Effects of Strip-cropping on Small Mammal Population Dynamics in Soybean Agroecosystems[1]

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ABSTRACT. The present study examined the effects of strip-cropping and harvesting practices on small mammal population dynamics in soybean agroecosystems. Small mammals were live-trapped in four treatments (three replicates each): soybean monoculture, soybean-clover, soybean-buckwheat, and soybean-corn. *Peromyscus maniculatus* was found in all four treatment types, whereas *Mus musculus* resided mainly in the soybean-corn treatment. *Peromyscus* population densities were significantly greater in the soybean monoculture during the week preceding harvest than in the soybean-clover strip-cropped treatment. *Peromyscus* population densities immediately increased following harvesting practices, then declined. Short-term changes in density were attributed to seed accessibility; long-term changes appeared to be in response to reduced crop cover resulting in increased predation. Populations of *Mus* were unaffected by harvest practices. Interestingly, more *Peromyscus* dispersed from strip-cropped treatments than from the monoculture (control) treatment. Female deer mice were found to have larger mean home ranges in the corn strip-cropped treatment than in the monoculture or buckwheat strip-cropped treatment suggesting an impact of spatial resource patterning on small mammal population dynamics.

INTRODUCTION

Recently much emphasis has been placed on an approach to agriculture more sustainable than that used in the past (e.g., NRC 1989, Barrett et al. 1990, Parr et al. 1990). Strip-cropping is a type of inter-cropping that represents an alternative approach to conventional agriculture. Although several studies have focused on the effects of strip-cropping on insect population dynamics (Kemp and Barrett 1989, Pavuk and Barrett 1993) and insect movement behavior (Risch 1981, Bohlen and Barrett 1990), no studies have been conducted to investigate the effects of strip-cropping on the population dynamics of small mammals. The present study was designed to investigate the effects of strip-cropping, including harvesting practices, on small mammal population dynamics and dispersal behavior within replicated monoculture (control) and strip-cropped soybean agroecosystems in southwestern Ohio.

MATERIALS AND METHODS

Study Site

The study was conducted at the Miami University Ecology Research Center located near Oxford, OH. The study area consisted of twelve 0.4-ha (75 m x 60 m each) agroecosystem plots (see Kemp and Barrett 1989 for aerial view of study site). Soybeans (*Glycine max* var. Williams 82) were planted 2-4 May 1992. Three plots were planted as soybean monocultures to serve as controls and the remaining nine plots were strip-cropped: three plots of soybean-corn, three plots of soybean-clover, and three of soybean-buckwheat. Corn (*Zea mayes* Hybrid County Mark 707) was planted on 4 May 1992, red clover (*Trifolium pratense*) was planted on 11 May 1991, and

buckwheat (*Fagopyrum esculentum*) was planted on 11 June 1992. Each strip-cropped treatment contained 14 alternating strips (six rows per strip) each 6 m in width. The 12 plots were aligned in two rows of six (Fig. 1). Ten meters separated each experimental plot, whereas 15 m separated all plots from surrounding habitats.

Census Procedures

Two hundred eighty-eight Sherman live traps (24 traps/plot) were uniformly distributed among treatments. Twenty-four traps were placed in the eight center strips in each strip-cropped plot. An equal number of traps were positioned at equivalent sites in each soybean monoculture plot. The distance between each trap within each strip was 15.7 m.

Trapping was conducted at least twice weekly from 12 September-20 November 1992 and consisted of 1,440 trap nights per treatment equally distributed before and after harvesting. Trapping was initiated at the beginning of seed (crop) maturation. Each plot was disturbed by harvesting practices from 12-25 October.

Traps, baited with peanut butter and supplied with cotton for nesting material, were set between 1900-2000 hours and checked the following morning between 0700-0800 hours. Traps were locked open between trapping dates, thus effecting a pre-baiting trapping regime (Smith et al. 1975). Captured individuals were identified to species, marked by toe clipping, weighed to the nearest 1.0 g, sexed, and the reproductive condition recorded. Reproductive condition for males was determined by position of testes (scrotal/non-scrotal) and for females by vaginal perforation (perforate/non-perforate), pregnant, and/or lactating.

Population density was estimated by the calendar-of-catches method (Petrusewicz and Andrzejewski 1962). Home range was determined by the inclusive boundary strip method (Stickel 1954). Dispersal behavior was
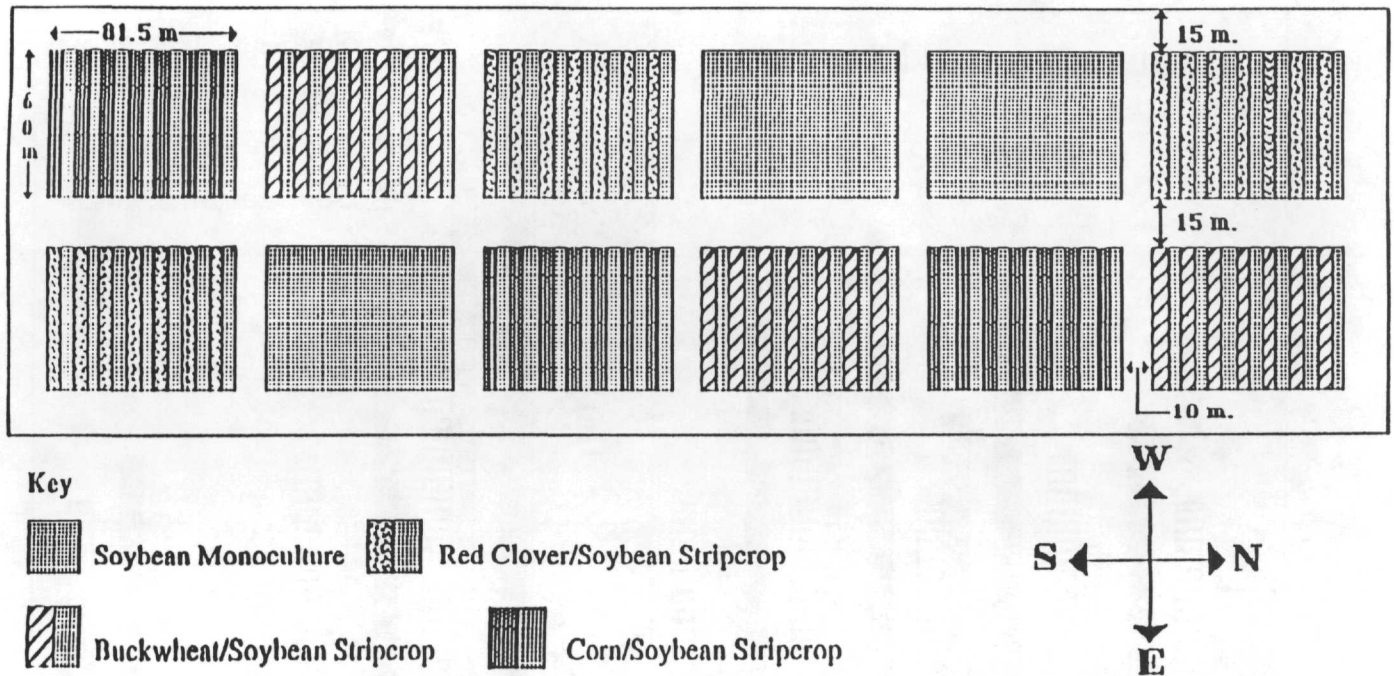
FIGURE 1.   Research design depicting 12 strip-cropped experimental plots (4 treatments, $N = 3$ each) at the Miami University Ecology Research Center.

examined as follows. Mice were considered residents if they were captured five or more times within the same treatment without dispersing between treatments. Dispersers were identified as animals that moved from one treatment to a different treatment without returning to the treatment where it originally resided and/or was initially captured.

Food availability per treatment during early winter was determined by the harvest method. Four random sites (each 0.5 m²) per plot were sampled on 10 December. Two seed samples were collected from each strip-cropped strip in each plot (excluding the soybean-clover plots) and two from each soybean strip. Four samples were collected from each monoculture plot.

Statistical Analysis

Bonferroni/Dunn (all means) tests were used to compare mean weekly population densities among treatments and to evaluate mean home range size among treatments and between sexes. Significant differences were determined at the $P < 0.05$ level of probability for all analyses.

RESULTS

Fifty-five female and 43 male deer mice (*Peromyscus maniculatus*), nine female and 12 male house mice (*Mus musculus*), and four female and one male meadow voles (*Microtus pennsylvanicus*) were captured during the investigation. All meadow voles were captured during the preharvest period; three females and one male vole were trapped in the soybean-buckwheat treatment and one female in the clover-soybean treatment.

Peromyscus mean population densities were consistently greater from mid-September through late-October in the soybean monoculture compared to strip-cropped treatments. A significant difference ($P < 0.05$) in mean

population densities was found for *Peromyscus* in soybean monoculture compared to the soybean-clover treatment during the week prior to harvest (Fig. 2). Mean population densities of deer mice increased in all treatments the week following harvesting except soybean/corn (Fig. 2). When population densities the week prior to harvesting were compared to densities per treatment immediately following harvest only the monoculture treatment was marginally significant ($P = 0.07$).

Mus only occurred in the soybean-corn and soybean-buckwheat treatments (Fig. 2). Population densities of *Mus* were typically greater in the soybean-corn strip-cropped treatment compared to other treatments. A significant difference ($P < 0.05$) in mean population densities of *Mus* was found between the soybean-corn and soybean-buckwheat treatments during the week of 25 September 1992. This difference in mean population densities between treatments was likely related to differences in crop cover resulting in differential rates of avian predation since corn was at maximum foliage at the time, whereas buckwheat was in the process of foliage senescence. House mice were no longer captured in the soybean-buckwheat treatment by the week of 2 October and no longer captured in the soybean-corn treatment by the week of 6 November 1992. Lack of cover due to harvesting likely attributed to increased predation of *Mus* during late October.

No *Peromyscus* dispersed from the soybean monoculture during the preharvest period (Table 1). Twenty-three residents and only two dispersers were recorded during the postharvest period. Deer mice in the soybean-clover treatment exhibited a similar pattern of dispersal behavior (i.e., 14 residents and two dispersers captured during preharvest, and 16 residents and two dispersers captured during postharvest). Interestingly, the soybean-
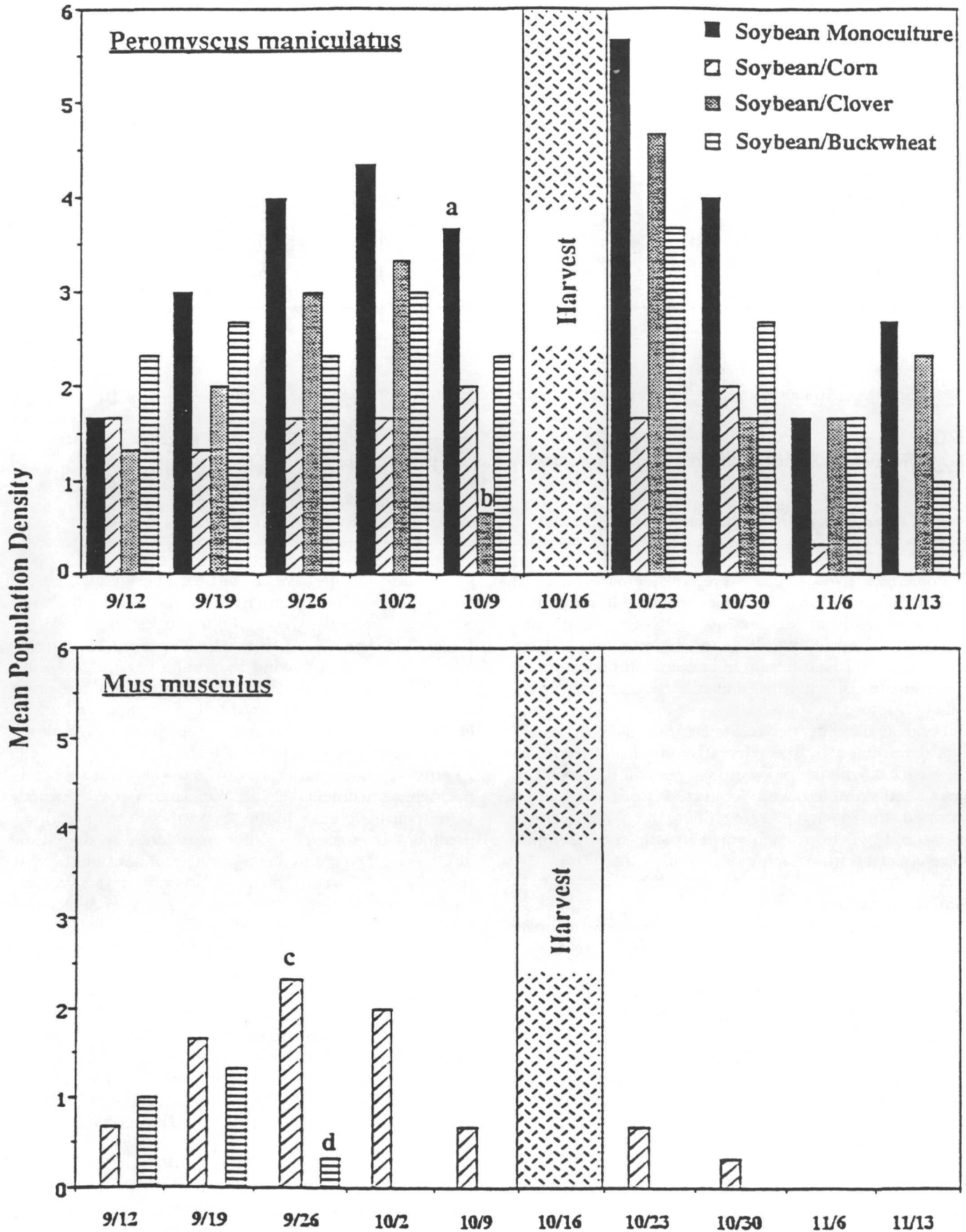
FIGURE 2. Estimated mean population densities of *Peromyscus maniculatus* and *Mus musculus* in strip-cropped agroecosystems. Significant differences (*P* <0.05) shown by different letters.

TABLE 1

Summary of small mammal dispersal behavior before and following harvesting practices in monoculture and strip-cropped soybean agroecosystems. Preharvest (12 Sept–11 Oct) and postharvest (26 Oct–20 Nov) values (N) summarized per treatment.

Species	Soybean (Monoculture)				Soybean (Clover)				Soybean (Buckwheat)				Soybean (Corn)			
	Preharvest		Postharvest		Preharvest		Postharvest		Preharvest		Postharvest		Preharvest		Postharvest	
	R*	D*	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Peromyscus																
Male	8	0	8	1	8	1	6	1	6	4	11	0	4	3	2	2
Female	13	0	15	1	6	1	10	1	7	3	3	2	6	0	4	1
Total	21	0	23	2	14	2	16	2	13	7	14	2	10	3	6	3
Mus																
Male	0	0	0	0	0	0	0	0	3	0	0	0	7	2	2	0
Female	0	0	0	0	0	0	0	0	3	0	0	0	6	1	0	0
Total	0	0	0	0	0	0	0	0	6	0	0	0	13	3	2	0

*R designates resident individual; D designates disperser.

buckwheat treatment had more *Peromyscus* dispersers ($N = 7$) than any other treatment during the preharvest period. Six resident *Mus*, however, remained within this treatment during the preharvest period. The least number of resident deer mice ($N = 10$) was found during the preharvest period in the soybean-corn treatment, whereas the greatest number of resident house mice ($N = 13$) was found in this treatment during this time. The number of deer mouse dispersers ($N = 3$) during preharvest was equal to that during the postharvest period. The population of *Mus* in the soybean-corn strip-cropped treatment consisted of three dispersers during preharvest and no dispersers during postharvest.

Mean home range values were determined only for the *Peromyscus* population because of small *Mus* and *Microtus* population densities and recaptures. A significant difference ($P < 0.05$) in mean home range for females was found between soybean-buckwheat and soybean-corn treatments and between soybean monoculture and soybean-corn treatments. No significant differences in mean home ranges for males were found between treatments. *Peromyscus* home range size in the strip-cropped treatments was larger than in the soybean monocultures. Also, males tended to have larger home ranges than females (Table 2). Small sample size prevented a valid pre- and post-harvesting comparison of mean home range size among treatments.

Visual observations confirmed that seeds were abundant in all treatments following harvesting practices. Seed sampling on 10 December 1992 showed that food remained plentiful. A substantial amount of soybeans (mean seeds ± S.D./0.25 m²) was present in both the monoculture ($\bar{x} = 17 \pm 9$) and the strip-cropped ($\bar{x} = 18 \pm 10$) treatments. There was also an abundance of buckwheat seeds in the soybean-buckwheat treatment ($\bar{x} = 101 \pm 27$) and corn ($\bar{x} = 5 \pm 4$) in the soybean-corn strip-crop treatment at this time. Clover seeds were not sampled in early winter due to small seed size and lack of visual abundance.

DISCUSSION

The present study represents the first attempt to investigate the effects of alternative agriculture on small mammal populations inhabiting strip-cropped soybean agroecosystems. Limited information was gained regarding *M. pennsylvanicus* because only five meadow voles were captured prior to harvest. Harvesting practices likely account for the disappearance of meadow voles during the postharvest period because voles have a propensity for heavy vegetative cover (Birney et al. 1976).

House mice were found mainly in the soybean-corn strip-crop treatment. This is expected because *Mus* prefer corn as the main food source (Fleharty and Navo 1983). *Mus* populations, however, reached peak densities during mid-September and failed to increase in density following harvesting. Interestingly, the least number of deer mice were captured in the soybean-corn treatment during

TABLE 2

Mean home range (m²) of resident Peromyscus maniculatus *in strip-cropped soybean agroecosystems.*

	Soybean Monoculture	Soybean/ Clover	Soybean/ Buckwheat	Soybean/ Corn
Male	ab 776 ± 33 $n = 2$	ab 1575 ± 33 $n = 2$	ab 1375 ± 638 $n = 4$	ab 1598 ± 332 $n = 2$
Female	a 710 ± 411 $n = 10$	ab 1050 ± 241 $n = 3$	a 674 ± 287 $n = 3$	b 1387 ± 33 $n = 2$

Different letters show home range differences per sex within (a) and between (b) treatments.

mid-September (Fig. 2) when *Mus* densities peaked within this treatment. Findings suggest that competition for food resources might have occurred at this time between these two granivorous small mammal species. *Mus* populations completely disappeared two weeks after harvesting although food (corn) was abundant, especially at ground level. This difference could not be attributed to dispersal behavior since no *Mus* dispersed from the soybean-buckwheat treatment throughout the study (Table 1). This suggests that predation, rather than energy, regulate *Mus* populations in harvested agroecosystems. Predation on small mammals has previously been shown to be related to crop cover in corn agroecosystems (Barrett et al. 1990). It is also possible that competition exists between populations of *Mus* and *Peromyscus* inhabiting these harvested habitats since deer mice have a propensity for more open habitats (see below).

Although deer mice inhabited all treatments, greater population densities were found in soybean monocultures. The increase in population density after harvesting was attributed to: a) an increase in food accessibility, and b) the resulting lack of cover which attracted new individuals. Linduska (1950) also observed a population increase in deer mice following harvesting of grain crops in Michigan. Several studies have documented the propensity of *Peromyscus* to inhabit the more open or disturbed types of agricultural habitat (e.g., Whittaker 1966, Froud-Williams et al. 1983, Barrett et al. 1990). *Peromyscus* population densities subsequently decreased during November in all treatments. This decrease was not from a lack of available food (grain), but most likely caused by predation. Barrett et al. (1990) also observed increased predation on deer mice in experimental corn plots at this site.

The large number of resident *Peromyscus* inhabiting soybean monocultures suggests that this simplified agroecosystem provided ideal habitat for this species. As reported in several previous studies (see review by Stickel 1968), *Peromyscus* males had a larger home range than females. In general, *Peromyscus* had a larger home range in strip-cropped treatments than in the monoculture treatment. Specifically, females in the corn strip-cropped treatment had a significantly greater mean home range size than females in the soybean monoculture or the buckwheat strip-cropped treatments. This difference was likely exacerbated by spatial resource patterning (Stueck and Barrett 1978, Kemp and Barrett 1989) within strip-cropped systems. The effect of spatial patterning was further substantiated because more deer mice dispersed from strip-cropped agroecosystems, whereas more residents were found in the more spatially homogeneous monoculture habitat. This suggests that strip-cropping affects small mammal population dynamics and dispersal behavior in agroecosystems. Harper et al. (1993) have also recently documented effects of habitat geometry on small

mammal population dynamics. Future studies need to focus on spatial patterns within the total agricultural landscape mosaic.

LITERATURE CITED

Barrett, G. W., C. S. Haviland, and D. H. Taylor 1990 Perturbation effects on deer mouse populations in corn agroecosystems. Ohio J. Sci. 90: 125-129.

Birney, E. C., W. E. Grant, and D. D. Baird 1976 Importance of vegetative cover to cycles of *Microtus* populations. Ecology 57: 1043-1051.

Bohlen, P. J. and G. W. Barrett 1990 Dispersal of the Japanese beetle (Coleoptera: Scarabaeidae) in strip-cropped agroecosystems. Environ. Entomol. 19: 955-960.

Fleharty, E. D. and K. W. Navo 1983 Irrigated cornfields as habitat for small mammals in the sandsage prairie region of western Kansas. J. Mammal. 64: 367-379.

Froud-Williams, R. J., R. J. Chancellor, and D. S. H. Drennan 1983 Influence of cultivation regime upon buried weed seeds in arable cropping systems. J. Appl. Ecol. 20: 199-208.

Harper, S. J., E. K. Bollinger, and G. W. Barrett 1993 Effects of habitat patch shape on meadow vole (*Microtus pennsylvanicus*) population dynamics. J. Mammal. 74: 1045-1055.

Kemp, J. C. and G. W. Barrett 1989 Spatial patterning: Impact of uncultivated corridors on arthropod populations within soybean agroecosystems. Ecology 70: 114-128.

Linduska, J. P. 1950 Ecology and land-use relationships of small mammals on a Michigan farm. Game Div., Mich. Dept. Conserv., Lansing, MI. 144 pp.

National Research Council 1989 Alternative Agriculture. National Academy Press, Washington, DC. 448 pp.

Parr, J. F., R. O. Papendick, I. G. Youngberg, and R. E. Meyer 1990 Sustainable agriculture in the United States. In: C. A. Edwards, L. Rattan, P. Madden, R. H. Miller, and G. House (eds.), Sustainable Agricultural Systems, Soil and Water Conservation Society, Ankeny, IA. pp. 50-67.

Pavuk, D. M. and G. W. Barrett 1993 Influence of successional and grassy corridors on parasitism on *Plathypena scabra* (F.) (Lepidoptera: Noctuidae) larvae in soybean agroecosystems. Environ. Entomol. 22: 541-546.

Petrusewicz, K. and R. Andrzejewski 1962 Natural history of a free-living population of house mice (*Mus musculus* Linnaeus). Ecol. Pol. Sec. A. 10: 85-122.

Risch, S. J. 1981 Insect herbivore abundance in tropical monocultures and polycultures: An experimental test of two hypotheses. Ecology 62: 1325-1340.

Smith, M. H., R. H. Gardner, J. B. Gentry, D. W. Kaufman, and M. H. O'Farrell 1975 Density estimates of small mammal population. In: F. B. Golley, R. Petrusewicz, and L. Ryszkowski (eds.), Small Mammal Productivity and Dynamics of Populations. Cambridge University Press, London, England. pp. 25-53.

Stickel, L. F. 1954 A comparison of certain methods of measuring ranges in small mammals. J. Mammal. 35: 1-15.

_____ 1986 Home range and travels. In: J. A. King (ed.), Biology of *Peromyscus* (*Rodentia*), Special Publication No. 2, American Society of Mammalogists. pp. 373-411.

Stueck, K. L., and G. W. Barrett 1978 Effects of resource partitioning on the population dynamics and energy utilization strategies of feral house mice (*Mus musculus*) populations under experimental field conditions. Ecology 59: 539-551.

Whittaker, J. O. 1966 Food of *Mus musculus*, *Peromyscus maniculatus bairdii* and *Peromyscus leucopus* in Vigo County, IN. J. Mammal. 47: 473-486.