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PRELIMINARY OBSERVATIONS OF THE AQUATIC INSECTS OF THE SMOKY MOUNTAINS: ALTITUDINAL ZONATION IN THE SPRING

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Abstract

The aquatic macroinvertebrate fauna in seven 'hypocrenon' streams, located on the southeast facing slope of a single ridge in the Smoky Mountains, was qualitatively sampled. The samples were collected at seven different altitudes. This design permitted an analysis of faunistic variations along an altitudinal gradient.

The data obtained in this study are compared with data presented in a number of European zonation studies. A number of interesting, and perhaps ecologically significant, parallels among the altitudinal distribution of the orders Ephemeroptera, Plecoptera, and Diptera in the Smoky Mountains and streams in Europe are discussed.

Introduction

The aquatic macroinvertebrate fauna of mountain streams and lakes has been studied intensively in Europe. Aquatic biologists have examined the influence of altitudinal gradients (Illies, 1952; Dittmar, 1955), temperature (Kamler, 1965), allochthonous material (Egglishaw, 1969), the effect of drought (Mackay, 1969), substrate variations (Stanford & Gaufin, 1974), and water chemistry (Minshall & Kuehne, 1969). With the exception of altitude, biologists in North America have examined a similar suite of parameters.

This is a discussion of the aquatic insect fauna observed in 'hypocrenon' (Illies & Botosaneanu, 1963) streams along an altitudinal gradient in the Smoky Mountains. Changes in physical and chemical parameters are considered, in part, to be the result of changes in altitude and are of secondary importance with regard to faunistic changes. The hypothesis that altitudinal variations may be primarily responsible for some aspects of faunistic zonation in mountain streams is examined.

A significant portion of this presentation is devoted to a very general comparison of data presented by European investigators, much of which has been summarized by Hynes (1970), and this data collected in the Smoky Mountains. Many generalizations are proposed, some more tenuous than others, and many more questions are asked than answered. The 'ecological' value of this study, and others of a similar nature, will be determined only by additional research.

Methods

Seven sampling stations were established on seven first order streams that drain the southeast slope of Thomas Ridge (Fig. 1). The ridge was selected because of its geologic uniformity. It consists of a thick mass of metamorphosed sedimentary rocks comprising the Thunderstone Formation. The stream substrate was composed of feldspathic sandstone, quartz-mica schist, garnet schist, kyanite-staurolite schist and quartzite cobbles.

Flow, temperature, pH, dissolved oxygen, stream width, depth and sample station altitude were measured. The particle size and condition of the substrate was carefully observed to insure similarity at each sampling station.

Macroinvertebrate samples were collected in June 1976, with a D-frame kicknet (pore size 452 microns). Samples were taken from the right and left banks, a riffle zone and a pool at each station following the procedures outlined by Frost, Hyni, and Kershaw (1971) to insure

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comparable samples. The macroinvertebrates in each sample were preserved in 70 percent alcohol and removed to the laboratory for analysis. The ensuing discussion is limited to the following insect orders: Coleoptera, Diptera, Ephemeroptera, Odonata, Plecoptera, and Trichoptera.

A similarity index, S.I., (Morgan, Hoff & Trumpf, 1976) was computed for each of the sample populations according to the following equation:

$$\text{S.I.} = \frac{2C}{A + B}$$

A = number of taxa occurring at sample station X
B = number of taxa occurring at sample station Y
C = number of taxa common to both sampling stations X and Y.

The index values may range from zero to one; zero indicating no similarity between the stations being compared and one indicating no differences. Index values ranging from 0.99 to 0.75 are indicative of minor community differences. Values ranging from 0.74 to 0.50 indicate moderately different communities, and index values below 0.49 are representative of extremely different communities. The index was used to establish the existence of faunistic differences and for gross community comparisons along the altitudinal gradient.

The total number of taxa collected at each station and the number of taxa in each of the orders reported were compared along the altitudinal gradient.

A frequency of occurrence index, based on the total number of organisms in each sample population, was also used for altitudinal comparisons. A regression analysis was used to form frequency classes for each taxon: common (more than 50 individuals), frequent (11 to 49 individuals), rare (2 to 10 individuals) and transient (1 individual).

Results and discussion

The selection of sampling stations on first order drainages on a single southeast facing ridge of uniform geologic material reduced numerous sources of variation that are, in themselves, the result of altitudinal change. The most obvious include changes in water chemistry due to substrate variations, the effect of distance from stream headwaters, change in aspect, difference in incident solar radiation, and variation in precipitation due to the rain shadow effect.

The physical-chemical parameters recorded at each sampling station are presented in Table 1. The stations were similar with respect to width, depth, flow, and dissolved oxygen. Major changes in temperature and pH were observed around 830 meters. Cooler temperatures were recorded at the higher altitudes and warmer temperatures were noted at the lower altitudes; a direct consequence of changing altitude. The pH shifted from acidic (5.8) at the higher altitudes to neutral (7.2) at the lower altitudes. The reason for this shift is not known. It may be caused by the presence of limestone outcroppings not observed by the author, the more rapid complexing and neutralization of organic acids due to increased temperature, or a change in the carbon dioxide equilibrium of ground water at the lower altitudes.

Community Similarity

The similarity index values (Table 2) indicate that the aquatic insect communities collected from the seven different altitudes were moderately to extremely different. The sample populations above 830 meters and those below appear to be two distinct groups. The index values indicate that a faunistic change occurred around 830 meters. This was the same altitude at which temperature and pH were observed to undergo significant increases. This observation is in accordance with those of Schmitz (1955), who suggested that the greatest faunistic shifts should occur in zones where changes in abiotic parameters are evident.

A trend toward sample population similarity at lower

TABLE 1

Physical and Chemical Characteristics of Sample Stations Along a 380 Meter Altitudinal Gradient

Station Number	1	2	3	4	5	6	7
Altitude (meters)	1020	925	830	780	720	670	640
Flow (m/min.)	21.2	28.1	29.7	30.2	20.1	27.7	21.9
Temperature (C)	12	13	15	15	16	16	16
pH	5.8	6.0	6.7	6.8	7.0	7.0	7.2
Dissolved Oxygen (mg/l)	>10	>10	>10	>10	>10	>10	>10
Stream Width (m)	4.8	3.8	5.1	3.5	3.9	4.5	3.2
Stream Depth (cm)	17.3	16.4	20.3	17.2	18.5	19.4	17.3

TABLE 2

Similarity Indices* Computed For Sample Populations Collected Along A 380 Meter Altitudinal Gradient

Sample Station		1	2	3	4	5	6	7
	Altitude (m)	1020	925	830	780	720	670	640
1	1020	1.00	0.69	0.52	0.45	0.41	0.48	0.49
2	925		1.00	0.42	0.43	0.46	0.47	0.49
3	830			1.00	0.51	0.53	0.54	0.53
4	780				1.00	0.40	0.53	0.56
5	720					1.00	0.52	0.56
6	670						1.00	0.60
7	640							1.00

*0.99-0.75 indicates great similarity
0.74-0.50 indicates significant differences
0.49-0.00 indicates extreme differences

altitudes becomes apparent when the total number of taxa and the number of taxa per order are examined (Fig. 2). The mean number of taxa collected at the stations located at 830 meters and above was 37. All of the stations were significantly different. It is interesting to note the large number of dipteran taxa. The mean number of taxa collected at all stations below 830 meters was 24, none of the stations were significantly different. In addition, there was a significant reduction in the number of dipteran taxa.

The diversity of dipteran larvae at higher altitudes would appear to be correlated with the cooler temperatures that may prolong the larval stage. However, Hall (1951) and Agnew (1962) have suggested that acid conditions, such as those observed, restrict the distribution of dipterans in England. The question as to why there are more taxa of dipterans at 830 meters and above is thus still present.

The complete absence of Ephemeroptera above 925 meters is interesting. This 'absence' at high altitudes has been observed by European investigators (Gledhill, 1960; Minshall & Kuehne, 1969; Crisp & Nelson, 1965). Their observations occurred at lower altitudes than those of this study. The difference is probably a result of the effect of latitude. In general, these investigators have eliminated temperature as the controlling factor; the existence of a parallel absence is apparent, but unexplained.

The last point of interest to be examined here is the presence of *Cordulegaster erroneus* only at the lowest altitude. This may be comparable to the observations of *Cordulegaster annulatus* in the lower reaches of northern German streams (Geijskens, 1935).

Frequency Distribution

Due to the limited ecological information available for the taxa collected, only the frequency distribution of selected taxa and aberrations in the distribution of others is discussed. Those interested in detailed treatment should refer to Table 3.

Ephemeroptera

No representatives of this family were collected above 925 meters. At 925 meters five genera occurred; of these, *Baetis* spp. and *Ephemerella* spp. present the most observable trends. The remaining genera are either rare or transient with no discernible trends. *Baetis* spp. was frequent at 925 meters, 830 meters, 780 meters and 720

TABLE 3

Frequency Distribution of Aquatic Insects Along A 380 Meter Altitudinal Gradient

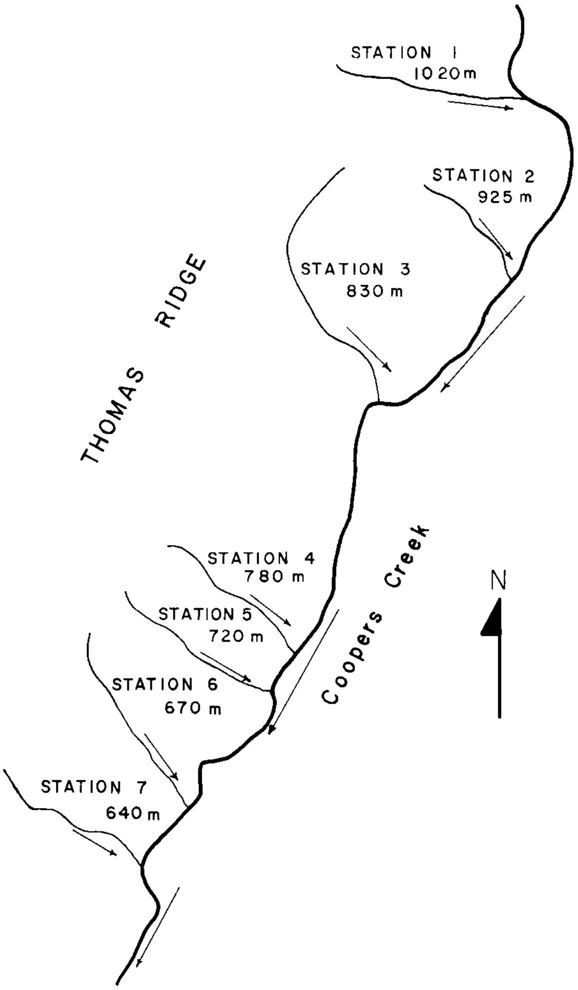
	1020	925	830	780	720	670	640
Ephemeroptera							
Baetidae							
Baetis spp		F	F	F	F		
Pseudocloeon spp.					R		
Ephemerellidae							
Ephemerella cornutella				F	F		
Ephemerella rossi		F	F	F	C	C	F
Heptageniidae							
Epeorus spp.		F	R	R	R	R	
Heptagenia spp.					T		
Stenonema annexum		R		R	R		T
Stenonema carlsoni						T	
Leptophlebiidae							
Paraleptophlebia spp.		F	T	T			T
Odonata							
Cordulegastridae							
Cordulegaster erroneus							T
Gomphidae							
Lanthus parvulus		R	R		T		T
Plecoptera							
Nemouridae							
Allocapnia spp.							R
Leuctra spp.	C	F	F		R	R	R
Nemoura wui	C	F	F	R	R	R	R
Peltoperlidae							
Peltoperla spp.	R	F	F	R		R	R
Perlidae							
Acroneuria abnormis				T			
Acroneuria georgiana		R	F	R	R	T	T
Acroneuria xanthenes		R					
Perlodidae							
Isogenus spp.	F	F	F	F	R	R	T
Isoperla spp.		F	T	R	R	R	R
Pteronarcidae							
Pteronarcys spp.		R		R	R	T	T
Coleoptera							
Elmidae							
Dubiraphia quadrinotata		R			R	T	T
Dubiraphia spp.		R					
Optioservus spp.		F	F	F	F	R	
Promoresia elegans		R		R	F	R	
Gyrinidae							
Dineutes spp.						T	
Psephenidae							
Ectopria nervosa		R	R	R	T	T	
Ptilodactylidae							
Anchytarsus bicolor	R				R		
Trichoptera							
Beraeidae							
Beraea nigritta			R	T			
Hydropsychidae							
Diplectrona spp.		C	F	R	R	R	R
Parapsyche spp.		F		R		R	T
Lepidostomatidae							
Lepidostoma spp.		R	R	R			F
Limnephilidae							
Pycnopsyche sp. 1	F						
Pycnopsyche sp. 2	F						

TABLE 3 (Continued)

	1020	925	830	780	720	670	640
Psychomyiidae							
Polycentropus spp.		R					
Psychomyiid Genus A	R	R	R		T		T
Rhyacophilidae							
Glossosoma spp.				T	R	T	
Rhyacophila fuscula	T			R	R		
Rhyacophila torva		T	R	R			T
Rhyacophila spp.	F	F				R	
Diptera							
Ceratopogonidae							
Culicoides spp.	F	R	R				
Palpomyia spp.	F	T	T				
Chironomidae							
Chironomini							
Microtendipes spp.		R					
Polypedilum aviceps		T					
Stenochironomus spp.		R					
Diamesinae							
Prodiamesa olivacea					T		
Orthocladiinae							
Brillia par	F				T		
Cardiocladius spp.		R	T				
Corynoneura spp.	F						
Eukiefferiella sp. 1	F	T	T				
Eukiefferiella sp. 2	F		T				
Nanocladius spp.	F						
Parakiefferiella spp.		T					
Paraphaenocladius spp.	C		T				T
Pseudoorthocladius spp.		R	T				
Thienemanniella spp.	F	R	T				
Tanypodinae							
Conchapelopia sp. 1		R	R				T
Conchapelopia sp. 2		T	T				
Tanytarsinae							
Cladotanytarsus spp.		R					
Micropsectra spp.	F						
Rheotanytarsus spp.					T		
Tanytarsus spp.		R					
Zavrelia spp.	F	R					
Rhagionidae							
Atherix variegata				T	R		
Dixidae							
Dixa spp.	R						
Empididae	R						
Simuliidae	T	R	R	R		R	
Tipulidae							
Antocha spp.	R		T				
Dicranota spp.			T		R		
Gonomyia spp.							R
Hexatoma spp.	F	F	R		T		T
Limonia spp.	T						
Ormosia spp.	R						
Pedicia spp.			T				
Polymeda spp.		F	R				
Tipula abdominalis					R		

*C: denotes frequency class of common (>50 individuals)
*F: denotes frequency class of frequent(11-49 individuals)
*R: denotes frequency class of rare (2-10 individuals)
*T: denotes frequency class of transient (1 individual)

meters. *Ephemerella,* represented by *E. rossi,* was frequent between 925 meters and 780 meters. Its frequency increased to common at 720 meters and 670 meters. It is interesting to note that a second species of *Ephemerella, E. cornutella,* was also distributed in the frequent category at 780 meters and 720 meters. In Europe Verrier (1953) and Crisp & Nelson (1965) have observed that *Ephemerella* and *Baetis* have inverse frequency distributions. The frequency observations made in this study are in general agreement with this observation. In addition, Ulfstrand (1968) noted that *Ephemerella* is probably a 'summer' genus, at least it appears to be more tolerant than *Baetis* to warmer temperatures. If this is the case, the observed increase of *Ephemerella* is in response to a thermal cue that is due primarily to decreasing altitude.



Plecoptera

Hynes (1961), Kamler (1965), Minshall & Kuehne (1969) and numerous others have shown that members of this order are abundant at higher altitudes. *Nemoura* spp. and *Leuctra* spp. were common at 1020 meters, became frequent at 925 meters, and more rare from 780 meters to 640 meters. This shift may be a thermal response, which again is the result of altitudinal gradient.

Another interesting parallel between the Smoky Mountain data and the data reported in the European studies cited is the shift in the ratio of *Ephemeroptera* to *Plecoptera* with changes in altitude. At the higher altitudes *Plecoptera* were common and *Ephemeroptera* were frequent; at the lower altitudes the *Ephemeroptera* were common and the *Plecoptera* were rare. In this investigation the shift occurred between 780 and 830 meters.

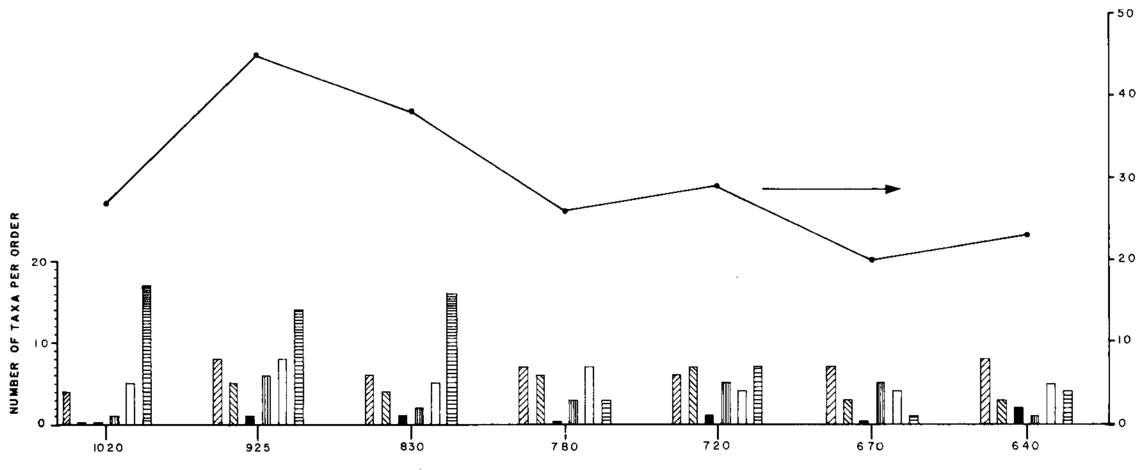


Figure 2. Total Number of Aquatic Insect Taxa and Number of Taxa per Order

An interesting point here is the change in Plecopteran feeding strategy. The herbivore-detrivore strategy *(Nemoura* and *Leuctra)* was shifted to a carnivorous strategy *(Acroneuria, Isoperla* and *Isogenus)* with decreasing altitude.

Coleoptera

The only coleopteran present at 1020 meters was *Anchytarsus bicolor.* In general, the genera *Dubiraphia* and *Ectopria* revealed the only decipherable distributional trends. *Dubiraphia* and *Ectopria* occurred from 925 meters to 640 meters, with the former being the more common. Studies in Ireland by Frost (1942) and Humphries & Frost (1937) suggest that the order in general is tolerant of warm water. The apparently limited occurrence of this order at lower altitudes agrees generally with these observations.

Trichoptera

European investigators such as Frossland & Muller (1962) and Petr (1961) have suggested that the seemingly random distribution of this order may be due to 2-year life cycles. However, most of the trichopterans collected in this study probably do not have 2-year life cycles. Hence, the reason for their random distribution remains an interesting question.

Diplectrona was common at 925 meters, frequent at 830 meters, and rare below the latter altitude. Psychomyiidae were rare at 1020, 925, and 830 meters and transient below 830 meters. A trend of feeding toward a detritus-herbivorous strategy, with only minor carnivory at all altitudes, was observed. It is interesting to note that the carnivorous families changed from Psychomyiidae to Rhyacophilidae at 830 meters.

Diptera

The only obvious trend in this order was the abrupt reduction in frequency below 830 meters (Table 3). Simuliidae demonstrated an increase in frequency below

1020 meters which remained constant to 670 meters. This indicates that they may be more important in the warmer waters of lower altitudes. Taxonomic difficulties with this family limit any further speculation on this trend that appears to be aberrant with respect to the other dipteran families.

Summary

The aquatic insect fauna in seven 'hypocrenon' mountain streams, located on the southeast facing slope of Thomas Ridge in the Smoky Mountains of North Carolina, were qualitatively sampled in the spring of 1976. The streams were sampled at altitudes ranging from 1020 meters to 640 meters. The substratum in each stream is composed of stones, gravel and cobbles of uniform geologic origin. Temperatures ranged from 12°C, at 1020 meters, to 16°C, at 640 meters. The pH varied from 5.8, at 1020 meters, to 7.2, at 640 meters. Stream discharge, width and depth were also measured.

Emphasis in this study was placed on the preliminary documentation of changes in the aquatic insect fauna along an altitudinal gradient. The design of the sampling program, seven 'hypocrenon' streams at seven altitudes, reduced numerous sources of variation that are, themselves, the result of altitudinal gradient. This, in effect, permitted an examination of the hypothesis that many faunistic changes may be the result of altitudinal changes.

In addition, the data obtained in this study are compared with data presented in similar European studies. A number of interesting, and perhaps ecologically significant, parallels among the distributional patterns of the orders Ephemeroptera, Plecoptera and Diptera in the Smoky Mountains and mountain streams in Europe are discussed.

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