HABITAT USE AND DEMOGRAPHY OF RED-HEADED WOODPECKERS IN WEST-CENTRAL ILLINOIS

BY

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THESIS

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ABSTRACT

For the last four decades, red-headed woodpeckers (*Melanerpes erythrocephalus*) have experienced steep population declines across much of eastern North America. The most pronounced declines have been in the Midwestern U.S. The causes of these declines are not fully understood, but have been attributed to the loss or degradation of preferred habitat, particularly because of changes in land use and management practices. Red-headed woodpeckers have been known to use a variety of habitat types, but little is known about specific habitat features associated with habitat use and reproductive success. During the breeding seasons of 2012 and 2013, I conducted surveys for red-headed woodpeckers and monitored nests to estimate reproductive success at seven sites in west-central Illinois. I detected red-headed woodpeckers at 32% of 502 points surveyed, and occupancy ranged from 0.15 to 0.76 among sites. I found few differences in vegetation structure between points where red-headed woodpeckers were detected relative to random points. Relative to randomly selected points, nest sites were characterized by greater abundance of large trees, snags, and dead limbs. Nest survival varied little among sites, but appeared to be greater for higher cavities, nests located in floodplain forest, and at nest sites surrounded by relatively little shrub cover. My results suggest that red-headed woodpeckers use a variety of available habitats on the modern Midwestern landscape, and will nest in areas with an open understory and dead limbs and snags, especially large snags, and reproduce successfully in a range of habitat conditions.

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CHAPTER 1

GENERAL INTRODUCTION

The red-headed woodpecker (*Melanerpes erythrocephalus*) is a species that has historically been associated with oak savannas (Brawn 2006) and that has experienced widespread population declines. Despite formerly being relatively widespread and common across much of eastern North America, red-headed woodpecker populations declined 2.8% per year between 1966 and 2012 (Sauer et al. 2014). Population declines have been especially steep in the Midwest; in Illinois, for example, a 4% annual decline has led to >80% population reduction over the past 46 years. As a result of these declines, the red-headed woodpecker has been labeled as a species of conservation concern at state, regional, and national levels (IDNR 2005, Potter et al. 2007, USFWS 2008). Although the causes of such dramatic declines are not fully understood, they likely include the loss and degradation of oak savanna habitat as well as changes in habitat management practices over the years (e.g., removal of dead limbs and snags and fire suppression). To compound the lack of knowledge on causes of population declines, knowledge of what constitutes quality habitat for this species is also poorly understood.

Despite being thought of as an oak savanna specialist, red-headed woodpeckers are known to use a range of other habitat types including golf courses, forest edges, open agricultural areas, and floodplain forests where snags are plentiful (Smith et al. 2000, Rodewald et al. 2005). The use pine forests by red-headed woodpeckers has been observed in some regions (Kilgo and Vukovich 2012), although many previous studies suggest this species is more dependent on open areas dominated by oaks and other hard mast trees (Smith et al. 2000). Past studies suggest that red-headed woodpeckers select nesting habitat characterized by large diameter, tall, dead trees in areas with scattered medium to large trees with little or no understory vegetation and an open canopy (Conner 1976, Ingold 1994, Rodewald et al. 2005, Vierling and Lentile 2006, King et al. 2007). However, much of what is known about red-headed woodpecker habitat use is based on nest-site selection studies conducted in the periphery rather than the core of the species' geographic range. Moreover, little is known about factors associated with successful reproduction of red-headed woodpeckers. In an effort to provide information useful for natural resource managers seeking to maintain or create habitat for this species, I sought to better understand the range of habitat conditions used by this species in contemporary Midwestern landscapes, including factors differentiating used and unused habitat, nest sites from surrounding available habitat, and relationships between habitat features and reproductive success.

THESIS ORGANIZATION

This thesis is organized into four chapters: Chapter 1 is a general introduction. Chapter 2 examines site-level occupancy and habitat characteristics at points where red-headed woodpeckers were detected relative to random points in west-central Illinois. Chapter 3 examines vegetation structure at nest-sites relative to randomly selected non-nest sites and the influence of habitat features on reproductive success of red-headed woodpeckers. Chapter 4 summarizes conclusions from the previous chapters and addresses management implications and important directions for future research.

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CHAPTER 2

RED-HEADED WOODPECKER HABITAT USE IN WEST-CENTRAL ILLINOIS

ABSTRACT

For the last four decades, red-headed woodpeckers (*Melanerpes erythrocephalus*) and other savanna and open woodland birds have experienced steep population declines across much of eastern North America. The most pronounced declines have been in the Midwestern U.S. The causes of these declines are not fully understood, but have been attributed to the loss or degradation of preferred habitat, particularly due to changes in land use and management practices. Red-headed woodpeckers are known to use a variety of habitat types, including golf courses, forest edges, and open agricultural areas and floodplain forests where snags are plentiful, but little is known about factors affecting habitat use across this range of habitat types. During the breeding seasons of 2012 and 2013, I conducted surveys for red-headed woodpeckers and collected habitat data at occupied and randomly selected unoccupied points at seven sites in west-central Illinois. I detected red-headed woodpeckers at 163 of 502 surveyed points, and occupancy ranged from 0.15 to 0.76 among sites. Only small snag density and percent shrub cover, bare ground, and leaf litter differed between occupied and random points, whereas variables found to be associated with red-headed woodpecker habitat use in other studies, such as density of large trees and snags, dead limb length, and limb-tree density did not differ. These results suggest this species may be able to successfully use a variety of wooded habitats in the Midwestern U.S., suggesting that availability of suitable breeding habitat may not be driving population declines for this species.

INTRODUCTION

The red-headed woodpecker (*Melanerpes erythrocephalus*) is a species that has experienced widespread population declines. Despite formerly being widespread and common across much of eastern North America, red-headed woodpecker populations declined 2.5% per year between 1966 and 2013 (Sauer et al. 2014). Declines have been especially steep in the Midwestern U.S.; a 4.3% annual decline in Illinois equates to >80% population reduction over the past 46 years. As a result of these declines, the red-headed woodpecker has been labeled as a species of conservation concern at state, region, and national levels (IDNR 2005, Potter et al. 2007, USFWS 2008). Red-headed woodpeckers have historically been most associated with savannas (Brawn 2006) and, although the causes of their dramatic population declines are not fully understood, they likely include habitat loss and degradation and changes in habitat management practices (e.g., removal of dead limbs and snags and fire suppression). To compound the lack of knowledge on causes of population declines, knowledge of what constitutes quality habitat for this species on a contemporary landscape is also poorly understood.

Oak savannas were historically among the most abundant successional habitat types in the Midwestern U.S. (Nuzzo 1986, McPherson 1997). Today, however, oak savannas are quite rare, encompassing <1% of their original Midwestern range (Heikens and Robertson 1994, McPherson 1997). The disappearance of savannas has largely been attributed to changes in land use such as increased row crop agriculture and urban development, and fire suppression (Nuzzo 1986). As the extent of savannas and other successional habitats has declined, so have populations of plants and animals that are associated with those areas. Nearly half of the North

American birds associated with terrestrial successional habitats have experienced population declines in recent decades (Askins 1993, Hunter et al. 2001).

Despite being thought of as an oak savanna specialist, red-headed woodpeckers have been known to use a range of other habitat types such as golf courses, forest edges, and open agricultural areas and floodplain forests where snags are plentiful (Smith et al. 2000, Rodewald et al. 2005). Much of what is known about red-headed woodpecker habitat use and nest-site selection comes from studies conducted in the periphery rather than in the core of the species' geographic range. These studies suggest that red-headed woodpeckers select areas with large diameter, tall, dead trees in areas with scattered medium to large trees with little or no understory vegetation and an open canopy (Conner 1976, Ingold 1994, Rodewald et al. 2005, Vierling and Lentile 2006, King et al. 2007). This species has been known to use pine trees in some regions (Kilgo and Vukovich 2012), but many previous studies suggest red-headed woodpeckers select for open areas dominated by oaks and other hard mast trees (Smith et al. 2000). Even though red-headed woodpeckers are known to use a range of habitat conditions, little is known about the specific habitat features that are important for influencing habitat use in these varying habitats.

To gain a better understanding of factors associated with red-headed woodpecker habitat use and provide guidance for natural resource managers seeking to provide habitat for this declining species, I surveyed for red-headed woodpeckers and compared habitat at used and unused areas in west-central Illinois. By focusing on a range of habitat types, I sought to identify important features for this species in habitats that are typical of contemporary Midwestern landscapes.

METHODS

Study Sites

I studied red-headed woodpeckers in 6 counties in west-central Illinois (Fig. 1), an area that retains significant numbers of this species (Sauer et al. 2014). I chose 7 study sites that represent a range of commonly available wooded habitats on current Midwestern landscapes, representing a gradient of open- to closed-canopy forest as well as both upland and floodplain forest. Study sites ranged in size from 117 to 1,345 hectares. Siloam Springs, Weinberg-King, Ray Norbut, and Scripps consisted of mature open- and closed-canopy forest interspersed with savanna, grassland, cultivated agricultural plots, and campgrounds. Buckhorn consisted of semi-open forest fragmented by fallow and cultivated agricultural fields. Sand Prairie consisted of scrub-oak savanna and open- and closed-canopy forest interspersed with dry sand prairie. Spunky Bottoms consisted of wetlands, floodplain riparian forest, and cultivated agricultural fields.

Red-headed Woodpecker Surveys

I conducted point count surveys for presence of red-headed woodpeckers from mid-May to August of 2012 and 2013. I conducted five minute unlimited-radius point counts between sunrise and 1100 CDT and recorded all birds seen or heard. No counts were conducted in heavy fog, high winds, or steady rain. Following the initial five minutes, I included an additional three minute count using a playback method developed by Shackelford and Conner (1997) to increase detection probability. The additional 3 minute playback survey consisted of broadcasting a red-headed woodpecker vocalization for 10 seconds each minute for three minutes while observing and recording the presence of woodpeckers between each playback. Points were systematically placed 250 m apart in all wooded areas at each study site. I repeated counts three times per breeding season, with the exception of one site (Sand Prairie) that was visited only twice in 2012. Observers were rotated among survey points to minimize potential bias.

Vegetation Sampling

To examine habitat use by red-headed woodpeckers, I sampled vegetation structure at all points where red-headed woodpeckers were detected, as well as an equal number of randomly selected non-detection points at each site. Habitat variables were sampled within 11.3-m radius plots using a modified BBIRD protocol (Martin et al. 1997). Plots were segmented into 4 quadrants and I recorded percent ground cover of selected variables and the number of trees and snags in 4 size classes. I visually estimated percent ground cover of grasses, forbs, shrubs, fallen logs (downed woody vegetation >2.5cm in diameter), bare ground, and leaf litter. I counted saplings (>30 cm tall and <2.5 cm diameter; excluding shrubs), poles (2.5-8 cm diameter at breast height [dbh]), small trees and snags (8-23 cm dbh), medium trees and snags (23-38 cm dbh), and large trees and snags (>38 cm dbh). For all ground cover measurements, I averaged the values from the 4 quadrants to get one value for the entire plot. For trees and snags, I added the values from the four quadrants to get a total count for each plot.

I estimated canopy cover in the 4 cardinal directions using a spherical densiometer from the center of each plot. Canopy height was estimated using a clinometer. Basal area was estimated using a 10 basal area factor (baf) prism from the center of each plot. I estimated of total length of dead limbs ≥10 cm in diameter present within each plot as well as the number of trees with dead limbs ≥1 m long and ≥10 cm in diameter.

Statistical Analyses

I estimated detection probabilities and occupancy from repeated visits to points using occupancy modeling in Program MARK (White and Burnham 1999). I compared candidate models (Table 2) for detection and occupancy and examined Akaike's Information Criterion adjusted for small sample size (AIC_c) values to determine the model that best fit the data.

I used a general linear mixed model (SAS PROC MIXED; Littell et al. 2006) to examine differences in habitat characteristics between occupied points and randomly selected points where no red-headed woodpeckers were observed. Point ID was added as a random effect to account for the non-independence of data from points that were sampled in both years. To account for the potential non-independence of points within a site being more similar to each other than to points at another site, site was added as a random effect. I considered differences to be statistically significant when p values were ≤ 0.05.

RESULTS

I visited 489 point count locations in 2012 (113 at Buckhorn, 36 at Ray Norbut, 45 at Sand Prairie, 35 at Scripps, 203 at Siloam Springs, 19 at Spunky Bottoms, and 38 at Weinberg-King) for a total of 1,425 surveys. In 2013, I added 13 point count locations at Spunky Bottoms and completed a total of 1,483 surveys. I detected ≥1 red-headed woodpecker at 89 of the 489 points in 2012 and at 122 of the 502 points in 2013. Pooling years, red-headed woodpeckers were recorded at 163 different count locations across all study sites. The best supported model for detection and occupancy had occupancy varying by site and detection remaining constant (Table 2). Occupancy at the 7 sites ranged from 0.15 to 0.76 and was greatest at Spunky Bottoms, a site dominated by floodplain forest, and least at Siloam Springs, a site characterized by a relatively closed canopy mature upland forest with small shrublands, grasslands, and campgrounds (Fig. 2). Detection probability from the best ranked model was 0.35 ± 0.03.

I found few significant differences in habitat variables between occupied and random points. Only 4 of 21 habitat variables analyzed significantly differed between occupied and random points (Table 1). Leaf litter was the dominant ground cover at all points, and occupied points had less litter as well as less shrub and greater bare ground cover relative to random points. There were no significant differences in the number of trees in each size class between occupied and random points. There were significantly fewer small snags present at occupied compared to random points, and although there were more large snags at occupied relative to random points, this difference was only marginally significant.

DISCUSSION

I found red-headed woodpeckers at all 7 sites I surveyed in west-central Illinois, but occupancy varied considerably among sites. However, point-level habitat variables generally did a poor job differentiating between areas where red-headed woodpeckers were detected, and those that were randomly selected. These results may suggest that larger-scale differences, such as site-level variables, may be explaining more of the variation in red-headed woodpecker habitat use. Occupancy was greatest at Spunky Bottoms, a site dominated by floodplain forest, wetlands, and agricultural fields. Spunky Bottoms presents a favorable situation in that natural disturbance in the form of seasonal flooding minimizes understory vegetation and creates an abundance of large snags and dead limbs for breeding and foraging opportunities. The floodplain forest is primarily a narrow corridor of riparian habitat with an abundance of edge habitat between the wetlands and the Illinois River. The juxtaposition of the forest to the wet areas may also offer a plethora of insects for foraging. The site with the lowest occupancy estimate was Siloam Springs. In addition to being the largest site I sampled, this site primarily consisted of mature upland forest with a relatively closed canopy. Siloam Springs also contained, shrublands, grasslands, and campgrounds, although these cover types were relatively uncommon. The red-headed woodpeckers that I detected were primarily congregated around the two campgrounds present at the site, areas that were characterized by very little understory vegetation, numerous snags and dead limbs on the edges of the campgrounds, and a relatively open canopy. The red-headed woodpecker is well known for ground foraging as well as flycatching, therefore, a high percentage of bare ground and short ground vegetation and ample open space for aerial foraging make the campgrounds a desirable location for this species. Plentiful snags on the edges of the campgrounds also provide many options for breeding activity.

Despite hosting as many or more red-headed woodpeckers than some of the smaller sites, the two largest sites (Siloam Springs and Buckhorn) had lower rates of occupancy than the smaller sites. While the larger sites may contain more potentially suitable habitat than smaller sites, much of the habitat at these large sites appeared to be less suitable for red-headed woodpeckers. Access to snags and dead limbs near open areas for foraging and breeding activity appears to be restricting occupancy at Siloam Springs and Weinberg-King compared to other sites. All of the other sites contained more hard exterior edge habitat and therefore, easier access to foraging habitat. Furthermore, personal observations suggest that red-headed woodpeckers are in fact actively using and defending open areas in close proximity to their nest-site.

I found few differences in habitat variables sampled between occupied and random points. This may suggest that red-headed woodpeckers are tolerant of a wider range of habitat conditions than previously assumed. Even if oak savannas are preferred, the general lack of savannas on contemporary Midwestern landscapes may have relegated red-headed woodpeckers into other, perhaps less-preferred, habitats. The use of other non-savanna habitats by this species (e.g., Smith et al. 2000, Rodewald et al. 2005) also suggests flexibility in habitat use.

In contrast to previous studies, I found that canopy cover, densities of large trees and snags, dead limb length, and limb-tree density did not differ between used and random points. Sedgwick and Knopf (1990) found that dead limb length, limb-tree density, and density of large trees were the most important habitat variable differentiating used and random points in cottonwood floodplains. As expected however, occupied points did have more bare ground and less shrub cover, perhaps pointing to the importance of open understory conditions (Conner 1976, Ingold 1994).

There are several potential reasons why I may have observed a lack of habitat differences between occupied and random points. One reason may be that the scale of vegetation sampling for this study did not adequately capture habitat conditions at a scale important for red-headed woodpeckers. Additionally, many of the detections were situated in close proximity to some sort of opening (e.g., agricultural edge or campground). Because many of the detections took place away from an opening, rather than at the opening, vegetation sampling also took place away the opening, thus the close resemblance to habitat present at random points. It is also possible the use of playbacks to increase detection may have drawn the birds away from the most preferred habitats toward areas more similar to random points. More research may be needed to evaluate the role of landscape level factors in influencing habitat use.

It is worth noting the many previous habitat use studies for red-headed woodpeckers focus on the scale of nest-sites rather than addressing factors on a larger scale (Conner 1976, Sedgwick and Knopf 1990, King et al. 2007). I attempted to focus on an intermediate scale of used versus random areas, and it just might be that the biggest differences are in fact at the nest-site scale. I did in fact find more habitat differences while focusing on the nest-site scale (Chapter 3).

Overall, these results suggest that red-headed woodpeckers use a wider range of habitat conditions than traditionally thought. This may have implications for conservation planning and management activities. Importantly, small forest patches with relatively closed canopies may harbor more red-headed woodpeckers in the Midwestern U.S. than many researchers and natural resource managers have realized. This appears to be especially true for floodplain forests, a habitat type that is fairly widespread in the region and potentially underappreciated in its importance for this species. It is also worth noting that, despite the use of playbacks, red-headed woodpeckers still had a fairly low detection probability at a rate of approximately 35%. There may be many red-headed woodpeckers that are missed by passive sampling approaches.

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TABLES AND FIGURES

Table 1. Habitat variables measured at points occupied by red-headed woodpeckers and at random points where no red-headed woodpeckers were detected in west-central Illinois, 2012-2013.

	Occupied		Random			
Variable	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Canopy height (m)	16.62	1.54	17.11	1.56	0.34	0.56
Canopy cover (%)	67.34	4.14	67.58	4.18	0.01	0.93
Basal Area (m^2/ha)	70.60	5.01	68.88	5.07	0.11	0.74
Saplings[a]	49.63	12.86	55.41	12.99	0.67	0.41
Poles[a]	19.97	1.84	20.32	1.87	0.03	0.86
Small trees[a]	9.09	0.62	10.01	0.62	2.21	0.14
Medium trees[a]	2.83	0.24	1.46	0.24	0.01	0.92
Large trees[a]	1.65	0.18	1.54	0.19	0.32	0.57
Small snags[a]	0.81	0.25	1.32	0.25	6.59	0.01
Medium snags[a]	0.20	0.04	0.20	0.04	0.00	0.99
Large snags[a]	0.06	0.02	0.02	0.02	3.51	0.06
Dead limb length (m)	9.88	1.27	8.72	1.30	0.67	0.41
Limb-tree density[b]	1.65	0.20	1.47	0.20	0.95	0.33
Grass (%)	18.79	3.03	16.90	3.07	0.50	0.48
Forb (%)	13.54	1.14	13.76	1.15	0.02	0.88
Shrub (%)	10.57	1.64	13.39	1.66	4.33	0.04
Fallen log (%)	4.78	0.73	4.45	0.74	0.31	0.58
Bare ground (%)	13.01	3.82	8.86	3.85	8.13	0.005
Leaf litter (%)	33.65	5.31	39.97	5.36	6.56	0.01

[a]Number per 11.3-m radius plot.
[b]Number of dead limbs >1 m in length and 10 cm in diameter per 11.3-m radius plot.

Table 2. Candidate models for occupancy (ψ) and detection probability (*p*) variation among sites (site) and sample rounds (t) for red-headed woodpeckers in western Illinois, 2012-2013.

Model	K	AIC_c	ΔAIC_c	w_i
ψ(site)*p*(.)	8	1686.08	0.00	0.70
ψ (site)*p*(site)	10	1688.06	1.98	0.26
ψ (.)*p*(site)	14	1692.05	5.97	0.04
ψ (site)*p*(t)	8	1707.94	21.86	0.00
ψ (.)*p*(.)	2	1757.78	71.70	0.00
ψ (.)*p*(t)	4	1760.08	74.00	0.00

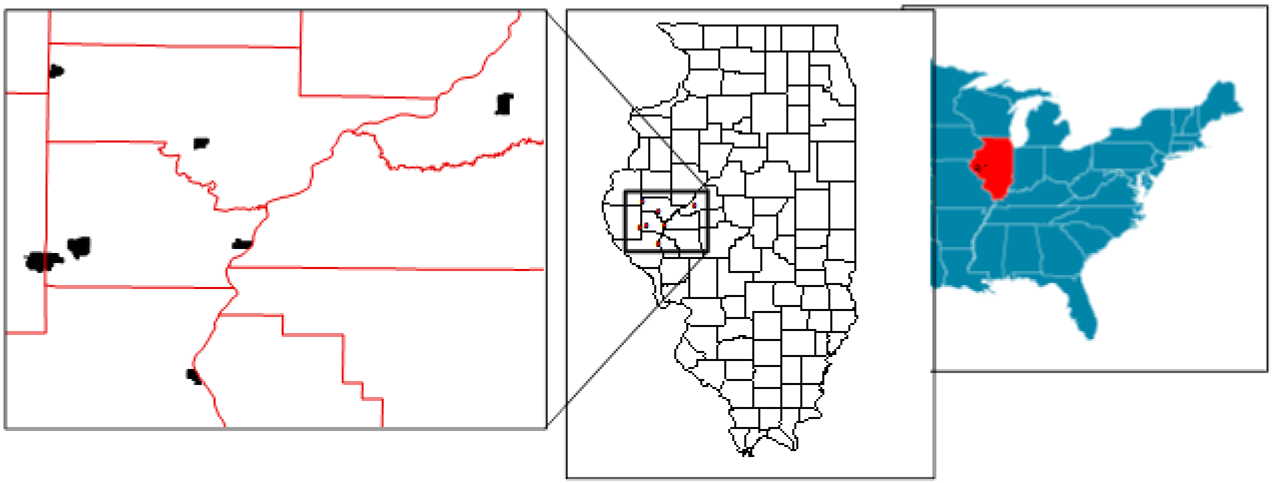

Figure 1. Locations of 7 sites where I examined red-headed woodpecker habitat use in west-central Illinois, 2012–2013.

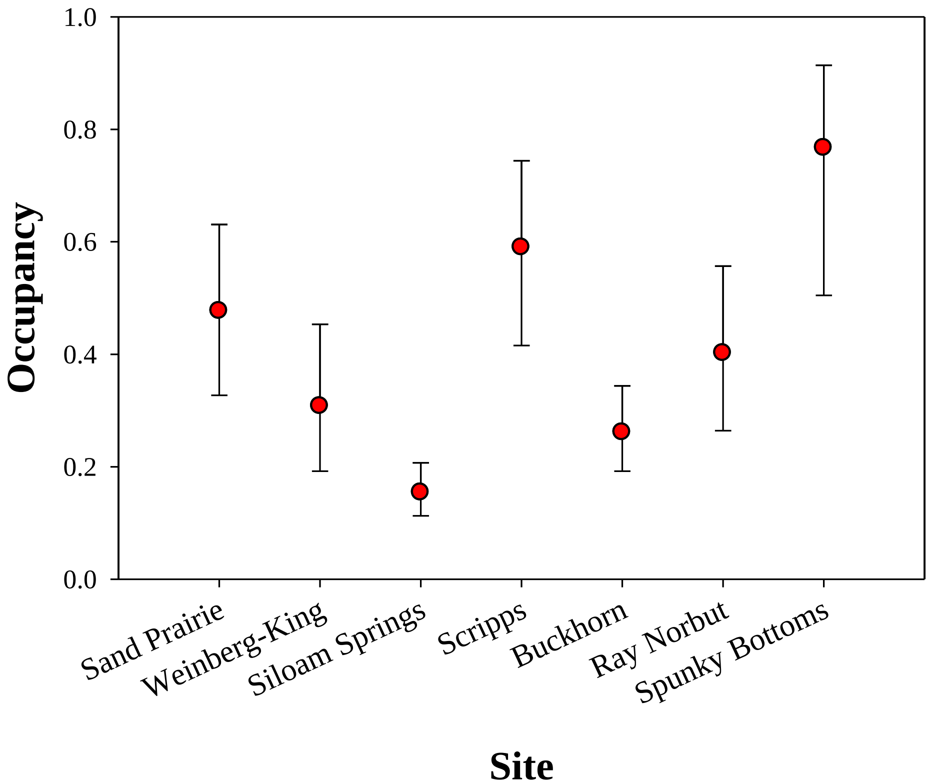

Figure 2. Estimated occupancy (± 95% CI) of red-headed woodpeckers at 7 sites in west-central Illinois, 2012–2013.

CHAPTER 3

RED-HEADED WOODPECKER NEST-SITE SELECTION AND NEST SURVIVAL

ABSTRACT

Red-headed woodpeckers (*Melanerpes erythrocephalus*) and other bird species associated with savannas and open woodlands have experienced population declines across much of eastern North America for at least 40 years. The steepest declines have occurred in the Midwestern U.S., and while the causes of such declines are unclear, they are largely attributed to the loss or degradation of habitat. While historically considered an oak savanna specialist, red-headed woodpeckers are known to use a variety of habitat types, and little is known about what constitutes quality habitat for this species. During the breeding seasons of 2012 and 2013, I examined nest-site selection and reproductive success of red-headed woodpeckers at six sites in west-central Illinois that represent a range of habitat conditions including both upland and floodplain forests as well as a gradient of open to closed-canopy habitats. Nest sites were characterized by greater abundance of large trees, snags, and dead limbs relative to randomly selected non-nest sites. These habitat characteristics generally were not strong predictors of nest survival, although shrub cover surrounding nests was associated with a decrease in nest survival, and higher nests were more likely to fledge young. Overall, these results suggest that even in non-savanna habitats, promoting red-headed woodpecker habitat by promoting the creation and retention of an open understory and dead limbs and snags, especially large snags, may be an effective management approach.

INTRODUCTION

The red-headed woodpecker (*Melanerpes erythrocephalus*) was once widespread and common across much of eastern North America but has experienced range-wide declines over the last four decades (Sauer et al. 2014). As a result of these declines, red-headed woodpeckers have been labeled as a species in greatest need of conservation at state, region, and national levels (IDNR 2005, Potter et al. 2007, USFWS 2008). The most dramatic declines, ranging from 2.5 to 6.2% per year, have occurred in the states in the Midwestern U.S. (Sauer et al. 2014). The causes of such declines are not entirely known but are assumed to be largely driven by habitat loss and degradation (Nuzzo 1986).

Red-headed woodpeckers have typically been identified as dependent on oak savannas, an abundant habitat type in the Midwestern U.S. at the time of European settlement (Nuzzo 1986, McPherson 1997). However, as with red-headed woodpecker populations, oak savannas have also declined. These declines have been attributed to changes in land use, including increases in row-crop agriculture, decreased use of land for livestock grazing, lack of disturbances such as fire, and increases in urban development (Nuzzo 1986). Today, oak savannas are recognized as a globally imperiled ecosystem and cover <1% of their original Midwestern range (Heikens and Robertson 1994, McPherson 1997).

Although red-headed woodpeckers are well-known to breed and forage in savannas and open woodlands, this species has also been known to use a range of other habitats, including golf courses and forested wetlands (Bock et al. 1971, Rodewald et al. 2005, Brawn 2006). Given the current rarity of savannas and open woodlands, these other habitats likely play an important role in red-headed woodpecker conservation by providing this species with a suitable alternative. However, despite using a variety of non-savanna habitat types, little is known about the relatively quality of these alternative habitats or the importance of specific habitat features for habitat use on reproductive success. Although studies have investigated habitat use of red-headed woodpeckers, particularly near the periphery of the species' geographic range (Conner 1976, Kilham 1977, Ingold 1994, Rodewald et al. 2005, Vierling and Lentile 2006), little is known about habitat use or reproductive success in the Midwestern U.S.

My study sought to better understand nest-site selection and reproductive success of red-headed woodpeckers breeding in a range of habitat types. More specifically, I located and monitored red-headed woodpecker nests in habitats ranging from open- to closed-canopy as well as upland and floodplain forest, examined habitat differences between nest and non-nest sites, and examined factors influencing nest survival.

METHODS

Study Sites

I studied red-headed woodpecker nest-site selection and reproductive success in five counties in west-central Illinois. I chose 6 study sites that represent a variety of commonly available habitats in current Midwestern landscapes (Fig. 3), including a gradient of open- to closed-canopy forest as well as both upland and lower floodplain forest. Study sites ranged from 117 to 1,345 ha. All sites consisted of some degree of forested habitat interspersed with remnant savannas, shrublands, grasslands, campgrounds, and fallow and cultivated agricultural fields.

Nest Searching and Monitoring

I located and monitored red-headed woodpecker cavities from mid-May to early September in 2012 and 2013. I located cavities in areas determined to be occupied following point count surveys (Chapter 2) or where red-headed woodpeckers were discovered opportunistically during other activities. Adult birds were located by listening for drumming and vocalizations, and I followed birds in an attempt to locate nest cavities. I examined the contents of cavities using a pole-mounted infrared camera (Huebner and Hurteau 2007). The pole-mounted camera use was limited to cavities ≤14 m. Cavities higher than 14 m were monitored from a distance using behavioral observations. Observers recorded all activity for up to 30 minutes. A cavity was considered to contain an active nest when at least one egg or nestling was present, and an adult was observed inside or within close proximity to the cavity. I recorded GPS coordinates and placed flagging ≥10 m away from nest cavities. Cavities were visited every 3-4 days until nestlings fledged, or the nest attempt failed. A nest was considered successful if at least one nestling fledged, and failed if all eggs were missing or destroyed, nestlings were missing from a cavity prior to the expected fledge date, or adults were not observed at or near the cavity during repeated visits. I deployed an infrared camera equipped with a time-lapse video recorder at a subset of nests to capture predation and fledging events (Benson et al. 2010, Cox et al. 2012).

Vegetation Sampling

I sampled vegetation structure at nest sites and at randomly selected non-nest sites. Habitat variables were sampled between mid-July and mid-September using a modified BBIRD protocol (Martin et al. 1997). For nest sites, sampling took place within 5- and 11.3- m radius plots centered on the nesting tree or snag. For random non-nest sites, I used a random number generator to select a random distance and direction within 100 m of each nest. I then centered the plot on the nearest tree or snag of suitable size for a cavity; as with nests, sampling took place within 5- and 11.3-m of the tree or snag. Plots were segmented into four quadrants, and within each quadrant I visually estimated percent ground cover of grasses, forbs, shrubs, fallen logs (downed woody vegetation >2.5cm in diameter), bare ground, and leaf litter within the 5-m plots and counted the number of saplings (>30 cm tall and <2.5 cm diameter; excluded shrubs), poles (2.5-8 cm diameter at breast height [dbh]), small trees and snags (8-23 cm dbh), medium trees and snags (23-38 cm dbh), and large trees and snags (>38 cm dbh) within the 11.3-m plots. For all ground cover estimates, the values from the four quadrants were averaged into one value for the entire plot. For trees and snags, the values from the four quadrants were summed to get a total count for each plot. Seasonal flooding in 2013 resulted in some plots (n = 23) being covered with water during nesting, but the water receded prior to nest termination, so I used post-nesting vegetation cover as with all other points.

At each tree or snag, I estimated canopy cover in the four cardinal directions using a spherical densitometer from the center of each plot. I estimated the average canopy and sub-canopy height around each point using a clinometer and estimated basal area using a ten basal area factor (BAF) prism from the center of each plot. I estimated the total length of dead limbs ≥10 cm in diameter as well as the number of trees with dead limbs ≥1 m long and ≥10 cm in diameter within each 11.3-m plot. I also used a clinometer to estimate nest tree or snag height paired with a random tree or snag. I measured the dbh of each nest and random tree or snag using a dbh tape. I recorded the condition where the cavity was located in each nest tree or snag as being alive, dead, or dead part of live. I counted the number of cavities present in each nest tree or snag as well as the number of cavities present in the entire plot.

Statistical Analyses

I examined differences in vegetation structure between nests and random points using a general linear mixed model (SAS PROC MIXED; Littell et al. 2006). Nest ID was included as a random effect to account for the pairing of nests and random locations, and site was also added as a random effect. I considered differences to be statistically significant when *p* values were ≤0.05. Any values presented in the Results section are means ± SE.

I examined variables associated with daily nest survival using the logistic-exposure approach (SAS PROC GENMOD; Shaffer 2004). I generated a set of candidate models (Table 3) for nest survival based on factors that may be important for habitat quality based on variables important for habitat use or that may influence the probability of nest predation. I evaluated candidate models with Akaike's Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002).

RESULTS

I located and monitored 41 cavities and 59 nesting attempts in 2012, and 55 cavities and 77 nesting attempts in 2013. When multiple nesting attempts occurred in the same snag or tree, that location was only used once for habitat use analyses, but no nests were excluded from nest survival analyses.

Of the 19 vegetation variables considered, eight significantly differed between nest sites and random points. Nest sites had greater numbers of large trees, medium and large snags, limb trees, as well as greater length of dead limbs and cover of fallen logs than random points, but lower abundance of pole-size trees (Table 4). Mean canopy cover, canopy height, and tree basal area at nest-sites and non-nest sites were comparable. Mean cavity height was 11.7 m ± 0.61 (1.1-26.4 m) and cavities were predominantly situated in vertical (93%) as opposed to horizontal (7%) substrates, and dead substrate (81%) compared to dead limbs of live trees (19%). No cavities were observed in living substrate. Because the majority of cavities were situated in snags, the tree species was generally unidentifiable; however, silver maple (*Acer saccharinum*) and eastern cottonwood (*Populus deltoides*) appeared to be frequently used nesting at floodplain nests and white oak (*Quercus alba*) appeared to be frequently used for nests in upland areas. The canopy at floodplain sites was dominated by silver maple and eastern cottonwood, while the canopy at upland sites was dominated by red oak (*Quercus rubra*), black oak (*Quercus velutina*), and white oak.

Of the 136 nesting attempts that I monitored and determined a fate, 79 (58%) were observed or believed to have fledged young. For nests where I could observe the contents during the incubation stage (n=62), mean clutch size was 4.2 ± 0.72. Successful nests fledged 2 ± 0.66 young. The overall mean DSR was 0.987 (0.983-0.990), assuming a 45-day nesting period this would correspond to 55% nest success. Nest failures were difficult to diagnose because only one nest equipped with video surveillance captured a predation event (raccoon) while all others equipped with cameras fledged young. The only other known predator was a black rat snake that was discovered in a cavity during a routine nest check. Because cavities are difficult to access for many predators, I suspect other factors such as starvation may have been the cause of many nest failures.

Two nest-survival models fit better than the constant survival model (Table 3). Daily survival rate (DSR) decreased with increasing shrub cover surrounding nests (Fig. 4) and increased with cavity height (Fig. 5). Even though the model ranked slightly below the constant-survival model, there was some evidence that survival was greater for floodplain relative to upland nests (Fig. 6). Mean DSR for nests in the floodplains and uplands were 0.991 (67%) and 0.984 (48%) respectively. Although there was some support for survival variation among sites ($\Delta AIC_c < 2$), with DSR values ranging from 0.954 to 0.994, 95% confidence intervals overlapped considerably. The only remaining model with $\Delta AIC_c < 2$ incorporated a positive effect of large tree abundance within a nest plot, although the 95% confidence interval of the parameter estimate indicates a weak relationship of this variable.

DISCUSSION

Despite the historical association of red-headed woodpeckers with oak savannas, I found this species nesting in a variety of habitats in west-central Illinois, including mature closed-canopy forests and floodplain habitats with and without standing water. Furthermore, estimated nest success (55%) in these areas was comparable to or exceeding values found in other areas. Berl et al. (2014) reported 32% nest survival in northern New York and Ingold (1994) reported only 31% of pairs successfully rearing young. On the contrary, Rodewald et al. (2005) and Hudson and Bollinger (2013) found higher nest success at ≥70% and 56% respectively. Collectively, these results suggest that non-savanna habitats may serve an important role in red-headed woodpecker conservation and that conservation and management activities should increasingly consider these areas as potential habitat.

The results of this study confirm the importance of large diameter trees and snags as well as the length and density of dead limbs for red-headed woodpecker breeding habitat. Vierling and Lentile (2006) and Gutzwiller and Anderson (1987) also found large snags to be an important component of nest-site selection. I found that dead limbs were significantly longer and more abundant at nest-sites compared to random (Table 4). King et al. (2007) and Sedgwick and Knopf (1990) also found similar results corroborating the importance of dead wood material for this species. However, in contrast to previous studies, I did not find nest sites to be associated with open canopy conditions such as those typically found in savannas. I found mean canopy cover to be 63% ±7.58, whereas Rodewald et al. (2005) in Ohio and King et al. (2007) in Wisconsin recorded 10% and 19.7% cover respectively.

The use of forested areas by red-headed woodpeckers, given suitable trees, snags, dead limbs, and understory structure, may provide natural resource professionals with viable management alternatives to savanna restoration. In particular, retaining or creating snags and decadent trees may create appropriate habitat for this species. However, even though I was studying red-headed woodpeckers in forested areas with relatively closed-canopies, I did observe that many of the snags and dead limbs used for breeding or foraging were close to an opening (e.g., agricultural edge, canopy opening, or campground). Although landscape context was not a focus of this study, larger-scale patterns such as distance to nearest edge or amount of edge habitat on the landscape may be important determinants of habitat use and are worthy of additional consideration and may be an important component of management.

Floodplain forests appeared to be particularly suitable for breeding red-headed woodpeckers. In addition to having high rates of occupancy (Chapter 2), a large number of my nests (n =53) were found in this forest type, and nest survival appeared to be greater than in upland sites. Periodic flooding in these areas, by creating snags and keeping understory vegetation to a minimum, likely contributes to making these areas particularly suitable for red-headed woodpeckers. Moreover, the presence of floodwater does not appear to deter use of these areas or affect reproductive success. In 2013, portions of two study sites were inundated with water for much of the breeding season. The number of birds using these areas and nest survival appeared to be unaffected by the flooding event, as results remained comparable to those from 2012.

Habitat characteristics associated with nest-site selection at my study sites had no noticeable effect on daily survival. Shrub cover was the only habitat variable associated with nest survival. Although the negative effect of this variable reinforces the idea that an open understory provides the best quality habitat for red-headed woodpeckers, the mechanism of shrub cover's effect on nest survival is unknown. It may be that understory vegetation hinders ground-level foraging, or that shrub cover is associated with increased use by nest predators. Another possible indicator of the importance of predation as a limit on reproductive success is the influence of nest cavity height on nest survival, perhaps related to accessibility by nest predators. However, even though nest predation appeared to be common, brood reduction also appeared to be common, even in ultimately successful nests. Nests that started with, on average, four eggs only fledged two young. Reasons for this decline are unknown, but could include poor hatching success or, more likely, starvation of nestlings. This suggests that factors influencing survival of nestlings, and later possibly fledglings as well, may be an important yet unstudied component of reproductive success and habitat quality in this species.

Overall, my results suggest that management actions focused on a range of habitat types, including upland and bottomland forests, may contribute to red-headed woodpecker conservation. In particular, actions that promote the creation and retention of dead limbs and snags, especially large snags, should be promoted. Areas with considerable hard mast production where understories can be kept open, either through management or as a result of flooding, may promote habitat quality. As this study has alluded to, floodplain forests that are subject to seasonal flooding appear to be much more valuable for red-headed woodpecker conservation than previously thought. Management actions to maintain these areas should be considered.

Given their use of a relatively wide range of habitat types, including successful reproduction, many questions remain about the causes of widespread population declines in red-headed woodpeckers. Changes in the availability of breeding habitat has likely contributed to population declines; however, other factors such as winter survival, starvation of nestlings and fledglings, or low rates of recruitment into the breeding population, may be driving declines more than breeding habitat availability and nest success. Additional research is needed to further investigate these and other potential causes of population declines of red-headed woodpeckers.

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TABLES AND FIGURES

Table 3. Relative support for models explaining variation in daily survival of red-headed woodpecker nests in west-central Illinois, 2012-2013.

Model	K	AIC_c	ΔAIC_c	w_i
Shrub cover	2	277.2	0.0	0.2
Cavity height	2	278.3	1.1	0.1
Constant survival	1	278.4	1.2	0.1
Floodplain vs. upland	2	278.7	1.5	0.1
Site	2	278.8	1.6	0.1
Large trees	2	279.0	1.8	0.1
Bare ground	2	280.1	2.9	0.0
Canopy cover	2	280.2	3.0	0.0
Total Snags	2	280.2	3.0	0.0
Floodplain/upland + canopy cover	3	280.2	3.0	0.0
Basal area	2	280.3	3.1	0.0
Year	2	280.3	3.1	0.0
Dead limb length	2	280.3	3.1	0.0
Nest stage	2	280.4	3.2	0.0
Large snags	2	280.4	3.2	0.0
Limb-tree density	2	280.4	3.2	0.0
Litter cover	2	280.4	3.2	0.0
Day of year	2	280.4	3.2	0.0
Cavities per tree or snag	2	280.6	3.4	0.0

Table 4. Habitat variables measured at red-headed woodpecker nest sites and at random non-nest sites in west-central Illinois, 2012-2013.

	Nest		Random			
Variable	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Canopy height (m)	17.96	2.41	18.78	2.46	0.47	0.49
Sub canopy height (m)	5.45	1.01	5.15	1.03	0.26	0.61
Canopy cover (%)	63.06	7.58	63.31	7.77	0.00	0.95
Basal area (m^2/ha)	48.16	13.52	55.11	14.29	0.72	0.40
Saplings[a]	32.52	8.69	35.25	9.00	0.20	0.66
Poles[a]	11.38	3.61	15.28	3.68	5.48	0.02
Small trees[a]	6.79	1.16	8.19	1.20	2.28	0.13
Medium trees[a]	2.42	0.45	2.61	0.48	0.18	0.67
Large trees[a]	2.16	0.52	1.47	0.53	3.85	0.05
Small snags[a]	1.78	0.46	1.29	0.48	1.09	0.30
Medium snags[a]	0.65	0.16	0.27	0.18	4.41	0.04
Large snags[a]	0.57	0.12	0.12	0.13	11.30	0.00
Dead limb length (m)	31.26	2.93	15.53	3.11	21.97	<0.001
Limb-tree density[b]	3.00	0.21	2.24	0.23	7.07	0.01
Grass (%)	30.35	9.94	30.57	10.01	0.01	0.93
Forb (%)	13.51	2.05	13.24	2.21	0.02	0.88
Shrub (%)	8.12	1.50	8.12	1.57	0.00	1.00
Fallen log (%)	7.82	1.59	4.97	1.66	4.54	0.04
Bare ground (%)	21.15	7.08	23.83	7.21	0.79	0.37
Leaf litter (%)	14.26	5.12	18.05	5.25	1.97	0.16
Nest tree height	20.12	2.05	18.44	2.20	0.31	0.58
Nest tree dbh (cm)	49.43	2.71	36.29	2.91	15.23	0.0001

[a]Number per 11.3-m radius plot.
[b]Number of dead limbs >1 m in length and 10 cm in diameter per 11.3-m radius plot.

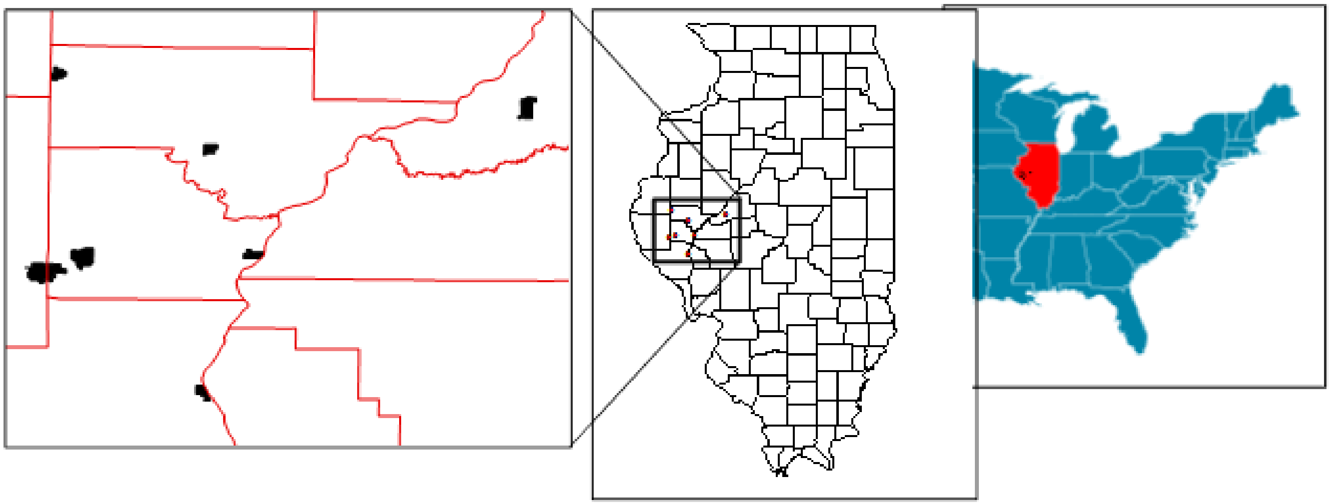

Figure 3. Location of 6 sites in west-central Illinois where I examined Red-headed Woodpecker nest-site selection and nest survival in 2012 and 2013.

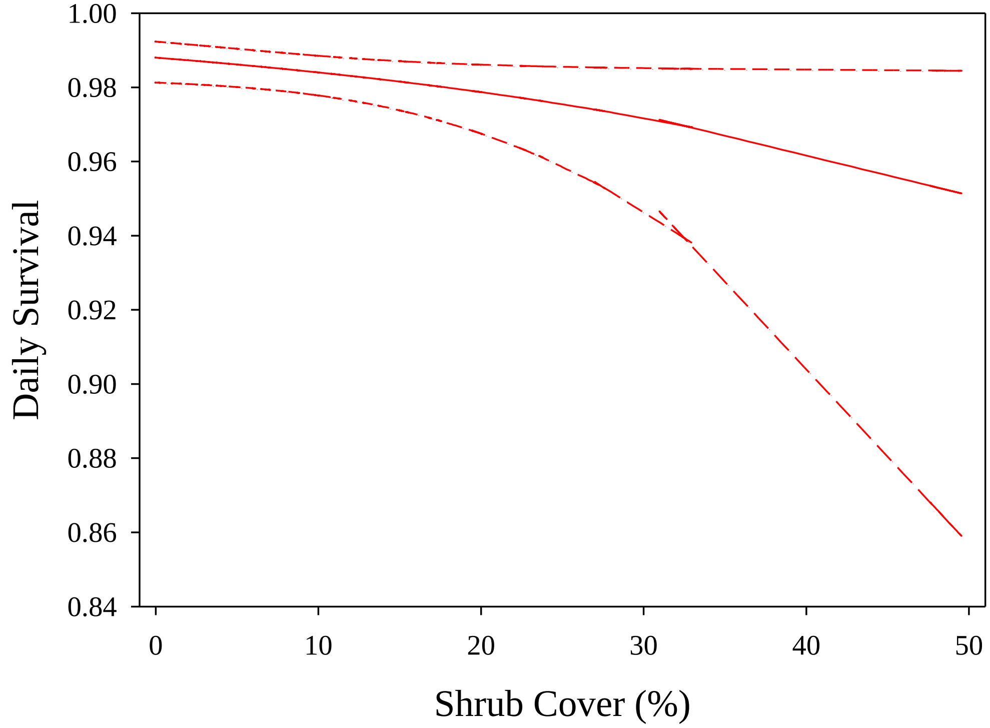

Figure 4. Daily survival rate (± 95 % CI) of red-headed woodpecker nests located in relation to percent shrub cover.

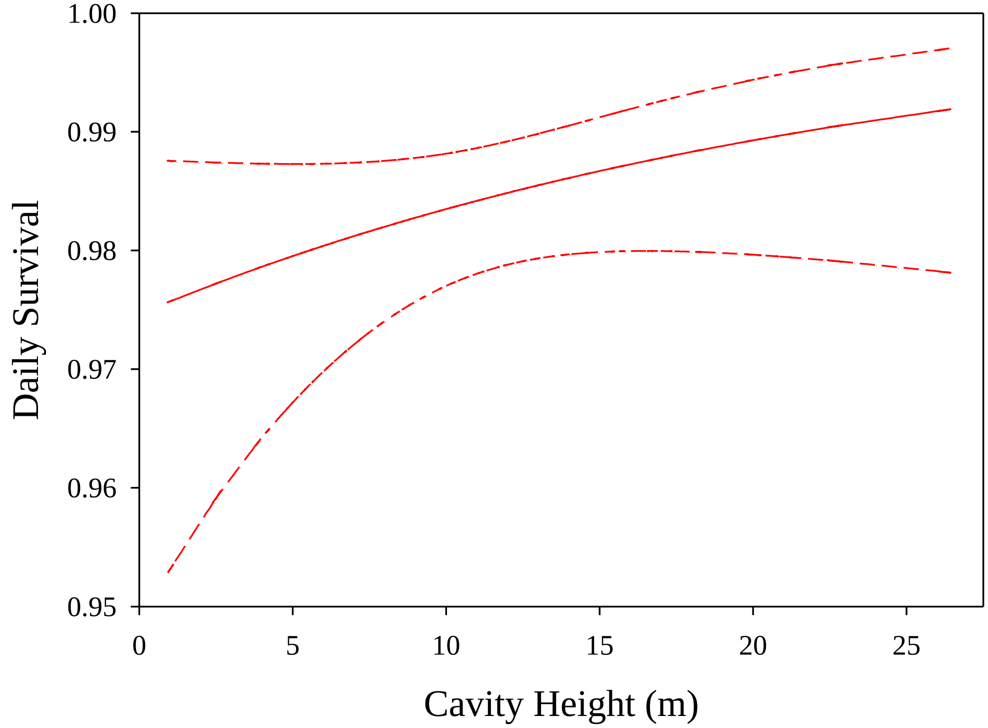

Figure 5. Daily survival rate (± 95 % CI) of red-headed woodpecker nests located in relation to height of cavity entrance from the ground.

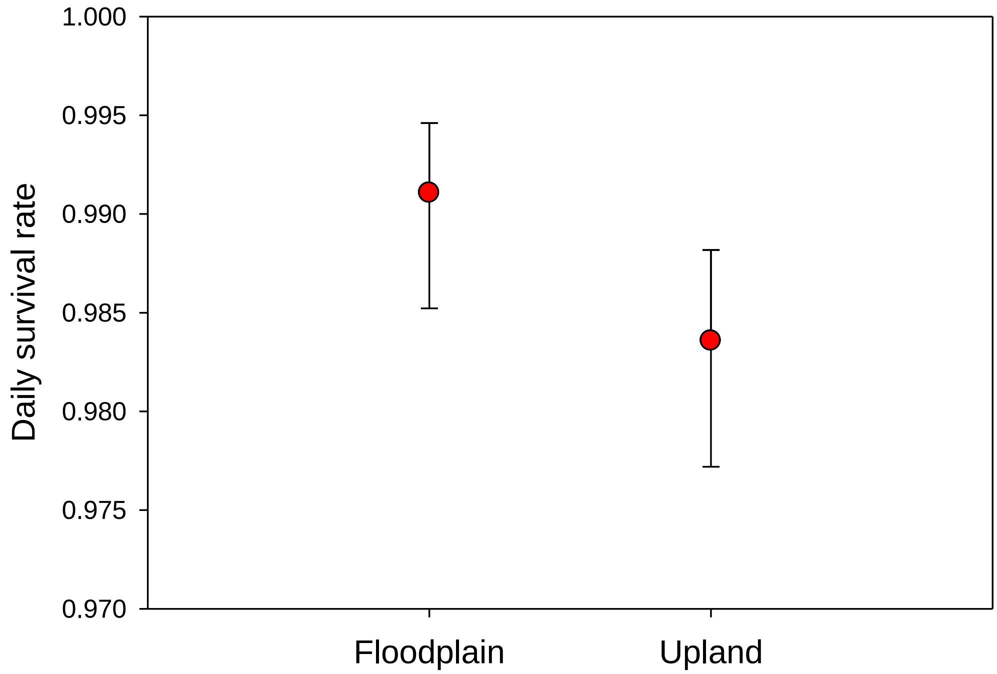

Figure 6. Daily survival rate (± 95 % CI) of red-headed woodpecker nests located in floodplain and upland forest sites.

CHAPTER 4

SUMMARY

The red-headed woodpecker (*Melanerpes erythrocephalus*) was once widespread and common across much of eastern North America. Oak savannas, the habitat type typically most associated with red-headed woodpeckers, were also historically common (Nuzzo 1986, McPherson 1997). However, changes to natural landscapes as a result of increased dominance of agricultural and developed land cover has forced many wildlife species to seek alternate habitats. Previous studies have revealed that red-headed woodpeckers use a range of habitat types other than savannas (Smith et al. 2000, Rodewald et al. 2005). Nonetheless, relatively little is known about what influences red-headed woodpecker habitat use, nest-site selection, and reproductive success, especially in the former core of the species' geographic range in the Midwestern U.S. The purpose of my research was to investigate the range of habitat conditions used by red-headed woodpeckers in a contemporary Midwestern landscape and to better understand vegetation features associated with habitat use, nest-site selection, and reproductive success of this species.

The main conclusions from Chapter 2 were that occupancy varied significantly among study sites that were sampled for red-headed woodpeckers, and that habitats occupied by this species had few differences in vegetation structure relative to areas where red-headed woodpeckers were not observed. Occupancy was greatest at a site dominated by floodplain forest, wetlands, and agricultural fields and was least at a large site primarily consisting of mature upland forest characterized by closed canopy conditions interspersed with remnant savannas, shrublands, grasslands and campgrounds. Although vegetation structure appeared to be poor predictors of what points were occupied by red-headed woodpeckers, my observations of occupied areas suggested that larger-scale characteristics, such as proximity to edges, may have played an important role in determining where the species was distributed. General conclusions regarding habitat use at occupied points were not as comparable to those in previous studies as I would have expected (Conner 1976, Ingold 1994, Rodewald et al. 2005, King et al. 2007). Variables found to be associated with red-headed woodpecker habitat use in other studies, such as density of large trees and snags, dead limb length, and limb-tree density did not differ in my study.

For Chapter 3, my main conclusions were that red-headed woodpeckers used a variety of habitats for breeding, characteristics of nest sites were similar to those observed in other studies, that reproductive success at my sites were comparable to values observed in past studies, and that habitat surrounding nest sites had little noticeable effect on nest survival. Nest sites were characterized by large trees, an abundance of snags and dead limbs, and open understory conditions void of shrub cover. Additionally, canopy cover was greater at nest sites than in many past studies (Rodewald et al. 2005, King et al. 2007). Shrub cover was negatively related to nest survival, which supports the importance of open understory conditions for this species. Nest survival varied little among sites, but was greater for higher nests and appeared to be greater for nests located in floodplain relative to upland forest.

Overall, my results suggest red-headed woodpeckers will use a wide range of habitats. Additionally, I would suggest that this species may be associated with edges more than was previously thought. Even though this species has experienced substantial population declines, my results suggest that red-headed woodpeckers in west-central Illinois will use wooded habitats in a landscape with few intact savannas remaining, providing that key nest-site characteristics are available. In particular, it would appear that available wooded habitats with abundant snags and little or no understory vegetation may provide breeding and foraging habitat that is a suitable surrogate for savannas or open woodlands. For the benefit of this species, natural resource managers should consider maintaining wooded areas with abundant snags and open understory conditions in areas where the red-headed woodpeckers are known to occur. I would also suggest that floodplain forests may be an undervalued habitat for red-headed woodpecker conservation in the Midwestern U.S., and these areas should be given greater attention by natural resource managers.

Furthermore, additional research investigating other factors that may contribute to declines, including winter habitat use and survival, potential food limitation for nestlings and fledglings, and factors influencing recruitment into the breeding population, is necessary to better understand the primary drivers of population declines for this species. My research suggests that habitat features have little noticeable effect on nest success. Although the availability and quality of breeding habitat may have played a role in population declines, it is likely that additional factors share responsibility.

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