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Forest Fragments in East-central Illinois: Islands or Habitat Patches for Mammals?

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ABSTRACT.—We surveyed the nonvolant mammals in 10 forest fragments embedded in a matrix of row crop agriculture in east-central Illinois to assess the impact of forest fragmentation on mammalian diversity and distributions. A total of 19 species were recorded during our study, including 16 native species that occur naturally in forest habitat. We found a significant species-area relationship and a significantly nested subset structure. In particular, gray squirrels, chipmunks and flying squirrels were only encountered in the larger, more continuous sites suggesting a negative effect of habitat fragmentation. Seven species were ubiquitous and we believe that several others occur periodically at all study sites, indicating that most mammalian species currently present have not had their distributions altered by changes in the intervening habitat. Though an analogy to oceanic islands may apply for some species, we believe that most mammals treat forest remnants as habitat patches rather than islands, and that mechanisms such as habitat selection, constraints due to home range size and differential dispersal ability best explain the observed distributions of mammals.

INTRODUCTION

Human activities in many regions of the world have led to the drastic reduction and fragmentation of much of the natural habitat (Wilcove *et al.*, 1986). Fragmentation reduces the total area of habitat, reduces patch size, increases the ratio of edge to interior in patches and increases the distance between patches (Murcia, 1995), which could lead to local extirpations. The effects of fragmentation on the biota remaining in remnant patches of natural habitat need to be determined to develop effective strategies for maintaining or restoring biodiversity (McCoy and Mushinsky, 1994).

In the midwestern United States much of the natural habitat has been converted to agricultural use. In Illinois about 81% of the land area is currently used for agriculture (Neely and Heister, 1987); 50% of the land area is covered by row crops (primarily corn, *Zea mays*, and soybeans, *Glycine max*). East-central Illinois was once dominated by wet prairie dissected by rivers and riparian forest (Iverson *et al.*, 1989) but row-crop agriculture

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now covers 75% of the land area (Mankin and Warner, 1997). The original prairie habitat has been lost from this region, and most remaining forest patches are farmstead woodlots, with the largest tracts of forested habitat generally following rivers (Nixon *et al.*, 1978). These forest fragments often resemble islands in a sea of agriculture, as they can have discrete boundaries and are separated by habitat types that can serve as barriers to inter-patch movement.

A positive species-area relationship has been observed in many studies of the biota of oceanic or habitat islands and may be a general property of ecological systems (reviewed in Rosenzweig, 1995). The distribution of taxa among islands also is often strongly nested (Patterson, 1987; Cook, 1995). Perfectly nested subset structure occurs when all species present in habitat patches of low species richness are present in all habitat patches of higher species richness, such that the rarest species are only found in the most species-rich areas (Patterson and Atmar, 1986). Nested subset structure has been noted by many researchers across a wide variety of habitat types in addition to oceanic islands and for a wide variety of taxa (mammals: Brown, 1971; Cutler, 1991; Mills, 1996; fish: Kodric-Brown and Brown, 1993; birds: Blake, 1991; Telleria and Santos, 1995; parasites within fish: Guegan and Hugué, 1994; desert plants: Silvertown and Wilson, 1994). Nestedness implies a predictable pattern of extinction, with the rarest species being at greatest risk (Patterson, 1987; Brown, 1995). A positive species-area relationship in conjunction with significant nestedness means that only the most species-rich sites will contain rare species, with smaller sites harboring only the most common species. Under these conditions, conservation strategies to preserve regional biodiversity should focus on preserving the largest tracts of habitat rather than a series of smaller tracts (Wright and Reeves, 1992).

Local communities of breeding passerine birds in forest fragments in east-central Illinois yielded a significantly positive species-area relationship (Blake and Karr, 1984; Blake, 1991), and the distribution of breeding passerines among fragments formed a nested subset pattern (Blake, 1991). In our study, we inventoried the nonvolant mammals present in the forest remnants examined by Blake (1991) to assess the effect of habitat fragmentation on the distribution of woodland mammals. We examined the relationship between mammalian species richness and area of forest remnant, and tested for nested structure among sites. Finally, we evaluated the applicability of island biogeographic models to explain the patterns found.

METHODS

We surveyed mammals (except bats) in 10 isolated forest fragments in Champaign, Piatt and McLean counties in east-central Illinois. Our study sites were the same as those inventoried for breeding passerine birds by Blake (1991) and Blake and Karr (1984), except that in two cases we considered two adjoining sections of forest as a single site whereas Blake treated them as distinct fragments (our Piatt Co. Forest Preserve = Blake's Piatt Co. Forest Preserve A and B, and our Atwood 2 = Blake's Piatt Co. sites of 5.1 and 6.5 ha). Characteristics and specific locations of each site are described in Blake (1983). In general, all sites possessed a mature canopy of deciduous hardwood forest and a well developed understory. Forest patches ranged in size from 1.8 to 600 ha. Four study sites (Funk's Grove, Hart Woods, Piatt County Forest Preserve and Allerton Park) were located along the Sangamon River and included patches of riparian forest. The remaining sites were woodlots occurring within the matrix of corn and soybean agriculture that dominates the landscape in central Illinois (Iverson *et al.*, 1989).

We compiled species lists of mammals for each site during surveys conducted from 1992–1994. Small rodents and shrews were surveyed by live-trapping using Sherman live traps

baited with millet, supplemented by pitfall trapping. In August 1992, each site was live-trapped for three nights. Traps were placed at 10-m intervals along line transects intended to sample as much of the site as possible. Trap lines avoided habitat edges, and were concentrated in mature upland forest dominated by oaks (*Quercus* spp.), hickories (*Carya* spp.) and maples (*Acer* spp.). Four lines of 40 traps (160 total) were set at most sites; the smallest site (1.8 ha) received only 40 traps, the second smallest site (2.3 ha) received only 80 traps and the largest site (600 ha) was sampled in two separate areas for a total of 320 traps. In Sept.–Oct. 1993 each site was live-trapped a second time for two nights. Numbers of traps varied slightly among sites, but were similar to efforts in 1992. Two pitfall arrays, each consisting of 2–3, 25-cm deep pitfall traps linked by a 3-m drift fence, plus 2–4 additional pitfall traps placed along downed logs for a total of 10 pitfall traps were set at each site in autumn 1993. Pitfall traps were monitored for 5 nights. The presence of moles at each site was determined by observations of tunnels and mounds.

We used wooden nest boxes with 3.1-cm diam entrance holes to survey flying squirrels (Sonenshine *et al.*, 1973). Boxes were attached to the trunks of mature mast-producing trees at a height of 4 m in autumn 1993, and checked for the presence of flying squirrels in winter, spring and autumn 1994. Ten nest boxes were distributed throughout most sites; the two smallest sites received only 5 boxes each and the largest site received 10 boxes at each of two separate sampling areas. Tree squirrels were surveyed by observing squirrels during other survey activities, and by visiting each site early in the morning in spring 1994 with binoculars specifically to identify squirrels.

Large mammals were surveyed by two methods. Track stations composed of two 1- by 0.5-m sheets of 0.32-gauge aluminum (track plates) that had been coated with soot from a kerosene torch were used to survey carnivores and omnivores (Barrett, 1983). Track plates were set side-by-side on a cleared level 1-m² area and baited with sardines. Five track stations were established at most sites and were monitored over five nights in both autumn 1992 and autumn 1993, with bait replenished or track plates replaced as needed; the two smallest sites received only 3 track stations each, and the largest received 5 stations at each of two sampling areas. In winter 1994, we visited each site within 48 h of a snowfall to survey sites for tracks of large mammals. Tracks of deer and other large mammals, as well as scats or pellets, also were observed opportunistically during other survey activities.

We evaluated the relationship between mammalian species richness and area of the study site using Pearson product-moment regression of log-transformed data (SYSTAT, 1992). A matrix of species presence and absence across sites was used to examine nestedness. Sites were arranged in decreasing order of species richness and species were listed in decreasing frequency of occurrence. The resulting data matrix was analyzed using Atmar and Patterson's Nestedness Temperature Calculator T (AICS, 1995), which uses a resampling algorithm to obtain a probability of obtaining the observed degree of nestedness by chance (Atmar and Patterson, 1993). This analysis was then repeated on a subset of the data that included the sciurid rodents and white-footed mouse, *Peromyscus leucopus*. These species are known to have strong preferences for wooded habitat in this region (Hoffmeister, 1989) and are small enough that many of our study sites could potentially support isolated populations.

RESULTS

We recorded 19 species of mammal in our surveys. Domestic dogs (*Canis familiaris*) or cats (*Felis catus*) were recorded at every site, but were excluded from analyses because they are not part of the native fauna. Captures of the prairie vole (*Microtus ochrogaster*) at two sites also were excluded from analyses because this species is a grassland specialist and is

TABLE 1.—The presence/absence matrix of woodland mammals. An X denotes that the species was present at the study site. AL = Allerton Park, FN = Funk's Grove, TR = Trelease Woods, PT = Piatt Co. Forest Preserve, HR = Hart Woods, BR = Brownfield Woods, AT1-3 = Atwood forest patches, and RT = Rittenhouse Woods

Species	AL	FN	TR	PT	HR	BR	AT1	AT2	AT3	RT
<i>Blarina brevicauda</i>	X	X	X	X	X	X	X	X	X	X
<i>Scalopus aquaticus</i>	X	X	X	X	X	X	X	X	X	X
<i>Peromyscus leucopus</i> *	X	X	X	X	X	X	X	X	X	X
<i>Sylvilagus floridanus</i>	X	X	X	X	X	X	X	X	X	X
<i>Didelphis virginianus</i>	X	X	X	X	X	X	X	X	X	X
<i>Procyon lotor</i>	X	X	X	X	X	X	X	X	X	X
<i>Odocoileus virginiana</i>	X	X	X	X	X	X	X	X	X	X
<i>Sciurus niger</i> *	X	X	X	X	X	X	X	X	X	
<i>Sciurus carolinensis</i> *	X		X	X	X	X				X
<i>Glaucomys volans</i> *	X	X		X	X					
<i>Mustela frenata</i>	X	X	X				X			
<i>Tamias striatus</i> *	X	X		X						
Fox (gray/red)	X	X	X							
<i>Canis latrans</i>	X	X								
<i>Mephitis mephitis</i>		X				X				
<i>Sorex longirostris</i>							X			
Total species/site	14	14	11	11	10	10	10	8	8	8
Area of site (ha)	600	65	24	44.7	28	24	16.2	11.6	2.3	1.8

* = Species with strong preferences for forest habitat

not generally associated with forest habitat (Hoffmeister, 1989). We could not distinguish between tracks of the red fox (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*). Therefore, all fox tracks were pooled in a single category. The number of species detected at a site ranged from 8 to 14 (Table 1).

Mammalian species richness was significantly positively correlated with area of the site, after data were log transformed ($r^2 = 0.80$, $P < 0.001$; Fig. 1). Distributions of all mammalian species ($n = 16$) displayed a significantly nested structure among sites ($T = 18.8^\circ$, $P(T < 18.8^\circ) = 0.002$). Within the subset of woodland specialists composed of the sciurid rodents and white-footed mouse ($n = 5$; Table 1), species richness was also positively correlated with area ($r^2 = 0.636$, $P = 0.006$) and displayed nested structure ($T = 11.8^\circ$, $P(T < 11.8^\circ) = 0.041$).

DISCUSSION

The significant species-area relationship and nested subset structure for nonvolant mammals in our study are consistent with results of similar analyses of breeding birds occupying these same forest fragments (Blake and Karr, 1984; Blake, 1991). Blake (1991) determined that for breeding passerines, the smaller isolated sites were populated with generalist species that occurred at all sites. In our study, 7 of the 16 species reported in Table 1 were detected in all study sites in both years of our surveys. These species made up the majority of the mammalian community at the smaller sites. With the exception of *Peromyscus leucopus*, these mammals also are habitat generalists in east-central Illinois (Hoffmeister, 1989).

White-tailed deer (*Odocoileus virginianus*) in this region frequently move between forest patches on a daily as well as a seasonal basis (Nixon *et al.*, 1991). Raccoons (*Procyon lotor*)

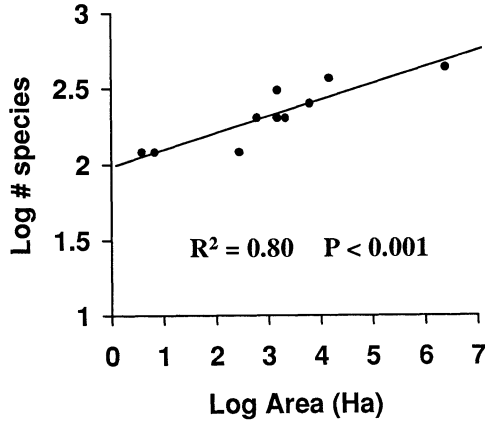


FIG. 1.—Log transformed species-area relationship for 16 mammal species detected in the 10 east central Illinois forest fragments surveyed in this study

and opossums (*Didelphis virginiana*) also are very mobile in agricultural landscapes, have home ranges larger than many of the smaller fragments and can disperse over considerable distances (Verts, 1963; Kaufmann, 1982). Forest remnants provide shelter and important foraging areas for these species, but the intervening matrix is not a significant barrier to movement as these species can be found throughout the landscape. The ubiquitous small mammals also are not restricted to forest habitat. Short-tailed shrews (*Blarina brevicauda*), eastern moles (*Scalopus aquaticus*) and eastern cottontails (*Sylvilagus floridanus*) all occur in grassland and agricultural habitats as well as forest, and thus use the intervening matrix extensively (Hoffmeister, 1989; Mankin, 1993). Although white-footed mice are primarily associated with forests in the midwestern United States, roadside ditches and crop fields may act as dispersal routes to facilitate movements between forest fragments (Cummings and Vessey, 1994).

Coyotes (*Canis latrans*), foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*) and long-tailed weasels (*Mustela frenata*) were only detected in the larger forest tracts (Table 1). These species all have home ranges larger than our smallest study sites, but even numbers that could be accommodated by our mid- to large-sized sites would be too small to constitute a viable population if isolated (Ables, 1969; Bekoff, 1982; Svendsen, 1982). Even though the gray fox prefers wooded habitat (Samuel and Nelson, 1982), these species all use a variety of habitats in the intervening nonforest matrix (Hoffmeister, 1989). We saw coyote tracks in the snow surrounding our three Atwood study sites but not in the sites, and coyotes have been radio-tracked in the vicinity of Trelease Woods (Heske and Miller, 1995). Further, an active red fox den was present in Brownfield Woods in 1991 (S. Buck, Committee for Natural Areas, University of Illinois, pers. comm.) and again in 1995 (D. L. Rosenblatt, pers. observ.), and red foxes have been seen near the Piatt County Forest Preserve (J. Brawn, Illinois Natural History Survey, pers. comm.) but we did not record fox tracks at these sites during our surveys. Thus, we believe that the absence of these species from many of our study sites was either due to habitat selection or was a sampling artifact. For example, some of the smaller sites may not have included areas that were attractive as den sites to coyotes or foxes. Snow-track surveys in larger sites provided a greater chance for detecting the wide-ranging individuals of these species. We expect that continuous monitoring over longer

periods of time would eventually yield records of coyotes, foxes and weasels in all of our study sites.

Several studies have examined the applicability of the theory of island biogeography to terrestrial habitat patches (Brown, 1971; Blake and Karr, 1984; Doak and Mills, 1994) with many concluding that island biogeographic models fail to adequately describe the nature of species distributions (Middleton and Merriam, 1983; Reed, 1983; McCoy and Mushinsky, 1994; Mills, 1996). The theory of island biogeography predicts that the species richness on an island is the result of a dynamic balance between rates of colonization and extinction (MacArthur and Wilson, 1967). Thus, a species will be absent from an island either because it has failed to reach the island or it has gone extinct some time after colonization. Alternative mechanisms for generating species distributions in fragmented landscapes are habitat selection, constraints due to the size of home ranges and differential mobility through the intervening matrix (Cook and Quinn, 1995; Laurance, 1995). Mills (1996) dismissed the principles of island biogeography as an explanation for the nested distribution of small mammals among forest patches separated by clearcuts in old growth forest in Oregon and concluded that the observed distribution was the result of species-specific responses to habitat fragmentation. Blake (1991) concluded that smaller forest fragments in central Illinois did not provide sufficient habitat for those bird species that are typically considered forest interior species. "Edge" species were found in all forests sampled, but "interior" species only occurred in the larger sites. Given the high vagility of these birds, many of which are migratory, interior species are probably capable of reaching the smaller fragments but actively select against breeding in them (Blake, 1991). Similarly, forest remnants may be more like patches of preferred habitat than islands for a large component of the mammalian fauna.

In contrast, the sciurid rodents (fox squirrels—*Sciurus niger*, gray squirrels—*S. carolinensis*, southern flying squirrels—*Glaucomys volans*, eastern chipmunk—*Tamias striatus*) and the white-footed mouse depend primarily on forest habitat for nest sites and mast, a major component of their diets (Hoffmeister, 1989; Koprowski, 1994a, b). Chipmunks require well-drained areas for burrows and hibernacula (Hoffmeister, 1989), and their absence from some of our study sites may be due to the lack of topographic relief and periodic flooding at those sites (*e.g.*, Trelease Woods). However, chipmunks are not encountered in agricultural fields (Henderson *et al.*, 1985; Cummings and Vessey, 1994), rarely venture far from forest edges and generally require treelines, hedgerows, or similar landscape features to move between forest patches (Henderson *et al.*, 1985). Similarly, flying squirrels are poor dispersers across open habitats as they rely upon gliding, and thus some sort of vertical structure from which to glide, for most long range movement (Hoffmeister, 1989). Both chipmunks and flying squirrels were only detected in our largest forest tracts, which were also well connected to other forested areas by riparian corridors.

Fox and gray squirrels are physically capable of moving long distances (Allen, 1943), but there are few data on actual interpatch movements by these species in agricultural landscapes. The wide distribution of the fox squirrel suggests that it is either highly mobile, allowing it to colonize vacant habitat quickly, or persistent (*i.e.*, low extinction rates) in forest fragments. Shepherd and Swihart (1995) did not record any interpatch movement by 49 radio-collared adult fox squirrels in forest fragments in Indiana and reported maximum distances moved along hedgerows of ca. 500 m. However, they did observe colonization by fox squirrels in a woodlot that was 800 m from the nearest tree. We found fox squirrels in our smallest study site at Atwood during both years despite heavy hunting pressure each fall. We expect that local extirpations are common under such conditions, and the persistence of fox squirrels at this site indicates that recolonization is a frequent occur-

rence. Ongoing radio-telemetry studies of gray and fox squirrels indicate that movements of several miles by dispersing squirrels may not be uncommon (D. L. Rosenblatt, pers. observ.). Gray squirrels appear more sensitive to habitat fragmentation than fox squirrels as long term trends have shown population declines in gray squirrels and increases in fox squirrels as forest cover is reduced (Allen, 1943; Nixon *et al.*, 1978). Experimental studies are currently being conducted to determine whether habitat selection, interspecific competition, or isolation of remnants and lesser dispersal ability of gray squirrels best explains the restricted distributions of gray squirrels in highly fragmented landscapes.

We believe that the significant species-area relationship and nested subset structure found in our survey of mammalian species in forest remnants resulted from species-specific processes rather than the general colonization-extinction model described in the theory of island biogeography. Species responded differently to the fragmented landscape based on a combination of habitat preference and dispersal ability. The majority of mammalian species are habitat generalists, move freely across the agricultural landscape and do not appear to be limited in their distribution by habitat fragmentation in this region. Only the woodland rodents show distributions that suggest forest patches may be isolated from each other. One forest specialist, the woodland vole (*Microtus pinetorum*), was not detected in any of our surveys and may have been extirpated from the region. For these species, the landscape may truly resemble an archipelago of forest islands amid a sea of inhospitable agricultural habitat.

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