Seasonal Changes in Soil Arthropod Species Diversity as Affected by Perturbation in Three Successional Communities in Northeastern Indiana

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Abstract

The effects of perturbation due to a long-term pesticide on seasonal changes in arthropod species diversity were studied on three successional communities: an oldfield, blackberry bramble and woodlot sites. Treatment plots received one application of chlordane using the recommended dosage in early May, and samples from control and treatment areas were collected and processed from mid-May biweekly until early December. Total arthropod diversity was highest in the blackberry zone. The oldfield and blackberry communities exhibited slightly less stability than the woodlot as indicated by oscillation in the recovery pattern and overall repression of species diversity in the treatment plots. With respect to the variety and evenness components of overall species diversity, neither exhibited a significant difference in the treatment versus control plots in the oldfield. In the blackberry site a significant difference was obtained in variety only. The evenness index of the woodlot exhibited a significant difference in the treatment and control plots over the last half of the sampling season.

Introduction

The effects of perturbation or stress on species diversity in successional terrestrial and aquatic communities has been a natural consequence stemming from the interest generated by MacArthur (6), Margalef (8) Hairston et al. (2) and many others in the field of ecosystem stability and diversity as it relates to community development.

Several authors including Barrett (1), Malone (7) and Shure (13) have investigated the effects of a short-term pesticide on the stability of oldfield ecosystems. Hurd et al. (3) studied the influence of soil enrichment by fertilization on abandoned hayfields. An excellent review of insect stability and diversity in agro-ecosystems is provided by van Emden and Williams (15). Tramer (14) has reported on the regulation of plant species diversity on an early successional oldfield.

The present study was designed to test the effects of a persistent pesticide, chlordane, on the seasonal diversity patterns of terrestrial arthropods in three successional terrestrial communities over a period of one year.

Study Area and Methods

This study was conducted on research property comprising approximately 6 hectares adjacent to the Indiana University-Purdue University at Fort Wayne Campus in Allen Co. Indiana. The three communities investigated were an abandoned oldfield, a blackberry

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bramble site and a mixed oak woodlot. The soil type is silt loam. The oldfield has been undisturbed since 1970 and the producer trophic level is composed of herbaceous perennials. Species of aster, daisy and goldenrod are typical of the broad leaved plants and timothy, orchard-grass, smooth brome and Kentucky bluegrass are the most important grasses. The blackberry bramble plot derives its character from species of wild blackberry and feral roses. It also has herbaceous species found in the oldfield and woody species such as box elder found on the third site, the woodlot. The blackberry bramble site has been undisturbed for at least 15 years. Red oak is the dominant overstory tree found in the woodlot and sugar maple dominates the sapling class.

Control and treatment plots each measuring 3.05 by 4.57 meters were established in the three zones. Two weeks prior to the first sampling date (mid May) each treatment plot received one application of a chlorinated hydrocarbon pesticide, chlordane, with a hand-carried sprayer. Application was at the recommended rate of ¼ pint per 46.5 sq. meters. Chlordane was used because of its high toxicity and persistence (Nash and Woolson, 10). Each treatment plot was sprayed only once during the 1975 season. Soil arthropods were collected by combining three subsamples each of which measured 5.0 by 7.5 cm. by use of a soil corer. Samples were taken every other week in control and treatment plots in each zone from mid-May to early December. Soil arthropods were processed through Berlese funnels and organisms collected were sorted to species and preserved in alcohol or on permanent slides.

Soil temperature was measured at the surface and at depths of 2.5 cm. and 7.6 cm. depths in the soil. Accumulative soil moisture measurements were determined at 2.5 cm. and 7.6 cm. depths after comparing wet and dry weights. Physical measurements were taken between 12 noon and 2 PM. Soil respiration was measured over a 24 hr. period using KOH absorption (Lundegardh 5, Kucera and Kirkham 4).

Physical Factors

A detailed statistical analysis of soil temperature, moisture and CO_2 evolution is reported in an adjoining paper and need only be summarized here. The woodlot exhibited a significantly lower temperature (Fig. 1) than the oldfield and blackberry zones at the 2.5 cm. depth as might be expected due to differences in density of vegetation. Soil temperatures exhibited a gradual increase that peaked in August and decreased abruptly in September. Soil moisture measurements from the woodlot were significantly higher than those of the other two zones due to the buffering effect of the overhanging vegetation and litter (Fig. 2). Soil moisture data at the 2.5 cm. levels in the oldfield exhibited no significant difference from that of the blackberry zone when compared over the entire season. The oldfield sustained a great increase in soil moisture during the month of June which accentuated the effect of the chlordane in the treatment plot. All three communities showed a decrease in soil moisture in July and August.

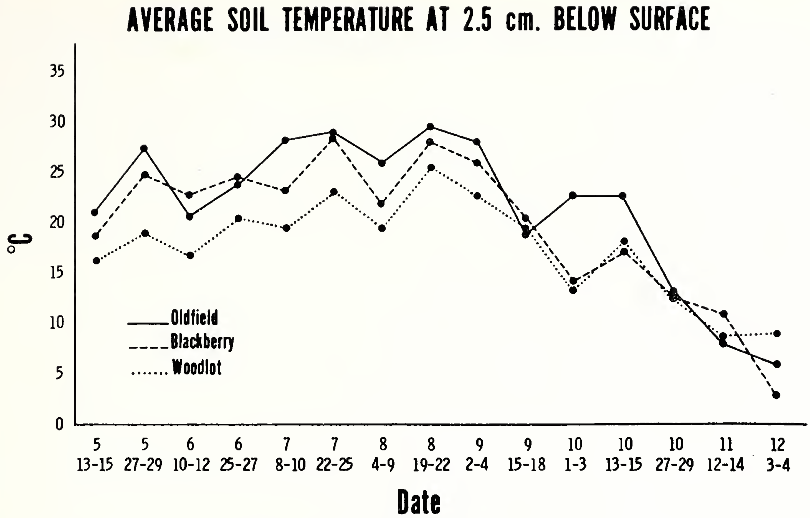

FIGURE 1. *Seasonal patterns in soil temperature at the 2.5 cm. depth in the oldfield, blackberry, and woodlot communities.*

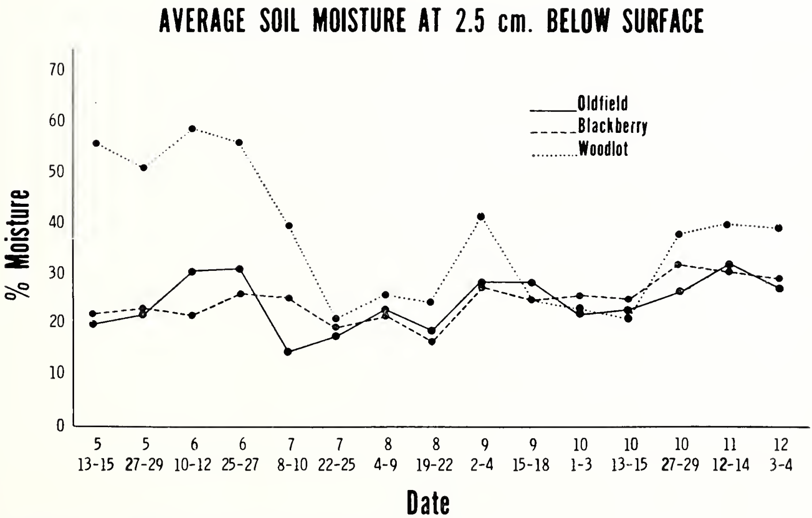

FIGURE. 2. *Seasonal patterns in soil moisture at the 2.5 cm. depth in the oldfield, blackberry, and woodlot communities.*

Seasonal Diversity Patterns

Species diversity as indicated by the Shannon Index, $\overline{H}$, (Shannon and Weaver, 12) when plotted over the entire season was significantly higher in the blackberry control zone than it was in either the oldfield or woodlot control areas (Fig. 3). Diversity values for the oldfield and woodlot controls were not significantly different from each other.

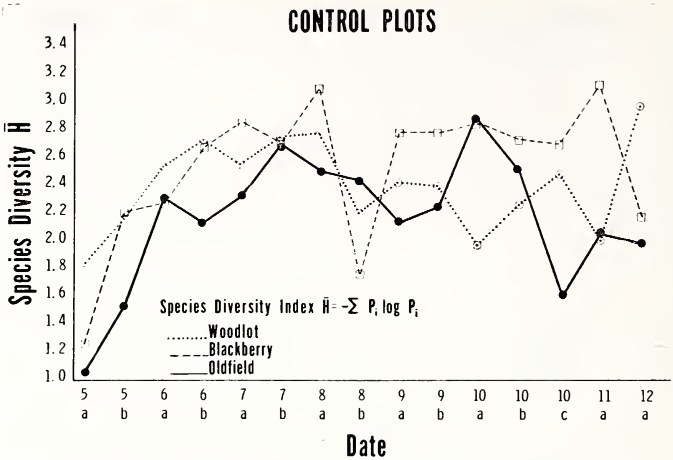

FIGURE 3. *Seasonal patterns in soil arthropod species diversity, H, in control plots of the oldfield, blackberry, and woodlot communities.*

All three control plots showed increased diversity throughout the early growing season as might be expected. The fluctuation in the blackberry control in late August was due to an abnormally large number of ants encountered.

Perturbation had its greatest effect in the blackberry zone (Fig. 4) as the treated area never fully recovered from the pesticide stress. The diversity index was broken down into its two components: Variety

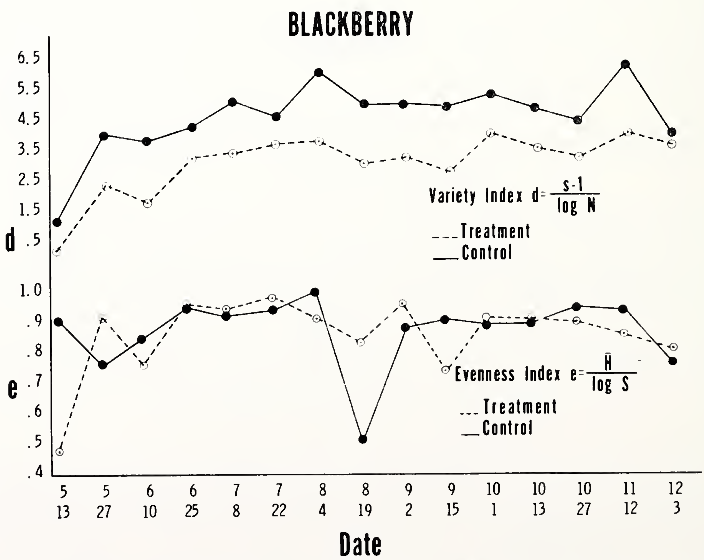

FIGURE 4. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the blackberry community.*

($d = \frac{S-1}{\log N}$) and evenness of individuals among the species ($e = \frac{H}{\log S}$) where S = number of species (Pielow, 11) and applied to each of the three successional sites. The blackberry stage showed a significant difference in the treatment and control plots with respect to the variety component only. The difference in diversity between the two plots is primarily due to the very high loss of "macro" predators from the experimental area (Fig. 5).

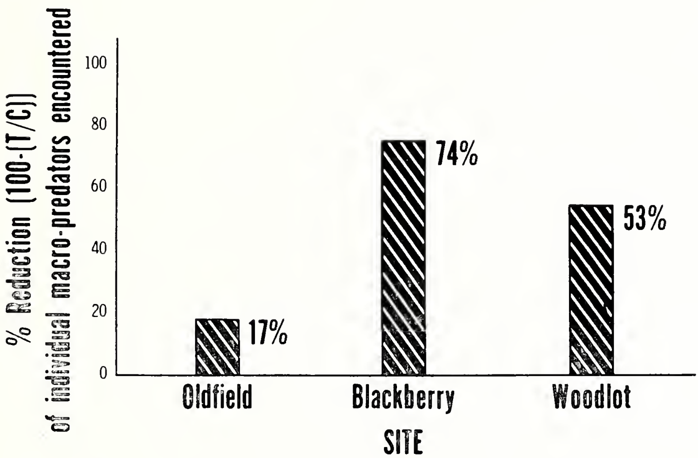

FIGURE 5. *Percentage reduction of individual predators due to perturbation by chlordane in three northeastern Indiana communities.*

Results in the oldfield show that what appeared to be recovery from insecticidal stress took place in May and early June with some treatment "overshoot" occurring (Fig. 6). In June, however, rainfall probably carried the pesticide into the 2.5-7.5 cm. zones of the soil which markedly affected diversity until late August. The blackberry and woodlot zones displayed similar but less profound reactions in late May. The oldfield showed only a 17% loss in "macro" predators over the season (Fig. 5) in addition to having only about a third as many predators as was found in each of the other two study sites.

The woodlot community exhibited a significant difference in the evenness component but for only the last half of the sampling season (Fig. 7). It is probable that the effect of the chlordane may have been repressed until it had fully passed through the upper layers of the litter zone and then affected only small percentages of different arthropod species.

Summary

Total arthropod diversity was highest in the blackberry community. In the blackberry site a significant difference between the treatment and control was obtained only in the variety component. With respect

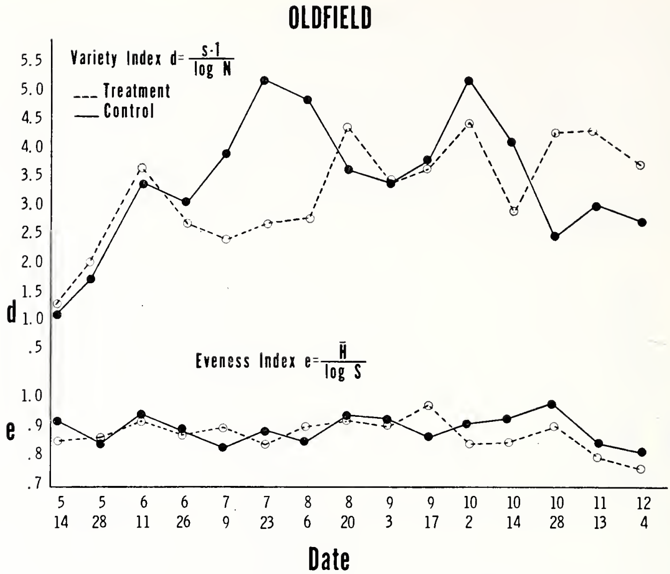

FIGURE 6. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the oldfield community.*

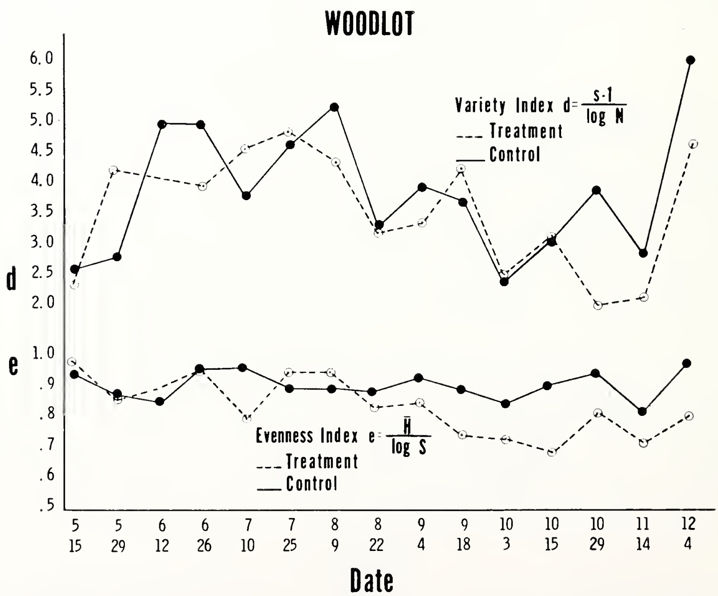

FIGURE 7. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the woodlot community.*

to the variety and evenness components of overall species diversity in the oldfield, neither exhibited a significant difference in the treatment versus control plots. The evenness index of the woodlot exhibited a significant difference in the treatment and control plots over the last half of the sampling season.

A definition of stability as advanced by Hurd et al. (3) (after May, 9) is that it is the ability of a system to maintain or return to its ground state after an external perturbation. This approach to stability is certainly operational and can be applied here. All three successional communities exhibited some lack of stability in that there was failure of the treatment zone to recuperate after being stressed (blackberry community) or extensive oscillation of the treatment throughout the sampling season as seen in the oldfield and to a lesser extent the woodlot.

Acknowledgments

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