had been sprayed to prepare for planting. No remnants of the nest or eggs could be found. The stilts did not return to this site that summer.

Interestingly, a second nest for Illinois and possibly the northernmost for interior North America was discovered by Kevin Richmond on 27 June 1994 approximately 190 miles north in Mason County at Lake Chautauqua National Wildlife Refuge just northeast of Havana off one of the lake's mid-levees. This nest contained two eggs and was observed by many birders through 1 July 1994. Unfortunately high water destroyed the nest on 3 July 1994.

These two confirmed nesting records for Black-necked Stilt in Illinois could be part of a dramatic expansion of the species' breeding range that has been occurring just to the south and west in the neighboring states of Missouri and Kentucky (Robbins and Easterla 1992, Palmer-Ball and Bennett 1993).

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* McKee
605 9th Ave.
Ottawa, IL 61350

* Fink
Route 1 Box 220
Ozark IL 62972

A Relationship Between Songbird Breeding Success, Small Mammal Abundance, and Fragmented Forests in Eastern Pennsylvania

by Gopaul Noojibail

The Problem

Initially, recorded population declines of neotropical migrant songbirds that breed in North America were attributed to loss of wintering habitat in Mexico, Central America, and the West Indies (Morton 1980, Ambuel and Temple 1983). Because these birds often congregate within tropical forests for over half the year, researchers believed that habitat loss resulting from widespread tropical deforestation would have detrimental effects on wintering populations leaving fewer birds to return north and reproduce (Askins et al. 1990).

> Small mammals were significantly more abundant in small forests compared with large forests.

Further study suggested that loss of nesting habitat in North America is also significantly contributing to the recorded population declines (Whitcomb et al. 1981). Extensive clear-cutting has reduced once large, uninterrupted tracts of forest to woodland "islands" isolated by "seas" of agriculture and suburban development (Robbins et al. 1986). From the perspective of many forest-interior songbirds, these fragmented matrices are less than optimal nesting habitat and considerably more hostile than the large forests in which many of these birds have evolved (Askins et al. 1990). The reduced breeding success of several neo-tropical species such as tanagers, warblers, thrushes, and flycatchers has been associated with external pressures resulting from the small sizes of forest fragments (Whitcomb et al. 1981, Wilcove 1985, Robbins et al. 1989).

There has been some success in identifying the mechanisms that lead to depressed songbird reproductive success. Although in most cases a combination of factors are believed to affect the avifauna, two major factors have been repeatedly identified (Whitcomb et al. 1981, Wilcove 1985). One is a high incidence of brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) that has been recorded in and near forest edges as this species continues to expand its range eastward (Brittingham and Temple 1983). The other factor, depredation of nests by a variety of animals, has been found to limit reproductive success of songbirds in small forests (Wilcove 1985, Martin

1987, Yahner and Scott 1988). Both of these factors have become serious obstacles to songbirds, hampering breeding efforts in extremely fragmented nesting habitats of the midwest (Brittingham and Temple 1983, Robinson 1992).

Attempts have been made not only to identify predators of songbird nests but also to assess the degree of impact predation has on songbird breeding efforts. Research has identified members of the corvid family (jays and crows), grackles (*Quiscalus spp.*), a variety of mammals (e.g. raccoons, opossums, mice, chipmunks, squirrels), and snakes (e.g. black rat (*Elaphe obsoleta obsoleta*) and black racer (*Coluber constrictor*) as potential threats to eggs and nestlings (Ricklefs 1969, Wegner and Mirriam 1979, Angelstam 1986, Martin 1987, Shaffer 1991, Andren 1992).

A Predator's View

Current theories suggest that many nest predators are generalists/omnivores, opportunistically robbing nests as they are encountered (Andren et al. 1985, Angelstam 1986). To actively search for nests would cost most predators more energy than they would ultimately gain. It is believed that although nutritious, eggs and nestlings comprise only a small percentage of a predator's total food consumption; possibly being as low as one percent in some incidences (Angelstam 1986). Theoretically, there should be little evolutionary benefit to specializing with a specific nest searching strategy as nests are often irregularly distributed over an area due to avian territoriality and are only available during a small window of time over the course of the year (Smith and Shugart 1987).

Though nests are probably not being expressly targeted by predators in most cases, increased predator densities often resulting from the animals' ability to easily penetrate fragmented woodlots and/or concentrate search efforts along forests edges can directly reduce songbird breeding success (Angelstam 1986, Andren and Angelstam 1988, Andren 1992).

Andren and Angelstam (1988) suggested that the frequency of nest predation by a particular species would be proportional to the relative abundances of this species within the fragment. In theory, potential predator species found in high abundances should be exerting the most pressure on songbird breeding efforts. Their research supported this hypothesis (Angelstam 1986, Andren 1992).

The Research

During the spring and summer of 1993, I was involved in part of a long-term project at Hawk Mountain Sanctuary in Pennsylvania investigating the effects of forest fragmentation on songbird reproductive success. The project entailed monitoring Ovenbird (*Seiurus aurocapillus*) breeding success over several years in both fragmented landscapes and large tracts of forest. This species is being studied because it has been identified as being sensitive to habitat fragmentation (Porneluzi et al. 1993).

In addition to monitoring breeding success, we attempted to discern whether a relationship existed between potential predator abundance and songbird breeding success in relation to forest size. Specifically, in forests where Ovenbird breeding success was low, was there a higher abundance of a predator species than in forests where breeding success was high? I focused on mammalian species, specifically small rodents, that had previously been identified as nest predators (Ricklefs 1969, Wegner and Mirriam 1979). The abundance of other potential predators was not measured due to constraints in time, person-power, and funding.

The study, though conducted and based in the eastern United States, has relevance nationwide as habitat fragmentation in America has been extreme and neotropical migrant population declines have been detected in many areas of the country including Illinois (Ricklefs 1969, Whitcomb et al. 1981, Robbins et al. 1989, Robinson 1992).

Ovenbird at Kankakee River State Park, Will County, 5 June 1991. This species is declining in Illinois and other states such as Pennsylvania. Research is being done nationwide to understand the reasons and find solutions. The pictured Ovenbird was defending fledged cowbirds when Joe B. Milosevich took these photos.

Methodology

Six study plots were located in forests ranging from 18.7 to >10,000 hectares in total area. These plots were split into two size classes, large (>100 ha) and small. The cut-offs for plot sizes were determined using information from studies done on minimum habitat requirements of songbirds (Robbins et al. 1989). All

sites were characterized by second growth, mixed-deciduous, oak dominated forest and all forest fragments were isolated from similar habitats by suburban development, agricultural fields, highways, or a combination of these.

We assessed the breeding success of Ovenbirds by monitoring color banded males and noting the presence or absence of mates and young during the breeding season (mid-May to mid-August). The decision was made not to search actively for nests because we believed this activity would put the nests at a greater risk of being detected by predators (Major 1989, Vickery et al. 1992). Furthermore, parental behavior of Ovenbirds precluded the need to locate nests. Since male and female Ovenbirds care for young (see Porneluzi et al. 1993), a male with fledged young was interpreted as successful.

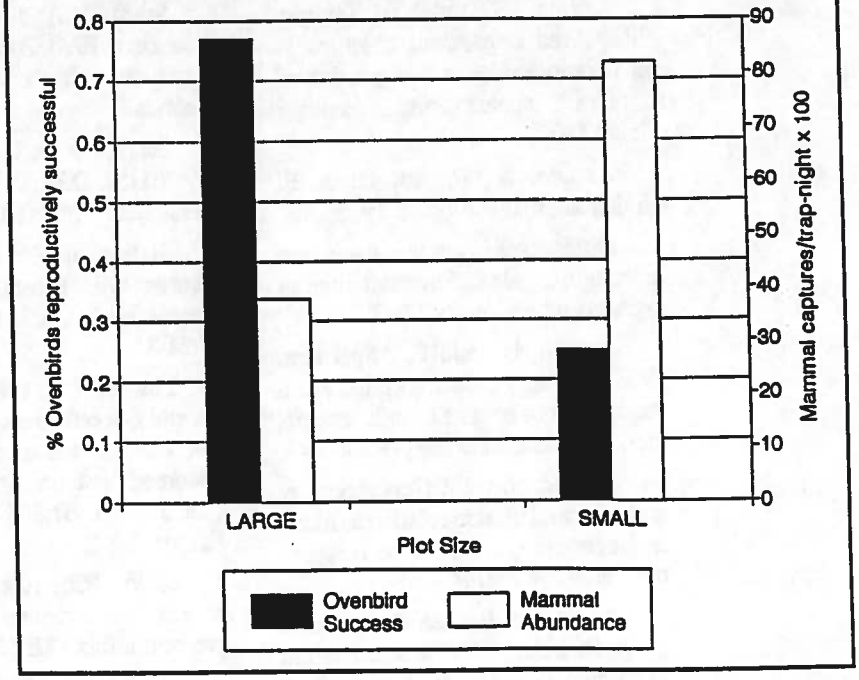
Mammalian abundance on each plot was obtained by live-trapping along transacts which ran through the middle of each plot. During the course of the season, 40 traps were set for three consecutive days at three different times over the songbird breeding season (one trap open for one 24 hour period = 1 trap-night; 360 trap-nights/fragment; 1080 trap-nights/size-class). One site of each size class was trapped per week although no two plots were trapped in consecutive weeks.

The results suggest a possible relationship between the small mammal community and songbird breeding success in small forests.

Traps were checked in the early morning (by 0830). To distinguish captures between trap days, each individual was marked on the abdomen with a non-toxic permanent marker. This enabled me to tally a total number of captures over three days and not count any one animal twice. Additionally, the weight, sex, and age (when possible) of each individual caught was recorded. The relative abundance (RA) of each species was calculated as the proportion of the actual number of individual animals caught on a given plot versus the total number of trap-nights multiplied by one hundred; RA per plot = [(total number of animals caught-recaptures)/(number traps-sprung traps)] x 100.

Chi-square tests, analyses that test for proportional differences between variables, were run on the RA to separately compare mammal abundances and Ovenbird breeding success in large and small forests.

Figure 1. Recorded data of small mammal abundances and Ovenbird reproductive success on three large (> 100 ha) plots in southeastern Pennsylvania from the 1993 breeding season.



Results and Discussion

Results suggested that the numerical differences of both Ovenbird breeding success and small mammal abundance found in large and small forests were statistically significant. While Ovenbird breeding success was extremely low in small, fragmented forests (25% success), success was relatively high on the larger study sites (77% success) (Goodrich et al. unpubl. data) (Figure 1). These results agreed with other studies and further supported the idea that small forest size and associated edges resulting from habitat fragmentation may negatively effect reproductive success of nesting Ovenbirds.

Small mammals were significantly more abundant in small forests compared with large forests (Noojibail et al. unpubl. data) (Figure 1). Examination of the differences in small mammal community composition in the different size forests indicated that the diversity of species captured was low for both forest size classes. Five species were captured with white-footed mice (*Peromyscus leucopus*) being the most abundant on all plots. Eastern chipmunks (*Tamias striatus*), grey squirrels (*Sciurus carolinensis*), flying squirrels (*Glaucomys volans*), and meadow voles (*Microtus pennsylvanicus*) were trapped less frequently (Figure 2).

Reasons for the high overall abundance of small mammals in fragmented matrices are speculative though there is evidence that the dispersal of many small mammals from

Figure 2

Numerical distribution of small mammal species captured on large (>100 ha) and small plots over a period of 108 trap-nights per size calss from mid-May to mid-August 1993 in eastern Pennsylvania.

SPECIES	LARGE	SMALL
White-footed mouse	133	292
Eastern Chipmunk	1	25
Grey Squirrel	2	0
Southern Flying Squirrel	1	0
Meadow Vole	2	0
Total	139	317

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fragmented woodlots may be impeded partially by the reluctance of these animals to navigate the surrounding farmland and clear cuts (Wegner and Merriam 1989).

Additionally, vegetative cover within the fragments was complex (Goodrich et al. unpubl. data), suggesting a greater variety of microhabitats to exploit. Increased resources could support large populations of animals over the season but at the same time may force individuals to exploit alternative resources such as nests (Nour et al 1993).

These results suggest a possible relationship between the small mammal community and songbird breeding success in small forests. All the mammals captured have been identified as potential nest predators (Wilcove 1985, Retisma et al. 1989, Yahner 1992, Nour et al. 1993 Seitz and Zegers 1993) and forests with low Ovenbird breeding success had high small mammal abundance.

Though white-footed mice were most abundant on all our study areas, we cannot implicate them as a dominant predator of Ovenbird nests on these plots. There is substantial evidence that a number of other species that predate on bird nests, including skunks, opossums, raccoons, jays, crows, and snakes, have the potential to exert severe pressure on songbird breeding attempts in small forests (Ricklefs 1969, Wegner and Mirriam 1979, Angelstam 1986, Martin 1987, and Nour et al. 1993). As the abundances of these species were not investigated, their effects on Ovenbird nesting success on the plots is unknown.

Forest fragmentation can also affect other wildlife. Current timber management philosophy maintains that large acreages of young forests combined with large amounts of forest edge are beneficial to wildlife. This may be true for species such as white tailed deer, Ruffed Grouse, Northern Cardinal, and Brown Thrasher but is clearly not the case for species sensitive to forest fragmentation (e.g. Ovenbird and Wood Thrush). Future research should focus on and provide a workable understanding of the complex dynamics of these ecosystems as a whole and utilize this information to implement more inclusive land management practices that involve and provide for wildlife on a more comprehensive level.

Acknowledgments

Thanks go to Laurie Goodrich and Margret Brittingham for overseeing and producing the project and for invaluable assistance to Gina Morgan, Liz Otterson in the field, and to Keith Bildstein for helpful critical suggestions. Special thanks to Hawk Mountain Sanctuary and the private landowners on which some of our plots existed.

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*Noojibail
2332 Marcy
Evanston, Il 60201