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Species-area relationship of migrants in isolated woodlots in east-central Illinois.—Many species of birds use woodlots temporarily for resting and foraging while on migration (Martin 1980, Graber and Graber 1983), and the loss of forest habitat and its fragmentation into isolated patches may adversely affect these birds (Graber and Graber 1983). Isolated patches of forest may be important particularly to migrants in highly disturbed landscapes where

natural habitat is rare (Martin 1980). East-central Illinois is primarily agricultural land that is unsuitable for many forest-dwelling species, although isolated woodlots are refuges for summer residents (Blake and Karr 1984). Because migrating birds encounter and use a variety of habitats during the course of migration, many species may use woodlots that are smaller than they generally require for breeding. Thus, small patches of forest may be more important for species preservation than conclusions drawn from studies of birds during the breeding season might suggest (Blake and Karr 1984).

Here I examine the relationship between area of isolated woodlots in east-central Illinois and number of species found in these woodlots during migration. I emphasize results collected in spring because dense foliage and the relatively inconspicuous behavior and plumage of many species made birds harder to detect in fall.

Methods.—A total of 14 woodlots, ranging in size from 1.8 to 600 ha, were studied during spring (1979–1981) and fall (1979–1980) migratory periods. Because of time constraints and adverse weather conditions, I was not able to include all woodlots in each season. Censusing in 1980 was more extensive than in either 1979 or 1981. Number and choice of woodlots were dictated by the landscape of east-central Illinois. Only woodlots that possessed a relatively mature canopy and well-developed understory, showed no evidence of recent heavy disturbance, and were surrounded by nonforest habitat were included.

I surveyed birds using the point-count technique (Ferry and Frochot 1970). Absolute sampling effort (number of observation points) increased with area in order to obtain a reasonably complete count of species present in larger woodlots. Points were at least 150 m apart.

I conducted censuses from sunrise until 2.5 h after sunrise on days with little or no wind and no precipitation. Weather patterns may strongly influence movements of migrants, but I did not attempt to correlate species numbers in individual woodlots with specific weather patterns. I attempted to minimize potential effects of changing weather patterns by sampling on days without storms, high winds, or other unusual weather. In addition, I censused woodlots in an order unrelated to their size, thereby reducing the potential for weather effects on the species-area relationship.

I visited each observation point for 10 min during a census and recorded all birds seen or heard within the canopy. Hawks and American Crows (*Corvus brachyrhynchos*) were excluded because these species regularly ranged far beyond woodlot boundaries. Nocturnal species also were not recorded. Census effort ranged from 4 to 17 days, with a majority of areas censused a total of 12–17 days. I regressed species number against the number of census days for each woodlot to determine the influence of census effort on species richness. Species richness was expressed as the total number of species recorded in a woodlot over an entire season. In addition, I grouped censuses by dates (using natural breaks of two or more days in censusing to define groups) to examine within-season changes in the species-area relationship during the spring and fall of 1980. Each day that a woodlot was censused was used as an estimate of species richness for that woodlot on that day.

I analyzed species composition on the basis of migratory status because this factor has been identified (e.g., Whitcomb et al. 1981) as particularly relevant to the study of the effects of forest fragmentation on bird communities. I assigned species to two major groups: those that breed in Illinois and those that do not (Bohlen 1978, Kendeigh 1982). The former group included permanent residents in Illinois (including all species for which at least some individuals are resident in east-central Illinois throughout the year), long-distance migrants that overwinter in Central and South America, and short-distance migrants that overwinter south of Illinois but north of the tropics. "Woodlot residents" included all species that bred on one or more of the woodlots surveyed in this study (Blake 1983). Species that do not breed in Illinois included long-distance migrants that winter in the tropics and short-distance migrants that either pass through Illinois or are winter residents.

TABLE 1
DISTRIBUTION OF SPECIES RECORDED DURING MIGRATION IN WOODLOTS IN EAST-CENTRAL ILLINOIS

Woodlot area (ha)	Total species	Breeding residents				Transients	
		Woodlot* residents	Permanent residents	Long-distance migrants	Short-distance migrants	Long-distance migrants	Short-distance migrants
1.8	45	13	7	11	9	10	8
2.3	58	19	9	12	15	12	10
4.7 ^b	39	19	11	10	8	5	5
5.1	60	20	11	16	13	13	7
6.5	64	22	11	14	14	12	13
16.2	58	18	12	14	13	10	9
24	67	31	12	15	14	14	12
24	58	29	10	14	13	12	9
28	61	36	12	17	14	9	9
40 ^b	40	22	12	8	8	6	6
65	64	33	13	16	11	15	9
65 ^b	54	37	11	18	13	6	6
118 ^b	54	33	11	17	11	9	6
600	84	48	13	23	16	16	15

* Includes permanent residents and long- and short-distance migrants that bred on one or more woodlots.

^b Censused a total of 4 or 5 days.

I evaluated species-area relationships according to the exponential function of Gleason (1922), where $S = k \ln A + c$, where S is number of species, A is forest area (in ha), and k and c are fitted constants. I used the exponential model rather than the power function ($\ln S = z \ln A + \ln c$) because the former model accounted for the greatest amount of variation in species number and because examination of residuals did not indicate that the power function resulted in a better fit. I tested species richness data for normality (Shapiro-Wilks Test, Barr et al. 1979).

Bird community composition.—Ninety-five species were recorded from one or more woodlots during one or more seasons. Species totals were highest in 1980 when there was greater coverage of all areas, and totals were higher in spring than in fall, at least in part due to lower detectability of species in fall. Species that breed in Illinois ($N = 62$) accounted for 65% of the total and included 17 permanent resident species, 30 long-distance migrants, and 15 short-distance migrants. Species that do not breed in Illinois included 18 long-distance and 15 short-distance migrants.

Species-area relationships.—Species totals for all seasons combined generally were correlated with number of census days, primarily a consequence of variation in number of transient species. When the four woodlots censused on five or fewer days (Table 1) were excluded, species totals for the remaining 10 woodlots correlated poorly with number of census days. Total species number correlated strongly with area (Species number = $4.8[\ln A] + 48.4$; $r^2 = 0.719$, $P < 0.01$; $N = 10$) (Table 1). In addition, number of species in all categories except short-distance migrants was correlated with woodlot area (Fig. 1). Many short-distance migrants preferred edge habitat and were scarce in forest interiors, and they appeared to be less restricted in distribution among woodlots by the area of the woodlot. Number of woodlot residents increased rapidly with area (Fig. 1), but number of permanent

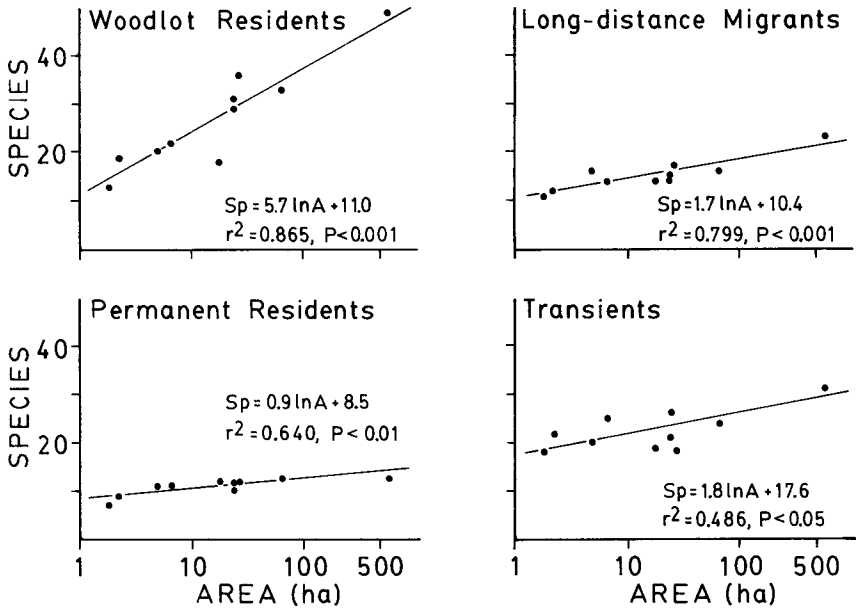


FIG. 1. Species number (Sp) within migratory categories plotted against natural log (ln) of woodlot area (A).

resident species changed little over the size range of woodlots surveyed (Table 1, Fig. 1). Number of transient species was correlated positively with area (Fig. 1), and many species occurred in small woodlots (Table 1).

I examined distribution of species within different migratory categories separately for each season. Total number of species correlated with area in all spring seasons (1979, $r^2 = 0.581$, $P < 0.05$; 1980, $r^2 = 0.745$, $P < 0.001$; 1981, $r^2 = 0.659$, $P < 0.05$) (Fig. 2). Number of woodlot resident species (Blake and Karr 1984) correlated with area in all years as well (1979, $r^2 = 0.755$, $P < 0.01$; 1980, $r^2 = 0.841$, $P < 0.001$; 1981, $r^2 = 0.769$, $P < 0.01$). Number of species of long-distance migrants correlated with area in 1979 ($r^2 = 0.585$, $P < 0.05$) and 1980 ($r^2 = 0.599$, $P < 0.01$), but not in 1981. Many long-distance migrants arrive in Illinois late in spring, a period that was not well covered in 1981 owing to frequent thunderstorms. Number of species that migrate short distances generally correlated poorly with area in all spring periods.

Number of woodlot and permanent resident species correlated with area in fall 1979 ($r^2 = 0.387$, $P < 0.05$ and $r^2 = 0.497$, $P < 0.05$, respectively), but no other group showed a significant correlation with woodlot area in fall 1979. By contrast, all categories exhibited a significant area relationship during fall 1980 when coverage of woodlots was most complete. Correlation between woodlot residents and area was higher during fall 1980 ($r^2 = 0.721$, $P < 0.01$) than in fall 1979, while that for permanent residents was similar to results from 1979. Although number of short-distance migrant species was not correlated with woodlot area in spring 1980, it was in fall 1980 ($r^2 = 0.421$, $P < 0.05$).

Total species richness correlated strongly with area (Fig. 2) during fall 1980. Species totals were lower overall during fall than during spring (Fig. 2), and the species-area relationship

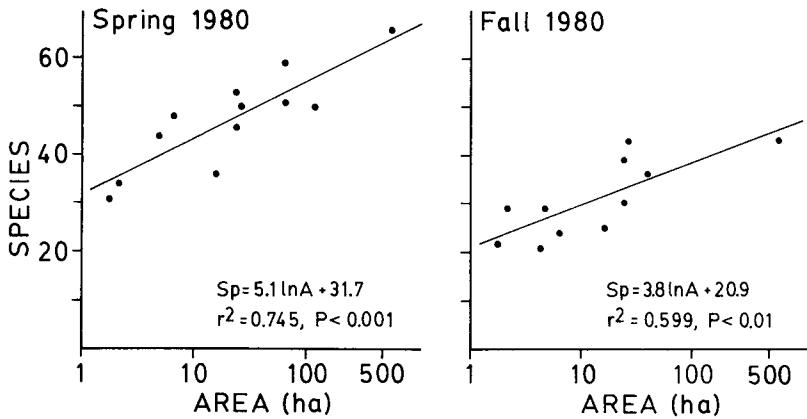


FIG. 2. Total number of species (Sp) recorded during spring and fall migratory periods in 1980 plotted against natural log (ln) of woodlot area (A).

had a higher intercept ($P < 0.05$) in spring than in fall. Slopes of the regression lines, however, did not differ ($P > 0.50$) between spring and fall 1980.

Species richness was correlated significantly with woodlot area in early (16 March–20 April, $r^2 = 0.471$, $P < 0.001$, $N = 24$) and late (1–31 May, $r^2 = 0.314$, $P < 0.01$, $N = 22$) spring 1980. The species-area relationship for the later period had a higher intercept (22.3 vs 9.7, $P < 0.001$) than during early spring, but slopes did not differ ($P > 0.10$). Thus the shape of the species-area curve remained constant during spring migration, but species richness increased. During fall 1980, species number correlated most strongly with area during early migration (26 August–10 September, $r^2 = 0.757$, $P < 0.001$, $N = 12$). During late summer and early fall, many migrating northern warblers pass through east-central Illinois, and the presence of these species influences the species-area relationship. Correlations between number of species and woodlot area were not as strong during middle (14–29 September, $r^2 = 0.234$, NS, $N = 13$) or late (2–28 October, $r^2 = 0.424$, $P < 0.05$, $N = 11$) fall migration.

Discussion.—Discussions concerning relative benefits of small and large reserves have concentrated on the breeding season (e.g., Simberloff and Abele 1982, Blake and Karr 1984). The relative importance of small forest tracts to birds during nonbreeding seasons can be related to the regional landscape pattern. The ability of migrants to pass successfully over highly disturbed landscapes may be increased by the presence of small patches of natural habitat. Larger woodlots accumulate a greater total number of species, but even small tracts may be used temporarily by a wide variety of species.

Recent studies by Graber and Graber (1983), however, indicate that small woodlots may not be sufficient as refuges for migrants if larger blocks of forest are not available also. Spring warblers were able to put on fat when foraging in southern Illinois, where total forest cover is extensive, but experienced a net energy loss while foraging in isolated woodlots in east-central Illinois (Graber and Graber 1983).

The greater species richness observed in Illinois woodlots during migration over that observed during summer (Blake and Karr 1984) was due both to the arrival of transient species that do not breed in the region and to the occurrence of species in woodlots smaller than those typically required for breeding. Many long-distance migrants (e.g., Ovenbird [*Seiurus aurocapillus*] and other warblers) occurred in a wider size range of woodlots than

during the breeding season (Blake and Karr 1984). Similarly, several permanent residents (e.g., Black-capped Chickadee [*Parus atricapillus*], Tufted Titmouse [*P. bicolor*], White-breasted Nuthatch [*Sitta carolinensis*]) were observed in smaller woodlots during migration than during summer (Blake and Karr 1984). The occurrence of these species in small woodlots during migration suggests that it is not an inability to colonize these woodlots that prevents their breeding in small woodlots during summer.

Many factors, including, but not limited to, high nest predation and parasitism in small forests may limit species occurrence during breeding seasons (e.g., Whitcomb et al. 1981); such restrictions would not apply during migration. Competitive interactions also may limit distribution of species during breeding seasons (Martin 1981), and Martin (1980) has suggested that in very small woodlots (<5 ha) competition may influence distribution of species during migration as well.

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