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Nest Success, Nesting Habitat, & Nestling Feeding Rates Of Red-Headed Woodpeckers In East-Central Illinois

Nathan Cole Hudson
Eastern Illinois University

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NEST SUCCESS, NESTING HABITAT, & NESTLING FEEDING RATES OF RED-HEADED WOODPECKERS IN EAST-CENTRAL ILLINOIS

(TITLE)

BY

Nathan Cole Hudson

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FOR THE DEGREE OF

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IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

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BY

Nathan C. Hudson

B.S., Eastern Illinois University, 2003

THESIS

Submitted in partial fulfillment of the requirements for the degree Master of Science
in the Department of Biological Sciences
in the Graduate School of
Eastern Illinois University, 2009

Charleston, Illinois

NEST SUCCESS, NESTING HABITAT, AND NESTLING FEEDING RATES OF RED-HEADED WOODPECKERS IN EAST-CENTRAL ILLINOIS

Nathan Cole Hudson
Department of Biological Sciences
Eastern Illinois University, 2009

The Red-headed Woodpecker (*Melanerpes erythrocephalus*) is a classic oak savanna species that has suffered significant population declines caused, in part, by extensive loss of savanna habitat and agricultural development. Despite consistent data that reveal a dramatic decline throughout much of their range, few studies have examined other possible explanations. In an effort to determine potential causes for their continued decline (as well as add to existing knowledge of nesting biology), we examined nest success and nesting micro-habitat features. We compared micro-habitat variables at: 1) golf and non-golf course sites, 2) successful and failed nest sites, and 3) nest and random sites. Furthermore, we examined nestling feeding rates to address previously unknown aspects of Red-headed Woodpecker life history. We examined provisioning patterns via the following measures (at four different nestling age classes): 1) time in the nest feeding and/or brooding by adults, 2) time between feeding and/or brooding trips, and 3) feeding rates.

Data from 28 Red-headed Woodpecker nests and their surrounding habitat were incorporated into a series of logistic-exposure models. The logistic-exposure models were designed to predict what specific explanatory variables had a significant effect on nest success. We discovered that nest success was higher in non-golf course habitat (59%) than in golf course habitat (51%; although, not significantly so). We found that cavity height was the most important predictor of nest success. Nest success was expected to drop dramatically as nest cavity height fell below 10 m.

In a comparison of nest sites on golf courses and in other habitats, mean canopy cover at random points was higher in other (i.e. non-golf course) habitats, and mean openness at random points was higher in golf course habitat. Golf course nest cavities had a more easterly orientation, and non-golf course nest cavities had a more southerly orientation. In a comparison of successful and failed nests, mean tree height was greater in successful nests. Furthermore, mean cavity height of successful nests was greater than that of failed nests. Random focal trees were significantly taller than nest site trees, and nest plots had significantly more snags and cavities than random plots. Red-headed Woodpeckers nested significantly more in dead trees (snags) than would be expected based on availability.

We determined that age class had a significant effect on the time spent in the nest feeding and/or brooding nestlings. Parents spent an average of 67 sec in the nest at the youngest age class declining to an average of 7 sec in the nest at the oldest age class. Age class, location, and their interaction had no significant effect on feeding rate or the time between feeding trips.

Conservation of snags and large DBH trees should provide greater access to nesting, roosting, and foraging sites for the Red-headed Woodpecker. Researchers should examine the efficacy of artificial substrate and tree branch girdling in creating more nesting site opportunities. Furthermore, estimates of juvenile and adult survival are of great importance. Future provisioning studies should incorporate nestling quantity, sex-specific foraging patterns, and nestling thermal ecology.

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CHAPTER 1:

Nest success and nest-site selection of Red-headed Woodpeckers (*Melanerpes erythrocephalus*) in golf courses and other habitats in east-central Illinois

ABSTRACT.—We examined nest success and nest-site selection of Red-headed Woodpeckers (*Melanerpes erythrocephalus*) in golf courses and other habitats in east-central Illinois. To determine what factors were important predictors of nest success, we fit a series of logistic-exposure models to our data. The models included a constant survival model, as well as models containing continuous, categorical, and age-specific explanatory variables. The goal of these models was to determine how nest success was affected by nest location, nest age, and various micro-habitat (cavity, nest tree, and nest stand) variables. Nest success was slightly higher in other habitats (59%) than on golf courses (51%), although not significantly so. Of 13 candidate models, cavity height (as the sole explanatory variable), nest age (as the sole explanatory variable), and the constant survival model were the 3 most supported, all of which had ΔAIC_c scores < 2. However, cavity height had the lowest ΔAIC_c score and, therefore, was the single most supported explanatory variable. We also compared nest-site micro-habitat variables at: 1) golf and non-golf course sites, 2) successful and failed nest sites, and 3) nest and random sites. In a comparison of nest sites on golf courses and in other habitats, mean canopy cover at random points was higher in other (i.e. non-golf course) habitats, and mean openness at random points was higher in golf course habitat. Golf course nest cavities had a more easterly orientation, and non-golf course nest cavities had a more southerly orientation. In a comparison of successful and failed nests, mean tree height was greater in successful nests. Furthermore, mean cavity height of successful nests was greater than that of failed nests. Random focal trees were significantly taller than nest site trees, and nest plots had significantly more snags and cavities than random plots. Red-headed Woodpeckers nested significantly more in dead trees (snags) than would be expected based on availability. Further study of Red-headed Woodpeckers is needed; however, the immediate preservation of old, large diameter snags will likely improve nesting opportunities and nest success of Red-headed Woodpeckers.

INTRODUCTION

The Red-headed Woodpecker (*Melanerpes erythrocephalus*; hereafter, RHWO) is an iconic species of oak-hickory (*Quercus-Carya* spp.) savannas, woodlands, and forest-edge habitats of eastern North America. RHWOs were once abundant, but likely suffered major population declines shortly after European settlement as a result of major loss of savanna habitat. The Midwest contained 11-13 million ha of savanna at the time of European settlement, but this habitat had virtually disappeared within 40 years after initial settlement (DeForest 1922, Gleason 1923, Cottam 1949, Curtis 1959, Smith 1975, Schroeder 1978, Bacone and Campbell 1980, Anderson 1982, Anderson 1983, Nuzzo 1986). By 1985, only 0.02% (~2,600 ha) of high-quality savanna was left (Nuzzo 1986). In more recent times, the removal of trees in urban areas, firewood cutting, clear-cutting, agricultural development, and river channeling have all been cited as major factors contributing to the continued decline of the RHWO (Pulich 1988, Ehrlich et al. 1992, Melcher 1998, Smith et al. 2000). It has also been suggested that fire suppression and the resulting encroachment of woody understory trees may be limiting nesting opportunities for the RHWO (Wilson et al. 1995, Smith et al. 2000, Rodewald 2003, Vierling and Lentile 2006). Fire suppression may not only limit the nesting habitat of RHWOs, but may also have a negative impact on arthropod densities and fly-catching opportunities (Turner et al. 1994, Wilson et al. 1995, Lentile 2004, Vierling and Lentile 2006).

Unfortunately, it is impossible to quantify the impact of historic European settlement on current RHWO populations. However, since the inception of the North American Breeding Bird Survey (BBS) in 1966, data indicate a continued, rapid decline in the abundance of RHWOs throughout most of their range. Since 1966, RHWO abundance has decreased by 2.6 percent/year in the BBS survey-wide range and by 3.4 percent/year in Illinois (Sauer et al. 2007). In particular, BBS data indicate that there has been a rapid decrease in RHWO abundance in the past 26 years. In Illinois, RHWOs showed a 0.3 percent/year decrease in abundance from 1966-1979 and a decrease of 5.6 percent/year from 1980-2006 (Sauer et al. 2007). In fact, the RHWO is listed as a "WatchList Species" by the National Audubon Society (2002) and by Partners in Flight (Rich et al. 2004).

In spite of being a readily recognized and declining species, there have been remarkably few studies of the RHWO. In fact, "despite numerous anecdotal observations of nests and some excellent studies of nesting biology, estimates of nest success remain few and uncertain" (Smith et al. 2000: p. 22). Unfortunately, accurate nest success estimates are a crucial component in understanding population trends. Nest success and nestling output are typically used to evaluate the overall quality of breeding habitats (Miller and Johnson 1978). Therefore, accurate estimates of nest success are an important first step in understanding the decline of this species. It is essential that nest success estimates are accurate so that the effect of nest success can be directly evaluated for its potential role in the decline of a species. Similarly, it is vital to have accurate estimates when comparing nest success in two or more distinct locations or habitats, especially when researchers are evaluating the potential effects of nesting in a highly managed, man-made landscape (e.g. golf courses).

Recently, researchers have begun to evaluate RHWO nest success and possible reasons for their continued decline. These studies have examined various aspects of RHWO nesting phenology, micro-habitat requirements, and the effects of fire in creating suitable habitat (Rodewald et al. 2005, King et al. 2007, Vierling and Lentile 2006). Vierling and Lentile (2006) examined nest success in a South Dakota population using techniques described by Shaffer (2004; logistic-exposure constant survival modeling). To our knowledge, no RHWO studies have been conducted using logistic-exposure modeling that incorporated various explanatory variables. One study has compared RHWO nest success on golf course and non-golf course habitat in the eastern United States (Rodewald et al. 2005). However, they likely overestimated true nest success due to the "apparent nest success" technique that they used. Nonetheless, their estimates of nest success implied that there may be little difference in the nest success of RHWOs in golf and non-golf course habitat in Ohio. Perhaps of greater importance was their primary goal, which was identifying what golf course features or suite of features were important predictors of RHWO presence. They found that golf courses being used by RHWOs had trees that were approximately 12% greater in diameter and had approximately twice as many hard-mast trees (e.g., oaks, hickories, American beech [*Fagus grandifolia*]), snags, and dead limbs. Also, habitat measurements taken at RHWO nests on golf courses showed that nest plots had approximately twice as many hard-mast trees, snags, and dead limbs as non-nest plots measured over the entire course

(Rodewald et al. 2005). King et al. (2007) found similar results in a population of RHWOs nesting in a restored savanna in Wisconsin. RHWOs nested in plots with greater basal area, cavity density, snag density, limb-tree (tree with dead limbs ≥ 1 m in length and ≥ 10 cm in diameter) density, and total dead limb length. They also determined that limb-tree density was the most useful predictor of RHWO nest presence (King et al. 2007). These studies suggest that RHWOs preferentially select areas that include large-diameter trees, a high number of snags, and a greater quantity of dead limbs.

These recent studies have begun to detail what habitat and micro-habitat features are important for supporting nesting RHWOs. In a similar effort, our study compared micro-habitat variables of nest-sites used by RHWOs (on golf courses and in other habitats) to random plots where RHWO nests were not found. In addition, through logistic-exposure modeling, we examined how micro-habitat variables and nest age affected RHWO nest success. Our specific objectives were: 1) to obtain and compare nest success estimates of RHWOs in east-central Illinois on golf courses and in other habitats using logistic-exposure modeling, 2) to use a series of logistic-exposure models to determine what explanatory variables were important predictors of nest success, 3) to compare golf course nest-site micro-habitat parameters to non-golf course nest-site micro-habitat parameters, 4) to compare successful nest-site micro-habitat parameters to failed nest-site micro-habitat parameters, 5) to compare nest-site micro-habitat parameters to random-site micro-habitat parameters, and 6) to use our data, in combination with other studies, to determine future RHWO research needs and offer management suggestions.

METHODS

Study Sites

Our study sites were river bottoms, upland woodlots, and golf courses surrounded by a matrix of cropland (primarily corn and soybeans) in east-central Illinois. The river bottoms were dominated by silver maple (*Acer saccharinum*), with American sycamore (*Platanus occidentalis*) and green ash (*Fraxinus pennsylvanica*) being common. Both the upland woodlots and the golf courses were dominated by oaks (*Quercus* spp.) and hickories (*Carya* spp.). Our study sites were Fox Ridge State Park, Coles Co., IL, Walnut Point State Park, Douglas Co., IL, Woods' Woods Campground, Douglas Co., IL, one privately-owned woodlot in Douglas Co., IL, one privately-owned woodlot in Coles Co., IL, Lakeview Park, Coles Co., IL, Charleston Country Club, Coles Co., IL, and Bent Tree Golf Course, Coles Co., IL. The study sites ranged in size from 2.0-835.3 ha ($\bar{x}$ = 156.8 ha).

Nest Searching and Monitoring

We began preliminary nest searching in late-March 2004. Initial searches were aimed at the discovery of RHWO pairs, previously excavated cavities, and potential nesting locations. If RHWOs were located, their behaviors and general location within the study site were recorded. When potential nesting locations or previously used cavities were located, we recorded the location within the study site and the GPS coordinates. We marked any potential nesting snags and snags with previously used cavities with a section of flagging tape to aid in the detection of these snags as the foliage became more prominent. We monitored our sites bi-weekly through April 2004 and every 1-4 days beginning in May 2004 and continuing through early-September 2004.

When we determined that a prospective nest was active, the general location of the nest within the site was recorded, the nest tree was flagged, and a GPS unit was used to determine the nest coordinates. We observed nests every 3-4 days to monitor progress. If the nest cavity was accessible (i.e. ≤ 15.2 m to cavity entrance and no cavity obstructions) we checked it with a telescoping camera system (see Appendix I), and recorded the contents of the nest (i.e. egg and/or nestling quantity). If a nest was not accessible by the camera system (e.g. due to height or structural barriers), we carefully observed it from ground level for 30 min, every 3-4 days, to determine if the nest was active. We considered a nest active if adult RHWOs were observed bringing food to the nest cavity. Any other clues that signified an active nest (e.g. nestling begging or nestlings poking their heads out of the cavity) were also noted. We continued nest monitoring via the camera system or observation periods for the duration of the nesting period (i.e. until the nest failed or fledged young). Fledged nests were apparent based on the lack of feeding trips to the nest and the presence of fledglings near the nest tree. Once fledglings were observed, we determined the approximate date of fledging based on the last nest check date when nestlings were present and the date of nestling discovery. We could easily determine nest failure or depredation in the nests that could be checked with the camera system. We carefully examined depredated nests with the camera system to look for eggshell fragments or nestling remains. We concluded that nests lacking eggshell fragments and/or nestling remains were depredated by snakes, and nests with obvious eggshell fragments and/or nestling remains were the product of mammalian predation (Best 1978). Nests that could not be reached by the camera system were monitored for feeding trips and for fledgling activity to determine the status of the nest (i.e. active or fledged, respectively). When we observed no further feeding trips and/or found no fledglings, the nesting attempt was determined to be a failure.

Micro-habitat Sampling

We began micro-habitat sampling in September 2004 using methods modified from Ingold (1989) and Li and Martin (1991). First, we recorded the following variables (for each nest tree): tree species, tree condition (dead or alive), cavity type (natural or excavated), substrate type (bole or limb), substrate condition (dead or alive), presence of bark at the cavity entrance, cavity-facing direction (degrees from north), tree height, cavity height, relative nest height (nest height/tree height), and diameter at breast height (DBH). Then, we used a 0.04 ha (11.3 m radius) circular plot centered around the nest tree, and determined the presence and quantity of the following: canopy cover (determined using a densiometer at the 4 cardinal directions at the perimeter of the plot), cavity density (total number of cavities in the plot), tree density (total number of trees in the plot with DBH ≥ 2.5 cm), snag density (total number of snags in the plot with a DBH ≥ 10 cm), and openness (the number of quadrants in the plot with no trees ≥ 2.5 cm DBH).

We determined a random site for each nest site by picking a direction (in degrees, 0-360) from a random numbers table. The random focal tree was then located by moving 50 m in the determined direction from the nest tree. The tree closest to the end of the 50 m transect, without going backwards on the transect, was determined to be the focal tree. If no tree was within a 10 m radius, we determined a new, random direction and the aforementioned steps were repeated until a suitable focal tree was located. Once we located a focal tree, a 0.04 ha circular plot was centered on this tree. We then recorded the following variables using the same techniques and criteria discussed above: tree species, tree condition, presence and quantity of other cavities, tree height, tree DBH, canopy cover, cavity density, tree density, snag density, and openness.

Statistical Analyses

Nest Success

We used PROC GENMOD (SAS Institute 1997) to fit a logistic-exposure model (Shaffer 2004) to our data using continuous (e.g. cavity, tree, and stand measurements), categorical (e.g. location and tree condition), and age-specific explanatory variables. Variables were analyzed using a Spearman's rho correlation test. When variables were highly correlated with one another, we used only one of the two variables in the analyses. We used a second-order variant of Akaike's Information Criterion (AIC_c; Burnham and Anderson 2002) to rank 13 candidate models from most to least supported. The models consisted of a global model (i.e. with all parameters included) and various combinations of other explanatory variables.

Micro-Habitat Variables

We used Mann-Whitney *U*-tests to evaluate differences between habitat variables in 1) successful and failed nests and 2) golf course and non-golf course nests. We used paired *t*-tests to evaluate differences in nest sites and random sites. We also used chi-square analysis and Fisher's exact tests to evaluate categorical variables. All data are presented as $\bar{x} \pm$ SE unless otherwise specified. The significance level for all analyses was set at $P \leq 0.05$.

RESULTS

Nesting Phenology and Success

We located 28 nests in the 2004 breeding season; 10 of the nests were on golf courses, and 18 nests were in other habitats. Mean nest initiation date (i.e. the date the first egg was laid) of the first nesting attempt ($n = 27$ nests) was 24 May ± 4 days. The earliest nest was initiated on 27 April, and the latest nest was initiated on 8 July. A known second nesting attempt was initiated on 23 July, after the pair had successfully reared one brood. That nest successfully fledged a second brood on 5 September. Of the documented 28 nesting attempts between the two habitats, 7 (25%) nests failed to fledge at least one young. Of the 7 failed nesting attempts, 3 failed during the incubation stage and 4 during the nestling stage. Five of the 7 nest failures could be attributed to nest predation. Of the 5 known depredated nests, small mammals (presumably southern flying squirrels [*Glaucomys volans*]) and snakes (presumably black rat snakes [*Elaphe o. obsoleta*]) were responsible for 2 failures each. The remaining depredated cavity was chiseled out along the cavity perimeter, and the nestlings appeared to have been pecked at repeatedly. The exact species responsible for this failure is unknown, but it appears that a woodpecker could have been responsible (seemingly a Pileated Woodpecker [*Dryocopus pileatus*]—due to the oval-shaped widening of the cavity entrance and their frequent presence at the site).

Of our 13 candidate models, the 3 most supported models had ΔAIC_c values < 2 (Table 1). A ΔAIC_c score ≤ 2 suggests that there is strong support for that particular model (Burnham and Anderson 2002). Our most supported model had a main effect of cavity height ($\Delta AIC_c < 0.001$, $w_i = 0.277$; Figure 1), and the 2nd most supported model had a main effect of nest age ($\Delta AIC_c = 0.840$, $w_i = 0.182$; Figure 2). The 3rd model was the constant survival model ($\Delta AIC_c = 1.783$, $w_i = 0.114$). Nests that were in higher cavities and further along in the nesting cycle were more successful. Nest success (according to the logistic-exposure model using a 44-day nesting period) was 51% in golf course habitat and 59% in other habitat ($\chi^2 = 0.09$, df = 1, P = 0.759). According to our logistic-exposure constant survival model, nest success over all nests (N = 28) was 56%. Under our linear logistic-exposure model, the odds ratio (Hosmer and Lemeshow 1989) for an increase in 5 m of cavity height resulted in a decrease of the daily mortality rate by a factor of 2.69. Similarly, the odds ratio for an increase in 5 days of nest age resulted in a decrease of the daily mortality rate by a factor of 1.38.

Micro-Habitat Variables

Mean canopy cover at random points was significantly higher at other habitat sites (50.9 ± 2.9%) than at golf course sites (37.5 ± 3.9%; $U = 37.5$, df = 1, P = 0.017). Mean openness at random points was significantly higher at golf course sites (42.5 ± 10.6 quadrants/ha) than at other habitat sites (16.3 ± 5.7 quadrants/ha; $U = 47.0$, df = 1, P = 0.041). Mean large tree density was greater at other habitat nest-sites (0.9 ± 0.3 trees/plot) than at golf course nest-sites (0.3 ± 0.2 trees/plot; $U = 57.0$, df = 1, P = 0.111; Table 4). Cavity orientation was significantly different with golf course nest-sites having a more easterly orientation (107.4 ± 32.0°) compared to other habitat nest-sites having a more southerly orientation (205.8 ± 22.7°; $U = 32.5$, df = 1, P = 0.008; Table 3). On non-golf course sites, nests were located in oaks (*Quercus*) and maples (*Acer*) over 88% of the time. These same tree species contained only 50% of the nests on golf course sites (Fisher's exact test, P = 0.123; Table 3).

In a comparison of micro-habitat features at successful versus failed nest-sites, mean tree height of successful nests was greater (17.8 ± 1.8 m) than failed nests (10.5 ± 2.2 m; $U = 27.5$, df = 1, P = 0.019; Table 6). Mean cavity height was marginally significantly greater in successful nests (12.7 ± 1.3 m) than in failed nests (8.2 ± 1.8 m; $U = 35.5$, df = 1, P = 0.056; Table 6). Mean large tree density was marginally significantly greater at failed nest sites (1.0 ± 0.3 tree/plot) than at successful nest sites (0.6 ± 0.2 trees/plot; $U = 43.5$, df = 1, P = 0.097; Table 7). Nests located in tree limbs were 7.3 times more likely to be successful than nests located in tree boles (Fisher's exact test, P = 0.091; Table 5). The presence of bark at the cavity entrance had a marginally significant effect on nest outcome (Fisher's exact test, P = 0.084; Table 5). Nests were 5.8 times more likely to be successful after nesting in a tree with bark present. Tree condition (i.e. alive vs. dead) also had a marginally significant effect on nest outcome (Fisher's exact test, P = 0.077; Table 6). Nests were 9.0 times more likely to be successful in a living tree.

Random focal trees were significantly taller (22.9 ± 1.1 m) than nest trees (15.9 ± 1.6 m; $t = 4.02$, df = 26, P < 0.001; Table 8). Nest sites (1.5 ± 0.3 snags/plot) had significantly more snags than random sites (0.6 ± 0.2 snags/plot; $t = 2.35$, df = 26, P = 0.027; Table 9), and also had significantly more cavities (5.0 ± 0.9 cavities/plot) than random sites (0.2 ± 0.2 cavities/plot; $t = 5.22$, df = 26, P < 0.001; Table 9). RHWOs selected dead trees for nesting more frequently than would be expected based on availability (Fisher's exact test, P < 0.001; Table 8). Of the random trees sampled, 100% were alive (n = 27), but only 48.1% (n = 13) of nesting attempts by RHWOs occurred in living trees. Furthermore, 9 of the 13 nesting attempts in living trees occurred in dead substrate within the living tree.

DISCUSSION

The logistic-exposure model indicated that cavity height and nest age were important predictors of nest success in RHWOs. It may be obvious that nest age was an important predictor of nest success—because with each day closer to the nest fledging young, the lower the chances are for the nest to fail (see Mayfield 1961). In fact, for every 5 day increase in nest age the daily mortality rate decreased by a factor of 1.38. It is also important to note that the constant survival model proved to effectively estimate nest success. The logistic-exposure constant survival modeling technique by itself is a better technique than the traditional Mayfield method because there is no assumption about nest failure dates, which are not known precisely in most nesting studies (Shaffer 2004). Cavity height had the greatest influence on nest success in RHWOs. In fact, with every 5 m of increase in cavity height the daily mortality rate decreased by a factor of 2.69.

It is important to consider why RHWOs would nest at lower heights, given the increase in failure rates. RHWOs may not be specifically "choosing" to nest lower, but the trees that meet their specific nesting needs may tend to be shorter. RHWO cavities that were at low heights were located in snags that had many similar characteristics. In particular, these snags were free of bark, had broken tops, were short, and had many cracks along the surface of the substrate. These snag features are caused by age and may be desirable to nesting RHWOs (Reller 1972, Conner 1976, Jackson 1976, Kilham 1983, Ingold 1989, Sedgwick and Knopf 1990, Withgott 1994, Smith et al. 2000). It has been hypothesized that RHWOs may choose these smooth-surfaced snags to deter snake predation, predominantly from black rat snakes (Withgott 1994). RHWOs may also choose these snags because they frequently contain surface cracks that many RHWOs use as an initial excavation point (Jackson 1976). Ingold (1994) hypothesized that cracks are used as a starting point for cavity excavation because RHWOs may be "weak" excavators. If RHWOs seek this suite of snag characteristics (for any of the reasons listed above), then, often times, these cavities will be located lower to the ground because the tops of these particular snags are prone to toppling due to advanced decomposition. In our study, 6 of the 7 failed nests were located in snags, and the other failed nest was located in a dead branch within a live tree. The 6 failed nests in snags were characterized by the aforementioned substrate conditions (all were short, partially toppled, and nearly devoid of any bark). In fact, these 6 failed nests had a mean cavity height of 6.8 ± 1.4 m and a mean tree height of 8.7 ± 1.4 m. The decomposition of these snags definitely appeared to result in a substrate that should have been much easier to excavate. Furthermore, we found that the smooth substrate of bark-free trees did not appear to hinder the climbing ability of snakes. Two of our nest losses appeared to be caused by snakes, and both of the cavities were located in snags free of bark. However, both cavities were located at heights < 7 m; therefore, it is conceivable that the benefits to climbing to a nest at low height may outweigh the risks (e.g. difficult climbing or falling because of smooth surface) for snakes.

Another explanation for the use of low cavities could be the shortage of other suitable cavity locations higher up. Older and/or more dominant nesting pairs could be utilizing the nest sites that allow for higher cavity placement, but younger or otherwise less dominant pairs may not be able to compete for these limited sites. A lack of other available cavity sites that allow for higher cavity placement, and that meet the specific criteria discussed previously, could force these subordinate pairs to nest in sub-prime locations (i.e. short, highly decomposed snags). Further examination of RHWO nesting sites is needed to more completely understand the specific characteristic(s) necessary for a suitable cavity site. Additionally, the quantity and extent of prime nesting trees (i.e. trees with large dead branches in the tops and/or slightly decomposed snags that have not toppled), within suitable habitat, needs to be investigated. Nonetheless, management of snags is likely an essential tool in curbing the declining RHWO populations. Management on golf courses may be of particular importance because of the frequent trimming and pruning of trees for aesthetic and safety purposes (Rodewald et al. 2005). Tree trimming in urban areas may also be negatively affecting RHWO populations (Pulich 1988).

An interesting finding of this study was the difference between cavity-facing direction in golf and non-golf course cavities. Golf course cavities faced in an easterly direction, whereas non-golf course cavities had a south-southwesterly orientation. A possible explanation for this could be the cavity temperature regulation that these varying orientations may provide. The golf courses had very little understory and a lower canopy cover percentage; therefore, these cavities may have heated more evenly throughout the day. With an easterly cavity orientation, the cavity could receive an initial warm-up in the early morning from direct exposure, but then as the sun moved to the south for the remainder of the day, the cavity would be more shaded. In the non-golf course cavities, the increased amount of foliage and resulting greater canopy cover may have slowed warming of the cavity. Therefore, a cavity with a more southerly exposure could take advantage of the longer direct sunlight that this exposure affords in an effort to reach and/or maintain some "ideal" temperature. Further examination of cavity orientation, cavity micro-climate, and their effects on nest success is warranted.

Bent Tree Golf Course supported the majority of the RHWO nests found in golf courses in our study. Although we did not examine landscape-level dynamics of the golf courses and their surrounding matrix, it was evident that Charleston Country Club was more isolated from other suitable habitat, as it was surrounded by residential neighborhoods and agricultural fields. Bent Tree Golf Course was located in a more rural area and was surrounded by a greater proportion of upland oak-hickory forest. Therefore, Bent Tree Golf Course was located in a landscape that was probably capable of supporting a larger RHWO population. Rodewald et al. (2005) found that rural golf courses were more than twice as likely to have RHWOs present when compared to urban courses. The reduced amount of suitable habitat surrounding Charleston Country Club most likely limited the population size that could be supported. Superficially, it appeared that the two courses were similar in overall design and vegetation structure. However, we did not quantitatively compare the habitat between the two golf courses.

A limitation of our research was that only 2 golf courses were examined. However, it appears that RHWOs may be more abundant on golf courses that are located near available, natural habitat and/or located in more rural areas. A landscape-level analysis of golf courses throughout Illinois would better describe the courses which may be best suited for RHWO habitation.

Implications

Nest success for RHWOs in east-central Illinois appears to be similar to other areas of the woodpecker's range (see Smith et al. 2000, Rodewald et al. 2005, Vierling and Lentile 2006). Our results showed the importance that cavity height played in nest success, and RHWO's propensity to nest in short snags (although nest success decreased). Therefore, it may be beneficial to experiment with tree branch girdling (instead of tree girdling) to provide the dead substrate RHWO's prefer while encouraging them to nest higher off the ground. This would increase the total dead limb density, which has been suggested to result in higher nest success (King et al. 2007). Additionally, snags should be retained where feasible because they provide foraging and roosting opportunities (Conner 1976, Sedgwick and Knopf 1990, Smith et al. 2000). Achieving some ideal ratio of dead snags (for foraging) to dead limb availability in live trees (for nesting) may give the RHWO the greatest nest success. However, this needs to be studied to determine how dead snag and dead limb availability interact to affect foraging opportunities for prey and nest success.

Researchers should examine the effectiveness of man-made structures as suitable RHWO roosting and nesting sites (see Peterson and Grubb 1983). These structures have the potential to alleviate some of the competition for access to suitable cavity trees. Also, man-made structures have the ability to increase the carrying capacity of cavity nesting birds in highly managed habitats (Franz 1961, Thomas et al. 1979, Peterson and Grubb 1983). Furthermore, these structures could be placed at an adequate height to reduce predation risk.

RHWOs appear to be successfully reproducing on golf-courses in east-central Illinois. Others have shown that golf courses provide suitable habitat at other locations within the RHWO's range (Rodewald et al. 2005). However, studies have shown that there may be a risk of pesticide exposure on golf courses resulting in deleterious effects on the animals using them (Kendall et al. 1992, 1993, Terman 1997, Gillihan 2000). Additional research needs to be conducted to investigate the potential effects of pesticide use on RHWO reproductive success. Similarly, research should examine the potential for pesticide accumulation in juvenile and adult birds and its impact on long-term survival and fecundity.

Nest success in this study was quite high, as might be expected for a cavity-nesting species (see Martin and Li 1992). Therefore, nest success may not be the primary reason for population declines in the RHWO. However, as an important next step, we believe that researchers should examine adult and juvenile survival rates, as well as productivity (mean number of female fledglings produced per nest per year). In fact, low juvenile and/or adult survival could be major contributing factors in the decline of RHWOs. Nonetheless, obtaining these estimates may prove to be difficult due to the RHWO being both monomorphic and monochromatic, as well as migration being determined largely by mast crop abundance (Smith et al. 2000).

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Table 1. Model parameters with corresponding ΔAIC_c values and weights from logistic-exposure modeling of nesting Red-headed Woodpeckers from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

Model Parameters	**ΔAIC_c**[a]	w_i[b]
Constant Survival[c]	1.78	0.11
Nest Type[e]	3.74	0.04
Cavity Height[c,d]	0.00	0.28
Nest Age[c]	0.84	0.18
Canopy Cover	3.63	0.05
Snag Density	3.83	0.04
Openness	3.64	0.04
Nest Type + *Nest Age*	2.73	0.07
Nest Type + *Nest Age* + *Cavity Height*	2.13	0.10
Nest Type + *Nest Age* + *Cavity Height* + *Canopy Cover*	3.48	0.05
Nest Type + *Nest Age* + *Cavity Height* + *Canopy Cover* + *Openness*	4.78	0.03
Nest Type + *Nest Age* + *Cavity Height* + *Canopy Cover* + *Openness* + *Snag Density*	6.96	<0.01
Nest Type + *Nest Age* + *Cavity Height* + *Canopy Cover* + *Openness* + *Snag Density* + *Large Tree Density*	8.40	<0.01

[a] Difference between AIC of the best fitting model and AIC of given candidate model.
[b] Probability that given model is the best model.
[c] Models with strong support (ΔAIC_c values ≤ 2).
[d] Best-fitting model.
[e] Golf vs. other habitat.

Table 2. Red-headed Woodpecker nest-cavity data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Golf (n = 10)		**Other (n = 17)**	
Variable	**n**	**%**	**n**	**%**
Cavity type				
Natural[a]	2	20	1	6
Excavated	8	80	16	94
Cavity location				
Bole	5	50	10	59
Limb	5	50	7	41
Cavity substrate condition				
Alive	2	20	2	12
Dead	8	80	15	88
Bark at cavity entrance				
Yes	7	70	9	53
No	3	30	8	47
Other cavities present				
Yes	7	70	12	71
No	3	30	5	29

[a] Natural cavities (e.g. hollow knotholes) are cavities that are created without the influence of a primary cavity nester.

Table 3. Red-headed Woodpecker nest-tree data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Golf (n = 10)				**Other (n = 17)**			
Variable	$\bar{x}$	**S.E.**	**n**	**%**	$\bar{x}$	**S.E.**	**n**	**%**
Tree data								
DBH (cm)	36.9	2.7			48.0	5.6		
Height (m)	15.9	2.2			15.9	2.2		
Cavity height (m)	11.1	1.4			11.8	1.6		
Relative height (%)	72.5	4.6			75.0	3.6		
Cavity facing direction (°)[a]	107.4	32.0			205.8	22.7		
Tree species								
Oak spp.			3	30			8	47
Maple spp.			2	20			7	41
Other spp.			5	50			2	12
Tree condition								
Alive			6	60			7	41
Dead			4	40			10	59

[a] Significant ($U = 32.5$, df = 1, $P = 0.008$).

Table 4. Red-headed Woodpecker nest-stand data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Golf (n = 10)		**Other (n = 17)**	
Variable	**$\bar{x}$**	**S.E.**	**$\bar{x}$**	**S.E.**
Stand Data[a]				
Canopy cover (%)	42.0	4.8	44.9	4.3
Snag density	1.0	0.4	1.8	0.4
Cavity density	5.3	1.5	4.9	1.2
Small tree density	8.9	2.5	12.7	4.1
Medium tree density	5.7	1.1	7.1	1.3
Large tree density	0.3	0.2	0.9	0.3
Total tree density	14.9	2.4	20.7	4.0
Openness (ha^{-1})	15.0	6.7	16.3	6.1

[a] All variables are measured in number/0.04 ha unless otherwise specified.

Table 5. Red-headed Woodpecker nest-cavity data from successful and failed nests located in golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May- August 2004.

	Successful (n = 20)		**Failed (n = 7)**	
Variable	**n**	**%**	**n**	**%**
Cavity type				
Natural[a]	3	15	0	0
Excavated	17	85	7	100
Cavity location[b]				
Bole	9	45	6	85
Limb	11	55	1	15
Cavity substrate condition				
Alive	4	20	0	0
Dead	16	80	7	100
Bark at cavity entrance[c]				
Yes	14	70	2	29
No	6	30	5	71
Other cavities present				
Yes	13	65	6	86
No	7	35	1	14

[a] Natural cavities (e.g. hollow knotholes) are cavities that are created without the influence of a primary cavity nester.

[b] Marginally significant (Fisher's exact test, P = 0.091).

[c] Marginally significant (Fisher's exact test, P = 0.084).

Table 6. Red-headed Woodpecker nest-tree data from successful and failed nests located in golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Successful (n = 20)				**Failed (n = 7)**			
Variable	$\bar{x}$	**S.E.**	**n**	**%**	$\bar{x}$	**S.E.**	**n**	**%**
Tree data								
DBH (cm)	47.1	4.8			34.8	2.5		
Height (m)[a]	17.8	1.8			10.5	2.2		
Cavity height (m)[b]	12.7	1.3			8.2	1.8		
Relative height (%)	72.8	3.5			77.6	4.4		
Cavity facing direction (°)	160.1	20.5			195.7	43.8		
Tree species								
Oak spp.			9	45			2	29
Maple spp.			5	25			4	57
Other spp.			6	30			1	14
Tree condition[c]								
Alive			12	60			1	14
Dead			8	40			6	86

[a] Significant ($U = 27.5$, df = 1, P = 0.019).
[b] Marginally significant ($U = 35.5$, df = 1, P = 0.056).
[c] Marginally significant (Fisher's exact test, P = 0.077).

Table 7. Red-headed Woodpecker nest-stand data from successful and failed nests located in golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Successful (n = 20)		**Failed (n = 7)**	
Variable	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**
Stand Data[a]				
Canopy cover (%)	43.5	3.9	44.8	5.2
Snag density	1.5	0.3	1.4	0.7
Cavity density	5.4	1.2	4.1	1.0
Small tree density	10.8	3.0	12.7	6.4
Medium tree density	7.2	1.1	4.9	1.3
Large tree density[b]	0.6	0.2	1.0	0.3
Total tree density	18.5	3.1	18.6	6.2
Openness (ha^{-1})	16.3	5.2	14.3	9.2

[a] All variables are measured in number/0.04 ha unless otherwise specified.
[b] Marginally significant ($U = 43.5$, df = 1, P = 0.097).

Table 8. Red-headed Woodpecker nest-tree and random-tree data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Nest (n = 27)				**Random (n = 27)**			
Variable	$\bar{x}$	**S.E.**	**n**	**%**	$\bar{x}$	**S.E.**	**n**	**%**
Tree data								
DBH (cm)	43.9	3.8			46.1	3.8		
Height (m)[a]	15.9	1.6			22.9	1.1		
Tree species								
Oak spp.			11	41			12	44
Maple spp.			9	33			6	22
Other spp.			7	26			9	33
Tree condition[b]								
Alive			13	48			27	100
Dead			14	52			0	0

[a] Significant ($t = 4.02$, df = 26, $P < 0.001$).
[b] Significant (Fisher's exact test, $P < 0.001$).

Table 9. Red-headed Woodpecker nest-stand and random-stand data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

	Nest (n = 27)		**Random (n = 27)**	
Variable	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**
Stand data[a]				
Canopy cover (%)	43.8	3.2	45.9	2.6
Snag density[b]	1.5	0.3	0.6	0.2
Cavity density[c]	5.0	0.9	0.2	0.2
Small tree density	11.3	2.7	8.7	2.1
Medium tree density	6.6	0.9	7.0	0.8
Large tree density	0.7	0.2	0.4	0.2
Total tree density	18.5	2.7	16.1	2.5
Openness (ha^{-1})	15.8	4.5	26.0	5.7

[a] All variables are measured in number/0.04 ha unless otherwise specified.
[b] Significant ($t = 2.35$, df = 26, $P = 0.027$).
[c] Significant ($t = 5.22$, df = 26, $P < 0.001$).

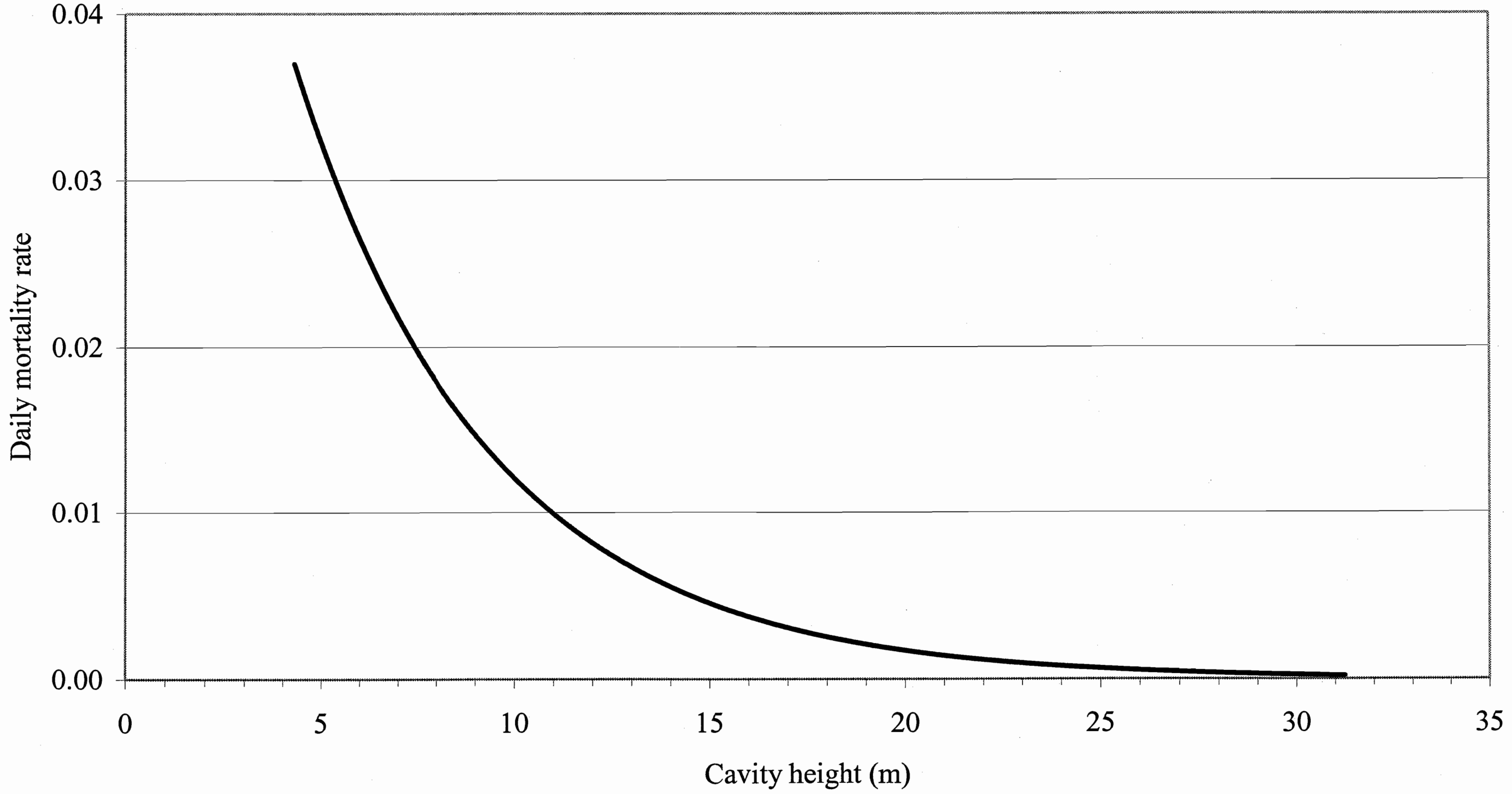

Figure 1. Daily mortality rates of Red-headed Woodpecker nests estimated from logistic exposure model with cavity height as the sole main effect. Data are based on 27 nests from golf course and other habitat in Coles and Douglas Co., Illinois, USA, May-August 2004.

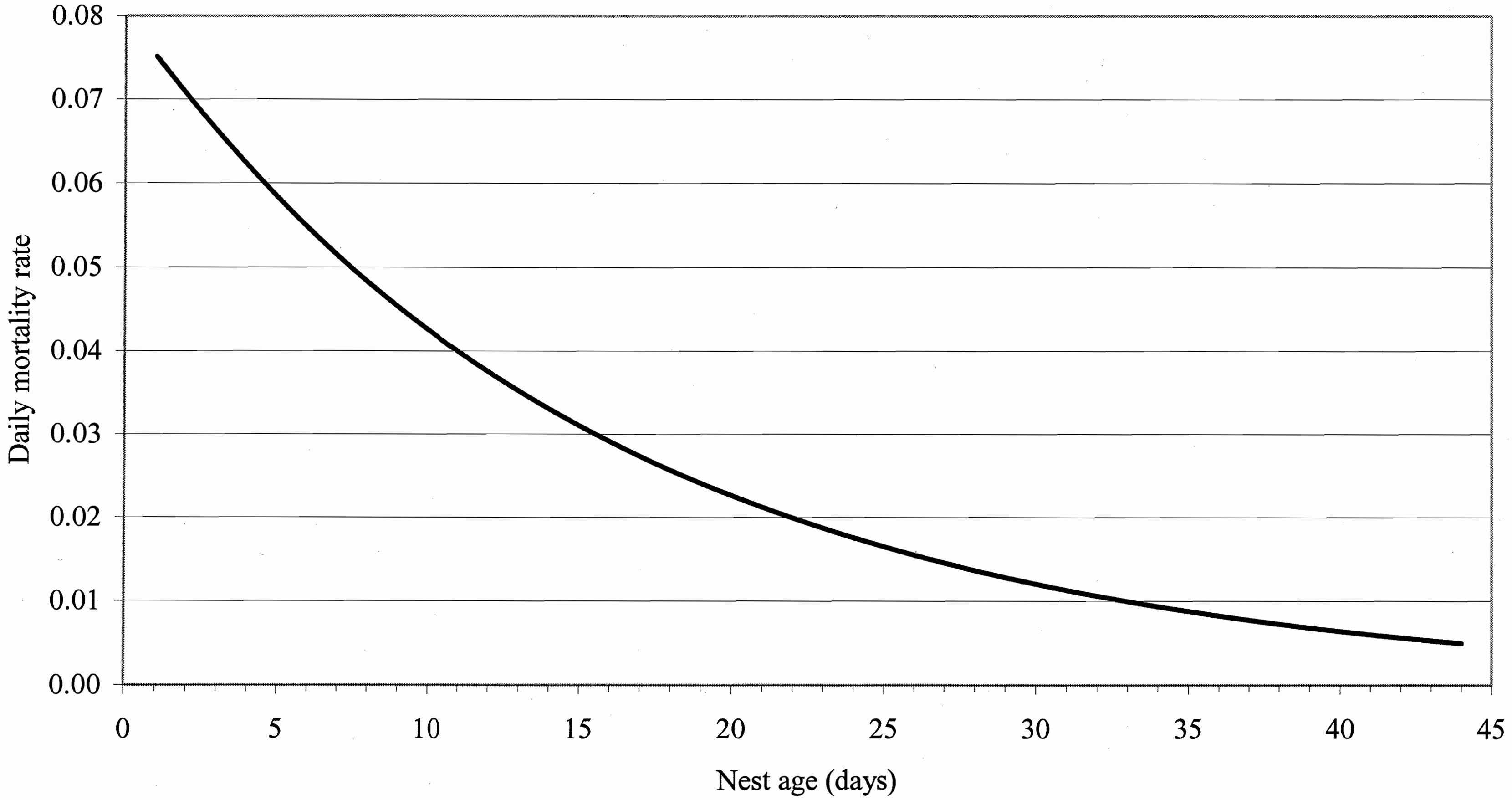

Figure 2. Daily mortality rates of Red-headed Woodpecker nests estimated from logistic exposure model with nest age as the sole main effect. Data are based on 27 nests from golf course and other habitat in Coles and Douglas Co., Illinois, USA, May-August 2004.

CHAPTER 2:

Nestling provisioning by Red-headed Woodpeckers (*Melanerpes erythrocephalus*) in east-central Illinois

ABSTRACT.—We determined the general patterns of Red-headed Woodpecker (*Melanerpes erythrocephalus*) nestling provisioning in east-central Illinois. We examined: 1) time in the nest feeding and/or brooding by adults, 2) time between feeding and/or brooding trips, and 3) feeding rates at four different nestling age classes. We determined that age class had a significant effect on the time spent in the nest feeding and/or brooding nestlings. Parents spent an average of 67 sec in the nest at the youngest age class declining to an average of 7 sec in the nest at the oldest age class. Age class, location, and their interaction had no significant effect on feeding rate or the time between feeding trips. We used Wilcoxon signed-rank tests to determine where the significant differences were in our treatment levels (i.e. 4 age classes). In a feeding trip time comparison, 5 of the 6 comparisons were significant. Only the age class 2 (7-12 day-olds) vs. age class 3 (13-18 day-olds) comparison was not significant. Further study of nestling provisioning rates is warranted. Specifically, exact nestling counts, sex of the feeding adult, sex-specific foraging strategies, an estimate of delivered prey volume, and nestling fledging weights need to be incorporated into future studies.

INTRODUCTION

Several factors may influence parental feeding behavior in altricial birds (Schadd and Ritchison 1998). Both brood size and nestling age are frequently responsible for distinct changes in feeding rates (Pinkowski 1978, Walsh 1978, Biermann and Sealy 1982, Wittenberger 1982, Breitwisch et al. 1986, Schadd and Ritchison 1998) and volume of prey delivered (Johnson and Best 1982, Breitwisch et al. 1986, Haggerty 1992, Schadd and Ritchison 1998). Commonly, nestling feeding rates are positively correlated with nestling age and brood size (Kendeigh 1952, Hussell 1972, Skutch 1976, Best 1977, Biermann and Sealy 1982, McGillivray 1984). Nonetheless, changes in nestling age or brood size can result in a shift in both the quantity and size of prey that parents deliver to nestlings, thereby altering the positive correlation commonly seen (Schadd and Ritchison 1998). In some species, larger broods have been shown to require less food (Best 1977, Walsh 1978, Pinkowski 1978, Johnson and Best 1982, Schadd and Ritchison 1998) presumably due to the lower thermoregulatory cost per nestling (Royama 1966, Mertens 1969, Seel 1969, Wittenberger 1982, Schadd and Ritchison 1998). Seemingly, one might expect that this same reduction in required food may occur as nestlings mature (resulting in increased body mass and reduced open space inside the nest) due to a similar decline in thermoregulatory costs.

The Red-headed Woodpecker (hereafter, RHWO) is a conspicuous bird of the eastern United States. It is a sexually monomorphic woodpecker that is associated with oak (*Quercus* spp.) savanna and woodland habitats. The RHWO is considered monogamous, and this species may form pair bonds that last several years (Ingold 1991, Smith et al. 2000). Both sexes participate in nestling provisioning (Jackson 1976), but little is known about the division of labor between the sexes (Smith et al. 2000). The average clutch size is 4.82 ± 0.09 SE, and clutch size does not vary significantly with latitude (Koenig 1986). The incubation period ranges from 12-14 days (Forbush 1927, Bent 1939, Jackson 1976, Skutch 1985, Smith et al. 2000), and nestlings develop slowly—spending 24-31 days in the nest before fledging (Bent 1939, Skutch 1985, Weathers et al. 1990, Smith et al. 2000). Parents continue to feed nestlings for approximately 25 days after fledging (Reller 1972).

The main objective of this study was to determine if RHWO provisioning patterns (i.e. time spent in nest feeding and brooding, time spent between feeding trips, and feeding rate [trips/30 min]) differed in relation to: 1) nestling age, 2) nest location (i.e. golf course vs. other habitats), or 3) the interaction of the two. Currently, no data have been published regarding RHWO feeding rates (Smith et al. 2000). Because RHWOs are monochromatic and monomorphic we could not differentiate the parent's sex. Therefore, we were not able to obtain sex-specific feeding rates. Also, because of the precarious placement and/or nest height of many RHWO nest cavities we were not able to determine the number of nestlings in many of the broods.

METHODS

Study Sites and Nest Monitoring

We began preliminary nest searching in late March 2004 on public and private lands in Coles and Douglas Co., Illinois, USA. Our sites consisted of a private and public golf course, two Illinois Department of Natural Resources (DNR) state parks, a city park, and three private woodlots. Golf course sites were dominated by oak (*Quercus*) and hickory (*Carya*) species. The other sites were located in upland woodlots (dominated by the oak-hickory community) and river bottoms (dominated by silver maple [*Acer saccharinum*]). Both the golf courses and the other sites were surrounded by a matrix of cropland.

When active nests were located, we marked them with flagging tape and recorded their GPS coordinates. If the nest cavity was accessible (i.e. $\leq$ 15.2 m to cavity entrance and no cavity obstructions), we checked it with a telescoping camera system (see Appendix I), and the contents of the nest were recorded (i.e. egg and/or nestling quantity). Beginning in late May 2004, we began recording feeding data on all active RHWO nests. We recorded all feeding data using 30 min observation periods from a fixed location near the nest. Observation points were located ≥ 50 m from the nest location to limit nest disturbance. We conducted observation periods every 3-4 days until the nest failed or fledged young. Before each observation period no data were recorded for 10 min to allow the birds to acclimate to our presence and consequently obtain unbiased provisioning patterns. When the 10 min grace time expired, we waited for the first parental provisioning trip to the nest. Once the first parent committed to feeding (i.e. stuck head into cavity with food or completely entered the cavity with food), we started the observation period. All provisioning trip start and stop times (time entering and time leaving the cavity after feeding and brooding, respectively) were recorded to the nearest second for the duration of the 30 min observation period. We closely watched the parents upon arrival at the cavity, and any distinguishable food items that were brought to the nest cavity were noted. We discerned the individual parents from one another when possible (i.e. typically when one parent arrived at the nest while the other parent that was occupying the nest left—however, this only allowed us to conclude that multiple birds were feeding nestlings, and it provided no information on sex-specific feeding rates). We also recorded any behaviors toward conspecifics or heterospecifics during the observation period.

Statistical Analyses

We used a PROC MIXED repeated measures analysis of variance (RMANOVA; SAS Institute 1997) to determine if nestling age, nest habitat (golf course vs. other), or the interaction of nestling age and nest habitat had an effect on: 1) the time parents spent in the nest feeding and/or brooding nestlings, 2) the time between feeding and/or brooding trips, and 3) the number of feeding trips made to the nest during the observation period (i.e. feeding rate). The feeding trip data were analyzed based on four nestling age classes: 1-6 day-olds, 7-12 day-olds, 13-18 day-olds, and 19+ day-olds. We used Wilcoxon signed-rank tests as a post-hoc analysis of our RMANOVA age classes to evaluate differences in provisioning trip time, time between feeding trips, and feeding rate. Data were pooled between the two locations (i.e. golf course and other habitat) in these analyses because location was shown to have no significant effect on nestling provisioning. All data are presented as $\bar{x} \pm$ SE unless otherwise specified. Due to multiple comparisons we used a Bonferroni correction with our Wilcoxon signed rank tests which resulted in a significance level of $P \leq 0.008$. For all other analyses we used a significance level of $P \leq 0.05$.

RESULTS

We discovered 28 active RHWO nests and obtained feeding observation data on 24 of those nests. Fourteen nests were located in other habitats, and 10 nests were located on golf courses. We began feeding observations on 27 May 2004 and continued through 3 September 2004. In all, we conducted 179 observation periods for a total of 89.5 hours of nest observation. We were not able to reach many of the nests with our cavity camera system to determine clutch or brood size. However, we were able to visually examine 11 total nests. We determined that the average clutch size was 3.50 ± 0.50 (N = 4), and the average brood size was 2.57 ± 0.43 (N = 7).

Age class had a significant effect on the time spent in the nest feeding and/or brooding nestlings ($F_{3,41} = 16.49$, $P < 0.001$). The time spent in the nest decreased at each age class from an average of 67 ± 11 sec at the youngest age class, to an average of 7 ± 1 sec at the oldest age class (Figure 1). Location ($F_{1,21} = 0.05$, $P = 0.831$) and the interaction of age class and location ($F_{3,41} = 0.18$, $P = 0.912$) did not significantly affect the time spent in the nest feeding and/or brooding nestlings. Post-hoc tests revealed that all age classes were significantly different except for the comparison of age class 2 vs. age class 3 ($z = -2.33$, $P = 0.020$).

Time spent between provisioning trips was not significantly affected by age class ($F_{3,41} = 0.26$, $P = 0.850$), location ($F_{1,21} = 2.05$, $P = 0.167$), or their interaction ($F_{3,41} = 0.24$, $P = 0.868$; Figure 2). Post-hoc analysis also showed no significant differences between the age classes.

There was no significant effect of age class ($F_{3,41} = 1.42$, $P = 0.251$), location ($F_{1,21} = 0.33$, $P = 0.570$), or their interaction ($F_{3,41} = 0.90$, $P = 0.450$) on the feeding rate of adult RHWOs provisioning nestlings (Figure 3). However, post-hoc analysis showed a marginally significant difference in the age class 1 vs. age class 3 comparison ($z = -2.20$, $P = 0.028$). Generally, the age class 3 nestlings were fed at a greater rate.

DISCUSSION

The time parents spent in the nest was significantly affected by age class, but not by location or the interaction of age class and location. This comes as no surprise because the needs of altricial nestlings change rapidly over a short period of time. In the early stages of altricial nestling's lives, parent(s) are obligated to spend more time brooding nestlings than feeding nestlings due to the limited ability of young nestlings to regulate their own body temperatures for any extended time period (Seel 1969). In fact, RHWO parents stayed in the nest for over 60 sec (each provisioning trip) at the youngest nestling age class (Figure 1). This is in contrast to the oldest nestling age class when parents spent < 10 sec in the nest after each provisioning trip (Figure 1). The time spent in the nest dropped precipitously between the 1st and 2nd age classes (Figure 1). Very little information exists on the development of RHWO nestlings (Smith et al. 2000). However, Weathers et al. (1990) examined the thermal ecology of nestling Acorn Woodpeckers (*Melanerpes formicivorus*), a congeneric woodpecker that shares several similarities in both parental care and nestling development (Koenig et al. 1995). They found a rapid increase in mean nestling body temperature between the ages of 9 and 13 days (Weathers et al. 1990). This closely coincides with our age class 2 nestlings (i.e. 7-12 day-olds) and the pattern that we observed. It also lends support to our suggestion that the thermoregulatory ability had increased in our age class 2 nestlings and may have been responsible for the patterns that we witnessed.

There was no significant effect of age class, location, or their interaction on time between provisioning trips. However, there was an interesting pattern that occurred in the age class 2 nestlings in the different habitat types (Figure 2). In general, the golf course parents spent less time between provisioning trips (and also made more provisioning trips) at this age class than did non-golf course parents (Figure 2). The reasons for this remain unclear; however, we can speculate that this may have been a result of the particular food items that parents were feeding nestlings at that particular age class and their availability and abundance in the respective habitat types.

Feeding rate was not significantly affected by age class, location, or their interaction. Nonetheless, when examining the average feeding rate among all nests (n = 24) at the four age classes the general pattern was as follows: the feeding rate increased rapidly between age class 1 and age class 2 nestlings, and then, the feeding rate slowed, but very gradually increased through age class 3 and age class 4 (Figure 3). The 1st age class had the lowest feeding rate because a considerable amount of time was spent brooding the nestlings at this stage (also, at this age class one parent is typically obligated to brooding, therefore, only one parent was foraging at a time [NCH pers. obs.]). In the 2nd age class a rapid increase in feeding rate was seen as growth progressed and nestlings were able to regulate their body temperature for longer periods of time (presumably, both sexes were feeding at this stage as brooding became less imperative). This rapid increase also parallels the rapid increase in nestling body temperature that Weather et al. (1990) documented in their study of Acorn Woodpeckers. This leads us to believe that RHWO nestlings gain increasing thermoregulatory control during this time period. In the final 2 age classes, the feeding rate only increased slightly, essentially coming to a plateau. This “leveling off” may have occurred for four possible reasons: 1) the nestlings required less energy intake due to decreased thermoregulatory costs, 2) the parents were delivering more food and/or larger prey at each trip, 3) parents altered the prey being fed to include more energy-rich species, or 4) some combination of the aforementioned strategies. However, the data that we collected did not allow us to make any conclusive determination about which of these patterns was likely occurring.

Implications

Habitat type had no significant effect on any of our nestling provisioning data in this study. These data, in conjunction with our logistic-exposure models of nest success (see Chapter 1), lead us to believe that RHWO are foraging and fledging young in a similar fashion in these two distinct habitat types. We feel that this is of particular importance because of the dramatic decline in the RHWO's historical habitat and the apparent propensity for RHWOs to use golf course habitat (Rodewald et al. 2005). Nonetheless, several factors need to be incorporated into future RHWO provisioning studies to fully understand parental investment and nestling development. Specifically, we feel the following variables are most pertinent: exact number of nestlings, sex of the feeding adult, sex-specific foraging strategies, an estimate of delivered prey volume, and nestling fledging weight. These factors should afford researchers the ability to address several of the most pertinent research needs outlined by Smith et al. (2000).

As previously pointed out, sex-specific behavior should be a vital component of future studies. In fact, 2 of the 5 variables that we mentioned were sex-based. However, to address these variables, adults need to be sexed and marked and sexing RHWOs in the field has been considered impossible (Smith et al. 2000). First, it is impossible to use plumage coloration to determine sex due to the monomorphic coloration of this species (Smith et al. 2000). Also, cloacal protuberances and brood patches are unreliable in sex determination (Pyle 1997, Smith et al. 2000). Nonetheless, RHWOs have nearly identical early breeding season behaviors as the dimorphic Red-bellied Woodpecker (*Melanerpes carolinus*; Kilham 1983). Therefore, it may be possible to accurately sex nesting pairs of RHWOs based on the knowledge of Red-bellied Woodpecker breeding behavior. Despite this, accurately identifying, capturing, and marking individuals may prove to be quite tedious. For absolute accuracy researchers may be forced to obtain tissue or blood samples so genetic techniques can be used to distinguish parental sex.

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Table 1. Mean feeding observation data from adult Red-headed Woodpeckers feeding nestlings at 4 age groups on golf courses, in other habitat, and in combined habitats in east-central Illinois.

Number of Feeding Trips (per 30 min)

	Age Group 1		Age Group 2		Age Group 3		Age Group 4	
Variable	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**
Location								
Golf	6.40	1.09	11.16	0.96	9.71	1.15	9.27	0.99
Other	7.86	1.22	7.29	0.60	8.64	1.16	9.24	1.44
Combined	7.10	0.81	8.85	0.59	9.04	0.84	9.25	0.89

Time in Nest (mm:ss)

	Age Group 1		Age Group 2		Age Group 3		Age Group 4	
Variable	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**
Location								
Golf	01:09	00:19	00:15	00:03	00:13	00:01	00:06	00:01
Other	01:04	00:13	00:21	00:05	00:12	00:01	00:06	< 00:01
Combined	01:06	00:11	00:18	00:03	00:12	00:01	00:06	< 00:01

Time Between Feeding Trips (mm:ss)

	Age Group 1		Age Group 2		Age Group 3		Age Group 4	
Variable	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**	$\bar{x}$	**S.E.**
Location								
Golf	02:21	00:18	02:07	00:09	02:32	00:14	02:43	00:13
Other	02:19	00:19	03:13	00:17	02:47	00:17	02:22	00:12
Combined	02:20	00:13	02:39	00:09	02:41	00:12	02:32	00:09

Figure 1. Mean single trip time in the nest for adult Red-headed Woodpeckers feeding and/or brooding nestlings at 4 age classes on golf courses, in other habitats, and in both habitats combined in east-central Illinois.

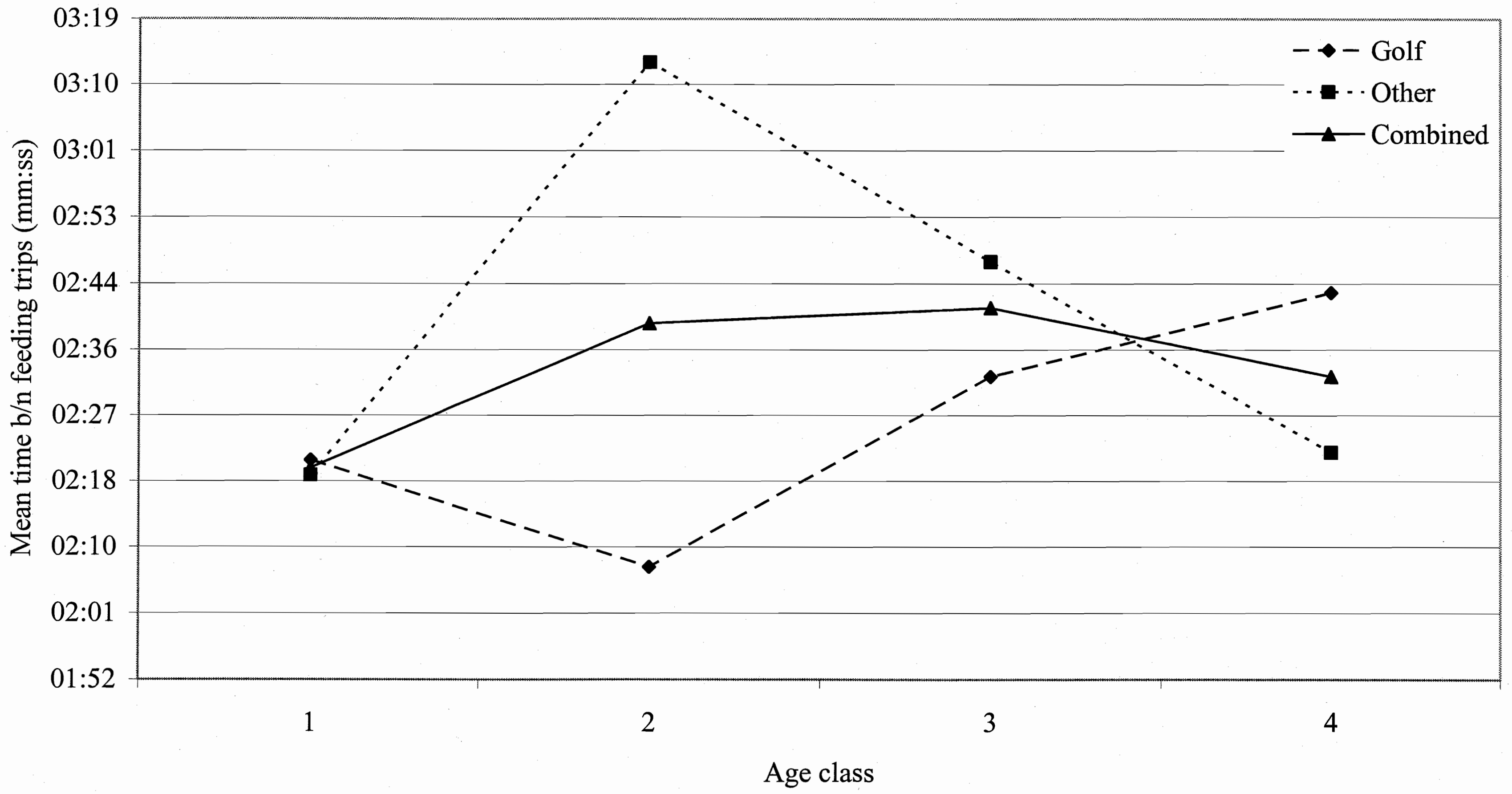

Figure 2. Mean time between feeding and/or brooding trips for adult Red-headed Woodpeckers feeding/brooding nestlings at 4 age classes on golf courses, in other habitats, and in both habitats combined in east-central Illinois.

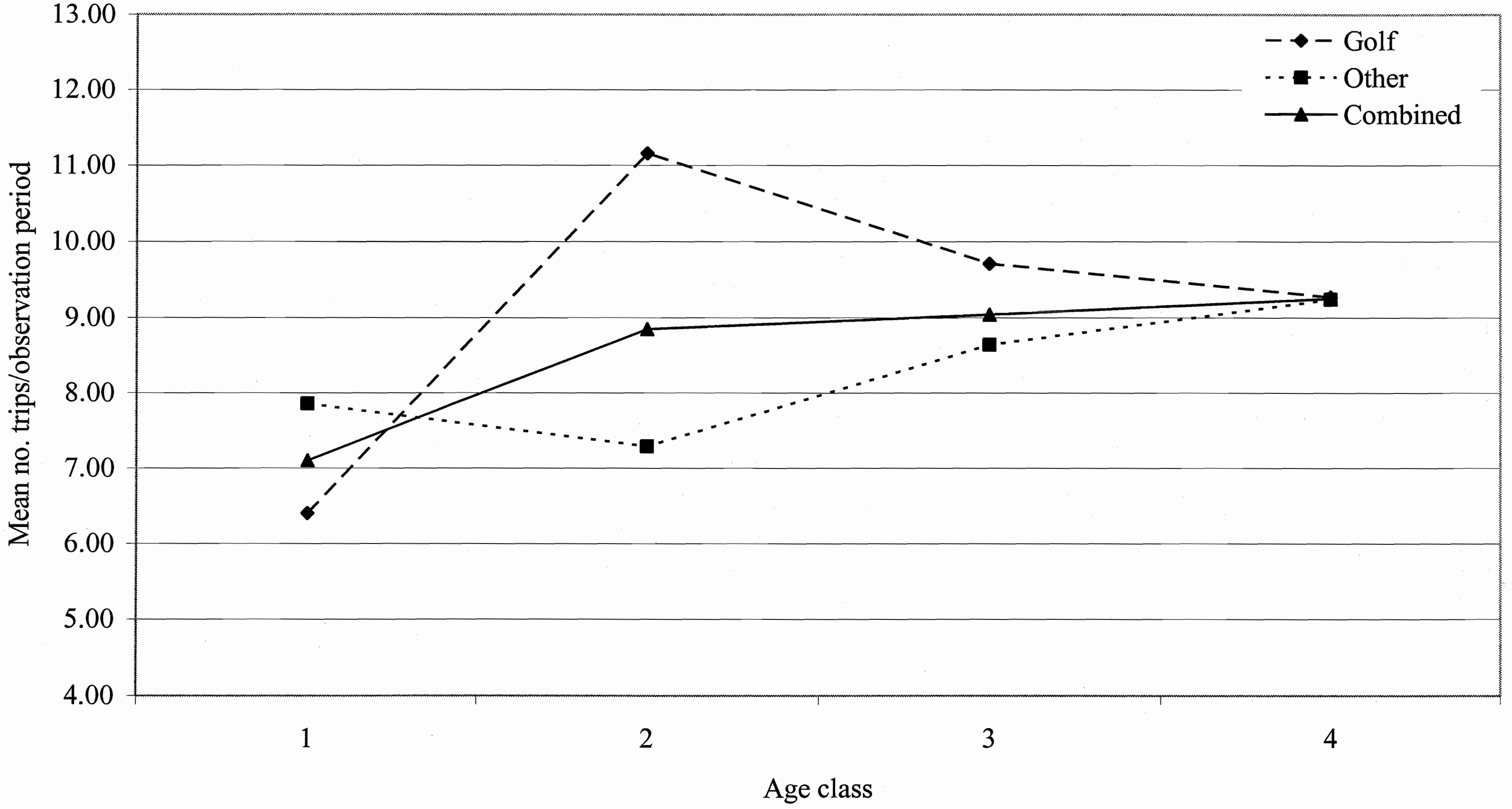

Figure 3. Mean number of feeding and/or brooding trips per 30 min observation period (± S.E.) by adult Red-headed Woodpeckers feeding/brooding nestlings at 4 age classes on golf courses, in other habitats, and in both habitats combined in east-central Illinois.

Appendix I. Cost-effective solution to high-priced cavity cameras.

ABSTRACT.—We describe a camera system to monitor nest cavities which performed well under typical field conditions and was simple and inexpensive to produce. The camera system was assembled from readily available components purchased through hardware retailers, electronics catalogs, and online electronics companies. The simplicity, adaptability, ease of assembly, and cost-effectiveness of this camera system make it an ideal alternative to other commercially-available, more expensive cavity camera systems.

INTRODUCTION

A common limitation of research is the acquisition of sufficient funds to cover the cost of needed equipment. If commercially-produced equipment is too expensive, the researcher must reconsider the research objectives or develop affordable, workable equipment with available, lower-cost components. Monitoring nest cavities presents researchers with specific problems, especially when the species' nest is located beyond the immediate reach of the researcher. DeWeese et al. (1975), Moriarty and McComb (1982), Purcell (1997), and Seidensticker and Kilham (1969) developed a periscope device, a fiber optic system, a fiberscope system, and a modified dental mirror device, respectively, to view the contents of small diameter nest cavities. However, all four of these systems required climbing to the entrance of the nest cavity, and Purcell's system was extremely expensive. Climbing to nests has inherent safety risks and increased costs to the researcher by way of time and climbing equipment.

Pole-mounted mirror systems were developed to allow researchers to discern nest contents, without climbing, by orienting the mirror system near the nest and viewing the reflection (e.g. Best and Stauffer 1980, Conner et al. 1986, Nichols et al. 1984, Patonde and White 1992). Although these systems are relatively inexpensive, they can be quite cumbersome in heavy vegetation and/or at high nest heights, and as the distance from the mirror to the viewer increases, it becomes more difficult to discern mirror images (Ouchley et al. 1994). Mirror systems are also inherently more difficult to use for cavity nesting birds with deep cavity chambers. Hayward and Deal (1993) developed a pole-mounted "nest-box checker" (NBC) to reliably monitor the contents of large nest boxes. However, this system would not be practical in monitoring small nest boxes or cavity-nesting bird species with small cavity entrances. Pole-mounted micro-video camera systems have been used to check the contents of nests and cavities (e.g. Ouchley et al. 1994, Proudfoot 1996, Reillo et al. 1999, Richardson et al. 1999). These systems eliminate the need to climb to the nest, and they can be used in relatively small cavities depending on the camera size. Proudfoot (1996), for example, developed a system that he used to monitor nest boxes and woodpecker-excavated cavities used by ferruginous pygmy-owls (*Glaucidium brasilianum cactorum*) nesting in cacti. His system appeared to work well, but the size of the camera (approximately 5.5 cm [H] × 2.3 cm [D] × 3.7 cm [W]) would restrict the use of the system in nest boxes and cavities with small entrance diameters (i.e. cavities with diameters ≤ 3.7 cm). Ouchley et al.'s (1994) system could reach cavities to 13.6 m, and it appeared to work well. However, this system is also hindered by its camera size of 7.0 cm (H) × 2.3 cm (D) × 4.6 cm (W).

The only system that has been published, possessing both telescoping capability (15.24 m) and a small diameter camera (3.05 cm), is the TreeTop Peeper™ II (Sandpiper Technologies, Inc., Manteca, CA; see Richardson et al. 1999). This commercial system was used to monitor nesting red-cockaded woodpeckers (*Picoides borealis*) in southern pine ecosystems. Reillo et al. (1999) also used a TreeTop Peeper™ II system, but they modified it by attaching a larger video camera (4 × 4 × 4 cm) that would not be suitable for small cavity entrances. However, the camera system that we developed has the capability of inspecting small diameter nest cavities (i.e. cavities with diameters ≥ 3.2 cm), and it costs substantially less than a similar camera system produced by Sandpiper Technologies, Inc. (Cabled TreeTop Peeper System™; $4925 [US]).

METHODS

We developed a nest cavity monitoring camera that consisted of an encased, miniature-board video camera attached to a telescoping, fiberglass measuring rod. The image was received through a video monitor mounted on the measuring rod. The camera and monitor were both powered by rechargeable battery packs. A video and power extension cable connected the video camera, the monitor, and the battery packs. The total system cost approximately $800 (US), and took approximately 2 hrs to assemble. This system is widely applicable and can be assembled with little knowledge of electronic components or assembly processes.

The primary components of the system included: 1) one 15.24 m (extended) fiberglass telescoping measuring rod (model # 90182, Crain® Enterprises, Inc., Mound City, IL), 2) a charge-coupled device (CCD) flat pinhole, board-encased color video camera (model # SSC-108CHR, MarBil Enterprises, Inc., Belleville, IL), and 3) a liquid crystal display (LCD) color monitor (model # 227GL-56NP, Lilliput® Electronics Co., Ltd., Quanzhou, China). The camera's dimensions were approximately 3.2 cm (H) × 1.3 cm (D) × 3.2 cm (W). The camera had a 3.6 mm wide-angle lens that could be adjusted to focus from approximately 5 cm to infinity, with 400 lines of resolution, and operational capability down to 0.1 lux. The camera came from the manufacturer with video and power connector ends. The video monitor's dimensions were 14.0 cm (H) × 3.2 cm (D) × 18.4 cm (W), with a 14.2 cm (diagonal) 4:3 thin film transistor (TFT) screen, and a 640 × 480 resolution. The monitor and the camera were powered with separate 12.0 V, 2000 mAh rechargeable nickel metal hydride (NiMH) batteries (model # SSC-12VRB, MarBil Enterprises, Inc., Belleville, IL). The monitor operated for approximately 2.5 hrs/battery charge; the camera operated for approximately 20 hrs/battery charge. We mounted the camera to the measuring rod via a 15.25 cm long, 0.635 cm diameter graphite archery shaft (Beman® Archery, Salt Lake City, UT). The camera, the monitor, and the battery packs were connected with a 15.24 m video and power extension cord. We used a cord wrap (i.e. a plastic extension cord organizer), attached directly to the bottom section of the measuring rod, to house the video and power cable when they were not in use.

To mount the camera to the measuring rod, we permanently attached outserts to each end of the graphite shaft using two-part epoxy. Once the epoxy had cured, we connected the graphite shaft to the measuring rod with a 2.54 cm aluminum, 90° angle bracket. We attached the bracket at the ¼" SAE threaded insert portion of the last section of the measuring rod. The camera and its bracket were then attached to the other outsert on the graphite shaft. The use of the graphite shaft (to mount the camera) resulted in a lightweight, rigid, and durable connection. The bracket allowed the camera to be adjusted at various angles by loosening two screws and retightening them once the desired position was achieved. However, due to the small size of the screws, the threads became stripped quickly after repeated retightening. To alleviate this problem, we positioned the camera at the most common angle and used two-part epoxy to permanently attach the camera to the bracket. We wrapped the camera's video and power cables around the graphite shaft and secured them with cable ties and electrical tape. The cables were secured to the shaft to streamline the system, as to avoid snagging upon cavity entrance and/or exit. This also helped eliminate the undue stress on the connections caused by the weight of the video and power extension cable upon extending the measuring rod.

We attached a 3 V miniature flashlight bulb (Maglite®, Mag Instruments, Inc., Ontario, CA) for additional illumination. We soldered the bulb to 22 gauge double-stranded doorbell wire and attached the bulb to the case of the board camera, near the lens, with a small drop of hot melt cement. We wrapped and attached the wire around the graphite camera connector shaft in the same fashion as described for the video and power cable coming from the camera. To allow for quick disconnect at the junction of the graphite shaft and the measuring rod, we equipped the ends of the doorbell wires with female spade terminals. We taped a 15.24 m length of the aforementioned doorbell wire to the video and power extension cables (i.e. the doorbell wire would wrap on the cord wrap with the video and power extension cables). We soldered one end of the wire to a universal 3 V AA battery power pack (Radio Shack®, Fort Worth, TX), and we fitted the other ends of the doorbell wires with male spade terminals to connect to the female spade terminals at the junction of the graphite shaft and the measuring rod. We mounted the battery power pack on the hose clamp that attached the cord wrap to the measuring rod. We removed the base of the adjustable tabletop stand that came attached to the video monitor, and we retained only the adjustable portion of the monitor and the monitor itself. We attached the adjustable monitor to a stainless steel hose clamp (with a ¼" SAE bolt and nylon stop nut) through a 0.635 cm diameter hole that was drilled through the hose clamp and aligned with a hole left in the monitor from the removal of the base. We then attached the adjustable monitor to the bottom section of the measuring rod with the hose clamp. We attached the cord wrap slightly below the monitor with another hose clamp.

RESULTS AND DISCUSSION

The total cost of the telescoping cavity camera system was approximately $800 (US). At a cost of $399, the pole was the most expensive component in this system. The camera, monitor, rechargeable battery packs (2), and miscellaneous components (wire, clamps, batteries, etc.) cost $140, $112, $64 (each), and approximately $20, respectively.

The cavity camera system was fully operational with one researcher. However, the time needed to check a cavity could be reduced with the help of an assistant to feed wire from the cord wrap and to "spot" the insertion of the camera into the cavity. We used the system to check cavities up to 13 m above ground level with relative ease. Presumably, the system should be functional up to the maximum length (15.24 m) of the pole. The insertion and extraction of the camera into nest cavities became hindered when wind speeds exceeded 20 km/h due to the flexibility of the measuring rod. However, these wind speeds were rarely encountered within the deciduous forests where we used this system. The insertion and extraction was significantly improved by attaching 0.635 cm diameter nylon rope to the aluminum corner brace that was used to attach the camera to the measuring rod. By applying slight pressure on the rope, to alleviate some of the flexibility in the measuring rod, the camera would typically insert and extract from the cavity with ease. On average, it would take approximately 3 minutes per cavity for a complete camera set-up, inspection, and disassembly. The only other difficulty we experienced was the failure of a video end. The failure was caused by the excessive stress placed upon the camera's video end when the camera was extended. This problem was alleviated by further taping the ends of the camera's video and power cable, to the graphite shaft, to eliminate this stress point.

The color camera provided excellent detail of the cavity and its contents. The one drawback of a color camera vs. a black-and-white camera is the increased amount of light needed to produce an image with a color camera. However, with the addition of the inexpensive, accessory light source, we believe the color camera could provide researchers information not available with black-and-white cameras. For example, color cameras may allow determination of nestling sex when the color of specific features (i.e. feathers) is indicative of sex (e.g. red-cockaded woodpeckers).

We developed this camera system to monitor the nest cavities of Red-headed Woodpeckers (*Melanerpes erythrocephalus*). However, this system should prove useful in monitoring other cavity-nesting species as well as in the monitoring of open cup nests. With little or no adaptation, we can foresee this system being used for the nest monitoring of other taxa as well. Furthermore, wireless components are becoming more available in the electronics market; therefore, these components have the ability to further streamline the system, but they come at a greater monetary cost. The widespread availability and selection of video components should allow researchers to develop a system that is appropriate for their specific research needs. The most valuable feature of this camera system was its ability to effectively and efficiently monitor the nesting attempts of a declining woodpecker species. Similarly, this system should prove most valuable in monitoring the nest productivity of threatened or endangered, cavity-nesting species.

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Appendix II. Red-headed Woodpecker nest-site and paired-site habitat and micro-habitat data from golf courses and other habitats in Coles and Douglas Co., Illinois, USA, May-August 2004.

Nest No.	Location	Date of Discovery	Nest Start Date	Nest Finish Date	Nest Start to Finish Days
BTGC 1	Golf	5/20/04	4/27/04	6/10/04	44.0
BTGC 3	Golf	5/26/04	5/6/04	6/19/04	44.0
BTGC 4	Golf	6/3/04	5/8/04	6/21/04	44.0
BTGC 5	Golf	6/4/04	5/2.5/04	6/15.5/04	44.0
BTGC 6	Golf	6/4/04	5/15/04	6/28/04	44.0
BTGC 7	Golf	6/4/04	5/23/04	6/28/04	36.0
BTGC 8	Golf	6/14/04	5/26/04	7/9/04	44.0
BTGC 9	Golf	6/15/04	5/7/04	6/20/04	44.0
BTGC 10	Golf	7/15/04	7/8/04	8/14/04	37.0
CCLUB 1	Golf	6/11/04	5/24/04	6/15.5/04	22.5
COLE 1	Other	5/30/04	5/9.5/04	6/22.5/04	44.0
COLE 2	Other	6/8/04	5/9.5/04	6/22.5/04	44.0
FRSP 1	Other	6/30/04	5/17.5/04	6/30.5/04	44.0
HUD 1	Other	6/20/04	5/27.5/04	7/10.5/04	44.0
HUD 1(2)	Other	8/31/04	7/23/04	9/5/04	44.0
LKVW 1	Other	6/30/04	6/12/04	7/30.5/04	48.5
WOOD 1	Other	6/15/04	5/27.5/04	7/10.5/04	44.0
WPSP 1	Other	5/25/04	5/6.5/04	6/19.5/04	44.0
WPSP 2	Other	6/25/04	6/25/04	7/10.5/04	15.5
WPSP 3	Other	6/12/04	5/10.5/04	6/23.5/04	44.0
WPSP 5	Other	5/18/04	5/7/04	6/20/04	44.0
WPSP 6	Other	6/23/04	6/17/04	7/31/04	44.0
WPSP 7	Other	6/12/04	5/31-6/4/04	6/23.5/04	19.5-23.5
WPSP 8	Other	6/1/04	5/13/04	6/3/04	21.0

WPSP 9	Other	6/25/04	6/9-6/23/04	6/27/04	4.0-18.0
WPSP 10	Other	6/25/04	5/13.5/04	6/26.5/04	44.0
WPSP 11	Other	7/9/04	6/24/04	8/7/04	44.0
WPSP 12	Other	6/4/04	5/16.5/04	6/29.5/04	44.0

Nest No.	**Incubating Exposure Days**	**Brooding Exposure Days**	**Total Exposure Days**	**Success**	**Tree Species**
BTGC 1	0.0	21.0	21.0	Successful	Ash spp.
BTGC 3	0.0	24.0	24.0	Successful	White Oak
BTGC 4	0.0	18.0	18.0	Successful	Sugar Maple
BTGC 5	0.0	11.5	11.5	Successful	Ash spp.
BTGC 6	0.0	24.0	24.0	Successful	Black Walnut
BTGC 7	6.0	18.0	24.0	Failed	White Oak
BTGC 8	0.0	25.0	25.0	Successful	Sugar Maple
BTGC 9	0.0	5.0	5.0	Successful	Ash spp.
BTGC 10	10.0	20.0	30.0	Failed	White Oak
CCLUB 1	0.0	4.5	4.5	Failed	Shagbark Hickory
COLE 1	0.0	23.5	23.5	Successful	E. Cottonwood
COLE 2	0.0	14.5	14.5	Successful	White Oak
FRSP 1	0.0	0.5	0.5	Successful	E. Cottonwood
HUD 1	0.0	20.5	20.5	Successful	Silver Maple
HUD 1(2)	0.0	5.0	5.0	Successful	n/a
LKVW 1	0.0	30.5	30.5	Successful	White Oak
WOOD 1	0.0	25.5	25.5	Successful	White Oak
WPSP 1	0.0	25.5	25.5	Successful	White Oak
WPSP 2	15.5	0.0	15.5	Failed	White Oak
WPSP 3	0.0	11.5	11.5	Successful	Red Oak
WPSP 5	7.0	26.0	33.0	Successful	Red Oak

WPSP 6	12.0	26.0	38.0	Successful	White Oak
WPSP 7	11.5	0.0	11.5	Failed	Silver Maple
WPSP 8	0.0	2.0	2.0	Failed	Silver Maple
WPSP 9	2.0	0.0	2.0	Failed	Silver Maple
WPSP 10	0.0	1.5	1.5	Successful	Silver Maple
WPSP 11	3.0	26.0	29.0	Successful	Silver Maple
WPSP 12	0.0	25.5	25.5	Successful	Silver Maple

Nest No.	Bark at Cavity	Other Cavities Present	Cavity Facing Direction (degrees)	Cavity Facing Cardinal Direction	Nest Tree DBH (cm)
BTGC 1	Yes	Yes	20	N	32.8
BTGC 3	Yes	No	250	W	26.2
BTGC 4	Yes	Yes	106	E	47.5
BTGC 5	Yes	Yes	70	E	24.6
BTGC 6	No	No	80	E	48.2
BTGC 7	Yes	Yes	103	E	33.8
BTGC 8	Yes	Yes	326	NNW	36.9
BTGC 9	No	No	34	NNE	46.7
BTGC 10	No	Yes	26	NNE	39.5
CCLUB 1	Yes	Yes	59	NNE	33.0
COLE 1	Yes	No	255	W	90.3
COLE 2	Yes	Yes	123	SSE	32.9
FRSP 1	Yes	No	162	S	63.6
HUD 1	No	Yes	201	SSW	95.8
HUD 1(2)	n/a	n/a	n/a	n/a	n/a
LKVW 1	No	Yes	216	SSW	29.5
WOOD 1	Yes	No	356	N	87.4
WPSP 1	Yes	No	346	N	32.8
WPSP 2	No	No	148	SSE	39.1

WPSP 3	No	Yes	257	W	30.6
WPSP 5	No	Yes	328	NNW	27.1
WPSP 6	Yes	Yes	162	S	47.8
WPSP 7	No	Yes	119	SSE	21.8
WPSP 8	No	Yes	92	E	40.9
WPSP 9	No	Yes	160	S	35.5
WPSP 10	Yes	Yes	276	W	49.3
WPSP 11	No	Yes	26	NNE	41.8
WPSP 12	Yes	Yes	271	W	50.6

Nest No.	Cavity Height (m)	Tree Height (m)	Relative Height (%)	Canopy Cover (%)	Small Tree Density[a]
BTGC 1	6.5	8.5	76.5	33.8	3
BTGC 3	11.3	20.0	56.3	28.8	12
BTGC 4	10.5	17.5	60.0	32.5	4
BTGC 5	8.3	16.0	51.6	40.0	0
BTGC 6	15.0	19.0	78.9	45.0	5
BTGC 7	4.3	5.8	74.1	38.8	9
BTGC 8	7.5	7.8	96.2	18.8	1
BTGC 9	18.0	27.8	64.9	65.0	25
BTGC 10	13.5	14.8	91.5	63.8	15
CCLUB 1	16.3	21.5	75.6	53.8	15
COLE 1	11.5	12.3	93.9	11.3	0
COLE 2	12.8	20.3	63.0	47.5	4
FRSP 1	31.3	39.0	80.1	71.3	29
HUD 1	12.5	14.0	89.3	40.0	5
HUD 1(2)	n/a	n/a	n/a	n/a	n/a
LKVW 1	5.1	9.4	54.7	22.5	0
WOOD 1	13.5	21.3	63.5	27.5	0
WPSP 1	14.8	17.5	84.3	65.0	34

WPSP 2	5.8	10.0	57.5	51.3	48
WPSP 3	5.5	10.0	55.0	61.3	13
WPSP 5	11.5	14.5	79.3	58.8	11
WPSP 6	16.3	17.3	94.2	52.5	2
WPSP 7	5.0	6.9	72.7	41.3	0
WPSP 8	5.5	6.8	81.5	20.0	0
WPSP 9	7.0	7.8	90.3	45.0	2
WPSP 10	18.0	31.3	57.6	65.0	50
WPSP 11	9.5	10.1	93.8	53.8	9
WPSP 12	14.5	22.8	63.7	30.0	8

Nest No.	**Medium Tree Density**[a]	**Large Tree Density**[a]	**Total Tree Density**[a]	**Openness**[a]	**Snag Density**[a]
BTGC 1	5	0	8	0	0
BTGC 3	5	0	17	0	3
BTGC 4	12	0	16	1	3
BTGC 5	7	0	7	1	1
BTGC 6	5	0	10	0	1
BTGC 7	0	0	9	2	0
BTGC 8	6	1	8	2	0
BTGC 9	1	0	26	0	1
BTGC 10	8	0	23	0	1
CCLUB 1	8	2	25	0	0
COLE 1	1	2	3	2	0
COLE 2	13	0	17	1	0
FRSP 1	10	0	39	0	0
HUD 1	5	0	10	1	3
HUD 1(2)	n/a	n/a	n/a	n/a	n/a
LKVW 1	0	0	0	3	2

WOOD 1	2	2	4	2	0
WPSP 1	5	1	40	0	2
WPSP 2	2	1	51	0	1
WPSP 3	11	0	24	0	2
WPSP 5	14	0	25	0	3
WPSP 6	19	1	22	0	1
WPSP 7	3	1	4	2	2
WPSP 8	9	2	11	0	1
WPSP 9	4	1	7	0	5
WPSP 10	3	0	53	0	4
WPSP 11	11	4	24	0	4
WPSP 12	9	0	17	0	0

Nest No.	Cavity Density[a]	Random Tree Species	Random Tree Condition	Cavities Present	Random Tree DBH (cm)
BTGC 1	8	Shagbark Hickory	Alive	No	30.4
BTGC 3	6	Black Oak	Alive	No	27.4
BTGC 4	15	White Oak	Alive	No	44.9
BTGC 5	1	White Oak	Alive	No	34.3
BTGC 6	4	Sugar Maple	Alive	No	40.4
BTGC 7	2	Shagbark Hickory	Alive	No	30.3
BTGC 8	1	Ash spp.	Alive	No	30.7
BTGC 9	11	Shagbark Hickory	Alive	No	60.1
BTGC 10	1	White Oak	Alive	No	49.9
CCLUB 1	4	Shagbark Hickory	Alive	No	44.8
COLE 1	1	Shingle Oak	Alive	No	54.2
COLE 2	2	Shagbark Hickory	Alive	No	27.5
FRSP 1	1	Sugar Maple	Alive	No	25.1
HUD 1	19	White Oak	Alive	No	78.4

HUD 1(2)	n/a	n/a	n/a	n/a	n/a
LKVW 1	5	Sugar Maple	Alive	No	51.5
WOOD 1	1	White Oak	Alive	No	94.0
WPSP 1	1	Sweet Gum	Alive	No	29.8
WPSP 2	7	White Oak	Alive	No	58.1
WPSP 3	4	Chinkapin Oak	Alive	No	23.5
WPSP 5	6	Black Oak	Alive	No	35.8
WPSP 6	3	White Oak	Alive	No	44.2
WPSP 7	7	Silver Maple	Alive	No	35.4
WPSP 8	2	White Oak	Alive	No	79.6
WPSP 9	6	Green Ash	Alive	No	39.0
WPSP 10	1	Silver Maple	Alive	No	37.7
WPSP 11	13	Silver Maple	Alive	No	46.2
WPSP 12	4	N. Hackberry	Alive	No	91.5

Nest No.	Random Tree Height (m)	Random Canopy Cover (%)	Random Small Tree Density[a]	Random Medium Tree Density[a]	Random Large Tree Density[a]
BTGC 1	22.0	28.8	1	6	0
BTGC 3	17.8	43.8	15	7	0
BTGC 4	22.3	31.3	0	3	0
BTGC 5	19.1	58.8	3	12	0
BTGC 6	26.5	21.3	0	5	0
BTGC 7	13.1	32.5	0	3	0
BTGC 8	17.3	40.0	0	6	0
BTGC 9	28.8	52.5	31	12	0
BTGC 10	23.3	43.8	15	9	0
CCLUB 1	18.8	22.5	0	1	1
COLE 1	19.8	26.3	3	12	0
COLE 2	18.8	38.8	2	5	0

FRSP 1	23.8	65.0	14	13	1
HUD 1	22.5	33.8	1	4	0
HUD 1(2)	n/a	n/a	n/a	n/a	n/a
LKVW 1	35.0	62.5	22	5	0
WOOD 1	22.8	36.3	0	0	3
WPSP 1	22.8	65.0	7	1	0
WPSP 2	24.3	61.3	39	6	0
WPSP 3	14.1	55.0	3	8	1
WPSP 5	24.8	57.5	34	8	2
WPSP 6	24.3	56.3	4	11	2
WPSP 7	19.5	50.0	3	7	0
WPSP 8	37.3	48.8	4	6	1
WPSP 9	25.8	56.3	9	12	0
WPSP 10	28.3	55.0	16	4	0
WPSP 11	18.8	57.5	4	4	0
WPSP 12	27.5	40.0	5	18	1

Nest No.	Random Total Tree Density[a]	Random Openness[a]	Random Snag Density[a]	Random Cavity Density[a]
BTGC 1	7	3	0	0
BTGC 3	22	0	0	0
BTGC 4	3	3	0	0
BTGC 5	15	1	1	0
BTGC 6	5	2	0	0
BTGC 7	3	3	0	0
BTGC 8	6	2	0	0
BTGC 9	43	0	5	2
BTGC 10	24	0	0	0
CCLUB 1	2	3	0	0

COLE 1	15	0	1	0
COLE 2	7	1	1	4
FRSP 1	28	0	1	0
HUD 1	5	1	0	0
HUD 1(2)	n/a	n/a	n/a	n/a
LKVW 1	27	0	0	0
WOOD 1	3	3	0	0
WPSP 1	8	0	0	0
WPSP 2	45	0	0	0
WPSP 3	12	1	1	0
WPSP 5	44	0	1	0
WPSP 6	17	0	0	0
WPSP 7	10	2	0	0
WPSP 8	11	0	3	0
WPSP 9	21	0	0	0
WPSP 10	20	2	0	0
WPSP 11	8	1	1	0
WPSP 12	24	0	1	0

[a] measured in number/0.04 ha