

# Effects of a Supplemental Food Source and Nest Density on Success of Artificial Ground Nests

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**Abstract:** Nest predation can limit avian recruitment and may be a proximate source of population declines in many avian populations. Because nest predation may be affected by availability of alternative foods and nest density, we used artificial nests and track counts to evaluate effects of supplemental food and nest density on nest success of artificial ground nests. Nest success was lower at 7 of 9 nest density classes when a supplemental food source was present. In the absence of supplemental food, nest success was inversely related to nest density, but when supplemental food was present, there was no relationship between nest density and nest success. Increased predation rates associated with supplemental food and a lack of a nest density effect suggested that impacts of nest density on nest success were minimized by the supplemental food. Moreover, supplemental food affected nest success for  $\geq 255$  m, the maximum distance a nest was placed from a feeder. Although some researchers have suggested that providing supplemental food near nesting habitat might help reduce predation on ground nests, we believe that placement of supplemental food within nesting habitat attracts predators and will likely have a detrimental effect on nest success.

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**Key words:** artificial nest, food availability, nest density, nest predation, supplemental food

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Prey availability (Pehrsson 1986, Vander Lee et al. 1999) and nest density (Keyser et al. 1998) have been shown to influence nest predation rates. Food availability alters predator-prey relationships (Pehrsson 1986, Schmidt 1999) and may reduce predation on target prey species by altering predator foraging behavior (Crabtree and Wolfe 1988, Vander Lee et al. 1999). In the presence of supplemental food, nest success remained constant (Crabtree and Wolfe 1988, Greenwood et al. 1998, Jones et al. 2002), doubled (Vander Lee et al. 1999), or decreased (Cooper and Ginnet 2000).

Nest predation is often considered density-dependent (Bergerud 1988, Lariviere and Messier 2001) with greater nest densities increasing the likelihood that a large number of nests may be destroyed by a single predator (Goddard and Board 1967). Picman and Schriml (1994) suggested that predators exhibited a numerical response to artificial nests because of increased nest densities.

Schmidt (1999) used foraging theory to model nest predation as an interaction between predators and food and predicted that increased food availability for predators would result in decreased nest predation. However, empirical studies have yielded conflicting results (see Vander Lee et al. 1999 and Cooper and Ginnet 2000). Because supplemental feeding of predators and prey have been suggested as a potential management tool, one objective of our study was to evaluate the effects of supplementally feeding predators on artificial nest success. A second objective was to determine the effects of nest density on artificial nest success.

## Study Area

Our study was conducted in Baker County, Georgia, on Ichauway, a former hunting plantation and current research facility of the Joseph W. Jones Ecological Research Center (JWJERC). The 11,700-ha JWJERC has one of the most extensive tracts of privately-owned longleaf pine (*Pinus palustris*) in the Southern Coastal Plain. Natural loblolly pine (*P. taeda*) stands, slash pine (*P. elliotii*) flatwoods, and mixed hardwoods were patchily distributed throughout the longleaf pine forest. Wiregrass (*Aristida beyrichiana*) and old-field grasses (e.g., *Andropogon* spp.) dominated the understory (Goebel et al. 1997), and plant species richness was great with over 1,000 vascular plant species on the property (Drew et al. 1998).

Prescribed fire was the most notable management practice on JWJERC. The majority of JWJERC was burned by prescription on a two-year rotation to reduce hardwood encroachment and fuel accumulation, while enhancing herbaceous ground cover and wildlife habitat. During the study, the site had widely scattered food plots consisting of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet (*Brachiaria ramosa*), cowpea (*Vigna* spp.), corn (*Zea mays*), and winter wheat (*Triticum aestivum*) on approximately 20% of the property. Potential nest predators on JWJERC included raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), striped skunks (*Mephitis me-*

phitis), gray foxes (*Urocyon cinereoargenteus*), red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), corvids, small mammals, and numerous snake species.

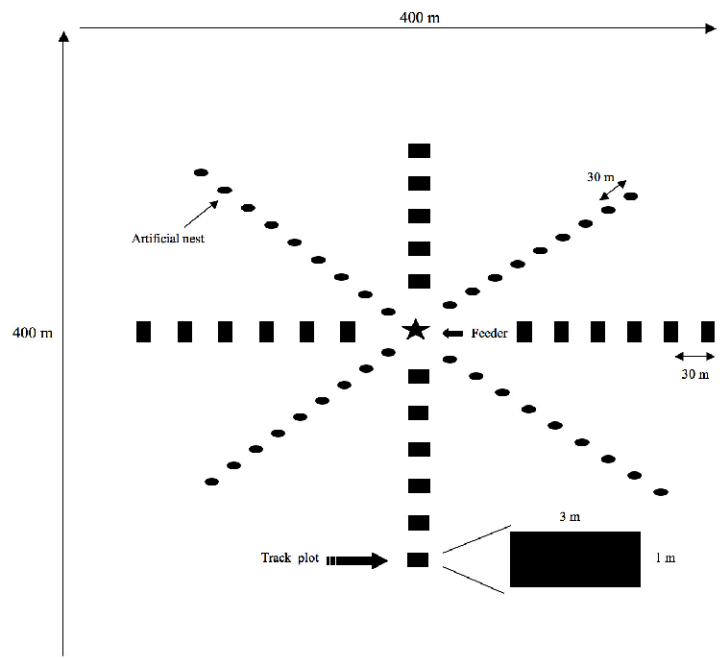
## Methods

### Sampling Design

We assessed nest predator foraging activities using a combination of track counts and artificial nests. We used artificial nests to evaluate effects of a supplemental food source and nest density on predation rates because artificial nests permit controlled experiments and do not require the time needed to locate and monitor natural nests (Major and Kendal 1996, King et al. 1999). However, we approached this research with the understanding that artificial nest experiments yield only an index of predation (Keyser et al. 1998) and are poor estimators of actual predation rates (Robinson et al. 2005).

To minimize habitat effects on predator detections, we identified all mature, open-canopy pine stands on the study area and randomly selected 12 sites for experimentation. We abandoned one site due to heavy rain and flooding during data collection; thus, we had 11 sample sites. We sampled 11 sites, three sites between 11 May and 18 June, three between 16 May and 23 June, three between 7 July and 10 August, and two sites between 13 July and 16 August. We constructed “hubs” (i.e., 16-ha census webs, Figure 1) within the selected sites to ensure consistent sampling among sites. We placed one weather-proof feeder with an opening to dispense food within each hub center. However, no food was provided in feeders until initiation of feeding trials. We established track plots ( $n = 24$ ) at 30-m intervals around each feeder by clearing a  $1 \times 3$ -m area and sifting the soil to provide a tracking surface; no bait or lure was used at track plots.

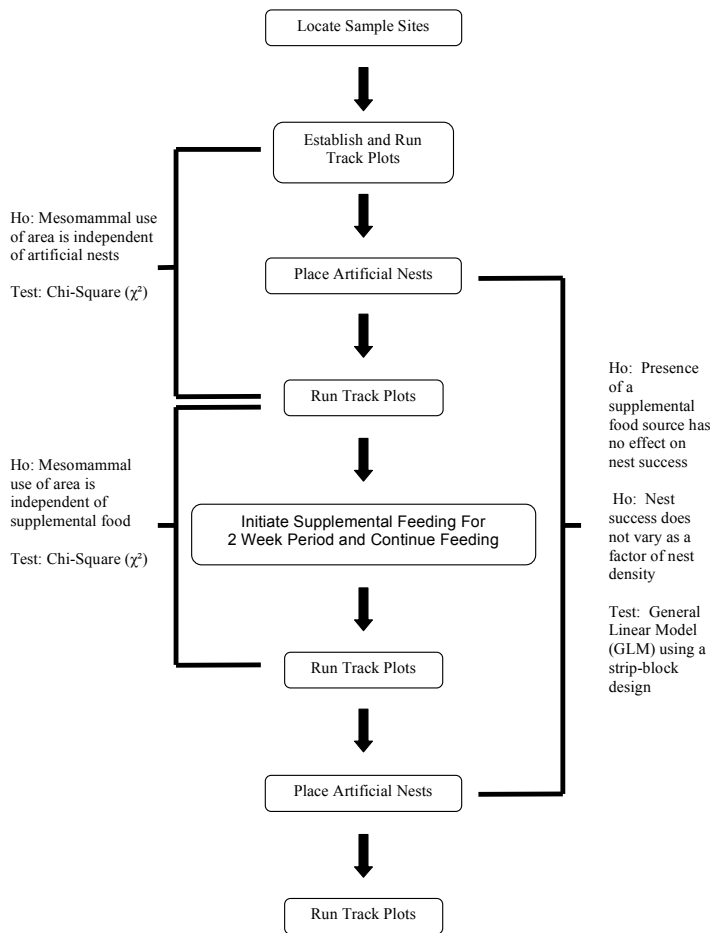
We used artificial nests consisting of two Japanese quail (*Coturnix coturnix*) eggs and one wax-covered wooden egg. Because small mammal predators may be unable to penetrate the quail egg shell (Ettel et al. 1998), the wax-covered wooden egg permitted identification of predators by tooth and beak marks (Jones et al. 2002). We washed all quail eggs in pond water to eliminate scent, and we wore rubber gloves and boots to minimize human scent contamination during nest construction. We constructed nests by creating a slight depression in the ground and placing eggs in this depression. Prior to egg placement, we pressed a nail into the ground in the middle of the depression. Upon returning to the nest, a metal detector allowed positive determination of the nest site through relocation of the nail, thereby ensuring accurate assignment of nest fate. We made no attempt to conceal the nest beyond cover from the immediate surroundings (Mankin and Warner 1992). We placed nests ( $n = 36$ ) at 30-m intervals in straight line transects ra-



**Figure 1.** Example of sampling layout containing 36 artificial ground nests and 24 track plots used to assess effects of a supplemental food source and nest density on success of artificial ground nests in southwestern Georgia, May–August 1999. Nest density was greater close to the center and decreased as distance from center increased.

diating out from feeders in northeastern, southeastern, southwestern, and northwestern directions; thus, each line contained nine artificial nests. We considered each distance from the nest to center of the hub as a density class; nests farther from the center of the hub were at lower densities. We placed a flag 15 m away from each nest to facilitate nest relocation and revisited nests seven days after placement and considered a nest depredated if any of the quail or wax eggs were damaged, missing, or out of the nest.

Our sampling regime followed a rigid sequence of events (Figure 2). First we established track plots and visited them for three consecutive days to identify and record animal tracks. We raked track plots after each visit. After completion of track plot sampling, we placed artificial nests and determined nest fate after seven days. We again raked track plots and revisited them for three consecutive days. Following the second round of track plot sampling, we provided commercial dry dog food *ad libitum* (Vander Lee et al. 1999) for two weeks to ensure that animals were acclimated to the supplemental food source before sampling was repeated during the feeding period. Dry dog food was used because preliminary research suggested that it was readily consumed by a variety of potential nest predators. All sampling techniques (e.g., track plot sampling, artificial nests, etc.) were repeated during the feeding period.



**Figure 2.** Sequence of sampling events used to address the effects of a supplemental food source and nest density on artificial nest success. Null hypotheses and statistical tests used to address null hypotheses are presented.

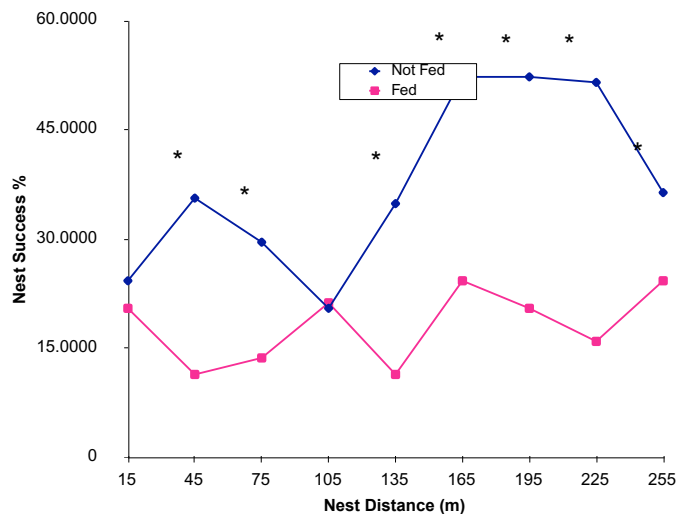
## Data Analysis

We applied a strip-block design with the whole plot factor of supplemental feeding treatment (food-supplemented or control) arranged in blocks consisting of the 11 different sites. Sites were considered the experimental unit of the analysis for effect of feeding treatment. The sub-plot factor of nest density consisted of the nine artificial nests spaced 30 m apart along the four transects. Because distances between nests could not be randomized, sub-plots were considered a stripped-plot effect. We analyzed nest density by considering the group of four nests at each density as the experimental unit. Nest success for each density was calculated by dividing the number of nests that survived at each density by four. We arcsine-transformed data on nest success to meet assumptions of analysis (Zar 1984). We used a general linear model (PROC GLM, SAS Institute, Inc., 1990) to analyze the transformed response variable of nest success.

We used two-way contingency tables and chi-square tests to determine if species-specific nest predator activity, as identified from evidence left on wax-covered wooden eggs (e.g., mesomammal, bird, or small mammal), was independent of treatments. Separate chi-square analyses were performed for each main effect (i.e., nest density and feeding treatments). We collapsed the nine nest densities into three density classes (Figure 1; high density, nests 1–3; medium density, nests 4–6; and low density, nests 7–9) to increase expected cell values (Cody and Smith 1997). Although we wished to examine species-specific visitations to tracking stations, there were too few visits by individual species to make valid comparisons. Therefore, we collapsed species-specific data and used contingency tables and chi-square tests to determine if presence of artificial nests and presence of a supplemental food source altered number of track stations visited by mesomammals.

## Results

We placed 792 nests during May–August 1999. We were unable to locate 48 (6%) nests which were excluded from analyses. We detected a significant feeding treatment and nest density interaction ( $F_{8,160} = 2.07$ ,  $P = 0.042$ ; Figure 3). Therefore, we examined the simple main effects based on the interaction means. Nest success differed ( $F_{8,80} = 3.63$ ,  $P = 0.001$ ) as a function of nest density during control periods, but not ( $F_{8,80} = 1.12$ ,  $P = 0.361$ ) during food-supplemented periods.



**Figure 3.** Artificial nest success (%) relative to distance (m) from a centralized location (i.e., a feeder) during food-supplemented and control periods in southwestern Georgia, May–August 1999. Distance from the centralized point is inversely related to nest density. Percentages at each distance-treatment combination are calculated from 44 nests. The asterisks (\*) represent significant ( $P \leq 0.05$ ) differences in nest success between food-supplemented and control periods.

Of 537 depredated nests, 105 (20%) wax eggs were not disturbed, six (1%) were moved, and the wax had melted from 33 (6%); thus, these nests were not used to determine cause of predation. Predator sign was identifiable on 137 (26%) wax eggs, and 256 (48%) wax eggs were missing. Small mammals accounted for 82 (60%) of the identifiable marks, whereas birds and mesomammals accounted for 35 (25%) and 20 (15%), respectively. Because so many wax eggs were missing, we created a predator class to represent missing eggs in our analysis. We detected no difference in nest predator assemblage between food-supplemented and control periods ( $\chi^2_3 = 4.96$ ,  $P = 0.175$ ) and nest density ( $\chi^2_6 = 9.89$ ,  $P = 0.13$ ).

There were fewer ( $\chi^2_1 = 8.12$ ,  $P = 0.004$ ) mesomammal visitations following artificial nest placement (105 visits before nest placement versus 74 visits after) providing evidence that presence of artificial nests did not result in increased use of sample plots by mesomammals. However, mesomammals increased ( $\chi^2_1 = 6.23$ ,  $P = 0.012$ ) within sample sites following the presence of supplemental food for 2 weeks (74 visits before food versus 101 visits after).

## Discussion

Our artificial nests suffered greater predation during food-supplemented periods than during control periods. Similarly, Cooper and Ginnett (2000) concluded that predation rates were greater on artificial nests located at sites with supplemental deer feeders in southwestern Texas. Others (Crabtree and Wolfe 1988, Greenwood et al. 1998, Jones et al. 2002) observed compensatory predation or increased nest success (Vander Lee et al. 1999) as a consequence of providing supplemental food to predators. We suggest these differences among studies are the result of the spatial arrangement of supplemental food. For example, Vander Lee et al. (1999) and Jones et al. (2002) provided food along the perimeter of study sites, while Cooper and Ginnett (2000) used feeders located within the treated sites.

In the absence of supplemental food, nest predation was greater at higher nest densities than at lower densities. Similarly, Reitsma (1992) observed a trend for increased predation at greater nest densities, and Keyser et al. (1998) concluded that nest clustering increased predation by large predators. Densely-placed nests assist predators in developing search images that may focus foraging in areas following initial foraging success (Tinbergen et al. 1967, Sugden and Beyersbergen 1986). Thus, systematic foraging (Shipley 1979, Stephens and Krebs 1986) due to a foraging reward (e.g., eggs) may have caused predators to prey more heavily upon nests at greater densities during control periods, whereas incidental encounters (Vickery et al. 1992) may best explain nest predation when nests exist at low densities.

Nests during food-supplemented periods suffered similar predation rates regardless of nest density. Cooper and Ginnett (2000) observed increased nest predation associated with a supplemental food source but, similar to our study, did not detect a consistent relationship between nest distance from feeder and nest success. Although artificial nests did not increase mesomammal detection rates at track count stations, presence of supplemental food did result in increased detections. However, the increase in mesomammal detection rates did not exceed the number of detections prior to the first round of artificial nest placement (i.e., the number of visits associated with the first establishment of track stations was approximately equal to the number of visits following placement of supplemental food). We speculate the initial response to track count stations is best described as mesomammals responding to a novel stimulus (i.e., bare earth; Heffernan et al. 2007), whereas detections at track-count stations following food placement was the result of increased mesomammal use of plots.

Our analysis of sign on wax-covered eggs revealed little evidence that presence of supplemental food or nest density affected the suite of nest predators depredating nests. Conversely, others (Crabtree and Wolfe 1988, Greenwood et al. 1998, Jones et al. 2002) documented that supplemental food provided to nest predators resulted in decreased mesomammal predation of nests while nest predation from other sources (e.g., corvids and small mammals) increased in a compensatory nature.

We assumed that nest placement during the control period did not affect artificial nest success during the feeding trial. We suggest this assumption was valid because two weeks elapsed between the end of the first artificial nest sampling effort and the start of the second sampling effort, and further because there was no apparent relationship between nest success and nest density during the first and second efforts (Figure 3). Moreover, our analysis of track-plot data supports this assumption regarding mesomammals. Unfortunately, we do not have empirical data to test this assumption among corvids, small mammals, and snakes. However, small mammals and snakes rarely used feeders (Jones 2001). Therefore, we suggest that the two-week period used to acclimate mesomammals to the food source eliminated carry-over effects that may have impacted results of the second artificial nest sample. Our argument in support of this assumption is not as strong for corvids, but because corvids were commonly detected at feeders (Jones 2001), we suggest that a potential carry-over effect from the first round of artificial nests was small relative to the attraction of the food source.

## Management Implications

Planting or encouraging growth of fruiting species such as plums (*Prunus americana*) and blackberries (*Rubus* spp.) to alter



predator foraging behavior during the nesting season has been suggested (Johnson 1970), and others (Vander Lee et al. 1999) have recommended supplemental prey as a mechanism to reduce predation. Our data indicate that providing supplemental food to predators can have the opposite effect.

We caution against providing supplemental food within avian nesting habitat. Our study indicated that the negative effects of a supplemental food extend  $\geq 255$  m from the food source, the maximum distance examined. Thus, a supplemental food source can result in increased nest predation within an area of  $\geq 20$  ha (an area equal to the smallest square that would enclose all artificial nests).

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