J. Field Ornithol., 71(2):207-216

IDENTIFICATION OF NEST PREDATORS AT FARM/FOREST EDGE AND FOREST INTERIOR SITES

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Abstract.—Using cameras at artificial ground nests we found no major quantitative differences in species richness or the relative abundance of nest predators photographed in farm/forest edge and forest-interior sites at five locations in eastern Pennsylvania. Raccoons (*Procyon lotor*) were the most commonly photographed visitors to nests at both farm/forest edge and forest interior sites, followed by female Baltimore Orioles (*Icterus galbula*), southern flying squirrels (*Glaucomys volans*), gray squirrels (*Sciurus carolinensis*), eastern chipmunks (*Tamias striatus*), and Gray Catbirds (*Dumetella carolinensis*). Rate of egg loss was higher at the edges than in the forest interior. Although the total number of photographs of predators averaged 11 among the five edge sites and 7.4 among interior sites, this was not significantly different.

IDENTIFICACIÓN DE DEPREDADORES EN LOS BORDES DE FINCAS/BOSQUES Y EN EL INTERIOR DE BOSQUES

Sinopsis.—Utilizando cámaras en nidos artificiales en los suelos, no encontramos diferencias cuantitativas mayores de la riqueza de especies o la abundancia relativa de depredadores de nidos fotografiados en el borde de fincas/bosques y en localidades del interior de bosques. El estudio se llevó a cabo en cinco localidades del este de Pennsylvania. Los mapaches (*Procyon lotor*) fueron los depredadores de nidos, más comunmente fotografiados en los dos tipos de localidades estudiadas. A éstos les siguieron hembras de *Icterus galbula*, varias especies de ardillas (*Glaucomys volans, Sciurus carolinensis, Tamias striatus*) e individuos de *Dumetella carolinensis*. La tasa de huevos perdidos fue mayor en el borde que en el interior de bosques. Aunque el número total de depredadores fotografiados promedio 11 en las cinco localidades de borde y 7.4 en las partes interiores, no hubo entre ambos diferencias significativas.

Nest predation is an important factor diminishing the breeding success of passerine birds (Martin 1993), and appears to increase with habitat fragmentation (Andrén et al. 1984, Wilcove 1985, Small and Hunter 1988, Yahner and Scott 1988). Although small-scale increases in fragmentation of forest habitat may increase avian richness and diversity by adding species normally associated with successional habitats without decreasing the diversity and abundance of forest-dwelling species (Derleth, et al. 1989), the effect of large-scale habitat fragmentation often is higher rates of nest predation at the habitat edge (reviewed by Paton 1994). Other studies have demonstrated that predation is not always higher at the habitat edge (Storch 1991, Haskell 1995, Hanski et al. 1996).

Although elevated rates of predation at the forest edge may extend 100–150 m into the forest, predation rates typically are much greater within 50 m of the edge than they are >200 m from the edge (Paton 1994). The reasons for this increased predation at the edge are not clear. Although the edge may attract a concentration of generalist predators, Heske (1995) found that activity levels of furbearers and abundance of small mammals at edges were not significantly higher than in forest interiors for agricultural/forest landscapes in Illinois. The edge effect may represent a different set of predators foraging there than those destroying eggs in the forest interior. Few studies have attempted to identify the species of predators involved or to examine the hypothesis that the species richness and/or species composition of the community of predators visiting the nests of birds at the forest edge is significantly different than that in the forest interior. Therefore, we examined this question by comparing predation at artificial ground nests at the ecotone between meadow/cropland and forest to that for the interior of large tracts of eastern deciduous forest. We hypothesized that (1) the composition of the predator community visiting nests at the edge would differ significantly from that for the forest interior, (2) the predation rate at the forest edge will be higher than that in the interior, and (3) the number of species of predators at the edge will be higher than that in the interior.

METHODS

This research was conducted at five locations near Hawk Mountain Sanctuary, Kempton, Pennsylvania (40°38′N 75°59′W). Three of our locations (Turn, Bailey, and Robertson farms) were on private properties within the forested south slope of Blue Mountain east of Eckville; one was on State Game Lands in the same valley but in the east slope and near Pine Swamp. The last was on Weiser State Forest lands northeast of Port Clinton, Pennsylvania and at least 8 km west of the other four sites. In general the landscape matrix of the area consisted of large blocks of approximately equal amounts of forested and agricultural land.

All five study locations were at least 1.5 km from each other and situated in a large (>200,000 ha) second-growth forest dominated by trees estimated to be at least 40 yr old (and in many areas as much as 60–100 yr old). The most common overstory species were red and white oak (*Quercus rubra* and *Q. alba*), beech (*Fagus grandifolia*), hickories (*Carya* spp.), sugar and red maple (*Acer saccharum* and *A. rubrum*), with some hemlock (*Tsuga canadensis*), and white pine (*Pinus strobus*).

At each location an edge study site and a forest interior study site were designated. Forest edge sites were located in "hard" edges (*sensu* Fenske-Crawford and Niemi 1997) within 15 m distance of cropland or hay meadows and ranged from being thick brambles to open stands. Most were used selectively for wood cutting. The interior sites were rocky, upland areas with much large coarse woody debris, and were >300 m from the farm/forest edge and approximately 300 m from the corresponding edge study site. Although we defined our edge as the ecotone between agricultural and forested lands, we placed all the interior sites >150 m from all fire and jeep roads, hiking trials, and forest gaps of >10 m radius.

Each station was equipped similarly to that of Major (1991) with one cup-shaped woven aviculture nest (10-cm diameter and 5-cm depth) and one remote camera located about 1.3 m from the nest. Each nest contained one Japanese Quail egg (*Coturnix coturnix*) that was positioned so that when the egg was disturbed a length of fishing line would pull a prop from the spring-loaded lever mechanism, thus depressing the camera shutter button. The nests were located on fallen logs, stumps, or rocks about 0.25–0.5 m off the ground in brambles and other inconspicuous locations and camouflaged with natural materials. Each morning the stations were checked, and the eggs replaced if they had been broken or removed. Because each nest/camera unit had to be reset after each disturbance, and thus each unit could record only one even per 24-h period, two nest/camera units were placed 10–15 m apart at each site to record any other predator activity at that site during the 24-h period. In the few cases where the visitor to the second nest was the same species as the first, we assumed that it was the same individual and did not include the second visit in the analysis.

The study was conducted in late May of 1994, 1995, and 1996 and at the height of songbird egg laying. Sampling was conducted for 10 consecutive nights in 1994, 17 nights in 1995, and 15 nights in 1996. The Weiser State Forest location was used in 1995 and 1996 only. All cameras, nests and eggs were treated in the same way so that the effect of human scent would be equally distributed across locations and sites. The nests were stored outdoors for 10–14 d before use to minimize human odors. Although we attempted to minimize the number of persons and the length of time spent at each nest, used disposable latex gloves when handling the eggs and tried not to generate visually obvious trails to the stations, we made no additional efforts to cover scent trails or to approach the nests from different directions.

RESULTS

Ninety-two photographs of potential egg predators were taken in 800 camera-nights (Table 1). Seven additional photographs, one each of White-tailed Deer (*Odocoileus virginianus*), Red-eyed Vireo (*Vireo olivaceus*), and Ovenbird and four photographs of bats, were excluded from the analysis because they appeared to be photographs of individuals that tripped the camera trigger wire incidentally to their movement and demonstrated no obvious attraction to the nest or egg. In decreasing order of abundance raccoons, sciurids (*Glaucomys volans, Sciurus carolinensis, Tamias striatus,* and *Marmota monax*), and female Baltimore Orioles (*Icterus galbula*) were the most commonly photographed visitors at the nests. Differences in the species lists for the edge and interior were slight. Gray Catbirds (three photos), woodchucks (*Marmota monax,* three), opossum (*Didelphis virginiana,* three), and black bear (*Ursus americanus,* one) were photographed only at edge sites. One Blue Jay (*Cyanocitta cristata*) and a white-footed mouse (*Peromyscus leucopus*) were recorded only in the interior. The relative frequency at which predator species were pho-

TABLE 1. Visitors at artificial nests at five locations in eastern Pennsylvania during the springs of 1994–1996. The Weiser location was used in 1995 and 1996 only. A total of 400 camera nights for farm/forest edge sites and 400 camera nights for forest interior sites were sampled.

Species	Edge						Interior					
	Turn	Weiser	Game	Bailey	Robertson	Total	Turn	Weiser	Game	Bailey	Robertson	Total
Raccoon *Procyon lotor*	8		3	14	5	30	6			12	4	22
Baltimore Oriole *Icterus galbula*		8				8	1	4			3	8
Flying Squirrel *Glaucomys volans*		1	1		2	4	1					1
Eastern Chipmunk *Tamias striatus*			2		1	3	1					1
Gray Catbird *Dumetella carolinensis*			3			3						0
Woodchuck *Marmota monax*			2	1		3						0
Gray Squirrel *Sciurus carolinensis*				2		2			2		1	3
Virginia Opposum *Didelphis virginiana*	1					1						0
Black Bear *Ursus americanus*					1	1						0
Blue Jay *Cyanocitta cristata*						0				1		1
White-footed Mouse *Peromyscus leucopus*						0					1	1
Total	9	9	11	17	9	55	9	4	2	13	9	37

tographed was similar in each habitat ($r_s = 0.97$, $P < 0.05$, df = 9). In addition, the number of species of predators photographed at the edge was higher than that in the interior for only three of the five locations (Table 1). There was no significant difference in the number of species photographed at the edge (Table 2) compared to the interior ($F_{1,4} = 0.68$, $P = 0.46$).

The number of photographs of predators taken at the edge was greater than that for the interior for three locations and equal to that in the interior for one other location. Overall, however, the mean number of photographs (11 and 7.4 for edge and interior, respectively) did not differ significantly from that for the interior ($F_{1,4} = 4.53$, $P = 0.10$).

Nest predation rate was higher at the forest edge than in the interior ($F_{1,4} = 9.18$, $P = 0.039$) with 116 eggs removed or destroyed during 400 camera nights at the edge sites compared to only 59 eggs in 400 camera nights at the interior sites (Table 2). Overall predation rates among the five locations were not significantly different ($F_{4,50} = 0.22$, $P = 0.924$).

DISCUSSION

A variety of factors influence rates of nest predation along forest edges including the landscape matrix, structure of the edge, and nature of the habitats producing the edge (Wilcove 1985, Seitz and Zegers 1993, Hanski et al. 1996, Bayne and Hopson 1997, Donovan et al. 1997). For example, using artificial nests to simulate the nests of ground-nesting Ruffed Grouse (*Bonasa umbellus*), Hogrefe, et al. (1998) found significantly higher rates of disturbance in suburban rather than rural landscapes which they attributed to higher densities of American Crows (*Corvus brachyrhynchos*) in the suburban landscape. The higher incidence of egg loss at the edge than in the interior in our study was consistent with the results of a number of other studies conducted in agricultural situations (Gates and Gysel 1978, Wilcove, 1985, Andrén and Angelstrom 1988, Small and Hunter 1988, Linder and Bollinger 1995). The results of Hanski et al. (1996), who found no edge effect in the nesting success of passerines, may be due in part to the regenerating forest nature of their landscape. In agricultural areas, where the species and abundance of predators utilizing the field matrix may depend a great deal upon farming practices, the forest edge may attract generalist predators from the field matrix who then concentrate their activities some distance into the forest. In regenerating forest landscapes, however, the edge may not attract forest-dwelling predators from the interior (Fenske-Crawford 1997). For agricultural/forest landscapes in Illinois activity levels of furbearers and abundance of small mammals at edges were not significantly higher than in forest interiors (Heske 1995); the highly fragmented character of this forest landscape may explain the lack of a significant edge effect on predator abundance. Indeed, the higher rates of predation on edge habitat nests may be due in part to higher levels of predation in saplings (Marini et al. 1995). Noojibail (1994) found that small mammals were more abundant and

TABLE 2. Number of eggs destroyed or removed, number of photographs, and number of species of predators photographed at five locations in eastern Pennsylvania. Data represent 400 camera nights at the farm/forest edge and 400 camera nights in the forest interior.

	Edge						Interior					
	Turn	Weiser	Game	Bailey	Robert-son	Total	Turn	Weiser	Game	Bailey	Robert-son	Total
Number of camera nights	84	64	84	84	84	400	84	64	84	84	84	400
Number of eggs removed or destroyed	31	6	26	34	19	116	15	2	2	28	12	59
Number of photographs	9	9	11	17	9	55	9	4	2	13	9	37
Number of species of predators	2	2	5	3	4	9	4	1	1	2	4	7

that Ovenbirds suffered lower reproductive success in small forest plots than in forest plots greater than 100 ha.

Artificial nests can provide accurate information concerning trends in rates of predation (Wilson, et al. 1998), although they underestimate the actual nesting success of real nests. Several studies have shown that Japanese Quail eggs may be too large for mice to depredate, thus this technique may underestimate the significance of small-mouthed predators (Roper 1992 and Haskell 1995). Indeed, Leimgruber et al. (1994) used cameras to determine that white-footed mice, as well as Gray Squirrels, were frequent visitors to artificial nests and thus may be important nest predators for small passerines. Other studies implicate mice as potentially important egg predators (Maxson and Oring 1978, Noojibail 1994, DeGraaf and Maier 1996, Bayne and Hopson 1997). Because our camera apparatus was designed to trigger the shutter whenever the egg was moved in its holder, we think that visits by mice would be recorded even if the mouse was unable to break or carry the egg. Nevertheless, the potential insensitivity of our technique to small-mouthed predators may explain the differences in the relative importance of mice in our study to that of Bayne and Hopson (1997), who used plasticine models of eggs and found that mice were the major predators of eggs in ground nests at agricultural edges. They found, however, that artificial nests on the ground and located at the forest edge in agricultural landscapes suffered significantly higher rates of predation than did edge and interior nests in continuous forest and logged landscapes, which is consistent with our results. The difference in the number of photographs and the number of eggs we found destroyed (Table 2) may be due to some combination of (1) weather effects, (2) shutter and camera battery failures (which seem to be inherent in this type of camera trigger mechanism), (3) the potential insensitivity of the apparatus to record small-mouthed predators, and (4) our decision not to include conspecific visitation to the companion nest/camera unit at the site during the same 24-h period.

Raccoons are common predators in forested, suburban, and rural landscapes in eastern North America that consume a variety of food items including bird eggs (Hoffmann and Gottschang 1977, Lotze and Anderson 1979, and Merritt 1987). Raccoons were predators at nests in several studies (Picman 1988, Reitsma et al. 1990, Leimgruber et al. 1994, Jobin and Picman 1997). Although raccoons were not photographed at their artificial nests, Fenske-Crawford and Niemi (1997) observed them in the mosaic of regenerating and mature forest in their study area. Raccoons were the most common visitors in the farm/forest landscape of our study. It is possible that individuals learned the locations of our sites and returned periodically to the nests, or that they followed our scent trails; thus inflating the incidence of predation by raccoons. The repeated visitation to the same nests by Baltimore Orioles and Gray Catbirds suggests that they may be targeting and destroying the eggs of potential competitors within their territories. Both sexes are aggressive defenders of territories during the nesting season in these two species. Sealy (1994) reported acts of egg destruction by both the Gray Catbird and Baltimore Oriole, and Picman (1988) found Gray Catbirds were important predators of quail eggs in an experiment with artificial nests.

Although we photographed eleven species of nest visitors during this study, each site was visited by at most only five species. Because predators destroyed eggs so infrequently and sporadically among sites, even though the habitat appeared to have the potential to support many types of predators, we speculate that this predation may be incidental to their normal patterns of foraging (*sensu* Vickery et al. 1992), although we have no data concerning the abundance and foraging movements of predators relative to the distribution of nests and other potential food items.

No obvious differences existed in the predator communities of forest edge and interior. The presence of woodchucks and Gray Catbirds at the edge are consistent with the habitat preferences of these species. Together, however, they only represent 6 of 55 (11%) of all visits to the edge nests and only 2 of 11 species of nest predators and seem unlikely to account for the higher rate of egg destruction at the forest edge. Unlike Bayne and Hopson (1997), we found that species richness of predators at the edge did not differ from that in the forest interior. This difference in findings may be due to the differences in landscapes. Our area was about 50% agricultural and 50% forested (both in large blocks); their farm area was 70% agricultural use and the forest patches were small (9–45 ha). The community of predators at the edge in our study is not much different than that in the interior of the forest. Heavier predation at the edge may be the result of greater abundance and diversity of potential prey, or the ease of hunting, or other factor that concentrates predators at the edge, but apparently is not due to a significantly different mix of predatory species at the edge.

ACKNOWLEDGMENTS

The following members of the Millersville University Field Ornithologists club assisted in the field: W. Stack, E. Stiles, S. Roth, J. Brooks, W. Vaupel, J. Frey, D. Evans, W. Stauffer, K. Yarwood, and J. Giacomo. We also thank the Pennsylvania Game Commission and the Pennsylvania Bureau of Forestry for use of public lands. Mr. and Mrs. Mark Bailey, Mr. and Mrs. John Turn, Mr. and Mrs. Bob Robertson, and Mr. and Mrs. Lester Bailey gave permission to use their properties. K. Bildstein and the staff of Hawk Mountain Sanctuary provided much logistic support, including use of camping facilities, and were invaluable in the conduct of this research. Financial support was provided by the Keever Fund and Faculty Professional Development Committee of Millersville University and a Neimeyer-Hodgson Grant from the Alumni Association of Millersville University. S. J. Ha, L. Sorber, and C. Schroeder made useful comments concerning the manuscript. The comments of T. Fenske, C. R. Chandler, and an anonymous reviewer greatly improved the quality of this manuscript. This is Hawk Mountain Contribution number 78.

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