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Patterns of Coleoptera Species Diversity in Contrasting White Pine and Coppice Canopy Communities[1]

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ABSTRACT: The pattern of Coleoptera species diversity in coppice hardwoods and white pine canopy communities was investigated. The information-theory index H(s) and the index D were used to measure diversity. The distribution of individuals within species was measured by using redundancy and evenness indices.

Diversity in the coppice was greater than in the white pine. The coppice canopy community followed a seasonal trend in diversity, evenness and redundancy. Diversity in the white pine community did not follow an apparent seasonal trend. Considerably fewer species and individuals occurred in the white pine, which tended to magnify the importance of the appearance and disappearance of dominant species and thereby to obliterate any seasonal trend in diversity, redundancy and evenness.

INTRODUCTION

Canopy insect investigations have most often been attempted at the population level. Very little information is available concerning the structure of canopy insect communities. The intent of this study was to investigate the pattern of Coleoptera species diversity in white pine (*Pinus strobus* L.) and coppice canopy communities through the use of information-theory indices of diversity.

Indices of diversity have been utilized in the study of an array of different communities. Margalef (1957) was perhaps the first to demonstrate the use of the information-theory approach to the analysis of natural communities. Subsequently Pielou (1966) examined the applicability of the various information-theory measures of diversity to different types of biological collections. A method for determining the evenness component of diversity was also considered. Wilhm (1967) compared several diversity indices through the analyses of benthic macroinvertebrates and concluded that the information-theory approach provided a suitable means of evaluating community structure.

The information-theory approach to community analysis has been found suitable in the study of abundance of soil microarthropods (Hairston 1959), bird species (MacArthur and MacArthur 1961), and arthropods in a 1-year-old field successional community (Richardson 1969), as well as many other natural communities.

METHODS AND MATERIALS

The present investigation was conducted at the Coweeta Hydrologic Laboratory in the Appalachian Mountains of western North Carolina. The study areas were located in white pine and coppice watershed catchment basins, which have been designated by the Forest Service as watershed numbers 17 and 13, respectively.

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Watershed 17 is a 13-ha plot which was planted in white pine in 1956. Invading deciduous vegetation has been removed annually. Watershed 13 is a 16-ha plot which was clear-cut of all woody vegetation in 1962. The cut vegetation was left in place and the area was allowed to revegetate naturally. The multistoried forest vegetation of watershed 13 is now dominated by *Quercus* and *Carya* species interspersed with an abundance of associated tree species typical of the Appalachian Mountains.

Canopy insect communities were reached by constructing platforms in the canopy at the approximate center of each watershed. Three methods were used in sampling the canopy insect fauna: window traps, sticky traps and Malaise traps. The window trap used in this study was a modification of the type used by Chapman and Kinghorn (1955). The frame of the trap was constructed from galvanized metal and was fitted with an inverted "U"-shaped drain which automatically siphoned excess rain water from the trough, but did not remove insect specimens from the kerosene which was used as a preservative. Three window traps were located in each watershed. The sticky traps consisted of ft-sq galvanized screens on which the commercial preparation "Stickem Special" had been applied. Four traps were located at each platform. The Malaise trap used in this study was a modification of those discussed by Southwood (1966). Each platform had one Malaise trap.

Captured insect specimens were removed approximately weekly from the window traps and Malaise traps on each watershed beginning on 4 July and terminating on 28 October 1969. Specimens were not removed from the sticky traps, but were used as a comparison with the efficiency of the window traps. Eleven samples were collected from each watershed.

Weekly samples were taken to the laboratory for sorting and identification. The insects collected in the window traps were washed in dioxane to remove the kerosene preservative and then placed in alcohol. All Coleoptera were separated from the samples, identified to family, and sorted according to species types. Comparisons of the sorted species types were made, where possible, with identified specimens in the Department of Entomology museum at the University of Georgia.

The various components of Coleoptera species diversity were then examined. Two species diversity indices were used: The Shannon-Weiner function, H(s) and the index D proposed by Margalef.

The Shannon-Weiner function, H(s) is

$$H(s) = -\sum_{r=1}^{s} p_r \log p_r$$

where s is the total number of species in a sample and p_r is the observed proportion of individuals that belong to the r-th species (r=1,2, . . . , s). In this study, natural logarithms were used. The information-theory diversity index, H(s) incorporates two parameters of community structure: the number of species present and the distribution of individuals among the species.

The second index of diversity used, D, is

$$D=\frac{(s-1)}{\log_e N}$$

where s is the total number of species and N is the total number of individuals in the sample. This index assumes that the number of species increases as the logarithm of the number of individuals. The apportioning of individuals within species is not considered by this index.

The apportionment of individuals within species can be measured by using the Lloyd and Ghelardi (1964) equitability index, ϵ, or the Pielou (1966) evenness index, J′. We elected to use evenness, which is

$$J'=\frac{H(s)}{H(s)_{max}}$$

where H(s) is the observed diversity of $H(s)_{max}$ is the maximum possible diversity for the sample in question. $H(s)_{max}$ is equal to $\log_e s$. Maximum $J'^{(1)}$ occurs when all individuals are equally apportioned among the species present in the sample. Minimum $J'^{(0)}$ is approached when one species contains many individuals and the other species contains few individuals.

The position of H(s) between the maximum and minimum theoretical extremes for a particular sample was determined by using a redundancy equation. Redundancy is an expression of the dominance of one or more species and is inversely proportional to the wealth of species. It is zero if each individual belongs to a different species and one if all individuals belong to the same species (Wilhm, 1967). Redundancy (Red.) is given by the expression

$$\text{Red.}=\frac{H(s)_{max}-H(s)}{H(s)_{max}-H(s)_{min}}$$

where H(s) is the calculated diversity for the sample, $H(s)_{max}$ is the maximum theoretical diversity for the sample, and $H(s)_{min}$ is calculated by placing a single individual in each species and all the remaining individuals in another species. For example, if a sample contained 10 species and 100 individuals, minimum diversity would obtain if species one had 91 individuals and the remaining nine species each had one individual.

RESULTS AND DISCUSSION

Differences in Coleoptera diversity for the coppice and white pine canopy communities were immediately evident. In all, 165 species were found in the coppice compared to only 35 species in the white pine. This marked difference in species composition was reflected in both diversity indices H(s) and D (Figs. 1 and 2).

Student's "t" test indicated a significant difference for H(s) and D between the two watersheds ($t=4.7512$ for H(s) and 52.7492 for D). Diversity was higher in the coppice than in the white pine. The H(s) measurements for the coppice followed a seasonal trend with peak diversity occurring through the month of August and tapering off towards the beginning and end of the summer. Maximum H(s)

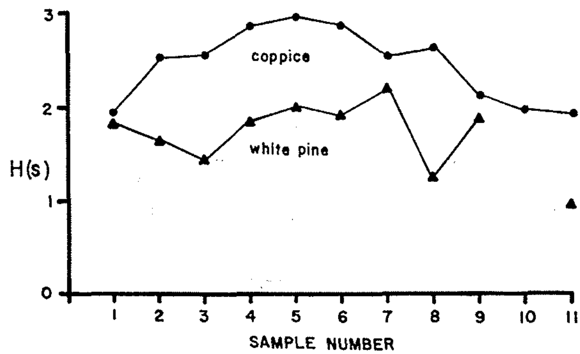

Fig. 1.—Coleoptera diversity as measured by H(s) for the coppice and white pine canopy communities. Sample numbers represent weekly collections beginning on 4 July and extending through 28 October 1969

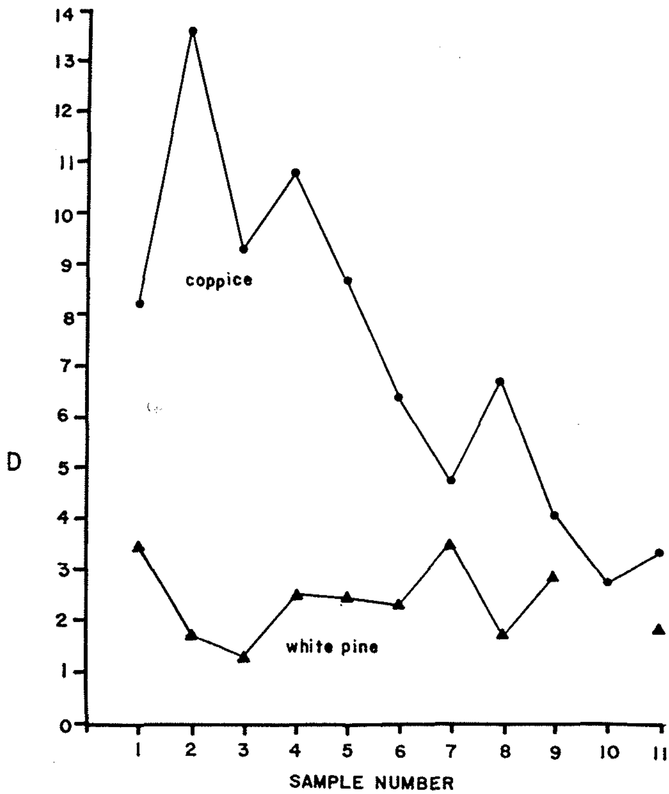

Fig. 2.—Coleoptera diversity as measured by D for the coppice and white pine canopy communities. Sample numbers represent weekly collections beginning on 4 July and extending through 28 October 1969

for the coppice was 2.9407 and the minimum was 1.9311. No readily observable pattern for H(s) was evident for the white pine community. Diversity was lower throughout the entire study. The highest value of H(s), 2.2048, occurred during the last week in August and the lowest (0.9691) occurred in the last week in June.

The lack of pattern in H(s) for the white pine canopy community can be at least partially explained on the basis of the abundance of insects in the samples (Table 1). Sample size, both with respect to number of species and number of individuals, was always considerably lower in the white pine than in the coppice. With small sample size, the seasonal appearance of a new dominant species or the disappearance of an old dominant species has a marked influence on diversity H(s). Both phenomena occurred in this study. The relative significance of a particular species in a large sample is somewhat less. Furthermore, although H(s) is reasonably impervious to sample size, which was one of our main justifications in using the measure, the interpretation of the significance applied to the values obtained from the index must consider extremely small sample size. The diminutive samples observed in the white pine (nos. 8, 9, and 11) were of little consequence to total Coleoptera diversity in the watershed.

The magnitude of the difference in D between the coppice and white pine was much greater than for the H(s) index. Comparison of sample size (Table 1) and the measurements of D (Fig. 2) reveals the strong influence of sample size on D, particularly in the coppice. In every instance when the number of individuals in the weekly coppice samples increased or decreased, there was a concurrent increase or decrease in the calculated value for D. In the white pine where the sample sizes were smaller, the fluctuation in the D values was less. Little seasonal trend in diversity, D, aside from the decline towards the latter part of the summer for the coppice, is evident (Fig. 1).

The measurements obtained in using H(s) can be altered not only by changing the species composition of a sample but also by changing the distribution of individuals within the species. The evenness index, J′, and redundancy (Red.) were used to measure the distribution of individuals within species in each community (Fig. 3).

TABLE 1.—The total number of species and individuals collected in weekly samples in 1969 by all methods from the coppice and white pine watersheds

Weekly sample No. and coll. dates		No. individuals per sample		No. species per sample	
		Coppice	White Pine	Coppice	White Pine
July 9	1	811	128	56	18
July 16	2	1146	196	97	10
July 26	3	795	91	63	7
Aug. 5	4	933	84	75	12
Aug. 13	5	293	59	50	11
Aug. 21	6	109	45	31	10
Aug. 28	7	58	13	20	10
Sept. 4	8	98	6	32	4
Sept. 10	9	50	8	17	7
Sept. 16	10	25	....	10	....
Sept. 27	11	26	8	12	5

In the coppice J′ increased along with diversity [H(s)] through the first 7 weeks of sampling and then oscillated at a high value for the remainder of the study. Redundancy decreased with increasing diversity through the first 7 weeks of sampling and then increased somewhat for the remaining 4 weeks. The complexity of the community increased from the beginning of the study through the month of August. With the onset of cooler weather in September, insect activity began to decrease and so did diversity. The evenness and redundancy measures were then subject to the influence of smaller sample sizes coupled with the disappearance of species, the effect of which has been discussed above. The disappearance of relatively rare species or the persistence of a common species would greatly affect the evenness and redundancy values.

The white pine community demonstrated no readily apparent pattern of evenness or redundancy. The explanation for the lack of pattern for H(s)—discussed above—was also applied to J′ and Red. The importance of sufficient sample size is particularly evident in

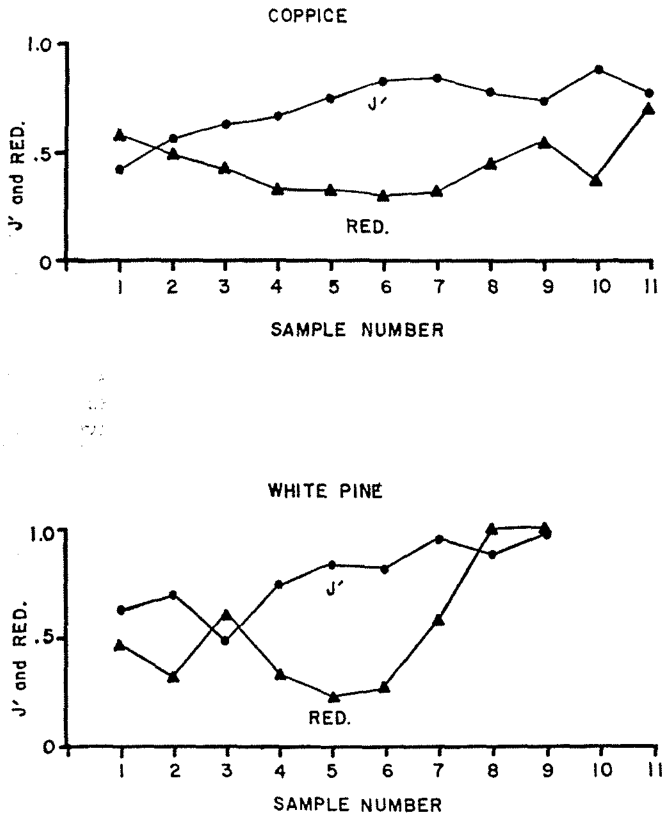

Fig. 3.—Redundancy (Red.) and evenness (J′) for the coppice and white pine canopy communities. Sample numbers represent weekly Coleoptera collections beginning on 4 July and extending through 28 October 1969

samples 8 and 9. In this instance redundancy is 1.0000 for both samples and evenness is .8962 for sample 8 and .9796 for sample 9. The inconsistency between the two measures results from the fact that H(s) and H_{min} are exactly the same. In this situation redundancy is equal to H_{max} divided by H_{max} which is one.

CONCLUSION

The multispecies, multistoried, coppice canopy community had more Coleoptera species and hence diversity, as measured by H(s) and D, than did the monoculture of white pine. The coppice community demonstrated a seasonal trend in diversity, redundancy and evenness. High diversity and redundancy and low evenness occurred in the coppice community towards the end of August. No seasonal trend was apparent in the white pine community.

The effect of sample size on the diversity of the two communities is apparent from the magnitude of difference observed for measurements obtained from both H(s) and D.

The lack of pattern for diversity, redundancy and evenness in the white pine community resulted from fewer species and individuals occurring in the community modified by the appearance and disappearance of species throughout the course of the study. The importance of the appearance and disappearance of species in the coppice community was somewhat offset by the larger number of individuals and species present.

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REFERENCES

CHAPMAN, J. A. AND J. M. KINGHORN. 1955. Window-trap for flying insects. *Can. Entomol.,* **87**:46-47.

HAIRSTON, N. G. 1959. Species abundance and community organization. *Ecology,* **40**:404-416.

LLOYD, M. AND R. J. GHELARDI. 1964. A table for calculating the 'equitability' component of species diversity. *J. Anim. Ecol.,* **33**:217-225.

MACARTHUR, R. H. AND J. W. MACARTHUR. 1961. On bird species diversity. *Ecology,* **42**:594-598.

MARGALEF, R. 1957. La teoria de la informacion en ecologia. *Mem. Real Acad. Cienc. Artes Barcelona,* **32**:373-449 (transl. by W. Hall, *Gen. Syst.,* **3**:36-71).

PIELOU, E. C. 1966. The measurement of diversity in different types of biological collections. *J. Theor. Biol.,* **13**:131-144.

RICHARDSON, J. I. 1969. Seasonal patterns in arthropod diversity in a one-year, old-field successional community. Unpublished M.S. Thesis, Univ. Georgia, Athens.

SOUTHWOOD, T. R. E. 1966. Ecological methods. Methuen and Co., Ltd., London. 341 p.

WILHM, J. L. 1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. *Water Pollut. Contr. Fed. J.,* **39**:1673-1683.

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