

Northern Cardinal *Cardinalis cardinalis*

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EXECUTIVE SUMMARY

Preferred breeding habitat: Areas with shrubs or small trees, such as forest edges, regenerating forest, marsh edges, successional fields, shrubby grassland, and shrubby plantings around buildings.

Nest placement: At a height of 1-2 m in a thick tangle of vines or twigs within a shrub or small tree.

Mean clutch size and fledging brood size (\pm SD):

- Non-parasitized nests: clutch 2.83 ± 0.68 ; brood 2.43 ± 0.86
- Cowbird parasitized nests: clutch 2.54 ± 1.12 ; brood 1.53 ± 1.31

Number of broods per season: Multiple, up to four.

Annual adult survival rates: Males and females: 65%.

Requirements for population stability ($\lambda \geq 1$):

- Fledge at least 2.2 own young per female per year
- Daily nest mortality $\leq 6.2\%$ ($\geq 22\%$ nest success) assuming zero parasitism
- Daily nest mortality $\leq 5.4\%$ ($\geq 26\%$ nest success) with 20% nest parasitism
- Daily nest mortality $\leq 3.9\%$ ($\geq 38\%$ nest success) with 40% nest parasitism
- Generally $\leq 20\%$ nest parasitism across BBIRD sites

Nest mortality and parasitism rates in relation to landscape context:

- Reported daily nest mortality rates of 5.2-7.6% in highly fragmented landscapes, intensively managed plantations, and recent clear-cuts.
- Nest predation rate is inversely correlated with distance to the forest edge, and positively correlated with the degree of fragmentation at local landscape scales.
- Nest parasitism rate is positively correlated with the degree of forest fragmentation at landscape scales, particularly within a 5-50 km radius.

The importance of spatial scale to the relationship between nesting success and landscape context:

- Any edge effects on nest parasitism appear to be strongly constrained by the degree of forest fragmentation at landscape scales, particularly within a 5-50 km radius.
- Nest predation appears to be most strongly correlated with edge effects at the patch scale that are not constrained by the degree of forest fragmentation at landscape scales.

General conclusions:

- Nest parasitism exerts as important an effect on Northern Cardinal λ as nest predation.
- Nest parasitism rate is most strongly correlated with the degree of forest fragmentation at landscape scales.
- Nest predation rate is most strongly correlated with patch-scale edge effects.
- Selective logging appears to add little to existing fragmentation effects, but clear-cut logging may elevate nest predation rates.

Management guidelines:

- Because small canopy openings promote the development of a dense understory preferred by Northern Cardinals, silvicultural practices that include group selection logging, small or narrow clearcuts, thinning to remove overmature trees, cutting trees larger than a specified diameter limit, or single-tree selection will generally benefit Northern Cardinal populations (Crawford et al. 1981). Large clear-cuts, intensive site preparation, and prescribed burning would generally be deleterious for Northern Cardinal populations, at least in the short term (Crawford et al. 1981).
- Given the relatively severe effect of cowbird parasitism on Northern Cardinal breeding productivity, any management efforts that reduce cowbird abundance, both locally and in the broader landscape (within up to a 15 km radius), will benefit cardinal populations.
- Given that nest predation rates may be elevated close to forest edges, particularly adjoining agricultural lands, the extent of forest/agricultural edges within preferred Northern Cardinal breeding habitat should be minimized where possible.

DETAILED and BACKGROUND INFORMATION

Distribution and habitat preference

The Northern Cardinal is a year-round resident within a range that extends throughout eastern and central North America, from south-eastern Canada to Mexico, and northern Guatemala and Belize (Halkin & Linville 1999).

The Northern Cardinal inhabits areas with shrubs and/or small trees, including forest edges and forest interior, shrubby areas in logged and second-growth forest, marsh edges, grasslands with shrubs, successional fields, hedgerows in agricultural fields, and plantings around buildings (Halkin & Linville 1999). It shows a preference for areas with dense understory vegetation (Anderson & Shugart 1974, Artman et al. 2001). In southern Texas, winter population density generally increased with shrub density: 47 birds/km² in grass-forb prairie; 2 birds/km² in scrubby grassland; 67 birds/km² in open brushland; 106 birds/km² in dense brushland; 114 birds/km² in 2-layer brushland; 148 birds/km² in oak woodland; and 692 birds/km² in riverine forest (Emlen 1972).

Cardinals generally benefit from human alteration of natural habitats throughout their range. The conversion of forests to agricultural and suburban areas increases the availability of suitable nesting habitat, and the provision of food at winter feeders enables Northern Cardinals to remain during winter in areas not suitable in the past (Halkin & Linville 1999). In the vicinity of Tucson, Arizona, cardinal densities were higher in suburban (10-40 birds/ km²) and urban (5-42 birds/ km²) habitats than in moderately-disturbed paloverde-saguaro (*Cercidium – Carnegia gigantean*) habitat (<6-11 birds/ km²: Tweit & Tweit 1986).

Nest site characteristics

The open-cup nest is placed in a thick tangle of vines or twigs, usually in shrubs or small trees at a height of 0.25-12 m, although the average height is usually 1-2 m (Laskey 1944;

Kinser 1973; Filliater et al. 1994). Nests are typically concealed by foliage, and territories with successful nests had higher foliage density and patchiness at 2 m height throughout the territory than did territories with unsuccessful nests (Conner et al. 1986).

Laying seasons

Earliest and latest Northern Cardinal nests in the BBIRD database were initiated on 10 April and 28 July respectively. However, most laying occurs within an 8-week to 9-week period: 30 April – 1 July at latitudes 30-35°N; 14 May – 8 July at latitudes 35-40°N; and 21 May – 15 July at latitudes 40-45°N (Figure 1). The peak in the laying season occurs approximately two weeks later at latitudes 40-45°N (week 11-17 June) than at latitudes 35-40°N (week 28 May - 3 June). The length of the laying season is estimated as 77 days at latitudes 35-40°N and 68 days at latitudes 40-45°N, yielding an average estimate of 73 days.

Other published data on laying dates suggest a more extended laying season, with earliest nests initiated from late March in the southern United States, and latest nests initiated in early August (Halkin & Linville 1999).

Assumptions in calculations of breeding productivity

Eggs are laid at daily intervals (Halkin & Linville 1999). BBIRD data indicate a mean clutch size in unparasitised nests of 2.83 (SD = 0.68, n = 280). The mean incubation period has been reported as 12.3 days (n = 16) in southern Ontario (Scott & Lemon 1996), and 12.8 days (n = 27) in southern Indiana (Kinser 1973). The modal nestling period is 9-10 days when the young are not disturbed (Halkin & Linville 1999), and BBIRD data indicate a 9.75-day (range 9-10 days; n = 4) nestling period. Re-nesting intervals are reported as 5.5 days (n = 37) following nest loss (Scott et al. 1987) and 5-33 days after successful fledging (Lemon 1957), with Kinser (1973) reporting a re-nesting interval of 13-14 days (n = 4) if only a single chick is fledged, but 19.2 days (n = 6) if more than one chick is fledged. Up to eight clutches may be initiated in a season (Kinser 1973; Filliater et al. 1994), and successful fledging of young reported in up to four nests per pair per season (Shaver & Roberts 1930).

To calculate breeding productivity, we used a 73-day laying season, a 24-day nesting period (2-day laying period, 12.5-day incubation period, 9.5-day nestling period), a re-nesting intervals of 6 days following nest loss and 17 days following successful fledging.

To corroborate the Ricklefs (1966) model of estimating seasonal breeding productivity, we compared model outputs to direct field measurements made by Scott and Lemon (1996) in southern Ontario. Using the daily mortality rate of 6.4% (n = 1,355 observation days) observed in this study population, the Ricklefs (1966) model estimated the mean number of broods per female over the season at 0.72, compared to the field measurement of 0.89 (n = 71 pairs). On the other hand, a simple, individual-based model using the same season and interval lengths, that assumes all females start laying on day 1 of the laying season, and may re-lay until day 73 of the laying season, estimates the mean number of broods per female at 0.84. This suggests that the Ricklefs (1966) model underestimates seasonal breeding productivity, and that the alternative, individual-based

model may more accurately estimate breeding productivity, despite a probable overestimation of the laying season length of individual females for this approach (see Figure 1 – not all females are likely to start on day 1 of a 73-day laying season).

Assumptions in calculations of finite rate of population increase (λ)

Approximately 65% of breeding birds in a southern Ontario study returned to the study area the following breeding season (Scott 1967). A mark-recapture study estimated annual adult survival at 60% (SE = 6%) in Maryland (Karr et al. 1990). Although adults of both sexes usually occupy breeding territories with the same or very similar boundaries from year to year (reviewed in Halkin & Linville 1999), breeding dispersal of up to 1.6 km has been observed (Smith 1969). Thus, these survival estimates probably underestimate survival. Survivorship of fledged young to 28 days after fledging was 80% in southern Ontario (Smith 1969), but no data on survivorship to 1 year exist. We assume an annual adult female survival rate of 65% and a juvenile survival rate of 32.5% (50% of the adult female survival rate estimate, following the hypothesis of Greenberg (1980) and Temple & Cary (1988) that juvenile survival is approximately 50% of adult survival among small, north-temperate passerines).

Effects of nest micro-habitat on probability of nest predation and parasitism

Few data. Filliater et al. (1994) found no differences in nest concealment, nest height, relative nest height, or distance from nearest edge of open habitat between successful and depredated nests.

Effects of Brown-headed Cowbird nest parasitism on host reproductive success

The average Northern Cardinal clutch size was 10% lower among parasitized nests (mean = 2.54; SD = 1.12; n = 59) than non-parasitized nests (mean = 2.83; SD = 0.68; n = 280). Northern Cardinal fledging success was 37% lower among parasitized nests (mean = 1.53; SD = 1.31; n = 19) than non-parasitized nests (mean = 2.43; SD = 0.86; n = 132). The mean number of Brown-headed Cowbird eggs laid per parasitized Northern Cardinal nest increased non-significantly ($F_5 = 3.86$; $P = 0.12$), and the mean number of host young fledged per successful nest decreased significantly ($F_6 = 105.64$; $P < 0.001$) as the site-specific parasitism rate increased (Figure 2). These data contrast with a study that found no impact of parasitism on fledging success in a population with 48% nest parasitism (higher than at any BBIRD site) in southwestern Ohio (Eckerle & Breitwisch 1997).

Table 1. Summary of Northern Cardinal breeding productivity and estimated finite rate of population increase (λ) across BBIRD sites.

Site	No. of nests	Clutch size ¹	Parasitism rate (%) ²	Daily predation rate (%) ³	Nest success (%) ⁴	Fledglings/ nest ⁵	Annual ^a fecundity ⁶	Annual ^b fecundity ⁶	λ^a	λ^b
Mississippi R., MN/WI	38	3.09	2.6	3.85	31.79	2.64	2.54	3.06	1.06	1.15
Hoosier Natl Forest, IN	116	2.90	12.1	5.77	22.58	2.38	1.83	2.18	0.95	1.00
Western Maryland	41	2.79	26.8	7.53	15.26	2.00	1.18	1.37	0.84	0.87
Wayne Natl Forest, OH	46	2.74	6.5	6.67	18.07	2.38	1.58	1.86	0.91	0.95
Columbia, Missouri	15	3.29	40.0	4.36	23.73	1.57	1.25	1.49	0.85	0.89
Northern Ohio	123	2.71	26.8	5.13	23.64	2.08	1.65	1.96	0.92	0.97
NW Monongahela Natl Forest, WV	6		16.7	7.14	16.89					
Pewaukee Lake, WI	16	3.25	25.0	7.03	12.48					
Ouachita Natl Forest, AR	81	2.78	6.2	4.16	34.20	2.43	2.45	2.96	1.05	1.13

¹Number of host eggs incubated in non-parasitized nests

²Percentage of nests that received 1 or more cowbird eggs

³Percentage of nests lost to predators per day

⁴Percentage of nests that produced at least 1 host fledgling or cowbird

⁵Number of host young fledged per successful nest

⁶Average number of host young fledged per female per year

^aEstimation using the Rickelfs & Bloom (1977) model

^bEstimation using simple individual-based model

Table 2. Summary of the best predictor variables (fragmentation indices) for the relationship between each of nest parasitism rate and lambda (individual-based model estimates) across plots (all plots with ≥ 5 nests) and sites (plot averages for scales of patch and 1-10 km radii) using multiple regression analysis. Spatial scales included: the patch of forest within which the study plot was embedded; 1-10 km radii of study plot centers; and 50-100 km radii of study site centers. Independent variables included: forest edge density; distance between plot center and nearest developed land cover edge; Fractal dimension; percent cropland cover; total edge density of all land cover types in the landscape; percent developed land cover; average forest patch size; average forest patch size of all patches >10 ha; Contagion; Shannon-Weaver index. In all cases, single parameter models were most parsimonious. Non-significant results included for comparison across scales. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Scale	Plots			Sites			
	Dependent variables	Independent variables	Adj. R^2	Slope	Independent variables	Adj. R^2	Slope
Patch	Parasitism	Forest edge density	0.06		To developed edge	0.14	
	Predation				To developed edge	0.31	
	Lambda	To developed edge	0.22		To developed edge	0.31	
1 km	Parasitism	Fractal dimension	0.08		% developed	0.05	
	Predation				% developed	0.14	
	Lambda	% cropland	0.08		% developed	0.02	
5 km	Parasitism	Fractal dimension	0.16*	2.4	Total edge density	0.28	
	Predation				Forest edge density	0.06	
	Lambda	% cropland	0.65		Fractal dimension	0.15	
10 km	Parasitism	Total edge density	0.15*	2.49	Total edge density	0.31	
	Predation				Fractal dimension	0.12	
	Lambda	Fractal dimension	0.5		Avg. patch size	0.15	
50 km	Parasitism				Avg. patch size >10 ha	0.35	
	Predation				Fractal dimension	0.32	
	Lambda				Contagion	0.18	
100 km	Parasitism				Shannon-Weaver index	0.31	
	Predation				Fractal dimension	0.18	

Lambda

Contagion

0.18

Effects of landscape-level habitat variables on nest parasitism

Among all plots, the parasitism rate on Northern Cardinal nests was significantly related to indices of forest fragmentation at the local landscape scales of within a 5-10 km radius, increasing as the degree of forest fragmentation within a 5-10 km radius increased (Table 2, Figure 3). There were no such significant relationships among sites (Tables 2-3), although there was a consistent pattern of an increase in nest parasitism with an increase in the degree of forest fragmentation across most spatial scales (Figure 4). There is a possibility that the relationship between nest parasitism and forest fragmentation may differ between regions (Figure 4), but there were insufficient data to test for such an effect.

Nest parasitism rate did not differ between forest adjoining an agricultural edge, and interior forest at least 2 km from the nearest agricultural edge in a cowbird-saturated forest in southern Indiana (Ford et al. 2001). Robinson et al. (1995) found that nest parasitism rate increased non-significantly as percent forest cover within a 10 km radius (an index of fragmentation) was reduced in a comparison of nine sites across the Midwestern United States.

In summary, the available evidence suggests that the nest parasitism rate on Northern Cardinal nests increases as the degree of forest fragmentation at local landscape scales increases.

Table 3. Correlations (r) between site means for landscape variables and each of nest parasitism rate, daily nest predation rate, and lambda (individual-based model estimates) among sites. Landscape variables include percent cover of grassland (planted pasture/hay and semi-natural grassland/herbaceous), forest, and cropland (row crops, small grains, fallow and orchards/vineyards) at 1-100 km radii.

	Parasitism rate vs			Daily predation rate vs			Lambda
	Grass	Forest	Crop	Grass	Forest	Crop	Forest
	r	r	r	r	r	r	r
		-0.33			-0.31		0.10
1 km	0.34	-0.36	0.41	0.14	-0.44	0.39	0.27
5 km	0.49	-0.55	0.40	-0.18	-0.38	0.21	0.46
10 km	0.43	-0.59	0.37	-0.24	-0.33	0.13	0.48
50 km	0.27	-0.56	0.33	-0.37	-0.18	-0.01	0.36
100 km	0.61	-0.41	0.15	-0.13	-0.21	0.10	0.23
150 km		-0.30			-0.12		0.07

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Effects of landscape-level habitat variables on nest predation rate

Among all plots, there were no discernable relationships between nest predation rate and any index of forest fragmentation at any spatial scale. Although the relationships were non-significant, daily nest predation rate generally increased with increasing degree of forest fragmentation across sites, particularly at the patch scale, where predation rate is inversely related to distance to the nearest developed edge, and within a 50 km radius of site centers among sites (Tables 2-3, Figure 5).

Daily nest predation was non-significantly higher within 20 m (4.8%) than at distances of 21-40 m (3.6%) of shrubland/mature forest edges within regenerating forest, glades, and forest-pasture edges in the Missouri Ozarks (Woodward et al. 2001). However, nest survival was nearly

twice as high in forest interior habitat than in forest adjoining an agricultural corridor in southern Indiana (Ford et al. 2001). Robinson et al. (1995) found that daily nest predation rate increased non-significantly as percent forest cover within a 10 km radius (an index of fragmentation) was reduced in a comparison of nine sites across the Midwestern United States.

To summarise, the available evidence suggests there may be weak edge effects on nest predation, and an increase in nest predation rate with increasing degree of forest fragmentation at landscape scales.

Effects of landscape-level habitat variables on the finite rate of population increase

Among all plots, lambda was most significantly negatively correlated with percent forest cover within a 5 km radius of plot centers (Table 2, Figure 6). Among sites, lambda was most positively correlated with average distance between plot centers and the nearest developed edge (Table 2, Figure 7).

Effects of silviculture on nest predation and nest parasitism

Selective logging added little to existing fragmentation effects in southern Illinois forests in which levels of both nest parasitism and nest predation were chronically high – nest parasitism (29-46%) and daily nest predation rate (5.13-6.83%) did not differ between selectively logged and uncut forest compartments (Robinson & Robinson 2001). Similarly, nest parasitism was not greater in forest adjoining large clear-cuts (8.3% parasitism, n = 12 nests) than in forest adjoining small, managed wildlife openings (25%, n = 4), interior forest (30.8%, n = 13) and exterior edge (7.1%, n = 14) in southern Indiana forests saturated with cowbirds (Winslow et al. 2000). Nest parasitism (range 7.7-11.1%) did not differ between 3-6 year-old regenerating clear-cuts, 12-15 year-old mid-rotation stands, and 17-23 year-old thinned stands in Arkansas pine plantations (Barber et al. 2001).

Daily nest mortality was non-significantly greater in intensively managed cottonwood plantations (6.7% daily mortality) than in mature bottomland hardwood forests (5.6%) in Louisiana (Twedt et al. 2001). Furthermore, daily nest mortality did not differ between cottonwood plantations regenerated by planting stem cuttings (6.5%) and those regenerated by coppicing (6.8%: Twedt et al. 2001). Daily nest mortality (mostly from predation) was somewhat higher in regenerating clear-cuts 3-6 years old (7.61% daily mortality) and 12-15 year-old mid-rotation pine plantation stands (6.69%) than in thinned, 17-23 year-old pine plantations (4.16%) and single-tree selection pine-hardwood stands (2.33%) in Arkansas (Barber et al. 2001).

To summarise, selective logging appears to add little to existing fragmentation effects on nest parasitism and nest predation rates, but clear-cut logging does appear to increase nest predation rates.

Silvicultural practices have variable effects on breeding densities. The Northern Cardinal showed avoidance of pole stands and preference for mature stands in central Appalachian hardwood forests, where the number of cardinals was directly related to total vegetation <1.8 m tall (Crawford et al. 1981). Breeding densities (mean number of territories/40 ha) were also greater in mature bottomland hardwood forest (38.5 territories) than in selectively harvested bottomland hardwood stands (29.2), or cottonwood plantations that were coppiced from root sprouts (23.2) or established from planted stem cuttings (18.7) in the Mississippi Alluvial Valley of Mississippi and Louisiana (Twedt et al. 1999). On the other hand, breeding densities (mean detections/10-min point count) were non-significantly different between clearcut (0.23), shelterwood (0.23), group selection (0.16), single-tree selection (0.13) and mature forest (0.07) in southeastern Missouri (Annand & Thompson 1997).

Effects of burning on nest success

No data on effects on nest success. However, breeding densities declined in response to annual (1-4 years) prescribed burns that reduced shrub and sapling density in a southern Ohio mixed-oak forest (Artman et al. 2001). Breeding densities were also significantly reduced by prescribed burning of pine forests in the Georgia Piedmont (White et al. 1999).

Effects of grazing/browsing on nest success

No data.

Overview of landscape-level habitat effects on breeding productivity and population growth rate

Nest parasitism by Brown-headed Cowbirds reduces Northern Cardinal fledging success from successful nests by 37% on average, resulting in nest parasitism having as important an effect on lambda as nest predation ($r_p = -0.93$ and -0.89 for nest parasitism and nest predation respectively). Given that both nest parasitism rate and daily nest predation rate are correlated, to various degrees, with distance to forest edge and the degree of forest fragmentation at landscape scales, it is not surprising that breeding productivity, and thus lambda, are relatively strongly influenced by distance to forest edge and local-landscape-level forest fragmentation.

Mapping predicted source and sink habitat

Mapping predicted source and sink habitat is problematic due to insufficient resolution in the relationship between lambda and landscape metrics of forest fragmentation across BBIRD sites.

MANAGEMENT GUIDELINES

Because small canopy openings promote the development of a dense understory preferred by Northern Cardinals, silvicultural practices that include group selection logging, small or narrow clearcuts, thinning to remove overmature trees, cutting trees larger than a specified diameter limit, or single-tree selection will generally benefit Northern Cardinal populations (Crawford et al. 1981). Large clear-cuts, intensive site preparation, and prescribed burning would generally be deleterious for Northern Cardinal populations, at least in the short term (Crawford et al. 1981).

Given the relatively severe effect of cowbird parasitism on Northern Cardinal breeding productivity, any management efforts that reduce cowbird abundance, both locally and in the broader landscape (within up to a 15 km radius), will benefit cardinal populations.

Given that nest predation rates may be elevated close to forest edges, particularly adjoining agricultural lands, the extent of forest/agricultural edges within preferred Northern Cardinal breeding habitat should be minimized where possible.

FILLING THE GAPS – FUTURE RESEARCH AND MONITORING NEEDS

An accurate estimate of annual adult female survival rate is critical for the estimation of lambda. Current survival estimates for the Northern Cardinal are based on a single year of data (Scott 1967) or a mark-recapture study that generally underestimates survival (Karr et al. 1990). A survival estimate for Northern Cardinal should be determined with intensive monitoring, over a period of at least five years, of a color-banded population occupying the interior of a large forest

tract where reproductive success is high, given that poor reproductive success may result in higher levels of breeding dispersal (e.g. Porneluzi & Faaborg 1999, Bayne & Hobson 2002).

Further data on nesting success in both small and large forest patches in landscapes with differing extents of forest fragmentation at broad scales in different regions within the breeding range of the Northern Cardinal would be useful for improving resolution in our understanding of the influence of landscape structure on breeding productivity, and thus on the patterns of sources and sinks in the landscape. These data are not difficult to collect, requiring a sample of ideally at least 25 nests (to give a sample of at least 10 successful nests for a reliable estimate of mean number of host young fledged per successful nest) that are monitored frequently enough to accurately determine their fate, and collected from a plot, up to 50 ha in size, of homogenous habitat whose center can be geo-referenced with a precision of approximately 30 meters (to allow plot-specific landscape features to be characterized from a digital land cover map). If any nests are located within 100 m of a habitat edge, measurements of the distance between that nest and the nearest edge would be useful for investigating patch-scale edge effects.

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Figure 1. Northern Cardinal laying season (number of new nests initiated each week) in relation to latitude. Laying season length estimated using the MacArthur index (Ricklefs 1966).

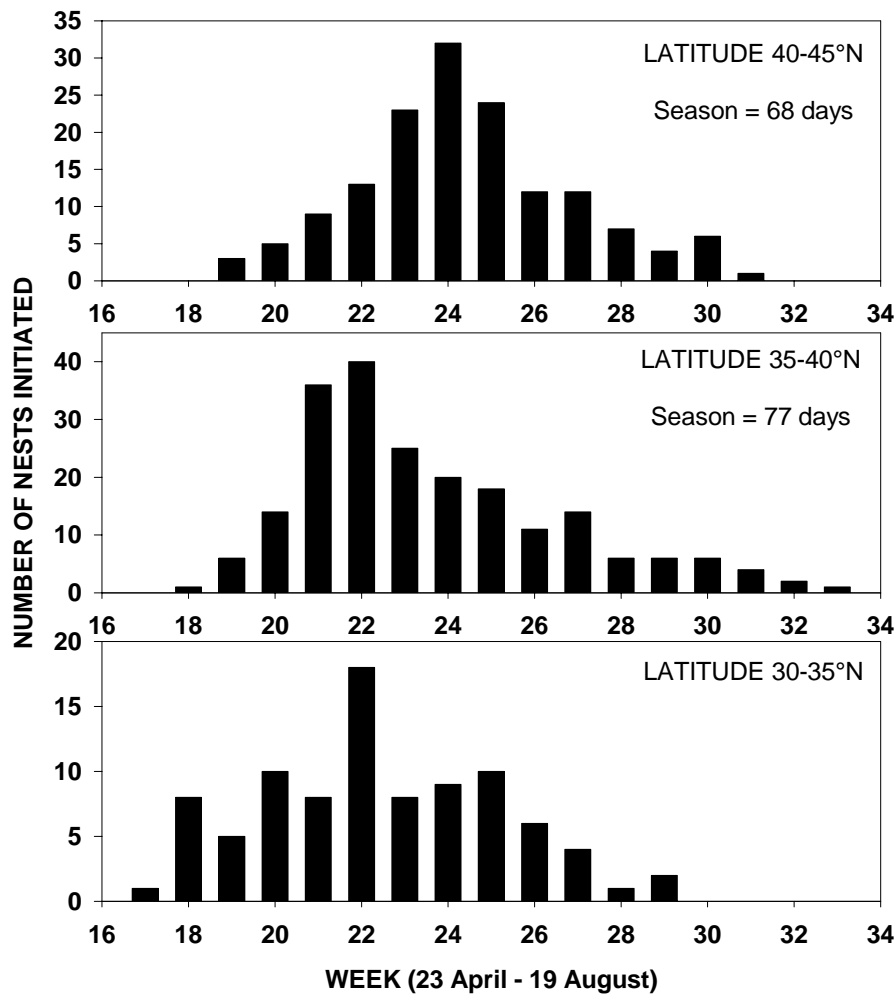


Figure 2. The mean number of Brown-headed Cowbird eggs laid per parasitized Northern Cardinal nest (top) increases non-significantly ($F_5 = 3.86$; $P = 0.12$), and the mean number of host young fledged per successful nest (bottom) decreases significantly ($F_6 = 105.64$; $P < 0.001$) as the site-specific parasitism rate increases.

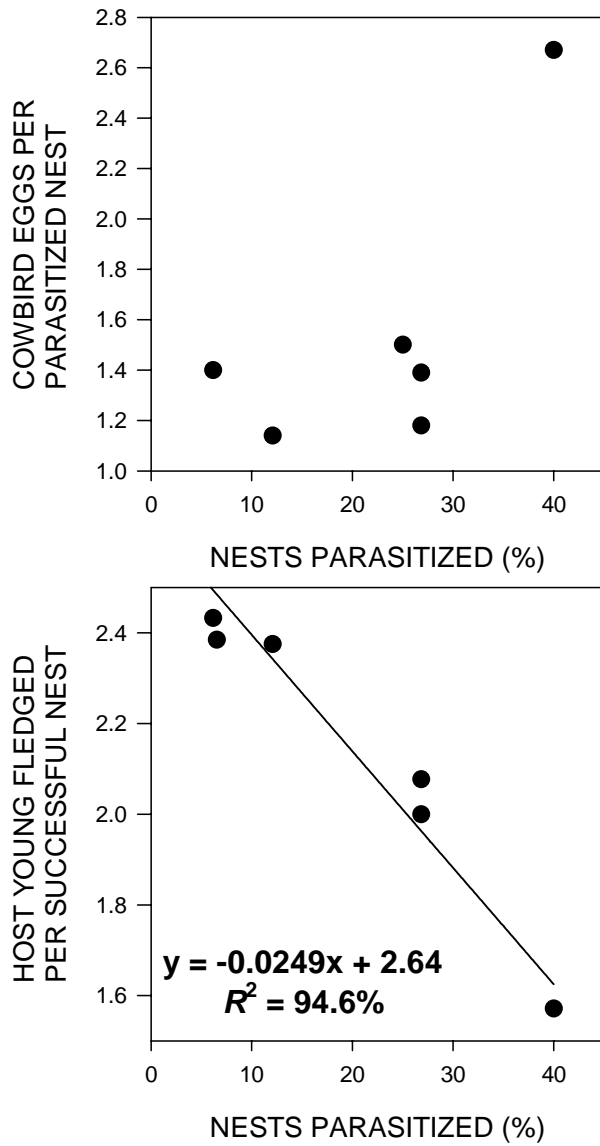


Figure 3. Relationship between nest parasitism rate (arcsine transformed) and various indices of landscape structure at spatial scales of the forest patch, and within 1-10 km radii of plot centers. Relative percent forest cover at the 100 km radius scale is classified as low, medium, or high.

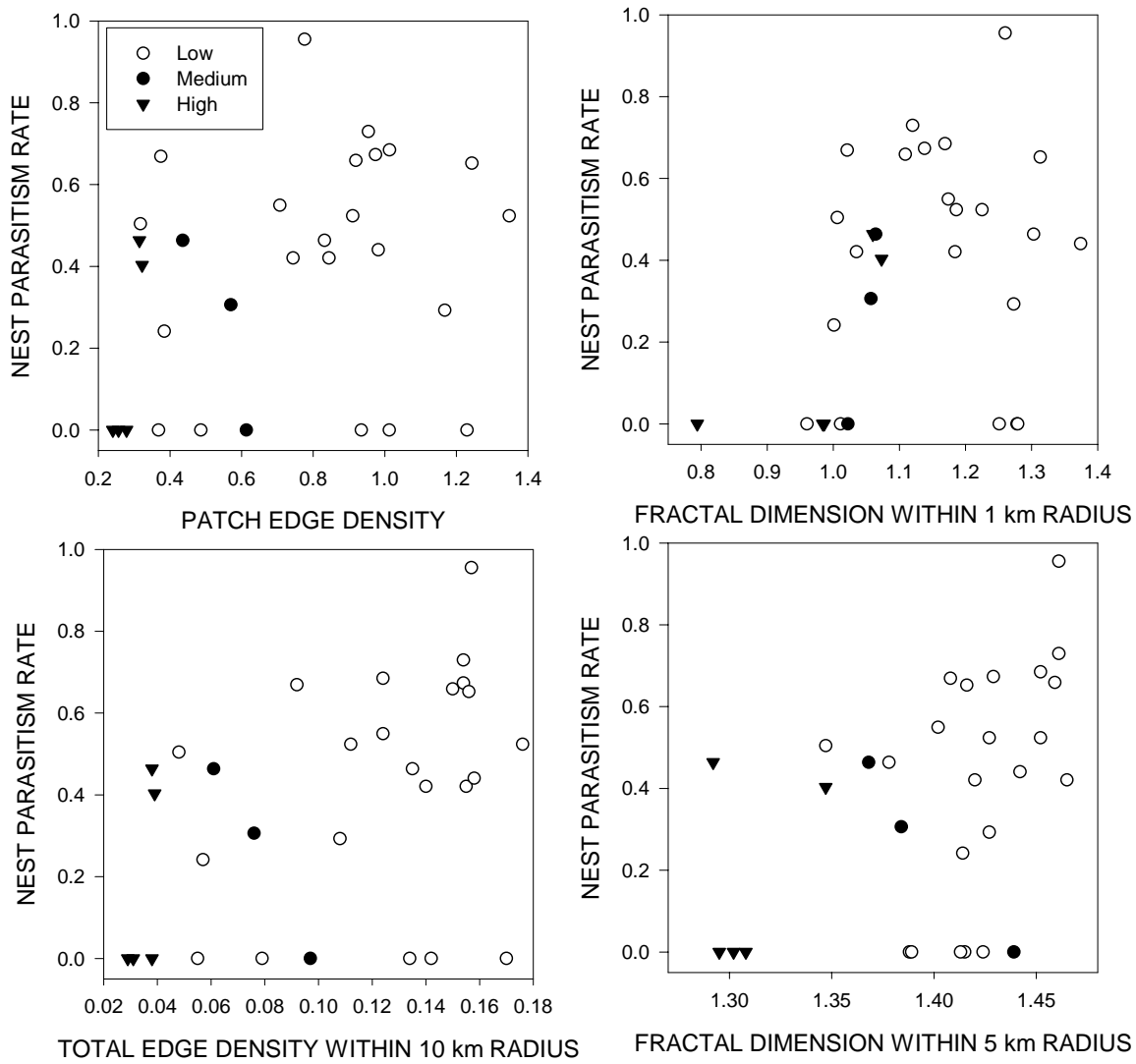


Figure 4. Relationship between nest parasitism rate (arcsine transformed) and various indices of forest fragmentation at spatial scales of the forest patch, within 1-10 km radii of plot centers (site averages), and 50-100 km radii of site centers. Sites are classified according to region: East; Northern MidWest; and Southern MidWest.

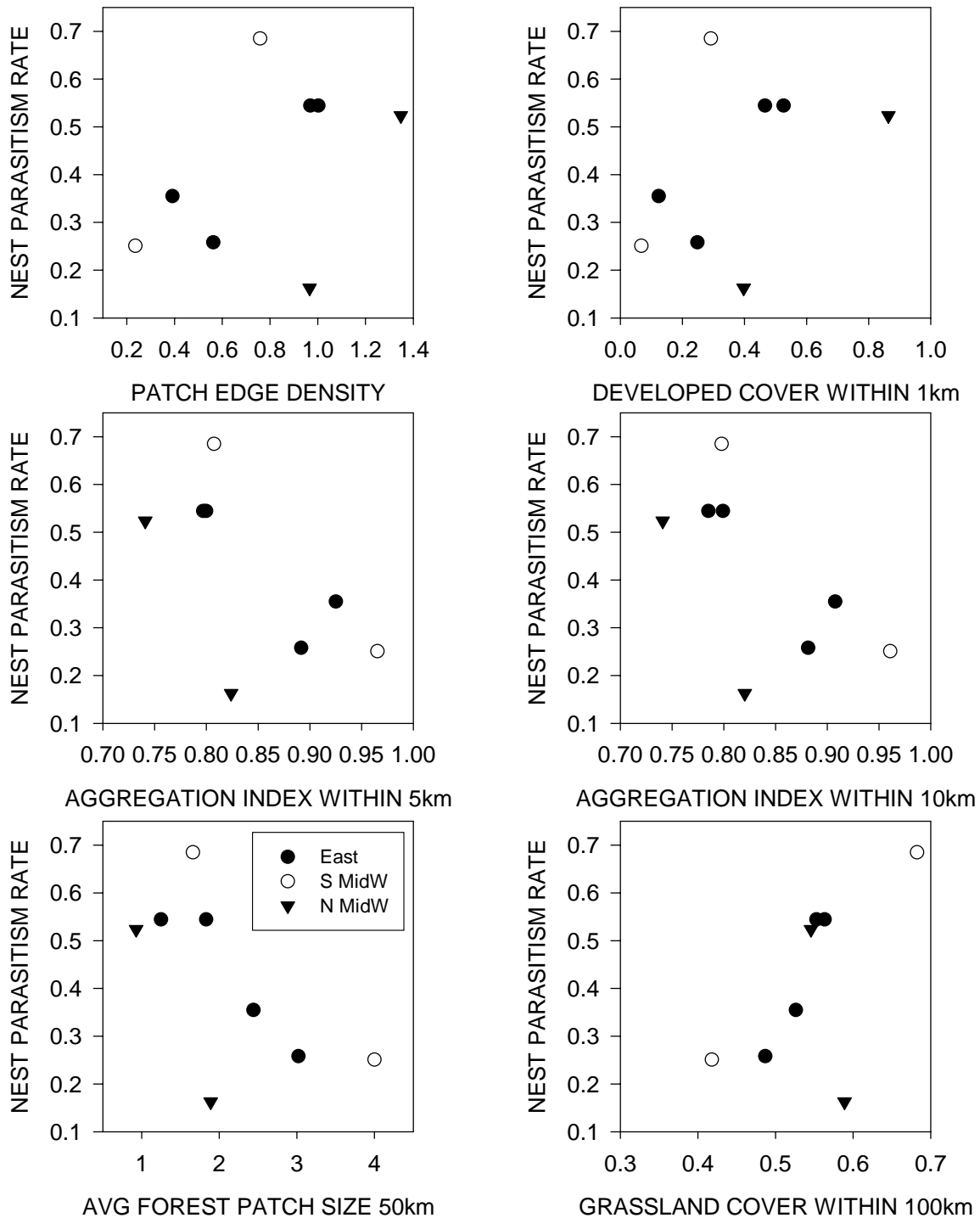


Figure 5. Relationship between daily nest predation rate and various indices of forest fragmentation at spatial scales of the forest patch, within 1-10 km radii of plot centers (site averages), and 50-100 km radii of site centers. Sites are classified according to region: East; Northern MidWest; and Southern MidWest.

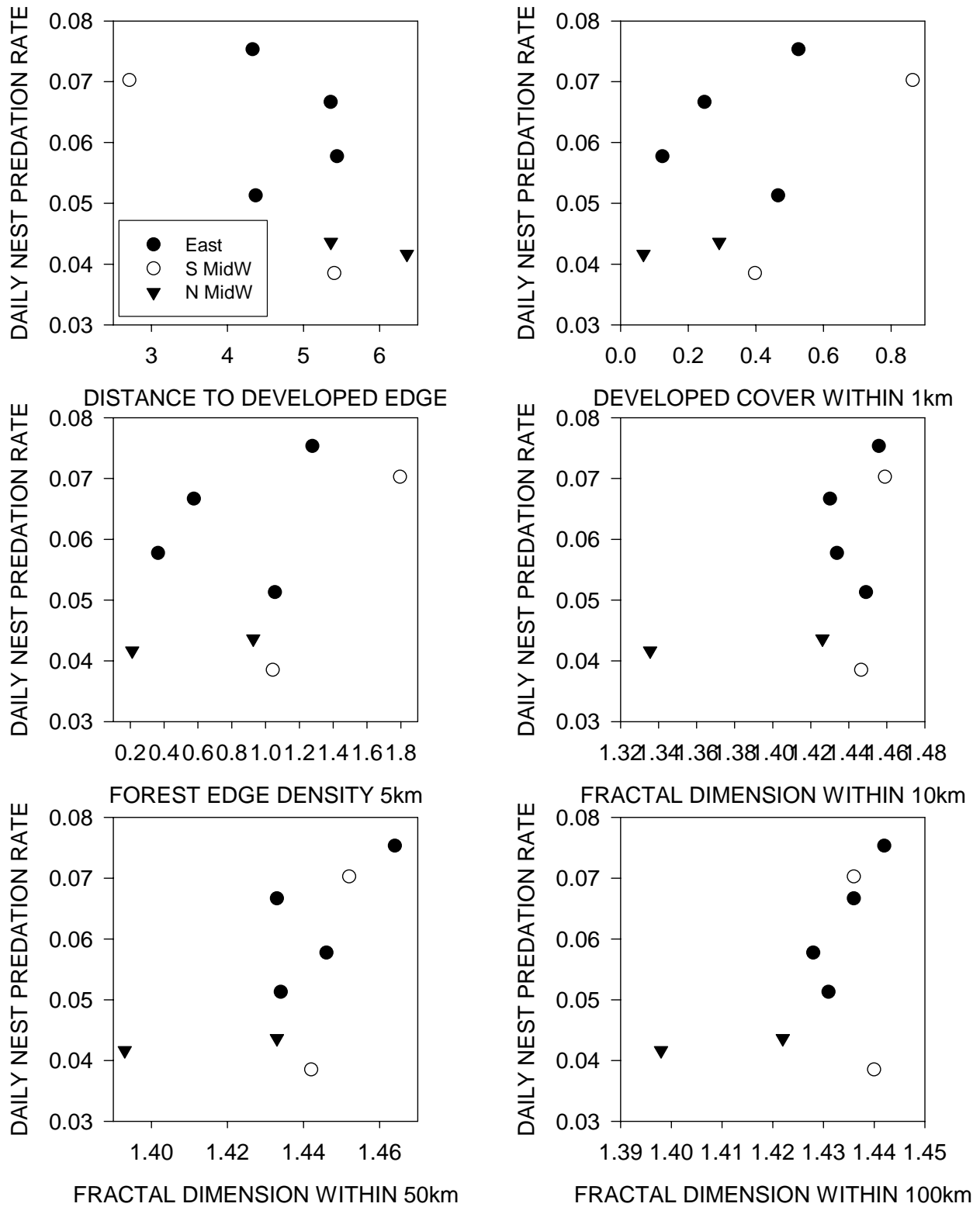


Figure 6. Relationship between Northern Cardinal lambda and percent cropland cover (arcsine-transformed) within a 5 km radius of BBIRD plot centers for all plots with ≥ 5 nests fledging young.

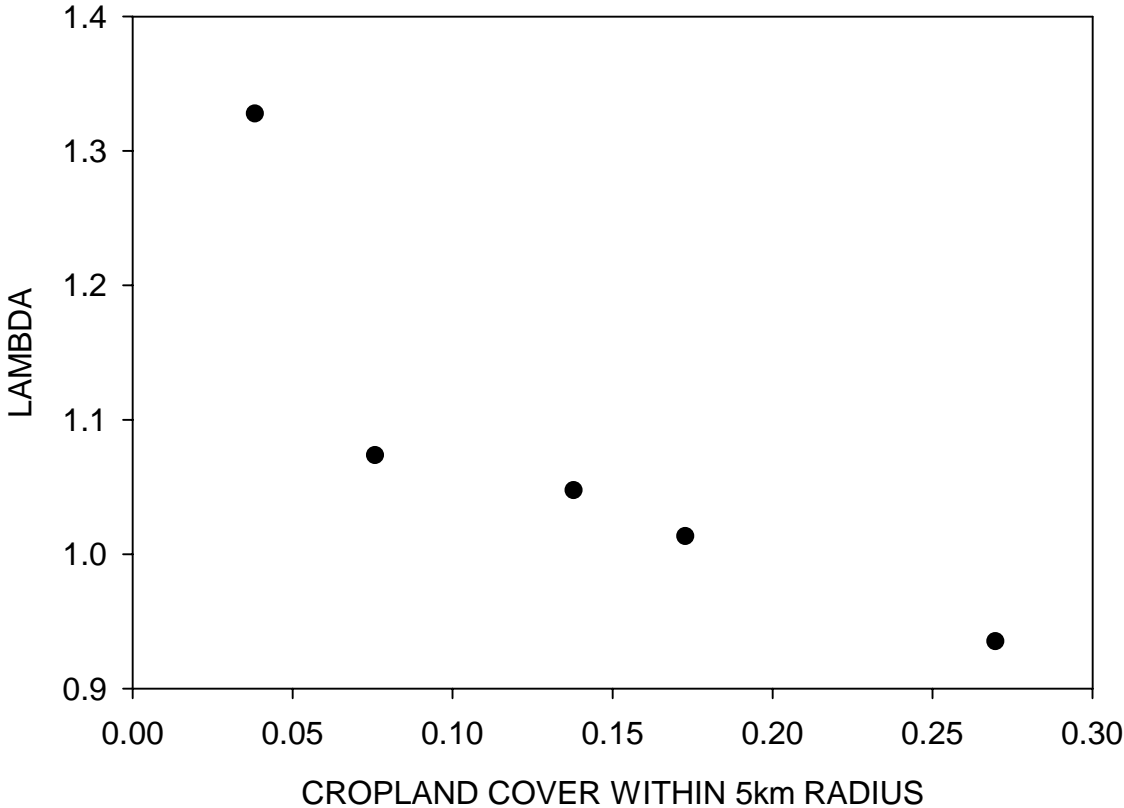


Figure 7. Relationship between Northern Cardinal lambda and mean distance of plot centers from the nearest developed edge (site averages) among BBIRD sites with ≥ 5 nests fledging young.

