THE EFFECTS OF HABITAT FRAGMENTATION ON THE SOUTHERN FLYING SQUIRREL (<u>GLAUCOMYS</u> <u>VOLANS</u>) IN SOUTHERN ILLINOIS

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ABSTRACT

We studied the effects of habitat fragmentation on the southern flying squirrel (*Glaucomys volans*) in 30 forest fragments in southern Illinois. The fragments ranged in size from 6.4 ha to 5264 ha, and had varying degrees of isolation. We placed 10 nest boxes in each habitat fragment and checked them monthly. We captured southern flying squirrels in 24 of the 30 fragments, and found definitive evidence of squirrel presence (i.e. nests and feeding stations) in 4 additional sites. Thus, only 2 fragments did not show any evidence of squirrel use suggesting that the southern flying squirrel may not particularly sensitive to the negative impacts of habitat fragmentation, at least in a primarily forested landscape like southern Illinois. However, the 2 sites where squirrels did not occur were small and isolated.

INTRODUCTION

Habitat fragmentation has been defined as a process in which one large, continuous tract of habitat is divided into smaller, more isolated tracts (Wilcove *et al.*, 1986). More recently, Lord and Norton (1990) have defined habitat fragmentation as simply the "disruption of continuity." Typically, fragmentation results in habitat patches which are reduced in overall size, and generally surrounded by less suitable habitat. In addition, habitat fragmentation, leads to an increase in the relative amount of habitat edge which has been associated with a plethora of changes to the physical and biotic environment. These changes, often called "edge effects," can have both negative and positive effects on wildlife populations (Yahner, 1988). The increase in habitat edge is beneficial to species which prefer edge habitat such as the indigo bunting (*Passerina cyanea*), raccoon (*Procyon lotor*), and opossum (*Didelphus virginianus*). The creation of edge can also be deleterious because it produces changes in the microclimate which can alter radiation fluxes, as well as cause changes in wind, soil moisture, and air temperature (Saunders *et al.*, 1991). Many species are extremely sensitive to edge effects. The increased edge may lead to heightened predation by omnivorous predators, whose densities are higher in edge habitat, and increased interspecific competition for nesting sites from edge species. Habitat fragmentation has been hypothesized to be a leading cause of the decline of neotropical migrant songbirds due to increases in the populations of parasitic brown-headed cowbirds (*Molothrus ater*), and nest predators (Robinson et al., 1995).

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Spatially, populations are affected by fragmentation in that movement between patches may be restricted, creating difficulties for dispersing animals (Merriam, 1995). Responses to habitat fragmentation vary by how the fragmentation is perceived by the individual, and is related to both the scale of the fragmentation (Lord and Norton, 1990) and the life history of the animal. For example, it would be much easier for a large animal, such as the white-tailed deer (*Odocoileus virginianus*), and habitat generalists like, raccoons and opossums to move between habitat patches after fragmentation. These species would find fragmented landscapes ideal because they can find food in both forest fragments and agricultural fields. They are also not especially tied to a particular habitat type so that there would be no difficulties to movement across agricultural fields. Species which are habitat specialists would find it much more difficult to move great distances between sites. For example many birds and mammals will not move even small distances between forest fragments. Wegner and Merriam (1979) found that white-footed mice (*Peromyscus leucopus*) and chipmunks (*Tamias striatus*) rarely moved from wooded areas into adjacent grassy fields. Similarly, they found that birds rarely flew directly across open fields (Wegner and Merriam, 1979).

Clearly, fragmentation may cause significant barriers to dispersing animals, and there has been an increasing interest in determining how landscape level characteristics affect the population dynamics and interpatch movements of mammals (Geuse *et al.*, 1985; Diffendorfer *et al.*, 1995; Shepherd and Swihart, 1995). The concept of the metapopulation has become a popular way to describe how populations develop into a shifting mosaic of temporary populations which are isolated from each other (as a result

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of fragmentation), yet maintain some level of dispersal between isolated patches. The original metapopulation model (Levins 1970) assumes that the habitat patches are of equal size, identical in quality, and evenly spaced within the environment. In addition, this model assumes an equal degree of movement between habitat patches. Because few, if any, fragmented landscapes fit this model perfectly, the term metapopulation has evolved from a rigid model with assumptions into a concept with loose definitions (McCullough, 1996). Certainly, an important component of metapopulation studies is the underlying causes of local extinctions, including the degeneration of the environment, demographic and environmental stochasticity, and genetic effects (Verboom *et al.*, 1993).

The overall size of habitat patches as well as the isolation of patches are important factors which must be considered when determining what effects habitat fragmentation may have on a species (Goodman, 1987). Several recent studies have focused on what effects area and isolation of habitat fragments have on the species composition, as well as the patterns of occupancy, of birds and mammals (Opdam *et al.*, 1985; Blake and Karr, 1987; Van Dorp and Opdam, 1987; Verboom and Van Apeldoorn, 1990; Van Apeldoorn *et al.*, 1992; Celada *et al.*, 1994). Van Dorp and Opdam (1987), using logistic regression, found that the size of woodlots was the most important predictor of whether or not a bird species would occur in a woodlot. Studies of red squirrels in the Netherlands and in Italy found that woodlot size and isolation (distance to nearest 'source area') are factors which influence presence or absence of this species in habitat fragments (Verboom and Van Apeldoorn, 1990; Celada et al., 1994).

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The purpose of this study was to determine how area of habitat fragments and isolation of fragments effects the southern flying squirrel (*Glaucomys volans*), a forest-obligate mammal, in the fragmented landscape of Southern Illinois. Agricultural practices and increased urbanization have decreased the forested area in Illinois from 38.2% in 1820 to approximately 12% in 1985 (Figure 1) (Iverson *et al.*, 1989). The southern flying squirrel is a species which is nearly always found in association with hardwood trees (Wiegl, 1978). These squirrels are secondary cavity nesters usually making their nests in woodpecker holes and other cavities (Mull, 1968). The majority of their diet consists of hard mast, especially acorns (Harlow and Doyle, 1990). Their primary means of locomotion over long distances is by gliding from tree to tree in a descending fashion (Giacalone-Madden, 1976). The combination of these life history characteristics make the southern flying squirrel an organism which could be susceptible to the negative impacts of forest fragmentation. This study examines how the size and isolation of forest fragments affects the patterns of occupancy and reproductive success of the southern flying squirrel in southern Illinois.

STUDY SITES

Thirty habitat fragments were selected in and around the Shawnee National Forest in Jackson, Johnson, Union, and Williamson counties in southern Illinois (see Appendix for location of counties). Of the 30 sites, 7 were classified as "very small" sites (6.4-10.4 ha), 7 were classified as "small" (26.4-81.2 ha) sites, 7 were classified as "medium" (100.7-223.1 ha) sites, and 9 were classified as "large" (645.2-5264 ha) sites (Table 1). The smallest sites were no less than 6.4 ha as this area would encompass the home ranges

of several squirrels. Home ranges have been reported to be anywhere from 0.41 to 3.8 ha

for females (Madden, 1974; Stone *et al.*, 1997) and 0.53 ha to 9.9 for males (Madden,

1974; Fridell and Litvaitis 1991). United States Geological Survey (U.S.G.S.) maps

(photo revised 1990) were used to identify and locate forest fragments. Sigma Scan™

(Jandel Scientific, Corte Madera, CA) was used to measure areas from the U.S.G.S.

maps. Isolation was defined as the distance a forest fragment was from the next nearest

fragment (≥ 5 ha in size). Isolation distances were measured on the U.S.G.S. maps.

METHODS

Nest boxes. Nest boxes were used to determine if flying squirrels were present in

the 30 habitat fragments. The nest box design was modified from Henderson (1992) with

a 3.3 cm diameter hole. Each of the 30 habitat fragments had 10 next boxes placed in it.

The nest boxes were placed 50 meters apart on a roughly square grid. The boxes were

placed approximately 2.2 m off the ground on the south side of the tree.

We installed the nest boxes between March and June 1996. The nest boxes were

checked monthly after installation with the exception of July and August when each box

was only checked once due to decreased usage of the boxes by squirrels in the warmer

summer months (Heidt, 1977). The first complete check of all thirty sites occurred in

July/August 1996. A final box check occurred in June 1997. Squirrels captured in the

boxes were sexed, weighed, and marked with an individually numbered metal ear tag.

We also noted the squirrel's reproductive condition. Body weight was used to distinguish

age classes (as in Raymond and Layne, 1988). Squirrels >50 g were classified as adults,

subadults were 25.1-50 g, and nestlings were <25 g.

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Vegetation. We attempted to select fragments which were as uniform in vegetation as possible. All sites were upland oak-hickory forests. In addition, we sampled vegetative characteristics at each site using 700-m^2 circular plots centered around each nest box tree. The species, height, bark texture (rated from 1-4 [smooth to very rough] as in Boardman, 1991), and diameter at breast height (dbh) of each nest box tree were recorded. Within the circular plots, all trees ≥ 8 cm dbh were measured (dbh) and identified to genus. Snags and logs were recorded and classified according to Thomas *et al.* (1979). Additionally, canopy cover was estimated with a densiometer, and ground cover was visually estimated using 1-m^2 circular hoops. Four estimates of canopy cover and ground cover were taken at each nest box tree at cardinal directions. Habitat variables selected for statistical analysis (see below) were modified from Stone *et al.* (1996) and Gilmore and Gates (1985). (See appendix for a complete list of habitat variables and methods of collection.)

Statistical analysis. Spearman rank correlations (ρ) were used to determine if there were any significant associations between flying squirrel abundance and forest fragment size or isolation (Minitab, Inc., 1989). Chi-square (χ^2) goodness-of-fit tests were used to determine if sex ratios were different from 1:1, and if sex ratios differed among the 4 size classes of our forest fragments. A Pearson product-moment correlation coefficient was used to determine if vegetative characteristics were related to fragment size using Statistical Analysis Systems (SAS; SAS Institute 1990). Forward stepwise logistic regression (SAS; SAS Institute 1990) was used to model factors which explained box usage by squirrels.

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RESULTS

Patterns of occupancy. Flying squirrels were present in 28 of 30 woodlots in southern Illinois. We captured flying squirrels in 24 of the 30 forest fragments and noted definitive evidence of squirrel presence (*i.e.* nests and feeding stations in nest boxes) at 4 additional fragments. Squirrels were absent from the 2 most isolated sites. The isolation of fragments had an inverse relationship with the likelihood of a capture at a given nest box and was the first variable entered into our logistic regression model. The remaining variables entered into the model all pertained to habitat characteristics. These variables were diameter at breast height of nest box tree, relative density of hard mast trees, and the number of fallen logs.

Overall, 75% of the 300 nest boxes were used by flying squirrels at some point during this study. No relationship existed between the percentage of nest boxes used in a fragment and area ($\rho = 0.126$, $P > 0.50$) or isolation ($\rho = -0.307$, $P > 0.10$) (Figure 2, Table 2). In addition, the total number of squirrel captures was not correlated with area ($\rho = 0.110$, $P > 0.50$) or isolation ($\rho = -0.252$, $P > 0.10$) (Figure 3). Similarly, there was no relationship between the number of recaptures per fragment and area ($\rho = 0.141$, $P > 0.20$) or isolation ($\rho = -0.321$, $P > 0.10$) (Figure 4). Finally, the number of individual squirrels (captures- recaptures) captured per woodlot was not significantly correlated with area ($\rho = 0.093$, $P > 0.50$) or isolation ($\rho = -0.221$, $P > 0.20$) (Figure 5). A sufficient sample size was not available to calculate densities for more than 2 of the woodlots sampled, negating any possible comparisons of flying squirrel density among sites.

Reproduction. Only 10 litters were found, and there was no relationship between number of litters found and area (ρ = -0.077, P > 0.50) or isolation (ρ = 0.341, P > 0.05) of woodlots (Figure 6). In addition, litter size was not significantly correlated with either area (ρ = -0.103, P > 0.50) or isolation (ρ = 0.368, P > 0.05) of fragments . Litters ranged in size from 2 to 4 with a mean litter size of 2.4 young. In addition, there was no relationship between the number of subadults captured and area (ρ = -0.233, P > 0.20) or isolation (ρ = 0.169, P > 0.20).

Sex Ratios. There was not a significant relationship between male captures and area (ρ = 0.023, P > 0.50) or isolation (ρ = -0.165, P > 0.20) of fragments. Female captures were not significantly related to area (ρ = 0.018, P > 0.50) or isolation (ρ = -0.201, P > 0.20) either. Sex ratios were calculated for comparison among area size classes (Figure 7). The sex ratio of squirrels in the extra small sites was 1.5 males to 1 female. The sex ratio of small and medium sites were 2.1:1 and 1.5:1, respectively. Finally, the sex ratio of large sites was 0.74:1. All sex ratios did not different from 1:1 except in the small sites (χ^2 = 6.23, df = 1, P < 0.01).

Vegetation. We determined the correlation coefficients between vegetative characteristics and area to ensure that the habitat was relatively uniform in fragments of different sizes. Pearson correlation coefficients revealed no significant relationships among habitat variables and area (all r < 0.344, all P < 0.05) (Table 4). Habitat variables included in this analysis were: % canopy cover, % ground cover, relative density of trees, relative density of hard mast trees, number of snags per sample plot, and number of logs per sample plot (see appendix for complete list of variable and sites). Variables

associated with each nest box tree (n = 300) including height of nest box tree, DBH of

nest box tree, distance to closest tree, and bark texture, were also correlated with area.

These variables also did not vary significantly with area (all r < 0.348, all P < 0.05).

Since no relationships were found between fragment size and habitat characteristics, we

assumed that the habitat was relatively similar among forest fragments.

DISCUSSION

We found that the southern flying squirrel is a common species in southern

Illinois woodlots. It occurred in 93% of our forest fragments of varying degrees of size

and isolation. Patch size does not appear to be a factor excluding squirrels from small

sites, assuming that habitat quality was good and isolation is not too extreme. Squirrels

were present in 6 of 7 woodlots that were between 6.4 and 10 ha, leading to the

conclusion that the area of the habitat fragment may not be the most important factor in

predicting squirrel occupancy in a woodlot. These findings somewhat agree with Nupp

and Swihart's (1997) findings in west-central Indiana, in that southern flying squirrels

were present only in continuous tracts of forest and woodlots > 6 ha which are in

proximity to other woodlots. All of the forest fragments we sampled were > 6.4 ha,

however, not all of our fragments, in which we found squirrels, were in proximity to

other fragments.

Southern flying squirrels were not present in the 2 most isolated woodlots

sampled. Populations in these woodlots may have become locally extinct, with

recolonization unlikely due to the distance which must be crossed for a dispersal event to

occur. Another problem which may have inhibited squirrels from occupying the two

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most isolated fragments may have been increased competition for food and nesting sites from fox (*Sciurus niger*) and gray squirrels (*Sciurus carolinensis*) in these sites.

Fahrig and Merriam (1985) designed a model of patch dynamics in White-footed mice (*Peromyscus leucopus*) in order to determine how population survival is affected by isolation. Their model predicted that mouse populations in isolated areas would more likely have reduced growth rates, and have a greater probability of extinction. Field data on this species supports the model. This model may hold true for southern flying squirrel populations as well as we found southern flying squirrels were not present in woodlots that were isolated by more than 0.5 km.

Southern Illinois is a primarily forested landscape at least in comparison to the northern and central parts of the state. In areas where the distances between patches are relatively small (*i.e.* <500 m) the probability of interpatch dispersal by flying squirrels is increased. Unfortunately, this study was not designed to address dispersal movements. Landscape connectivity is often associated with the persistence of species in fragmented landscapes (Taylor *et al.*, 1993). Many species rely upon at least some level of connectivity in order for dispersal to take place. For species such as chipmunks (*Tamias striatus*) and white-footed mice, vegetated fence rows play an important role in connecting populations between woodlots (Wegner and Merriam 1979; Henderson *et al.* 1985). Indeed, southern flying squirrels were more likely to occur in areas with higher levels of connectivity such as large, contiguous forests > 645 ha, and forests which had shorter distances between patches. However, I was not able to document movement between patches or the use of habitat corridors.

If young males are the dispersers in this species, it would seem that they should occur more often in smaller, more isolated woodlots. Although not statistically significant, there did tend to be a female biased sex ratio in larger sites. This trend toward more females in the largest sites could possibly lead to greater reproductive success in these larger sites. However, not enough litters were found to make any predictions in this area, highlighting the importance of longer studies.

While the southern flying squirrel appears to be an abundant species in southern Illinois forest fragments, this study does support the idea of a flying squirrel metapopulation with local extinctions highly possible in areas which are extremely isolated. However, flying squirrels were still common even in our smallest sites. Further work is necessary to determine dispersal patterns in this animal, as well as to what extent habitat corridors are used. Additionally, long term studies on the survival of this species in fragmented landscapes are needed.

Acknowledgments

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Table 1. The site abbreviations, areas, size classifications, and isolation distances of 30 habitat fragments located in southern Illinois.

Site	Area (ha)	Size Class	Isolation (m)
SU	6.4	VS	146
CE	6.6	VS	439.2
BU	7.2	VS	122
HC	8.4	VS	73.2
TW	8.4	VS	634.4
CP	10	VS	73.2
FA	10.4	VS	390.4
RL	26.4	S	366
HF	29	S	195.2
BK	34.8	S	195.2
WA	40.6	S	536.8
VT	56	M	97.6
HA	64	M	73.2
DN	81.2	M	73.2
RY	100.7	M	73.2
RT	102	M	73.2
WO	160.8	M	73.2
RO	186.2	M	73.2
BB	188.4	M	219.6
TR	212	M	122
CL	223.1	M	146.4
DR	645.2	L	0
GC	658.2	L	0
IM	772.8	L	0
PA	908.8	L	0
DK	1061.6	L	0
TT	1623.6	L	0
HH	2568	L	0
LG	2613.4	L	0
PI	5264	L	0

Table 2. Spearman rank correlations of data collected from southern flying squirrel nest boxes and area and isolation of habitat fragments in southern Illinois. P-values are in parenthesis.

Variable	Area	Isolation
Number of Captures	0.110 (P > 0.50)	-0.252 (P >0.10)
Number of Recaptures	0.141 (P > 0.20)	-0.321 (P >0.10)
Number of Individuals	0.093 (P > 0.50)	-0.221 (P >0.20)
Number of Male Captures	0.023 (P > 0.50)	-0.165 (P >0.20)
Number of Female Captures	0.018 (P > 0.50)	-0.201 (P >0.20)
Number of Subadult Captures	-0.233 (P > 0.20)	0.169 (P >0.20)
Number of Litters	-0.077 (P > 0.50)	0.341 (P >0.05)
Mean Litter Size	-0.103 (P > 0.50)	0.368 (P >0.05)
% Nest Boxes Used	0.126 (P > 0.50)	-0.307 (P >0.10)

Table 3. Correlations of mean habitat variables associated with southern flying squirrel nest boxes placed in 30 habitat fragments in southern Illinois and the area of the fragment.

Variable	Pearson r	P-value
Distance to Closest Tree	-0.146	0.442
Diameter at Breast Height of Nest Box Tree	0.347	0.061
Height of Nest Box Tree	0.244	0.193
Bark Texture of Nest Box Tree	-0.288	0.123
% Canopy Cover	0.120	0.527
% Ground Cover	-0.343	0.063
Relative Density Trees	-0.178	0.346
Relative Density Hard Mast Trees	-0.098	0.608
# of Snags	-0.177	0.350
# of Logs	0.204	0.279
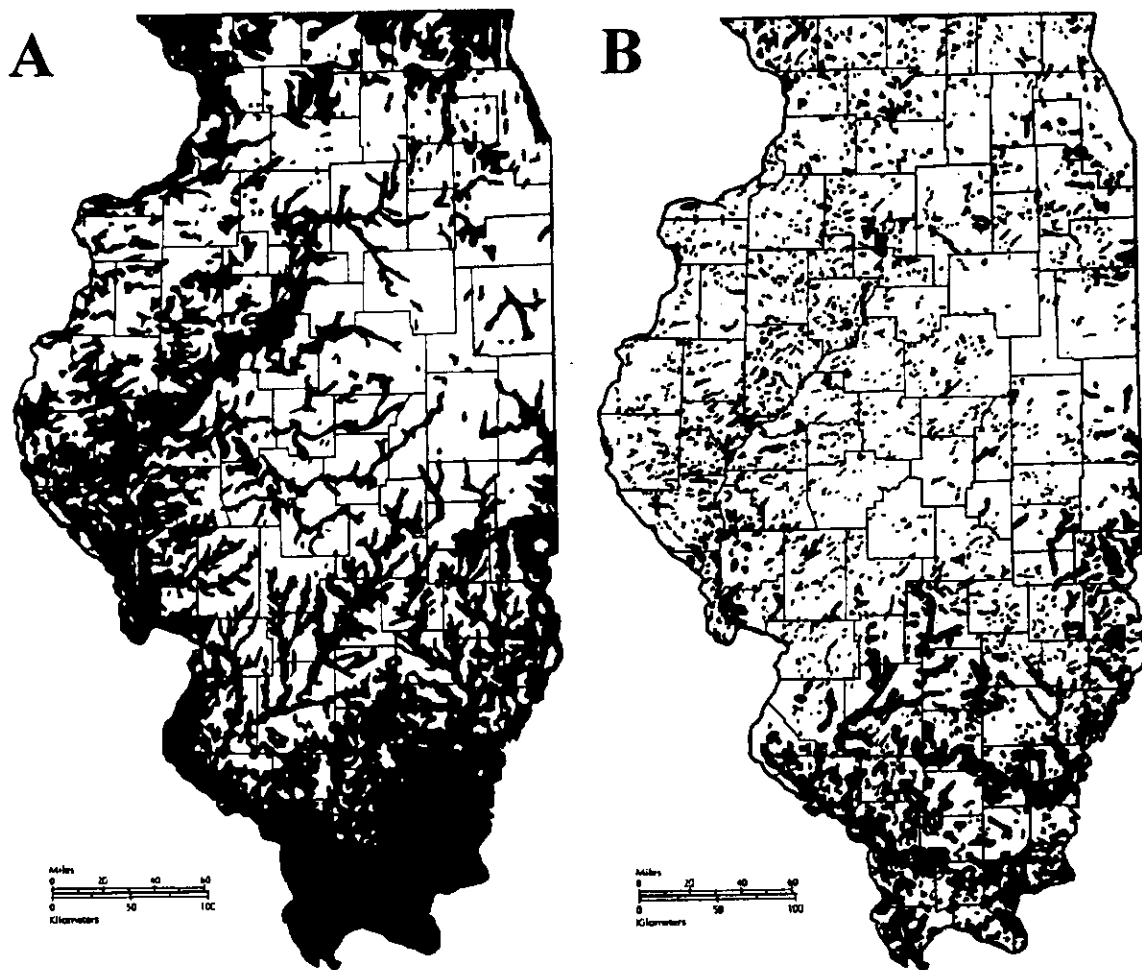
Figure 1. The forested cover of Illinois in 1820 (A), and 1975 (B).
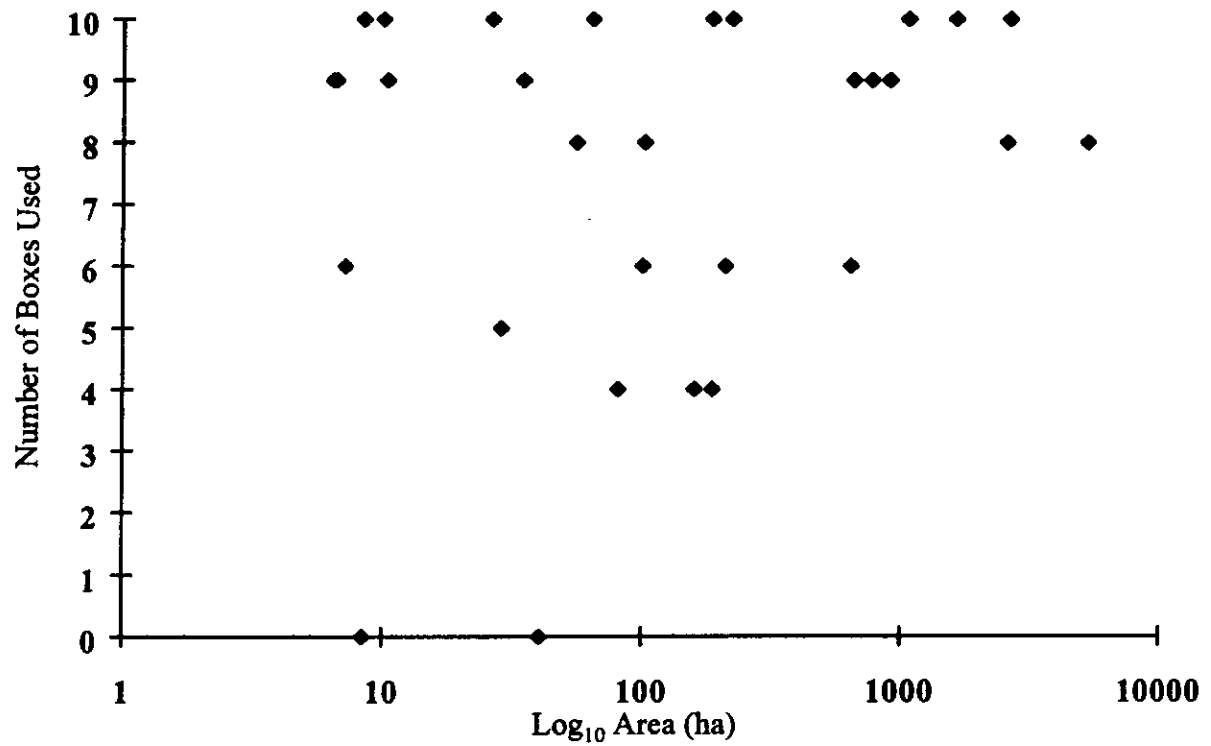
Figure 2. The number of southern flying squirrel nest boxes used (out of 10) in each of 30 habitat fragments in southern Illinois plotted against the $\log_{10}$ area (ha).
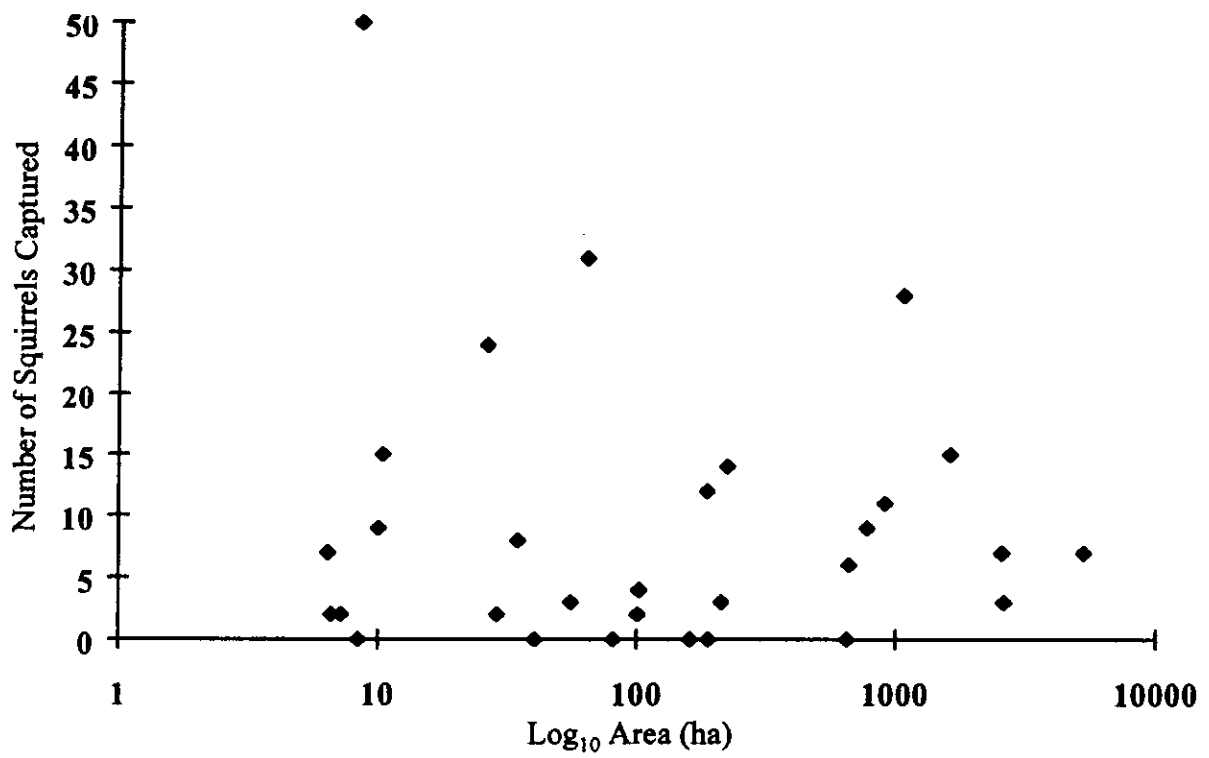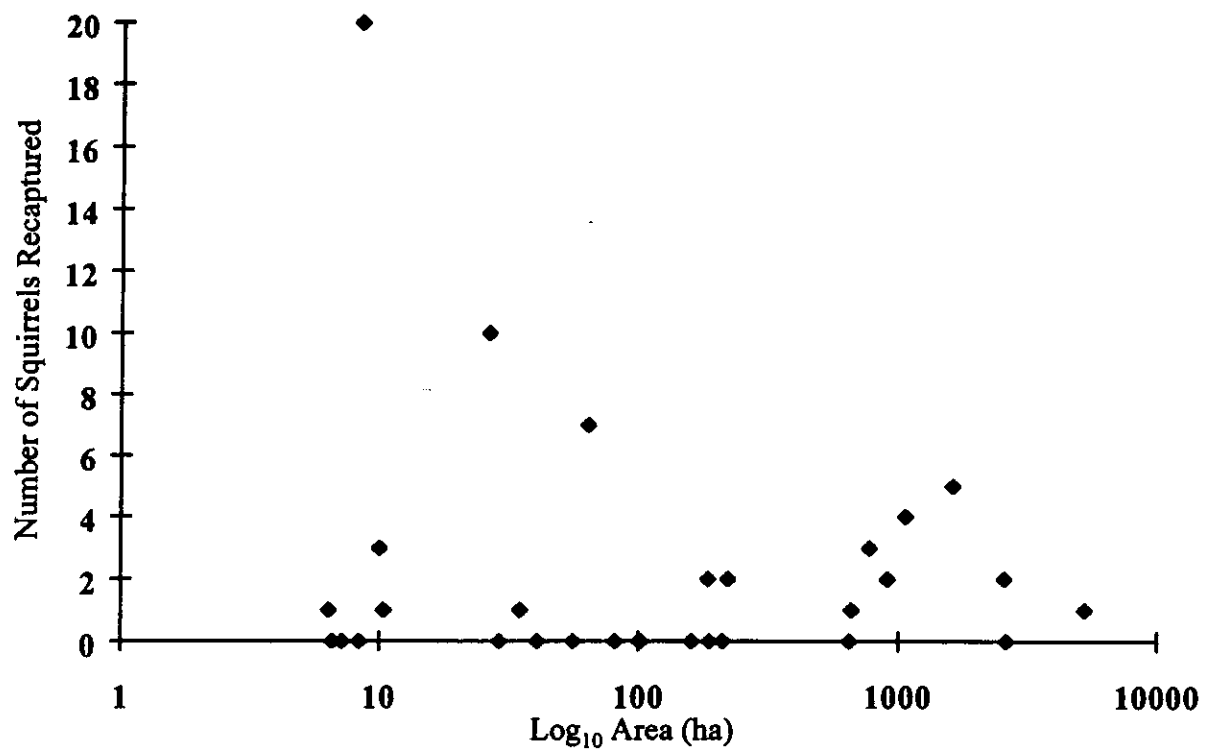
Figure 3. The number of southern flying squirrels captured from nest boxes placed in 30 habitat fragments in southern Illinois plotted against the $\log_{10}$ area of the fragments.
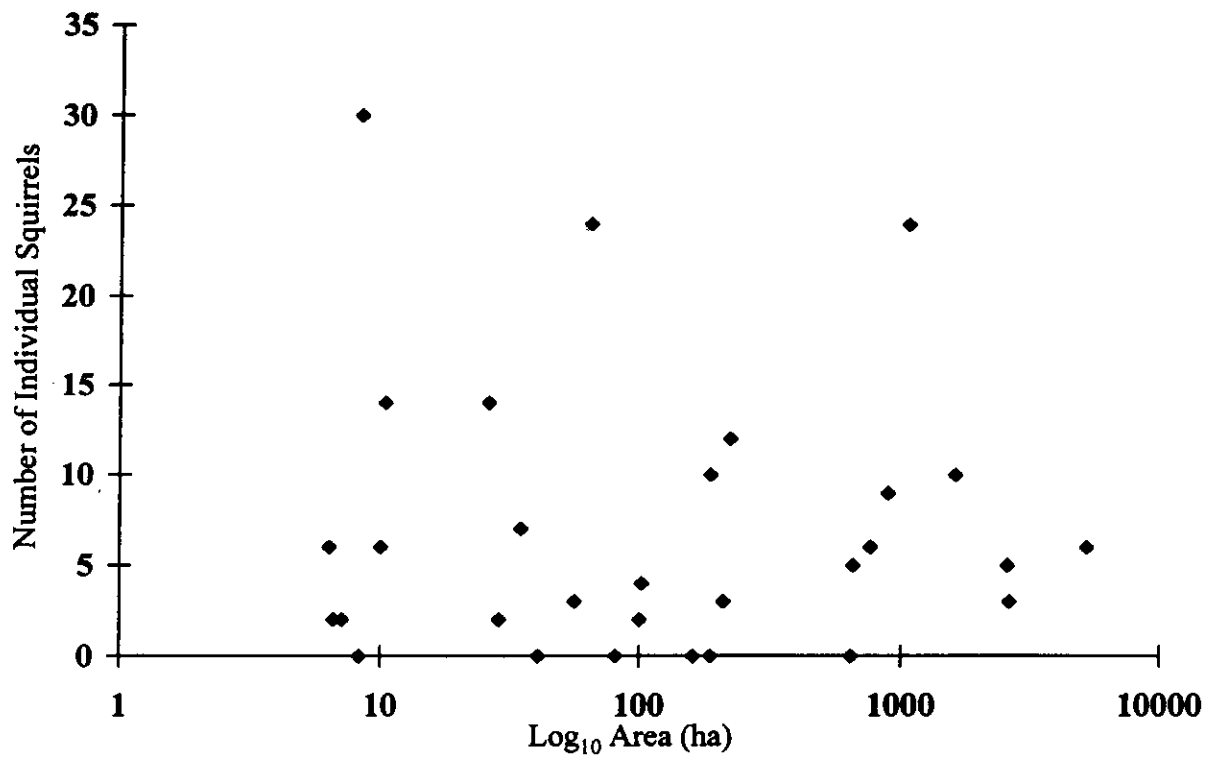
Figure 4. The number of southern flying squirrels recaptured from nest boxes placed in 30 habitat fragments in southern Illinois plotted against the $\log_{10}$ area of the fragments.

Figure 5. The number of different individual (captures - recaptures) southern flying squirrels captured from nest boxes placed in 30 habitat fragments in southern Illinois plotted against the $\log_{10}$ area.
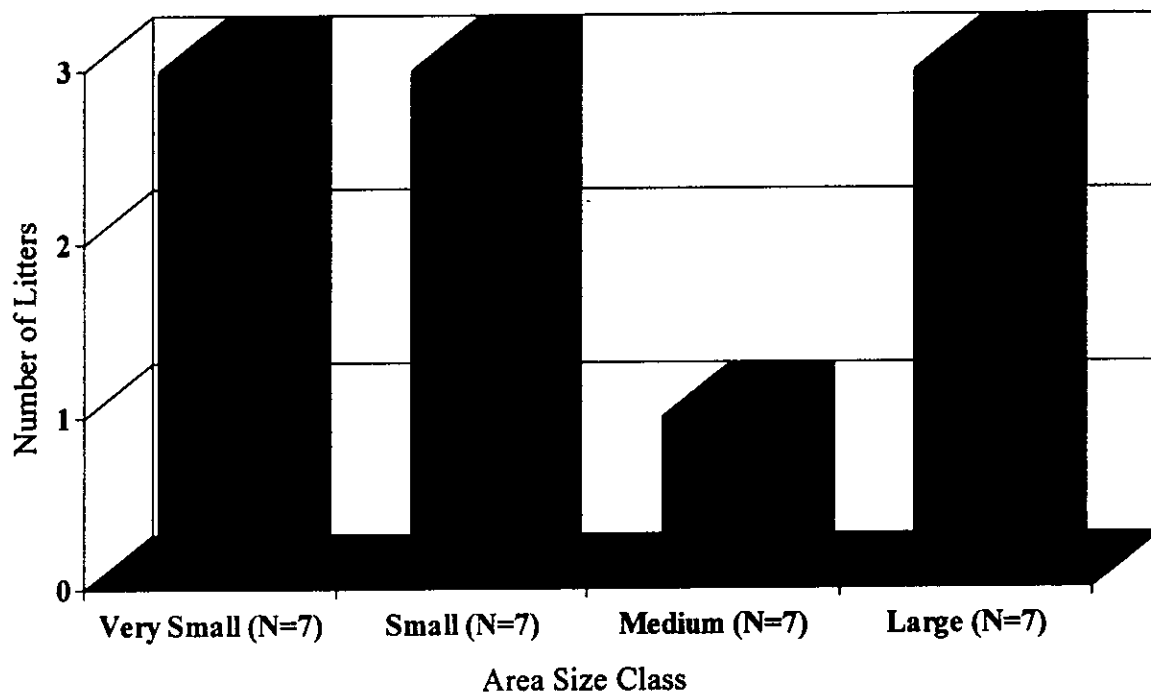
Figure 6. The number of southern flying squirrel litters found per area size class of habitat fragments in southern Illinois. "Very small" fragments ranged in size from 6.4-10.4 ha (N=7). "Small" fragments ranged in size from 26.4-81.2 ha. "Medium" fragments ranged in size from 100.7-223.1 ha, and "large" fragments ranged in size from 645.2-5264 ha.
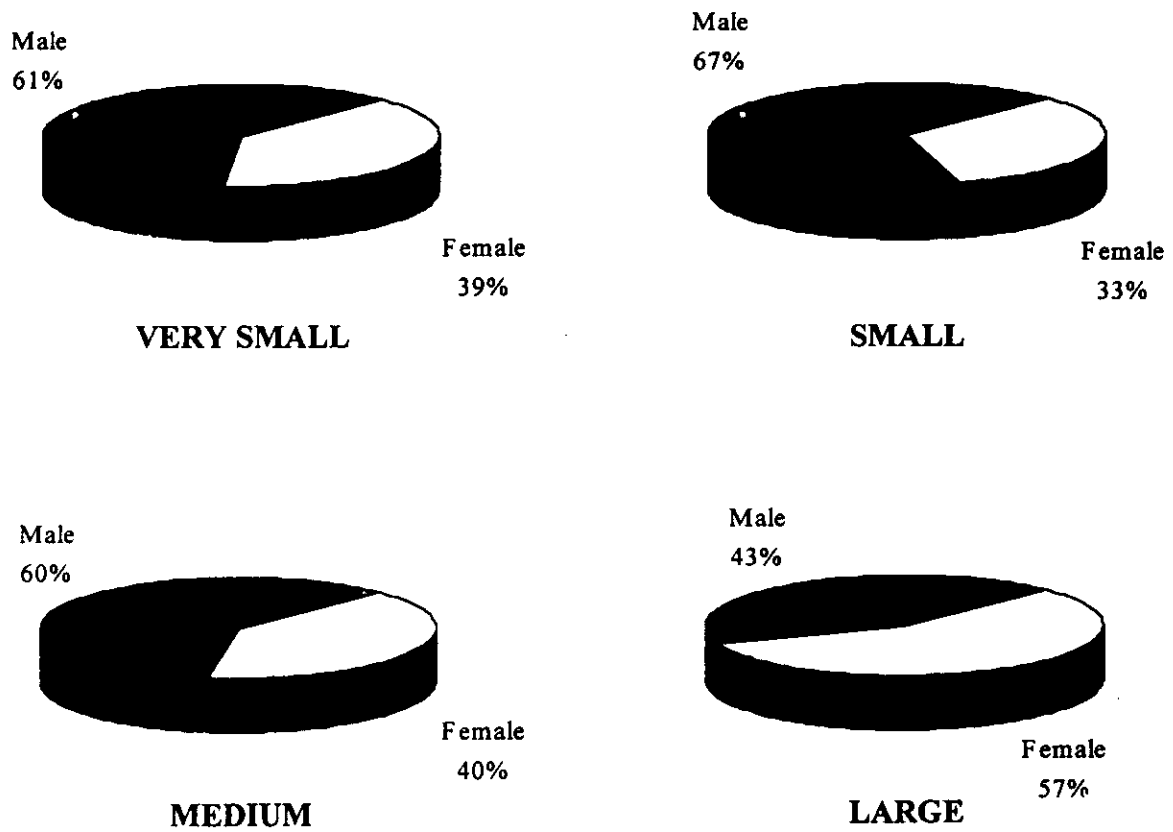
Figure 7. The sex ratios (expressed as a percentage) of southern flying squirrels in 4 area size classes of habitat fragments in southern Illinois. "Very small" fragments ranged in size from 6.4-10.4 ha (N=7). "Small" fragments ranged in size from 26.4-81.2 ha. "Medium" fragments ranged in size from 100.7-223.1 ha, and "large" fragments ranged in size from 645.2-5264 ha.