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SENSITIVITY OF UNDERSTORY PLANT SPECIES TO THE EDGE ENVIRONMENT OF ISOLATED WOODLOTS IN EAST-CENTRAL INDIANA

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INTRODUCTION

The forests of central Indiana have been fragmented since the late 1800's through clearing for agriculture (DenUyl, 1954) with remaining woodlands characterized by edge (forest-agriculture boundary) and interior environments. Wales (1972) defined edge as a "vegetal transition zone" between forest tracts bordered by adjacent agricultural fields. Edge environments have been shown to have higher light levels, higher ground surface temperatures, and increased evapotranspiration rates than interior environments (Geiger, 1966; Wales, 1972). Plant communities occupying edge environments have been shown to be structurally and compositionally different from those of interior environments (Bruner, 1977; Gysel, 1951; Ranney, 1978; Schmelz and Lindsey, 1970).

Studies have shown that the influence of edge in plant communities extends up to 30 meters in forests of this region (Bruner, 1977; Raney, *et al.,* 1981). Therefore, the small size of most remnant woodlots in Indiana may result in most having a large edge zone with little or no interior zone (Levenson, 1976; Sharpe, *et al.,* 1981).

Densities of individual plant species with distance from the forest-agriculture edge are examined in this paper to determine their sensitivity to the differing environments of the xeric edge and mesic interior. The effects of edge aspect on species density gradients were also examined. Total density of herbaceous and shrub species was compared for differences relative to distance from the edge interface and differences between aspects.

STUDY SITE

The Davis-Purdue Agricultural Center, located in Randolph County, Indiana (Figure 1), within the Bluffton Till Plain section of the Central Till Plain Natural Region (Homoya, *et al.,* 1985), is representative of the fragmented forest landscape of the agricultural areas of Indiana. The four woodlands on this farm, having areas of 2.3, 8.1, 13.5, and 20.6 ha, served as the study site. The largest woodland is a remnant, old-growth forest designated by the National Park Service as a National Natural Landmark (Parker, *et al.,* 1985), while the three remaining smaller woodlands are managed for timber production. These woodlands are inhabited by a complex of mesic and upland depressional wet site species with a significant component of oak and hickory species (Parker, *et al.,* 1985; Schmelz and Lindsey, 1970). Each woodland is surrounded by intensively managed agricultural fields. The forest-agricultural edge, the subject of this paper, was estab-

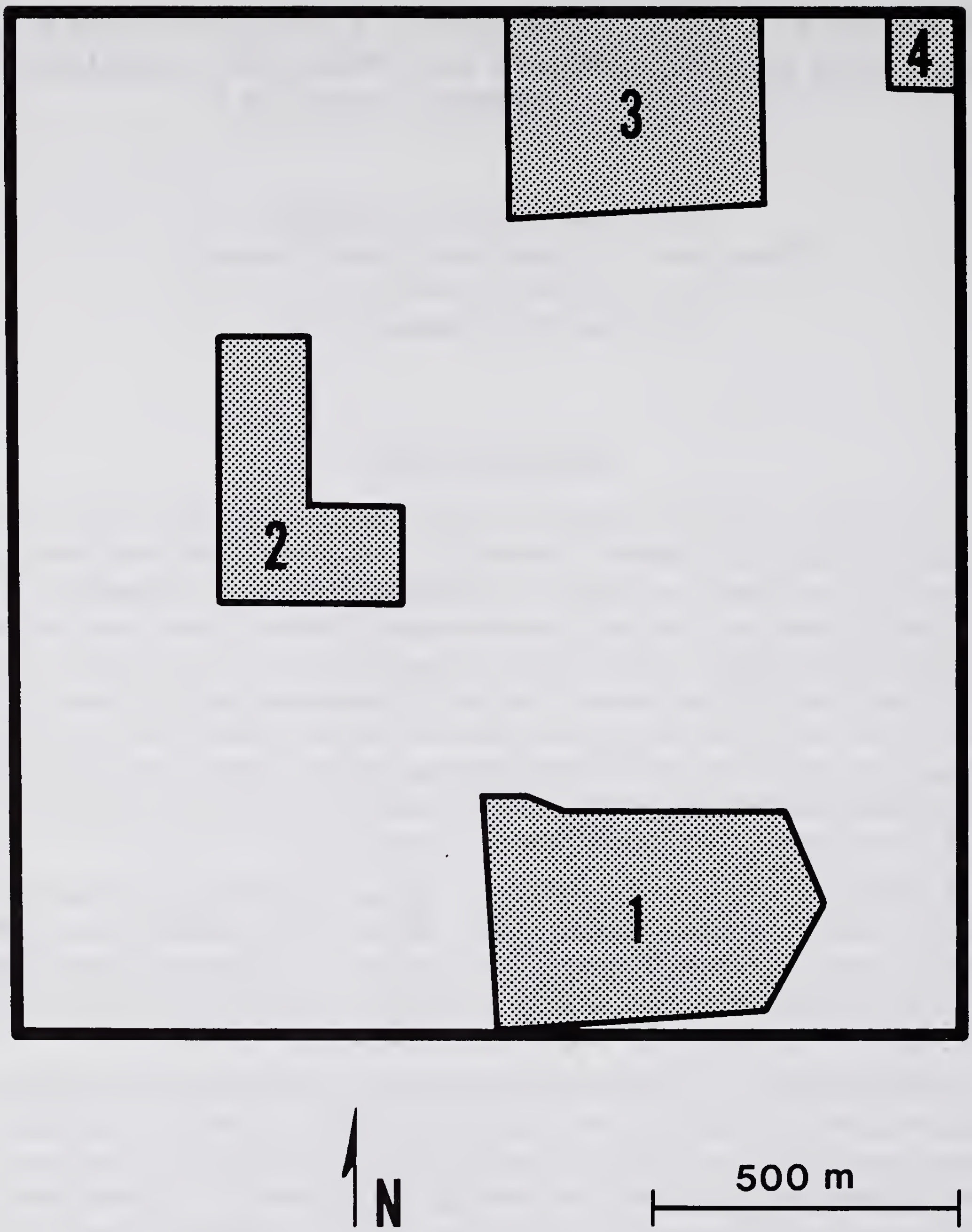

FIGURE 1. The four woodlots of the Davis-Purdue Agricultural Center are located within the same section of land and are separated by significant distances. The sizes of the woodlots are 2.3, 8.1, 13.5, and 20.6 ha.

lished prior to Purdue University acquisition in 1917 and is maintained annually by plowing or mowing.

MATERIALS AND METHODS

Forty-eight transects were established in the four woodlands; six transects in each of the north and west aspects of each woodland. These two aspects were chosen to represent the two extremes of environment in the edges of isolated woodlots with the west aspect considered the most xeric and the north the most mesic (Bruner, 1977; Raney, *et al.*, 1981). Transects were randomly placed along each aspect at least 5 meters apart and were not located within 30 meters of a parallel forest edge. Transects in all woodlands extended less than one-half the

TABLE 1. Density gradient (number individuals per plot) by aspect for selected herbaceous and woody seedling species. Different letters denote significant differences (SNK, $P < 0.5$).

Species	Aspect	Distance from edge (meters) 0.5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Cerastium	North	0.8a	2.5ab	2.1ab	2.8ab	3.3ab	2.8ab	4.1b	3.9b
spp.	West	1.5a	1.0a	1.1a	2.1a	1.8a	1.6a	2.3a	2.0a
Cornus	North	0.7a	0.5a	0.4a	0.2a	0.4a	0.1a	0.1a	0a
racemosa	West	0.5a	0.2ab	0.1ab	0.2ab	0.1ab	0b	0.1ab	0b
Cystopteris	North	0a	0.3ab	0.4ab	0.4ab	0.6ab	0.5ab	0.5ab	1.1b
fragils	West	0.1a	0a	0a	0a	0a	0.3a	0.5ab	1.0b
Menispermum	North	0.5a	0.8a	0.3a	0.4a	0.3a	0.3a	0a	0a
canadense	West	1.4a	1.2a	1.5a	0.8a	0.5a	0.6a	0.6a	0.2a
Toxicodendron	North	3.4a	2.6ab	2.7ab	2.6ab	2.2ab	1.6ab	1.3b	1.0b
radicans	West	1.3a	1.6a	1.1a	1.3a	0.6a	0.6a	0.9a	1.1a
Urtica	North	1.1a	0.7a	1.9a	2.3a	1.2a	1.0a	2.2a	2.9b
dioica	West	0a	0a	0.7ab	0.4ab	0.6ab	0.7ab	0.2ab	1.9b

distance to the opposite side of the forest, thus minimizing intrusion of edge effects from the opposing edge.

Data collection for herbs and woody seedlings began on May 15 and was completed by June 10. A line intercept sampling method was utilized by stretching a steel tape along each 40 m transect. Each transect was divided into eight, five meter plots. All herbaceous individuals touching or overhanging the steel tape were tallied by species in each plot.

Two-meter wide belt transects, subdivided into four 10 meter long plots, were used to sample shrub and tree species (the shrub strata) along the same 40 meter transects used for seedlings and herbaceous species. All woody stems greater than one meter in height and less than 10 cm dbh within one meter of either side of the transect center line were tallied by species in each plot.

All four woodlands were combined for statistical analysis. Statistical treatment of the data was by analysis of variance using SAS PROC GLM (SAS Institute, 1985). All tests were performed at the 0.05 level of significance. The Student-Newmen-Keuls (SNK) means separation test was used to examine significance of aspect and distance from edge for all species pooled and for individual species. An analysis of covariance was run to determine if species responded to canopy gaps.

RESULTS AND DISCUSSION

The total number of herbaceous and woody seedling species encountered in the sampling was just over 100. Because some species occur infrequently, the number of species tested for response to proximity to the edge was reduced to 37 for statistical analyses. The 37 species selected were chosen, because they occurred

TABLE 2. Density gradient (number of stems/ha) by aspect for selected shrub and tree species (< 10 cm dbh) with distance from the forest/cropland edge. Means with different letters denote statistical significance (SNK, $P < .05$).

		Distance from edge (meters)			
Species	**Aspect**	**0-10**	**10-20**	**20-30**	**30-40**
Celtis occidentalis	North	167a	146a	125a	83b
	West	625a	208b	125b	125b
Cornus racemosa	North	2167a	938b	708b	146b
	West	1833a	333b	146b	83b
Crataegus spp.	North	500a	146a	83a	63a
	West	521a	125b	42b	21b
Fraxinus americana	North	437a	271ab	167ab	104b
	West	625a	458a	458a	271a
Quercus rubra	North	125a	42b	21b	21b
	West	250a	63b	63b	0b

in sufficient quantities for analysis, or if infrequent, obviously exhibited a trend in density change with distance from the edge.

A significant difference in density of herb and woody seedlings was found between the north and west aspects. Within the forty meter sampling zone, the west and north edges had densities of 48.5 and 55.1 individuals per plot, respectively. Densities of the shrub strata between aspects was also significantly different, but in contrast to the herbs and seedlings, the highest density was within the west aspect with 6200 stems per ha compared to the north aspect with 5150 stem per ha. The different density response to aspect between herbs and shrubs may occur because the herbs are responding with higher densities to greater moisture levels and lower surface temperatures within the north edge. The shrubs probably respond in great density within the west edge due to higher light intensities here than would occur in the north edge. Higher shrub densities may modify the environment for herbaceous species, resulting in lowered densities for herbs on western edges.

Because of the contrast in microclimate between the west and north edge, the density distribution for individual species should show variability in response to distance from edge between aspects; that is, the edge zone will be deeper on the west side of the forest. This is indicated by density gradients for *Cystopteris fragilis, Menispermum canadense,* and *Urtica dioica* but is not clear for other species (Table 1). Shrubs responding similarly are *Crataegus* spp., *Celtis occidentalis, Fraxinus americana,* and *Quercus rubra* (Table 2). *Cornus racemosa,* while apparently an edge species, has higher densities in northern than in western edges.

When all species of herbs and woody seedlings were pooled for both aspects, the density of individuals showed no significant response with distance from the edge. However, shrub density was significantly higher within the first 10 meters

TABLE 3. Mean density (number of stems/ha) of selected shrub and tree species (< 10 cm dbh) with distance from the forest/cropland edge in woodlands at the Davis-Purdue Agricultural Center. Means with different letters denote statistical significance (SNK, P < .05).

	Distance from edge (meters)			
Species	0-10	10-20	20-30	30-40
Celtis occidentalis	385a	145b	145b	125b
Cornus racemosa	2000a	635b	395b	145b
Crataegus spp.	510a	105b	95b	40b
Fraxinus americana	530	315b	280b	270b
Quercus rubra	190a	40b	40b	20b
All species combined	7300a	5520b	5080b	4820b

TABLE 4. Mean density of selected herbaceous and woody seedling species with distance from the edge. Means with different letters denote statistical significance (SNK, P < .05) for densities of species with distance.

	Distance from edge (meters)							
Species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Certastium spp.	1.2a	1.8abc	1.6ab	2.5abc	2.6abc	2.2abc	3.2bc	2.9c
Cornus racemosa	0.6a	0.4ab	0.3b	0.3b	0.2b	0.1b	0.1b	0b
Cystopteris fragilis	0.1a	0.1a	0.2a	0.2a	0.3a	0.4a	0.5a	1.1b
Menispermum canadense	0.9a	1.0a	0.9a	0.6ab	0.4ab	0.5ab	0.3ab	0.1b
Sanicula marilandica	4.3a	6.7b	7.2b	7.0b	7.4b	6.9b	7.9b	8.2b
Toxicodendron radicans	2.4a	2.1ab	1.9ab	1.9ab	1.4ab	1.1b	1.1b	1.1b
Urtica dioica	0.1a	0.3ab	1.3ab	1.3ab	0.9ab	0.8ab	1.2ab	2.4ab
All species combined	49a	53a	51a	55a	50a	50a	52a	55a

from the edge (Table 3). This agrees with Ranney's (Ranney, *et al.*, 1981) conclusion that shrub densities decrease toward the interior. Wales (1972) also concluded that species with vigorous asexual reproduction or that are shade intolerant were more important in the edge. Species richness (species per plot) was also found to be highest in the first 10 meters from the edge, which also concurs with the findings of Ranney, *et al.* (1981).

When individual species of herbs and woody seedlings were examined, two general responses were found (Table 4): 1) species with increasing densities nearer the edge *(Menispermum canadense, Toxicodendron radicans,* and *Cornus racemosa);* and 2) species which were more dense toward the interior *(Sanicula marilandica, Urtica dioica, Cerastium* spp., and *Cystopteris fragilis).* Some species exhibited the the trend more strongly than others, but all trends were signficant.

Herb, shrub, and tree (seedlings) species were found to respond to canopy gaps due to tree falls. Herbs and tree seedlings, which had a positive response to canopy gaps, included *Aesculus glabra, Cornus racemosa, Geum vernum, Osmorhiza longistylus,* and *Solidago* spp. Shrubs and saplings showing a positive response were *Celtis occidentalis, Ostrya virginiana, Rubus occidentalis, Vitis* spp., and *Smilax* spp. These species were also typical of those found in higher densities near the edge. However, although soil temperature increases in canopy gaps similar to edges (Collins, *et al.,* 1985), canopy gaps do not represent edge conditions, since gaps lack the prevailing, below-canopy wind conditions and lower moisture levels characteristic of edges (Bruner, 1977; Collins, *et al.,* 1985; Geiger, 1966; Ranney, *et al.,* 1981). Wales (1972) considered that canopy gaps may have masked some of his data on edge gradients but concluded after investigation that the effect was minimal.

The results of this study are in accord with previous studies which found that plants react to microclimatic differences in the edge as compared to the interior of forest fragments. However, previous studies have not identified herbaceous species indicative of interior conditions. This study suggests that the distribution of some species in terms of density is responsive to an edge gradient. Generally, species showing the greatest affinities for edge zones are vines and intolerant woody species (Table 2). Two species with high fidelity for interior conditions are *Urtica dioica* and *Cystopteris fragilis*. The latter is a potential indicator species of interior conditions. Its significant increase in density within the 35-40 meter distance interval is apparent.

The depth of response by some species is also significant, since it shows edge effects to be deeper than previous studies have revealed. The data suggest that 35-40 meters is the depth of edge effects on the plant community. However, more data are needed to examine species change at distances beyond 40 meters from the edge.

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