late fall, obtaining a catchable size in early winter; thus explaining the large increase in numbers of Chironomidae and Simulidae in the January collection. Furthermore, Zelt and Clifford (1972) report that a net with a pore size of 300µ misses over half the fauna by number. It seems likely, therefore, that other insects in addition to Chironomidae and Simulidae larvae were not adequately collected during their young stages.

The failure to collect young specimens with fairly coarse meshed nets has been reported in many studies. One consequence of using a coarse net is that apparent increases in numbers are frequently observed during periods when numbers of organisms are probably falling, but an increasing proportion of the surviving specimens are attaining a catchable size (Hynes, 1970b). It is likely that the winter increase in total number collected in this study was due to several factors including: more favorable collecting conditions and the course mesh net used for this study. However, any sampling method selects for particular species. One consequence of using a net with a smaller pore size is that the pores become quickly clogged with sand and detritus reducing the flow of water through the net which subsequently creates eddy currents that allow large, strong swimming species to escape collection. If the more mature specimens escape, their relative abundance in samples will be underestimated. In addition, for most species important taxonomic characteristics are not clearly visible during the early stages of development and failure to collect late instar specimens frequently creates problems of taxonomic identification. Since the total numbers of organisms collected was not as important in this study as the determination of relative abundance of taxa or mere presence-absence of species, I believe that mesh size did not appreciably affect this study. This conclusion is substantiated by the data which indicates definite seasonal and longitudinal trends for the more abundant genera collected.

SEASONAL CHANGE IN NUMBERS OF SPECIES

Seasonal fluctuations in the numbers of species collected in Sinking Creek indicate temporal change in community composition. Seasonally species appear and then disappear in collections as one species after another completes the aquatic portion of its development. Some insect species are present in collections at certain, often quite specific, times during the year (Hynes, 1970b). In Sinking Creek, immature insects observed during specific seasons include some species of Plecoptera and Trichoptera collected only in the fall and winter (winter species) and some Ephemeroptera that were collected only in the spring and summer (summer species). In contrast, other species were present in collections throughout the year. Since immature insects of various species require different periods of time to complete the aquatic portion of development, some species produce more than one generation a year (bivoltine), other species produce a single generation a year (univoltine), and still other species require periods exceeding a year (multivoltine). Variations in types of insect life histories and in season of occurrence (i.e. summer and winter species) partially explains the seasonal fluctuations in numbers of species present at any one time. Seasonal variations in numbers of species collected in Sinking Creek are illustrated in Fig. 8. The data indicates that 97 taxa of immature insects were collected in the study area throughout the year. Seasonally, species numbers varied considerably from month to month during the summer, winter, and spring, but remained relatively constant in the fall.

Fig. 8 Seasonal changes in number of species collected at Stations 1, 2, 5, and 8 on Sinking Creek.


110
100
90
80
70
60
50
40
30
20
10
NUMBERS OF SPECIES
Jy
Au
S
O
N
D
Ja
F
Mr
A
My
Ju
MONTHS

The number of species collected in the summer varied from a low of 55 in July to a high of 75 in September. Emergence and subsequent reproductive activities of sexually mature organisms partially explains monthly variations, i.e. decreasing numbers of species attributable to emergence, and increasing numbers resulting from recruitment due to hatching. The numbers of species collected in the fall varied from a low of 67 in October to a high of 70 in December, while a slightly larger variation was observed in the winter with 74 species present in January and 84 species in March. The observed increase in numbers of species in the winter may be explained, in part by the presence of winter stoneflies (Plecoptera) which hatch in the fall grow rapidly in the winter and emerge in late winter or spring. In the spring, the numbers of species collected varied from 77 in April to 69 in May. Throughout the study the greatest numbers of species were collected in winter with an abundance peak in March, while the lowest number of species were collected in summer.

The presence or absence of individual species at specific times throughout the year influenced monthly fluctuations in numbers of species, with 33 of the 97 species present in collections throughout the year, 8 species absent from collections for one month and 34 species absent for two or more consecutive months. In addition, 22 species were considered uncommon in collections because less than 50 organisms per species were observed in combined samples from all four stations throughout the study. The presence of uncommon species of Sinking Creek may include organisms which inhabited portions of the study area in relatively low numbers due to a variety of natural control factors, organisms that drifted into the stream from other portions of the watershed, organisms that hatched from eggs deposited by adults entering the watershed by chance from adjacent streams, and organisms inadequately collected. Although an explanation of the presence of uncommon species was not apparent from my data, monthly fluctuations in numbers of species can be partially explained by the presence or absence of uncommon species.

SEASONAL CHANGE IN COMMUNITY DOMINANCE

Another indication of temporal change in community composition is the seasonal fluctuation of numerically dominant species collected in Sinking Creek. Combined samples from all four stations show five genera numerically dominated monthly collections of non-dipteran insects throughout the year. These genera include: *Baetis vagans* McDunnough (Ephemeroptera: Baetidae), *Ephemerella lata* Morgan (Ephemeroptera: Ephemerellidae), *Cheumatopysche* sp. Wallengren (Trichoptera: Hydropsychidae), *Optioservus* sp. Sanderson (Coleoptera: Elmidae), *Stenelmis* sp. Dufour (Coleoptera: Elmidae).

In the summer (July through September) *Stenelmis* sp. and *Optioservus* sp. larvae were co-dominant genera, with each genus comprising as much as 18% of the monthly collections. In the fall Optioservus sp. was dominant in October and December representing 19% and 15% of the total monthly collections respectively, while Cheumatopsyche sp. comprised 25% of the November collection. Cheumatopsyche sp., which represented approximately 12% of each monthly collection dominated the January and February samples. March through May appeared to be a transition period with the dominant genus changing each month, i.e., E. lata was numerically dominant in March, Stenelmis sp. in April, and B. vagans in May. In June Optioservus sp. was once again dominant, representing 12% of the total collection.

Seasonal changes in the numerically dominant genera reflect the life history pattern of the insects and may be in accordance with changes in abundance and type of food available (Mackay and Kalff, 1969). As suggested by Sheldon (1972), abundance may be positively correlated with versatility of feeding habits, i.e., omniverous organisms have a larger food supply than organisms with specialized feeding requirements. The larger food supply available to omnivores might support greater numbers than would be possible for organisms having restricted food preference. If organism abundance is a function of versatility of feeding habits, then seasonal change in dominant species may be influenced by changes in type of food available, e.g. algae in the summer and detritus in the fall and winter. In Sinking

Creek, omnivores apparently dominate numerically throughout the year, with the summer insect fauna being dominated by _Stenelmis_ sp. and _Optioservus_ sp. which feed on algae and detritus, and the winter fauna being dominated by _Cheumatopsyche_ sp. which feed chiefly on detritus (Coffman, Cummins and Wuychek, 1971). The dominance of omnivores throughout the year is probably explained by food availability. However, food supply does not adequately explain why one genus of omnivore numerically dominates another. Such an explanation may require an analysis of population control factors. Although an adequate explanation was not obtained regarding factors controlling numerical dominance from this study, the observed seasonal change in dominant organisms indicates that the composition of the insect communities in Sinking Creek continuously changes with season.

TEMPORAL DISTRIBUTIONS OF SELECTED SPECIES

As indicated in the section on seasonal change in numbers of species, temporal change in the abundance of immature insects of a particular species is dependent upon the time required for completion of the aquatic portion of the life history. Figures 9 and 10 show the monthly frequency (number of individuals collected each month per total number collected the entire year at all stations) of the 36 major species collected in Sinking Creek during the study year. It is apparent from the figures that the relative abundance of individual species varied with time throughout the year.

Fig. 9 Temporal distribution of selected Ephemeroptera in Sinking Creek (dotted line indicates less than one percent).

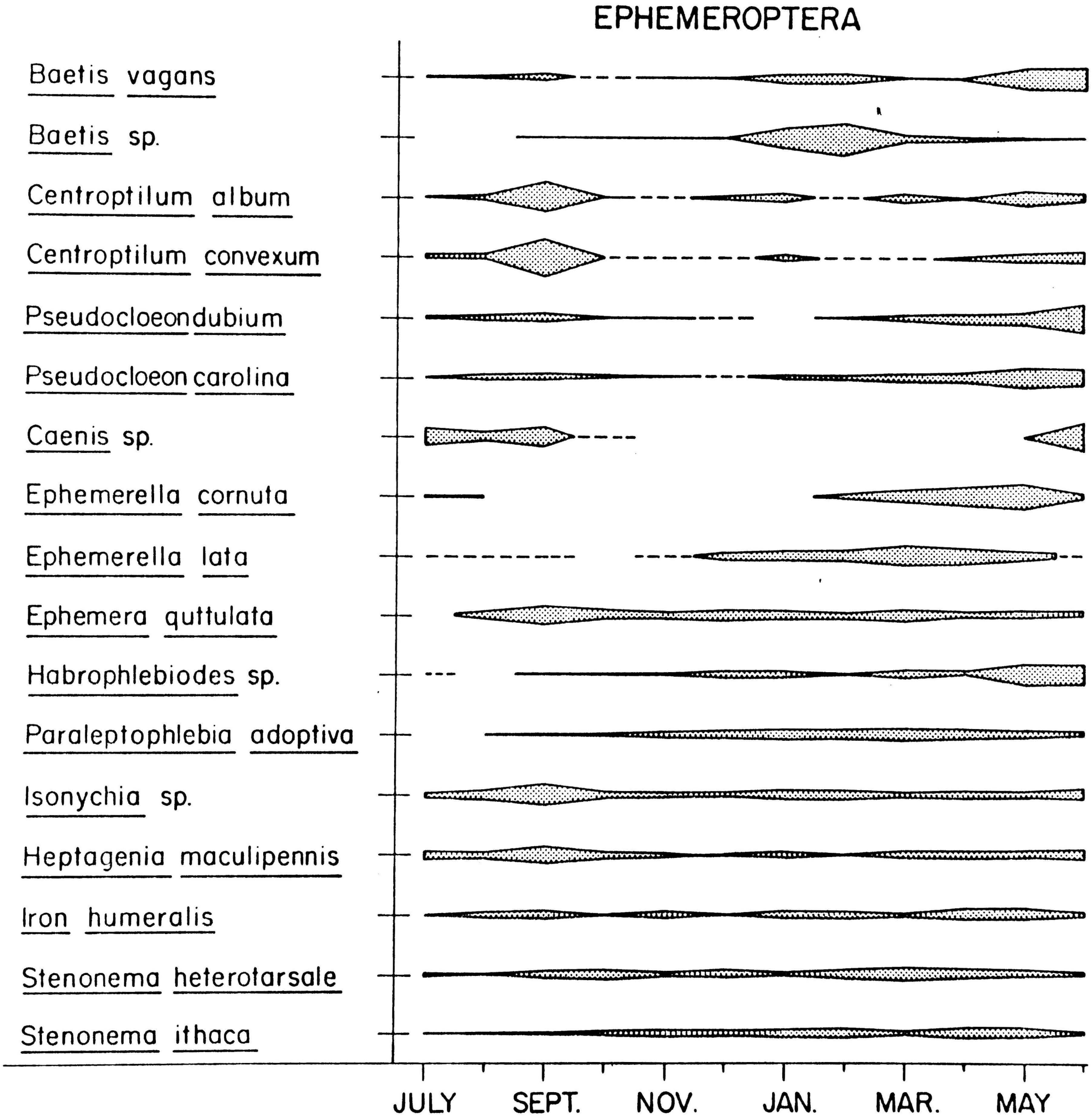
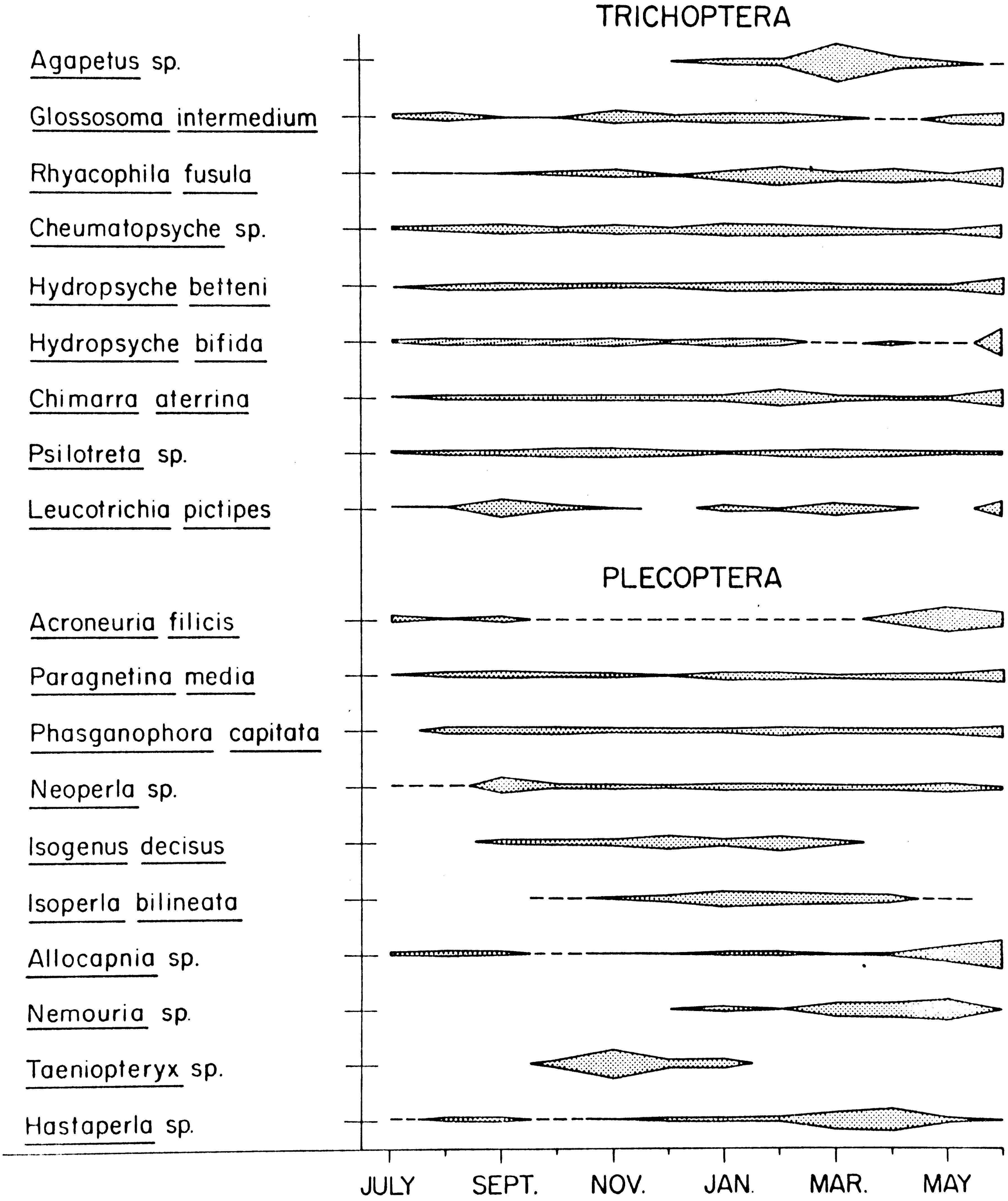

EPHEMEROPTERA
Baetis vagans
Baetis sp.
Centroptilum album
Centroptilum convexum
Pseudocloeon dubium
Pseudocloeon carolina
Caenis sp.
Ephemerella cornuta
Ephemerella lata
Ephemera guttulata
Habrophlebiodes sp.
Paraleptophlebia adoptiva
Isonychia sp.
Heptagenia maculipennis
Iron humeralis
Stenonema heterotarsale
Stenonema ithaca
JULY
SEPT.
NOV.
JAN.
MAR.
MAY

Fig. 10 Temporal distribution of selected Trichoptera and Plecoptera in Sinking Creek (dotted line indicates less than one percent).


TRICHOPTERA
Agapetus sp.
Glossosoma intermedium
Rhyacophila fusula
Cheumatopsyche sp.
Hydropsyche betteni
Hydropsyche bifida
Chimarra aterrina
Psilotreta sp.
Leucotrichia pictipes
PLECOPTERA
Acroneuria filicis
Paragnetina media
Phasganophora capitata
Neoperla sp.
Isogenus decisus
Isoperla bilineata
Allocapnia sp.
Nemouria sp.
Taeniopteryx sp.
Hastaperla sp.
JULY
SEPT.
NOV.
JAN.
MAR.
MAY

Of the 36 numerically dominant species considered, 21 were present in collections throughout the year and 15 species were absent for one or more months. Organisms absent from one or more monthly collections include: *Ephemera guttulata* Picket (Ephemeroptera: Ephemeridae) and *Leucotrichia pictipes* Banks (Trichoptera: Hydroptilidae) collected in greatest abundance in the late summer, *Taeniopterix* sp. Picket (Plecoptera: Nemouridae) collected in greatest abundance in the fall, *Baetis* sp. Leach (Ephemeroptera: Baetidae), *Ephemerella lata* Morgan (Ephemeroptera: Ephemerellidae), *Paraleptophlebia adoptiva* McDunnough (Ephemeroptera: Baetidae), *Agapetus* sp. Curtis (Trichoptera: Rhyacophilidae), *Isogenus decisus* Walker (Plecoptera: Perlodidae) and *Isoperla bilineata* Say (Plecoptera: Perlodidae) collected in greatest abundance in the winter, and *Pseudochloeon dubium* Walsh (Ephemeroptera: Baetidae), *Ephemerella cornuta* Morgan (Ephemeroptera: Ephemerellidae), *Habrophlebiodes* sp. Ulmer (Ephemeroptera: Leptophlebiidae), *Nemouria* sp. Picket (Plecoptera: Nemouridae) and *Phasganophora capitata* Picket (Plecoptera: Perlidae) collected in greatest abundance in the spring. One species was observed to have two abundance peaks separated by a period when organisms were not collected, i.e., *Caenis* sp. Stephens (Ephemeroptera: Baetidae) collected in greatest numbers in the spring and summer. Although inadequate collecting methods may explain the absence of a particular species for periods throughout the year, the absence of a species from collections may indicate periods when organisms are not present as nymphs or larvae, i.e., organisms may be present as pupae (Trichoptera) or unhatched eggs (Ephemeroptera and Plecoptera). Of the 15 species of Ephemeroptera, Plecoptera and Trichoptera absent for various periods throughout the study, organisms absent from monthly collections for relatively long periods include: Caenis sp. absent from November to May, Taeniopterix sp. absent from February to September and Agapetus sp. absent from July to November. The absence of organisms from collections due to variations in life histories coupled with seasonal variations in organism abundance indicate temporal change in the composition of insect communities in Sinking Creek.

LONGITUDINAL DISTRIBUTIONS OF SELECTED SPECIES

Spatial differences in the distributions of stream macrobenthos have been reported at the community and population levels. These differences may be indicated by changes in the species composition of intergrading communities or by changes in the relative abundance of a population along a stream gradient (Elgmork and Saether, 1970). Changes in species composition are the result of variations in species ranges from source to mouth of a stream (Barber and Kevern, 1973). Likewise changes in the relative abundance of a population correspond to environmental change along a stream gradient. Environmental change may cause peaks in organism abundance to occur at points where conditions are most favorable, i.e., 'optimum' relative to the range of conditions available (Minshall, 1968).

An indication of the longitudinal distribution of particular species in a stream can be demonstrated by observing the relative abundance of the species at specific points in the stream over a given time span. Figures 11 and 12 show the longitudinal distribution of selected species in Sinking Creek based upon relative abundance observed at each station throughout the study period. Relative abundance is expressed by the yearly total number of individuals of a particular species collected at a station as a percent of the yearly total number of specimens of that species collected at all four stations. It is apparent from Figures 11 and 12 that many of the species collected were ubiquitously distributed throughout the length of the stream. Of the 36 numerically dominant species considered 33 species were collected at all stations. Organisms absent at one or more stations include: Phasganophora captita Picket (Plecoptera: Perlidae) collected at Stations 1 and 2; Leucotrichia pictipes Banks (Trichoptera: Hydroptilidae) collected at Stations 2, 5, and 8; and Ephemera guttulata Picket (Ephemeroptera: Ephemeridae) collected at Stations 5 and 8. Anchytarsus sp. Gverin (Coleoptera: Ptilodactylidae) collected only at Station 1 is not included in the figures. It appears that the majority of the species collected are eurytopic forms. However, an analysis of the relative abundance of each

Fig. 11 Longitudinal distribution of selected Ephemeroptera in Sinking Creek (dotted line indicates less than one percent).

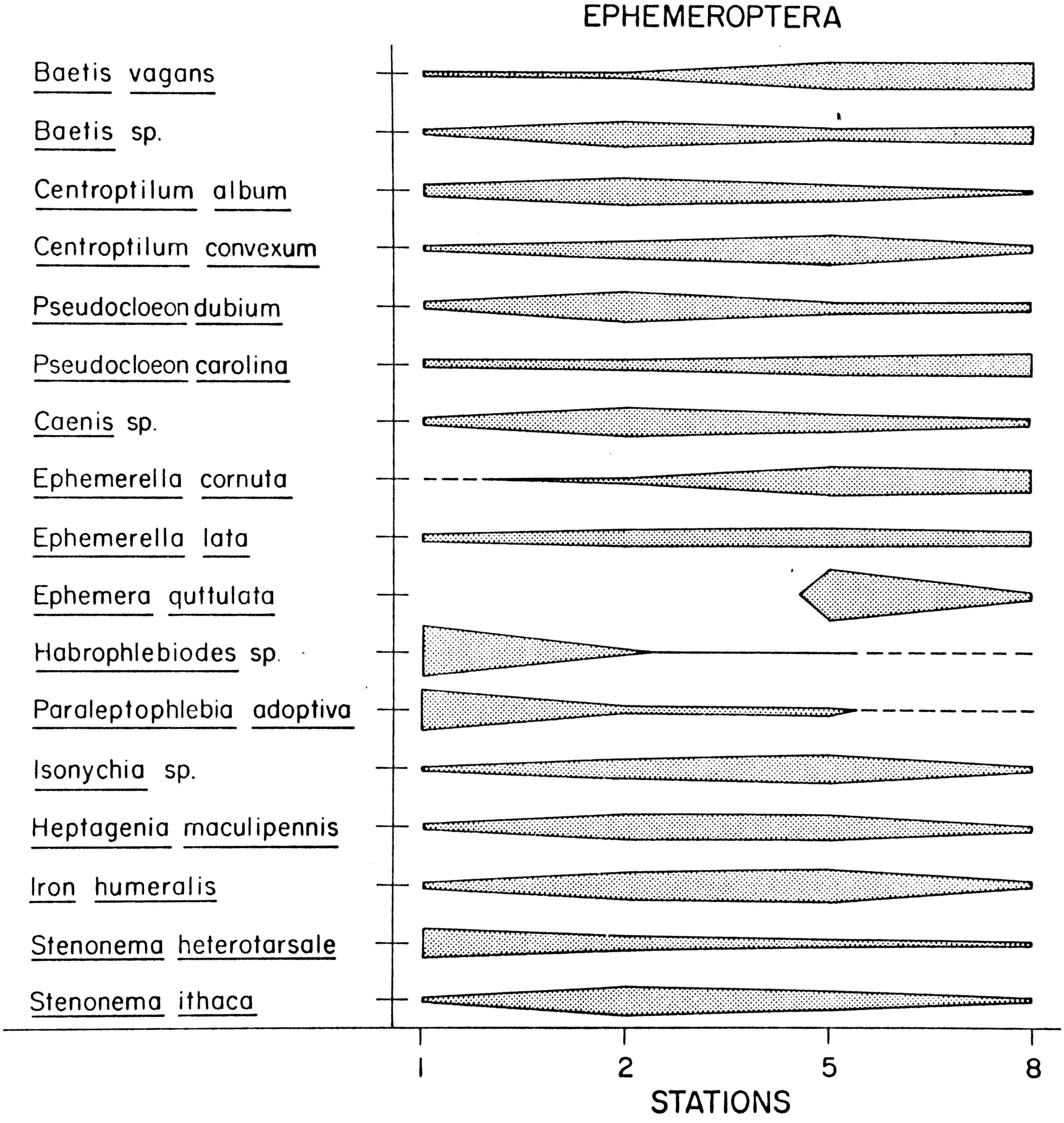
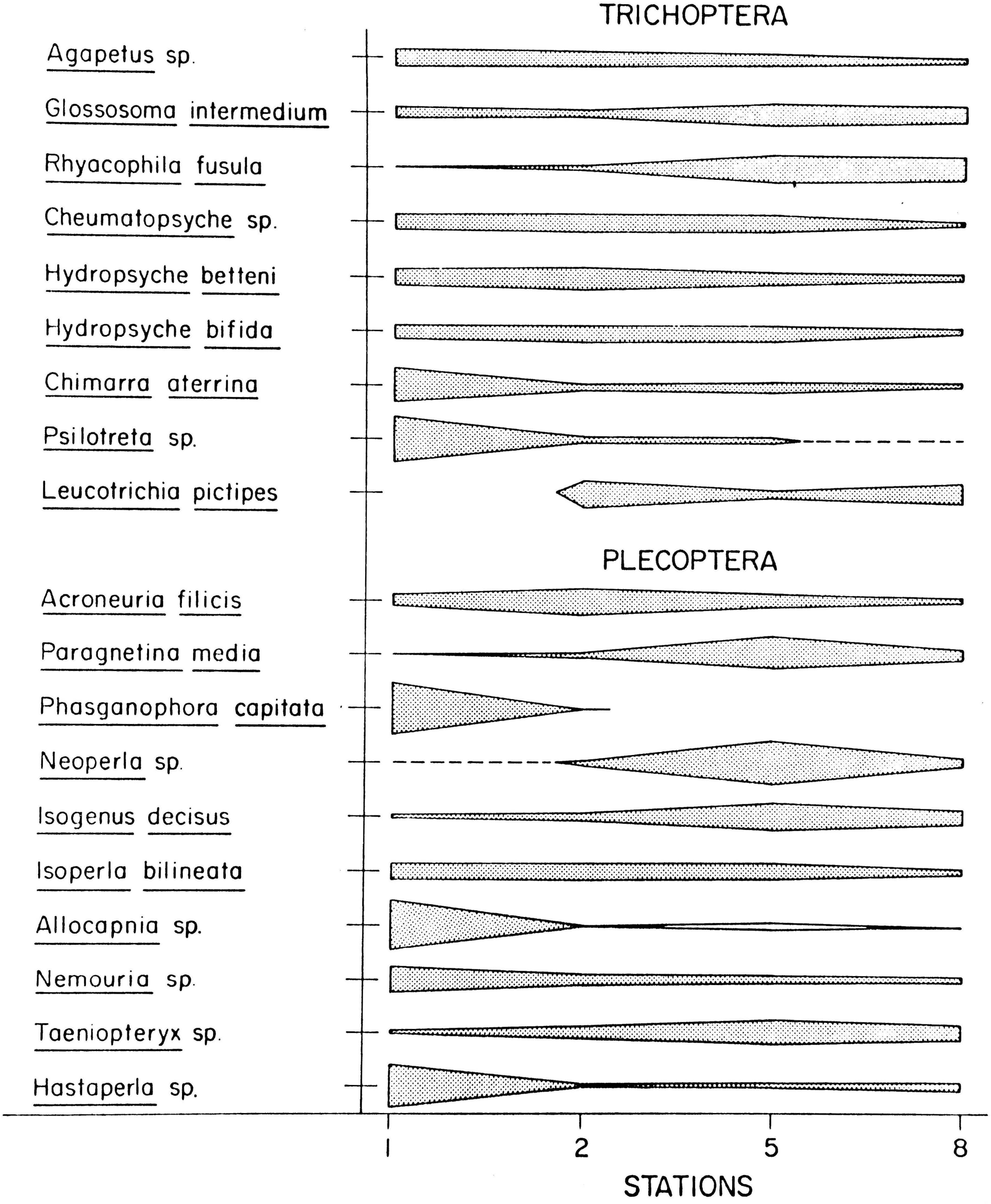

EPHEMEROPTERA
Baetis vagans
Baetis sp.
Centroptilum album
Centroptilum convexum
Pseudocloeon dubium
Pseudocloeon carolina
Caenis sp.
Ephemerella cornuta
Ephemerella lata
Ephemera guttulata
Habrophlebiodes sp.
Paraleptophlebia adoptiva
Isonychia sp.
Heptagenia maculipennis
Iron humeralis
Stenonema heterotarsale
Stenonema ithaca
1
2
5
8
STATIONS

Fig. 12 Longitudinal distribution of selected Trichoptera and Plecoptera in Sinking Creek (dotted line indicates less than one percent).


TRICHOPTERA
Agapetus sp.
Glossosoma intermedium
Rhyacophila fusula
Cheumatopsyche sp.
Hydropsyche betteni
Hydropsyche bifida
Chimarra aterrina
Psilotreta sp.
Leucotrichia pictipes
PLECOPTERA
Acroneuria filicis
Paragnetina media
Phasganophora capitata
Neoperla sp.
Isogenus decisus
Isoperla bilineata
Allocapnia sp.
Nemouria sp.
Taeniopteryx sp.
Hastaperla sp.
1
2
5
8
STATIONS

species collected indicates that 30 were collected in greater numbers at one station and fewer numbers at the other stations, i.e., nine species were collected in greater numbers at Station 1, seven at Station 2, twelve at Station 5, and one at Station 8. Four species were collected in approximately equivalent numbers at two or more stations, they include: *Heptagenia maculipennis* McDunnough (Ephemeroptera: Heptageniidae) and *Hydropsyche bifida* Banks (Trichoptera: Hydropsychidae) collected at Stations 2 and 5; and *Cheumatopsyche* sp. Wallengren (Trichoptera: Hydropsychidae) and *Isoperla bilineata* Say (Plecoptera: Pelodidae) were collected at Stations 1, 2, and 5.

Several species demonstrated marked change in the numbers of specimens collected at two successive stations. This change is illustrated by variations in kite width with increasing kite width representing increasing relative abundance. Species demonstrating marked change in relative abundance at successive stations include: *Paraleptophlebia adoptiva* McDunnough (Ephemeroptera: Leptophlebilidae), *Habrophlebiodes* sp. Ulmer (Ephemeroptera: Leptophlebiidae), *Psilotreta* sp. Banks (Trichoptera: Odontoceridae), *Paragnetina media* Walker (Plecoptera: Perlidae), *Neoperla clymene* Newman (Plecoptera: Perlidae), *Allocapnia* sp. Claasen (Plecoptera: Nemouridae) and *Hastoperla* sp. Ricker (Plecoptera: Chloroperlidae).

Paraleptophlebia adoptiva, *Habrophlebiodes* sp., Psilotreta sp., Allocapnia sp. and Hastoperla sp. were collected in greater numbers at Station 1 than at Station 2, with more than 70% of the specimens of each species collected at Station 1 and less than 15% at Station 2. Conversely, P. media, and Neoperla sp. were more abundant at Station 5 than at Station 2, with more than 70% of the specimens of each species being collected at Station 5 and less than 10% at Station 2.

An analysis of the data indicates that at least two different types of distribution were observed in Sinking Creek: some species had a restricted distribution indicated by their absence at one or more stations; other species were present at all stations. The relative abundance of each species present at all stations, however, varied at points along the stream gradient. Variations in relative abundance include species collected in greater numbers at Station 1 and/or 2 and in decreasing numbers at the remaining stations, species collected in greater numbers at Stations 2 and/or 5 and in decreasing numbers at Stations 1 and 8, and species collected in greater numbers at Stations 5 and/or 8 and in fewer numbers at Station 1 and 2. If it is assumed that the peaks in organism abundance illustrated in this study occur at stations where environmental conditions are most favorable relative to the conditions available at the four stations, then spacial variations in the relative abundance of individual species occur in response to changes in stream environment. These environmental changes may include variation in temperature, substrate, current velocity, and food availability.

TEMPORAL AND SPACIAL SEGREGATION OF CLOSELY RELATED SPECIES

The diversity of aquatic insect fauna is often enhanced by temporal and spatial segregation of closely related organisms. This segregation insures the efficient utilization of vital resources, i.e., food and space, and reduces interspecific competition (MacKay and Kalff, 1969). Closely related species may be temporally separated by type of life history. Aquatic insects exhibit diverse types of life histories which allow species to develop at different times of the year. When extensive overlap in emergence periods occurs, closely related species may differ markedly in size with the young at different stages of growth, i.e., one is always smaller than the other. Usually the smaller, possibly younger, organisms inhabit crevices and utilize food particles which are not suitable for use by the larger specimens (Mackay, 1972). Closely related species, if not temporally segregated, may be spacially separated. Spacial segregations occur when species occupy different stretches of a stream, different types of substrate, or different areas of the same habitat (Grant and Mackay, 1969). The segregation of closely related organisms, either through space, time, or a combination of both may partially explain the diverse insect fauna collected in Sinking Creek.

CLOSELY RELATED SPECIES EXHIBITING SPACIAL SEGREGATIONS

Obvious examples of closely related species exhibiting spacial segregations in Sinking Creek occurred in two families of Ephemeroptera (Baetidae and Heptageniidae) and one family of Plecoptera (Perlidae). The Baetidae included *Centroptilum album* McDunnough *Centroptilum convexum* Ide, *Pseudocloeon dubium* Walsh, and *Pseudocloeon carolina* Klapálek. The Heptageniidae were represented by *Stenomena heterotarsale* McDunnough and *Stenomena ithaca* Clemens and Leonard. The Perlidae included *Phasganophora capitata* Picket, *Paragnetina media* Say, *Acroneuria filicis* Frison, and *Neoperla clymene* Newman.

The spacial segregation of *Centroptilum album* and *Centroptilum convexum* is indicated by an analysis of longitudinal changes in organism abundance (Fig. 11). Approximately one-half (46%) of all *C. album* collected were from Station 2 while 21%, 29% and 4% were collected at Stations 1, 5, and 8, respectively. On the other hand, 50% of the total number of *C. convexum* were collected at Station 5 and abundance decreased to 12% at Station 1, 29% at Station 2 and 9% at Station 8. Variations in the relative abundance of organisms collected at various points along the stream indicate that *C. album* increased in abundance from Station 1 to Station 2 then decreased at Stations 5 and 8, while *C. convexum* was collected in greatest numbers at Station 5. Although both species were collected at all stations, approximately two-thirds of all _C. album_ collected were spacially segregated from 59% of the _C. convexum_ i.e., sixty-seven percent of all _C. album_ were collected at Stations 1 and 2 while 59% of all _C. convexum_ were collected at Stations 5 and 8.

A second example of spacial segregation of closely related species is illustrated by _Pseudocloeon carolina_ and _Pseudocloeon dubium_ (Fig. 11). Abundance of _P. carolina_ nymphs increased steadily in a downstream direction with 13%, 17%, 30%, and 40% of the specimens being collected at Stations 1, 2, 5, and 8, respectively. Conversely, the relative abundance of _P. dubium_ increased from 12% at Station 1 to 51% at Station 2, then decreased to 20% and 17% at Stations 5 and 8, respectively. The data indicate that _P. dubium_ was collected in greater numbers at Stations 1 and 2, while _P. carolina_ was more abundant at Stations 5 and 8, i.e., 63% of the _P. dubium_ nymphs were collected at Stations 1 and 2 while 70% of the _P. carolina_ occurred in samples from Stations 5 and 8. Although these closely related species did not occupy different points along the stream gradient, partial spacial segregation is evident from variations in respective abundance peaks.

Stenonema ithaca and _S. heterotarsale_ illustrate a third example of the spacial segregation of closely related organisms (Fig. 11). The data indicate that approximately one-half of all _S. ithaca_ collected were at Station 2. The number of organisms decreased at the other stations with 9% at Station 1, 37% at Station 5 and 6% at Station 8. Fifty-seven percent of the total number of *S. heterotarsale* were collected at Station 1 and abundance decreased steadily in the downstream direction with 29%, 12% and 4% of the specimens being collected at Stations 2, 5, and 8, respectively. Although both species of *Stenonema* were more abundant at Stations 1 and 2, approximately one half of all *S. heterotarsale* were collected at Station 1, while 90% of all *S. ithaca* were collected at Stations 2, 5, and 8. This observed spacial segregation of closely related organisms probably reduced interspecific competition.

Four genera of stoneflies (Plecoptera) illustrate the fourth example of the spacial segregation of closely related organisms (Fig. 12). The distribution of each species included increased abundance of organisms at one of the four stations and decreased abundance at the remaining stations. Ninty-nine percent of the nymphs of *Phasganophora capitata* were collected at Station 1, 1% were collected at Station 2, and *P. capitata* was not collected at Stations 5 and 8. *Acroneuria filicis* was collected in greater numbers at Station 2 and in lesser numbers at the remaining stations. The relative abundance of *Neoperla clymene* decreased from 80% at Station 5 to 1% at Station 1, 7% at Station 2 and 12% at Station 8. *Paragnetinia media* was collected in relatively low numbers at Stations 1, 2, and 8, while 71% of the total nymphs collected were taken at Station 5. Thus, *Phasganophora capitata* was spacially segregated from *N. clymene* and *P. media*. Furthermore, two-thirds of the *A. felicis* collected (at Stations 1 and 2) were spacially segregated from 92% of the *P. media* and *N. clymene* (collected at Stations 5 and 8). Since the observed distributions of *P. media* and *N. clymene* were similar with greatest abundance of both organisms collected at Station 5, it is possible that interspecific competition was reduced by organisms occupying different types of substrate or different areas of the same habitat.

CLOSELY RELATED SPECIES EXHIBITING TEMPORAL SEGREGATIONS

Two families of Ephemeroptera (Ephemerellidae and Leptophlebiidae) and one family of Plecoptera (Perlodidae) illustrate temporal segregations of closely related organisms collected in Sinking Creek.

The temporal segregation of closely related Ephemerellidae is illustrated by *Ephemerella lata* and *Ephemerella cornuta* (Fig. 9). *Ephemerella lata* was collected throughout the year, with relatively low numbers of organisms collected from July through November, 1972. Numbers increased in the December samples, rose steadily from January through February and peaked in March. Numbers of *E. lata* decreased in the spring and the June collection contained numbers roughly comparable to those observed the previous Fall. The spring decrease is attributable to a combination of emergence and mortality.

Ephemerella cornuta was not collected from August through January, which may be explained by egg diapause during the higher water temperatures of summer and fall or by failure to collect young nymphs which may have hatched during the fall and grew slowly in the early winter. Numbers of *E. cornuta* increased in the February, March, April, and May collections and decreased in June. A comparison of the monthly fluctuations in the abundance of *E. lata* and *E. cornuta* indicates that organisms were either not collected or observed in relatively low numbers in the summer and fall. During the remainder of the year, the data indicate that the two species were temporally segregated. *Ephemerella lata*, was most abundant in March, while an abundance peak for *E. cornuta* was observed in May (a period of decreasing numbers of *E. lata*). Furthermore, *E. lata* was collected from December through June. The appearance of *E. lata* earlier in the winter indicates that this mayfly either hatched early in the year, or grew more rapidly than *E. cornuta*. Thus *E. lata* nymphs were probably larger and in later stages of development than *E. cornuta* throughout the winter and early spring. In addition, *E. lata* decreased in numbers in April and May indicating emergence, while a similar decrease in numbers of *E. cornuta* was not observed until June. This difference in apparent times of emergence as well as differences in periods of greatest abundance illustrates the temporal segregation of *E. lata* and *E. cornuta*.

Leptophlebiidae which exhibited temporal segregation include *Paraleptophlebia adoptiva* and *Habrophlebiodes* sp. *Paraleptophlebia adoptiva* was collected in relatively low numbers from July to October, numbers of organisms increased monthly during the fall and winter with an abundance peak in March. In the spring *P. adoptiva* decreased in numbers with 16% and 6% of the yearly total being collected in May and June respectively. This decrease may be attributed to emergence. Relatively low numbers of *Habrophlebiodes* sp. nymphs were observed from July to November with less than 1% of the yearly total collected each month. One exception occurred in August when *Habrophlebiodes* was absent from collections. Abundance increased slightly in the winter and early spring fluctuating from a low of 2% to a high of 11% of the yearly total, and peaked in May and June. A comparison of the monthly fluctuations in numbers of *P. adoptiva* and *Habrophlebiodes* sp. indicates *P. adoptiva* nymphs increased in abundance in the winter and decreased in the spring, while *Habrophlebiodes* sp. nymphs were collected in relatively low numbers in winter and in greater numbers in spring. In addition, an increase in the abundance of *P. adoptiva* nymphs was observed in October and November while a similar increase in the abundance of *Habrophlebiodes* sp. nymphs was not observed until December and January. Temporal differences associated with increases in organism abundance and variations in occurrence of abundance peaks illustrate the segregation of *P. adoptiva* and *Habrophlebiodes* sp.

Isoperla bilineata and *Isogenus decisus* illustrate the temporal segregation of similarly adapted stoneflies. *Isoperla* was present in October through May collections with an abundance peak in January while *Isogenus* nymphs were observed from September to March with increased abundance in December (23% of the yearly total) and February (26% of the yearly total). Although abundance peaks for both organisms were observed in the winter, it appears that *I. decisus* nymphs hatched, matured, and emerged earlier in the year (September to March) than *I. bilineata* (October to May) e.g. in March and April 37% of the yearly total *I. bilineata* nymphs were collected while 5% of the *I. decisus* nymphs were observed during the same period, thus *I. decisus* probably emerged slightly early in the year than *I. bilineata*. Variations in periods of presence and absence of individual species coupled with variations in monthly relative abundance illustrate the temporal separation of *I. bilineata* and *I. decisus*.

CLOSELY RELATED SPECIES EXHIBITING SPACIAL AND TEMPORAL SEGREGATIONS

Organisms exhibiting spacial and temporal segregations are represented by one family of Ephemeroptera (Baetidae), one family of Trichoptera (Rhyacophilidae) and one family of Plecoptera (Nemouridae). The Baetidae include *Baetis vagans*

McDunnough and *Baetis* sp. Leech. *Glossosoma intermedium* Klapálek and *Agapetus* sp. Curtis represent the Rhyacophilidae and the Nemouridae include *Nemoura* sp. Picket, *Allocapnia* sp. Claassen and *Taeniopteryx* sp. Picket.

The spacial and temporal segregation of *B. vagans* and *Baetis* sp. is indicated by an analysis of seasonal and longitudinal fluctuations in relative abundance (Figs. 9,11). *Baetis vagans* was collected in relatively low numbers from July to December. Relative abundance increased to 10% of the yearly total in January and February, then decreased to 2% and 1% in March and April respectively. Organism abundance increased and peaked in May (34%) and June (34%). The number of *B. vagans* nymphs collected increased in the downstream direction with 4%, 4%, 43% and 49% of the yearly total being collected at Stations 1, 2, 5, and 8, respectively. Conversely, *Baetis* sp. was not collected in July and August and relatively low numbers (1% of yearly total) were collected monthly from September to December. Organism abundance increased in January (32%), peaked in February (49%) and decreased in March (10%), April (4%), May (2%) and June (not collected). The greatest number of *Baetis* sp. were collected at Station 2 (42%) while fewer numbers of organisms were collected at the remaining stations i.e. 6% at Station 1, 19% at Station 5, and 32% at Station 8. A comparison of seasonal and longitudinal variations in relative abundance indicates that 48% of the *Baetis* sp. nymphs were spacially separated (collected at Stations 1 and 2) from 92% of the B. vagans nymphs (collected at Stations 5 and 8). In addition, Baetis sp. was most abundant in winter while B. vagans was collected in greater numbers in summer. Seasonal and longitudinal differences in peak abundance illustrate the segregation of closely related Baetidae.

A comparison of the spacial and temporal distributions of closely related Rhyacophilidae indicates that Glossosoma intermedium larvae were collected in greatest numbers in November (20%) and June (17%); throughout the remainder of the year organism abundance varied from 14% in January to less than 1% in April. The greatest number of G. intermedium larvae were collected at Station 5 (40%). Organism abundance decreased at the remaining stations with 21% collected at Station 1, 14% at Station 2 and 24% at Station 8. Agapetus sp. larvae, on the other hand, were not observed in the July through November samples. Larvae were present in collections throughout the remainder of the year with an abundance peak in March (64%) and April (23%). Agapetus sp. larvae were collected in greater numbers at Stations 1 (33%) and 2 (30%) and in lesser numbers at Stations 5 (25%) and 8 (12%). The abundance peak of Agapetus sp. in March coupled with the greater numbers of larvae collected at Stations 1 and 2 indicate the larvae were spacially and temporally segregated from G. intermedium which was most abundant in November and June at Stations 5 and 8.

The spacial and temporal segregation of Nemoura sp., Allocapnia sp., and Taeniopteryx sp. is illustrated by variations in seasonal and longitudinal abundance peaks (Figs. 10, 12). Nemoura sp. nymphs were observed in the December through June samples with an abundance peak in May. The relative abundance of Nemoura sp. nymphs decreased in the downstream direction with 47%, 23%, 16%, and 13% collected at Stations 1, 2, 5, and 8, respectively. Taeniopteryx sp. nymphs were collected from October through January with an abundance peak in November. Organisms were most abundant at Stations 5 and 8 where 47% and 28% of the yearly total were collected, respectively. Although Allocapnia sp. nymphs were collected throughout the year, more than three-quarters of the yearly total appeared in the spring samples and 88% of all organisms were collected at Station 1. The spacial and temporal segregation of closely related Nemouridae is indicated by variations in organism abundance with Taeniopteryx sp. collected in greatest number in November at Stations 5 and 8. Allocapnia sp. most abundant at Station 1 in May and June, and Nemoura sp. collected in peak abundance from March through May at Stations 1 and 2. Thus Taeniopteryx sp. was spacially and temporally separated from Allocapnia sp. and Nemoura sp. while Nemoura sp. was temporally segregated from Allocapnia sp.

CLOSELY RELATED SPECIES EXHIBITING NEITHER SPACIAL NOR TEMPORAL SEGREGATIONS

Organisms which did not exhibit apparent spacial or temporal segregations are represented by one family of Trichoptera (Hydropsychidae) including *Cheumatopsyche* sp. Wallengren, *Hydropsyche* Nr. *betteni* Ross and *Hydropsyche* Nr. *bifida* Banks (Figs. 10, 12).

Larvae of *Cheumatopsyche* sp. *H*. Nr. *betteni* and *H*. Nr. *bifida* were collected throughout the year at all four stations. The longitudinal distributions of each of the three species were similar with greater numbers of larvae collected at Stations 1, 2, and 5 and fewer numbers collected at Station 8. The relative abundance of *Cheumatopsyche* sp. was 31%, 33%, 32%, and 4% at Stations 1, 2, 5, and 8, respectively, while 33%, 40%, 23% and 5% of the *H*. *betteni* larvae were collected at each of the four respective Stations (1, 2, 5, and 8). Similarly, 25%, 30%, and 32% of the *H*. *bifida* were collected at Stations 1, 2, and 5 respectively, while 13% were collected at Station 8. Seasonal variations in the relative abundance of each of the three organisms were similar with the greatest abundance of *H*. Nr. *betteni* and *H*. Nr. *bifida* occurring in June and the largest number of *Cheumatopsyche* sp. being collected in February and June. Similarities in the seasonal and longitudinal distribution of *H*. *betteni*, *H*. *bifida*, and *Cheumatopsyche* sp. larvae indicate organisms were neither spacially (i.e., each species inhabiting different portions of the stream) nor temporally separated.

Cheumatopsyche sp. has been reported to be a detritivore, while several species of *Hydropsyche* including *Hydropsyche betteni* are carnivors (Coffman et. al., 1971). Since differences in food preferences may reduce interspecific competition, the three species coexist without the benefit of spacial and/or temporal segregation.

SPECULATIONS ON A FACTOR INFLUENCING THE DISTRIBUTIONS OF SELECTED SPECIES

Several investigators have attempted to correlate the distribution of aquatic insect species with specific environmental parameters. Minshall (1968), for example, reports that variation within the basic community type in Morgans Creek results primarily from the interplay of temperature, substrate and flow. Similarly, Mackay and Kalff (1969) suggest that the current which is responsible for a stony substrate also reduces the accumulation of food material. The apparent relationship between current, substrate and food availability influences the occurrence and abundance of aquatic insects with particular species occurring in greater numbers where food is readily available (Hynes, 1970b). Although some environmental relationships have been recognized, it is often not possible to correlate specific environmental relationships with the longitudinal distribution of a particular species. This inability to adequately explain the longitudinal distributions of some species collected in Sinking Creek arises from a lack of information on their particular environmental requirements for temperature, substrate and current velocities. It is possible, however, to speculate on the influence of food on the longitudinal distributions of selected species in Sinking Creek.

The importance of food as a factor influencing the distribution of several insect species has been demonstrated in a single riffle where increased organism abundance was correlated with increasing amounts of detritus present at various sampling sites (Egglishaw, 1969). In Sinking Creek, *Baetis vagans* McDunnough (Ephemeroptera: Baetidae) and *Pseudocloeon carolina* Klapalek (Ephemeroptera: Baetidae) were collected at all stations. Both *B. vagans* and *P. carolina* appeared in relatively low numbers at Stations 1 and 2, while numbers of specimens increased at Stations 5 and 8. Since food availability reportedly affected species abundance throughout a riffle, the increasing amounts of detritus and algae associated with increasing length of flow may have influenced the observed distribution of *B. vagans* and *P. carolina* at various points in Sinking Creek.

The influence of food on the distributions of species which feed primarily on material other than algae and detritus is illustrated by two carnivorous species. Greater numbers of *Isoperla bilineata* Say (Plecoptera: Perlodidae) and *Isogenus decisus* Walker (Plecoptera: Perlodidae) were collected at stations where their reported prey also appeared to be more abundant. The reported prey of *Isoperla* and *Isogenus* include: *Allocapnia*, *Paraleptophlebia*, *Baetis*, *Centroptilium* and *Pseudocloeon* (Minshall, 1967). Prey were collected in relatively greater numbers at Stations 1, 2 and 5 with *Paraleptophlebia adoptiva* and *Allocapnia* sp. being most abundant at Station 1, *Baetis* sp., *Centroptilium album* and *Pseudocloeon dubium* at Station 2, and *Baetis vagans* and *Centroptilium convexum* at Station 5. Of the 7 prey species considered, 5 were collected in relatively low numbers during the fall and winter which is the period when _I. decisus_ and _I. bilineata_ were observed in Sinking Creek. It is possible, however, that the nymphs of the five prey species hatched in the fall and grew slowly during the winter; their small size allowing them to escape collection. Assuming that these nymphs were present in the fall and winter, they would have been suitable prey for the stoneflies. The observed abundance of prey thus changed not only from station to station but also from month to month possibly indicating a succession of prey species existed in the study area. Such a succession would not only insure a large number of prey at each station but also a large variation in their size. This size variation among species would occur with the hatching of eggs and the growth of nymphs at different times throughout the year. Since _Isoperla bilineata_ and _I. decisus_ exhibit egg diapause, the hatching of nymphs might occur over an extended period of time due to variations in length of diapause (Minshall and Minshall, 1966). Nymphs which hatched earlier in the year might be larger than those which hatched at a later date. Because of physical limitations younger nymphs might require smaller prey than older, larger organisms.

Various size prey, available from a succession of species, would represent an adequate supply of food which may have influenced the observed distribution of the stoneflies. Although food supply may partially explain the distribution of the predators other environmental factors including temperature, interspecific competition, and current velocity, probably influenced the abundance of _I. decisus_ at Stations 1 and 2; i.e. prey were collected in relatively large numbers at Stations 1 and 2, while _I. decisus_ was collected in relatively low numbers.

CONCLUSIONS

Monthly measurements made in Sinking Creek from July, 1972 through June, 1973 indicated general trends in the seasonal and longitudinal variations of selected physical and chemical parameters. Physical parameters included temperature, conductivity, color and turbidity. Water temperatures followed air temperatures at all eight stations reaching maximum values in the summer, minimum values in winter, and exhibiting rapidly changing values in the spring and fall. During the summer maximum water temperatures (23°C) at Stations 1 and 2 were generally lower than at other stations, while generally maximum water temperatures(25.5°C) were recorded at Station 2. Yearly means for specific conductance were lower at Station 1, of intermediate values at Stations 2 through 7 and greater at Station 8. Longitudinal variations for color and turbidity included generally lower yearly means at Station 1 than observed at the remaining stations.

Chemical parameters included dissolved oxygen, hydrogen ion concentration (pH), alkalinity, total hardness, total phosphate, nitrate iron, manganese, silicia and sulfate. Throughout the year dissolved oxygen was near or above saturation, with measurements indicating dissolved oxygen super saturation being not uncommon. Seasonal and longitudinal variations in pH were not conspiciously evident and were not considered in detail. Yearly means for alkalinity and total hardness increased in the downstream direction, while seasonal variations for both parameters included lower solute concentrations during low flow. Total phosphate measurements indicated yearly means were similar at all eight stations. Yearly means for nitrate increased from Station 1 to 2, then fluctuated at Stations 3 through 8. Iron measurements indicated a larger yearly mean and a greater range at Station 1 than at the other stations. Chemical parameters which did not exhibit conspicious seasonal and longitudinal variation included manganese, sulfate and silica.

Biological sampling of immature aquatic insects collected in Sinking Creek indicated seasonal variations in total numbers of organisms and species collected. The greatest numbers of organisms were collected in September, 1972 and June, 1973, while the smallest numbers were collected in July, 1972. Seasonal changes in numbers of species included 33 species present in collections throughout the year, 8 absent from collections for one month, 34 absent for two or more consecutive months and 22 species considered uncommon.

Temporal change in community composition was indicated by seasonal change in numerically dominant organisms. Five genera numerically dominated monthly collections in Sinking Creek.

The temporal and spacial distributions of 36 selected species were considered. The temporal distribution of the 36 species included 21 present in collections throughout the year and 15 absent for one or more months. Two different types of longitudianl distributions were observed in Sinking Creek. Some species had restricted distributions indicated by their absence at one or more stations. Other species were present at all stations, however, varied in organism abundance at points along the stream gradient.

Closely related species exhibited spacial and/or temporal segregations. Obvious examples of closely related species exhibiting spacial segregations in Sinking Creek occurred in two families of Ephemeroptera (Baetidae and Heptageniidae) and one family of Plecoptera (Perlidae). Two families of Ephemeroptera (Ephemerellidae and Leptophlebiidae) and one family of Plecoptera (Perlodidae) illustrated the temporal segregation of closely related species. Organisms exhibiting spacial and temporal segregations were represented by one family of Ephemeroptera (Baetidae), one family of Trichoptera (Rhyacophilidae) and one family of Plecoptera (Nemouridae). Closely related organisms which did not exhibit apparent spacial or temporal segregations were represented by one family of Trichoptera (Hydropsychidae).

Speculations on the possible influence of food on the longitudinal distribution of one family of Ephemeroptera (Baetidae) and one family of Plecoptera (Perlodidae) indicate the need for further study correlating the food habits and longitudinal distributions of aquatic insects in Sinking Creek.

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APPENDIX I

STATION DESCRIPTIONS

At Station 1, located 320 meters downstream from State Route 625 (U.S. Geol. Serv. Craig Spring, Va. Quadrangle, 7.5 minute series, No. 4959 III E). The riffle was 3.1 meters wide and at normal flow varied from .1 to .25 meters deep. Rubble, gravel, and coarse sand comprised the substrate with particle size not exceeding 0.4 meters in diameter. Upstream of the State Route 625 bridge the stream flowed through areas of dense overhanging brush and stands of trees, whereas the area downstream of the bridge consisted of pasture on both banks of the stream.

Station 2 was located 1.45 kilometers downstream of the State Route 42 bridge near Maywood School (Map ref. same as above). Downstream from this bridge, the stream flowed parallel to State Route 629 and through an area characterized by large areas of cleared land used primarily for agriculture. Trees and brush were present only in scattered locations along the stream banks. The riffle was approximately 6.1 meters wide and flow varied from 0.2 to 0.4 meters deep. The substrate consisted of rubble, gravel, and coarse sand with particle size less than .5 meters in diameter.

Station 3 was located 650 meters downstream from the State Route 627 bridge near Valley Mill (Map ref. same as Station 1). Downstream from the bridge the stream flowed through areas of dense overhanging brush and trees. The riffle was 8.0 meters wide and average depth varied from 0.2 to 0.4 meters. Rubble, gravel and coarse sand comprised the substrate with particle size not exceeding 0.4 meters in diameter.

Station 4 was located 470 meters downstream from the State Route 629 bridge and 920 meters upstream from the State Route 630 bridge (U.S. Geol. Serv. Newport, Va. Quadrangle 7.4 minute series no. 4958 IV N.W.) the collecting transect was 10.5 meters wide and flow varied from 0.1 to 0.4 meters deep. The substrate consisted of gravel to cobble sized rocks, particle size was less than 0.2 meters in diameter.

Station 5 was located near the village of Huffman, Virginia (Map ref. same as above) and approximately 300 meters upstream from the confluence of Sinking Creek and an unnamed tributary from Happy Hollow. Drainage from several agriculture barns, decomposing organic matter remaining after private refuse had been burned, and a pile of spent coal slag, all characterized the northwest bank of the riffle. No attempt was made to determine possible effects of this run-off. However, it is likely that any influence may have been minimal due to the possible channelization of run-off and the increased current velocity in the riffle area. Both banks of the stream were cleared of trees and used extensively by grazing cattle. All samples were collected on the northwest side of an island located 2.5 meters from the southwest bank of the stream. The collecting area was approximately 14.7 meters wide and the substrate consisted of scattered boulders, gravel, and coarse sand. Except for the large boulders, some of which were 1 to 2 meters in diameter, particle size was less than 0.5 meters in diameter. Average depth varied from 0.1 to 0.3 meters.

Station 6 was located 30 meters downstream from the State Route 703 bridge (same map ref. as Station 4). The riffle was 11 meters wide and average depth varied from 0.2 to 0.5 meters. The substrate consisted of coarse sand, gravel, and rubble with particle size less than 0.5 meters in diameter.

Station 7 was located near the village of Newport, Va. and 920 meters downstream from the State Route 42 bridge (samemap ref. as Station 4); the riffle was 13 meters wide and average depth was 0.2 to 0.5 meters, the substrate consisted of mud, gravel, and rubble with particle size less than 0.3 meters in diameter.

Station 8 was located approximately 100 meters downstream of the U.S. Route 460 bridge and parallel to State Route 730 (U.S. Geol. Serv. Eggleston, Va. Quadrant, 7.5 minute series, No. 4858 I N.E.). The left bank facing downstream was tree-lined while the right bank rose sharply about 2 meters to pasture level. The riffle was approximately 18 meters wide and average depth was 0.2 to 0.4 meters. The substrate consisted of gravel to cobble sized rocks, particle size was less than 0.3 meters in diameter.

APPENDIX II

SPECIES LIST

EPHEMEROPTERA

Baetidae

Isonychia sp. Eaton
Baetis vagans McDunnough
Baetis sp. a Leach
Centroptilum convexum Ide
Centroptilum album McDunnough
Pseudocloeon carolina Klapalek
Pseudocloeon dubium Walsh
Caenis sp. Stephens
Tricorythodes sp. Ulmer
Ephemerella lata Morgan
Ephemerella cornuta Morgan
Ephemerella deficiens Morgan
Habrophlediodes sp. Ulmer
Paraleptophlebia adoptiva McDunnough

Heptageniidae

Stenonema heterotarsale McDunnough
Stenonema ithaca Clemens and Leonard
Stenonema pudicum Hagan
Stenomena fermoratum Say
Iron humeralis McDunnough
Iron tenius Traver
Heptagenia maculipennis Walsh
Heptagenia hebe McDunnough
Ironopsis sp. Traver
Cinygmula sp. McDunnough
Ephemera guttulata Picket

TRICHOPTERA

Hydropsychidae

Hydropsyche betteni Ross
Hydropsyche bifida Banks
Cheumatopsyche sp. Wallengren

Rhyacophilidae

Rhyacophila fuscula Walker
Rhyacophila lobifera Betten
Rhyacophila vibox Milne
Glossosoma intermedium Klapalek nigrior
Agapetus sp. Curtis

Philopotamidae

Chimarra socia Hagan
Chimarra aterrima Hagan
Sortosa sp. Navas

TRICHOPTERA (cont.)

Hydroptilidae

Leucotrichia pictipes Banks
Ochrotrichia sp. Mosely
Tascobia sp. Ross
Neotrichia sp. Curtis

Goeridae

Goera sp. Curtis

Odontroceridae

Psilotreta sp. Banks

Helicopsychidae

Helicopsyche borealis Hagan

Limnephilidae

Drusinus sp. Betten
Neophylax sp. McLachlan
Pycnopsyche guttifer Walker

Psychomyiidae

Psychomyia sp. Picket
Psychomyii Genus A. Ross

Brachycentridae

Brachycentrus sp. Curtis

PLECOPTERA

Perlidae

Phasganophora capitata Picket
Paragnetina media Walker
Paragnetina immarginata Say
Acroneuria filicis Frison
Acroneuria xanthenes Newman
Neoperla clymene Newman
Perlesta placida Hagan

Chloroperlidae

Hastaperla brevis Banks

Nemouridae + Perlodidae + Peltoperlidae + Taeniopterygidae + Capniidae

Hastaperla brevis Banks
Isoperla bilineata Say
Isoperla clio Newman
Isogenus decisus Walker
Isogenus subvarians Banks
Taeniopteryx sp. Picket
Brachyptera sp. Newport
Allocapnia sp. Claassen
Nemoura sp. Picket
Peltoperla maria Needham and Smith

COLEOPTERA

Psephenidae

- *Psephenus* sp. Haldeman
- *Ectoparia* sp. LeConte

Elmidae

- *Optioservus* sp. Sanderson
- *Stenelmis* sp. Dufour
- *Dubiraphia* sp. Sanderson
- *Zaitzevia* sp. Champion
- *Promoresia* sp. Sanderson
- *Gonielmis* sp. Sanderson
- *Limnius* sp. Erichson

Gyrinidae

- *Gyrinus* sp. Muller

Ptilodactylidae

- *Anchycteis* sp. Horn
- *Anchytarsus* sp. Guerin

Dytiscidae

- *Oreodytes* sp. Seidlitz

MEGALOPTERA

Corydalidae

- *Nigronia* sp. Banks
- *Corydalus* sp. Latreille

Sialidae

- *Sialis* sp. Latreille

ODONATA

Aeshnidae

- *Boyeria* sp. MacLachlan

Gomphidae

- *Lanthas* sp. Needham

Calopterygidae

- *Calopteryx* sp. Leach

Libellulidae

- *Sympetrum* sp. Newman

LEPIDOPTERA
- Pyralidae
  - *Cataclysta* sp. Hubner

DIPTERA
- Tipulidae
  - *Hexatoma* sp. Latreille
  - *Antocha* sp. Osten Sucken
  - *Tipula* sp. Linnaeus
- Heleidae
  - *Palpomyia* sp. Meigen
- Tabanidae
  - *Tabanus* sp. Linnaeus
- Empididae
  - *Hemerodromia* sp. Meigen
- Rhagionidae
  - *Antherix* sp. Green
- Blepharoceridae
  - *Philorus* sp. Kellogg
- Simuliidae
- Chironomidae

SPACIAL AND TEMPORAL DISTRIBUTIONS OF SELECTED IMMATURE AQUATIC INSECT SPECIES COLLECTED IN SINKING CREEK, VIRGINIA

by

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(ABSTRACT)

An investigation of the occurrence and distribution of portions of insect communities in selected riffles along the longitudinal gradient of Sinking Creek, Virginia was conducted over a twelve month period. Seasonal changes in total numbers of individuals and species were observed. Temporal changes in community dominance occurred throughout this study. Change in community composition was illustrated by variation in community dominance and in total numbers of individuals and species collected.

The observed temporal and spacial distributions of thirty-six species were considered. Temporal distributions illustrate variations in the length of time individual species require to complete the aquatic portion of their life cycle, while differences in the observed longitudinal distribution of particular species indicate population responses to environmental change at points along the stream gradient.

The spacial and/or temporal segregation of closely related organisms was indicated by seasonal and/or longitudinal differences in the relative abundance of particular species. Except for one family Hydropsychidae selected closely related species exhibited either spacial separations, temporal separations, or a combination of both spacial and temporal separations. Speculations on factor influencing the distributions of selected species are included.

Baseline data indicate seasonal and longitudinal fluctuations of physico-chemical parameters during this study. A discussion of these seasonal and longitudinal fluctuations is included.