Prothonotary Warbler Nest Success and Vegetation Characteristics in a Fragmented Oklahoma Landscape

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In 2003, I studied the relationship between prothonotary warbler (*Protonotaria citrea*) nest success and vegetation characteristics in a fragmented Oklahoma landscape. Forty nest boxes were monitored for reproductive success and vegetation characteristics were measured at nest boxes and 40 random points within the same stands. Thirty-five successful nests fledged a mean of 3.9 young/nest, whereas five nests failed to produce any fledglings. Although nest boxes occurred in small habitat fragments (4–12 ha), 88% of nest attempts fledged ≥1 fledgling/nest, which suggested this species was not area sensitive. Logistic regression produced a moderately successful model that used vegetation characteristics to predict nest success compared to random points within the landscape. Overall, nest success was positively associated with increased percent ground cover (water), understory vegetation density, and overstory canopy cover. No successful model was produced to predict successful nests versus unsuccessful nests by using vegetation characteristics. Prothonotary warbler were highly successful in small habitat fragments in a heterogenous landscape.

INTRODUCTION

Prothonotary warblers (*Protonotaria citrea*) are a secondary-cavity nesting species occurring in the eastern United States (Petit 1999). Previous research focused on the eastern (Blem and Blem 1991), northern (Walkinshaw 1953, Flaspohler 1996), and central (Petit 1989) portions of the prothonotary warblers' range. However, a paucity of data exists for reproductive success and habitat characteristics at the western extent of this species' range, which occurs in Oklahoma, Texas, and Kansas (Petit 1999).

Walkinshaw (1938, 1953) performed early life history studies of prothonotary warblers in Michigan without the benefit of nest boxes; however, these birds readily use nest boxes similar in dimension to natural nest cavities of downy woodpeckers (*Picoides pubescens*) (Walkinshaw 1953, Fleming and Petit, 1986). Prothonotary warbler nest box use and breeding biology has been extensively studied in Tennessee (Petit 1989), Virginia (Blem and Blem 1991, Cartwright 1997) and Wisconsin (Flaspohler 1996).

These warblers predominantly nest in flooded bottomland hardwood forests and riparian areas (Blem and Blem 1991, Petit 1999). Kahl et al (1985) reported that prothonotary warblers used stands with a canopy height of 16-20 m, extensive overstory canopy cover (50–75%), and sparse understory cover due to standing water. Prothonotary warblers may be an area-sensitive species that avoids forests that are <100 ha or riparian strips that are <30 m wide (Kahl et al 1985).

The objective of this study was to determine reproductive success of prothonotary warblers and examine habitat relationships in a fragmented forest at the western margin of the species' range.

METHODS

This study was conducted at Tishomingo National Wildlife Refuge (NWR) in south-central Oklahoma from April to July 2003.

Tishomingo NWR is 6,700 ha of fragmented landscape, which consists of bottomland hardwood stands with upland forest, wetlands, agricultural fields, and the Cumberland Pool of Lake Texoma. Prothonotary warblers were predominantly found in two small fragments on the north side of the refuge. The Sandy Creek site is 10–12 ha of willow (*Salix* spp.) and oak trees (*Quercus* spp.), which is periodically inundated with 0–1 m of water. The westernmost site consists of 4 ha of primarily buttonbush (*Cephalanthus occidentalis*) and dead hardwood trees with 0–1.5 m of water throughout the breeding season.

Twenty prothonotary warbler nest boxes were installed adjacent to standing water in April, and the remaining 20 boxes were placed >30 m from standing water (Petit 1989, Twedt and Henne–Kerr 2001). These early placement criteria had little biological meaning due to dramatically fluctuating water levels throughout the summer. Boxes were attached to metal posts and snake guards were installed after clutch completion (Blem and Blem 1991). Boxes were checked every 3–7 d until nesting was initiated (Martin and Geupel 1993). Nests were then checked more frequently to determine mean clutch size, number of eggs hatched, and number of young fledged per nest (Flaspohler 1996).

For each nest box, vegetation characteristics were quantified with a modified location-centered method (James and Shugart 1970, Larson and Bock 1986). Inside each 10 m radius circular plot, the following variables were measured: overstory height, midstory height, overstory canopy cover at the box, understory vegetation density 0–1.8 m (Nudds 1977), ground cover (i.e., percent water, bare ground, grass, forb, and woody vegetation), number of dead trees, total number of trees >5 cm diameter at breast height (dbh), number of trees 5-25 cm dbh, and number of trees >25 cm dbh were measured. Vegetation was also characterized at 40 random points within the study site for statistical comparison. Random points were selected using a random compass bearing and distance from each nest box.

Table 1. Reproductive parameters of prothonotary warbler (*Protonotaria citrea*) nests at Tishomingo National Wildlife Refuge, Oklahoma, from May–July 2003.

Parameter	Number of Nests	$\bar{x}$	SD	Range
Clutch size	40	4.4	0.9	3–6
Number hatched	36	4.0	1.2	1–6
Number fledged	35	3.9	1.2	1–6

Logistic regression with stepwise model selection was used to test two hypotheses: (1) that there were no differences in vegetation characteristics at successful nest boxes (i.e., fledged ≥1 young) compared to unsuccessful boxes that failed to produce ≥1 young due to infertile eggs, predation, or nestling mortality and (2) that there were no differences in vegetation characteristics at successful nest boxes compared to random points within stands with nest boxes. Thirty-five successful nests were recorded and five of the 40 random samples were randomly selected and omitted to make equal sample sizes for analysis.

RESULTS

Prothonotary warblers made 40 nesting attempts and 88% of all nests produced ≥1 fledgling / nest. Eighty-nine percent (24 / 27) of first nesting attempts produced ≥1 fledgling / nest, whereas 85% (11 / 13) of second nesting attempts produced ≥1 fledgling / nest; reproductive success was high throughout the nesting season (Table 1). Prothonotary warblers experienced a mean partial brood loss of 0.5 fledglings / nest. Nine nestlings died in the nest and 22 infertile eggs were recovered from nests. Seven nest boxes contained dummy prothonotary warbler nests and five nest boxes were not used by any avian species, although several

Table 2. Mean (± SD) of vegetation variables measured at successful (*n* = 35) and unsuccessful (*n* = 4) prothonotary warbler (*Protonotaria citrea*) nest boxes compared to random points (*n* = 35) at Tishomingo National Wildlife Refuge, Oklahoma, in 2003.

Vegetation Variable		Successful	Unsuccessful	Random
Overstory height (m)		13.4 ± 6.4	15.0 ± 3.9	14.1 ± 6.7
Midstory height (m)		3.5 ± 3.1	1.8 ± 2.4	4.2 ± 3.3
Overstory canopy cover (%)		61.5 ± 21.8	56.0 ± 26.1	60.1 ± 29.9
Understory vegetation density				
	0–0.3 m	35.5 ± 21.2	38.5 ± 19.4	28.1 ± 21.2
	0.3–0.6 m	34.9 ± 19.6	30.8 ± 14.6	26.5 ± 20.9
	0.6–0.9 m	36.9 ± 19.0	34.0 ± 22.5	31.6 ± 23.3
	0.9–1.2 m	44.6 ± 20.5	34.8 ± 18.2	34.8 ± 27.3
	1.2–1.5 m	59.9 ± 21.9	49.8 ± 21.8	49.2 ± 29.7
	1.5–1.8 m	70.9 ± 23.3	70.8 ± 30.5	64.9 ± 31.9
Percent of ground cover				
	Water	34.3 ± 27.8	35.0 ± 10.0	19.7 ± 30.5
	Bare ground	3.2 ± 8.3	3.8 ± 4.8	3.3 ± 9.4
	Grass	13.3 ± 17.1	20.0 ± 27.4	12.2 ± 16.0
	Forbs	31.5 ± 20.7	28.9 ± 16.5	37.4 ± 27.2
	Woody	15.9 ± 16.6	12.5 ± 8.7	27.4 ± 26.2
Number of dead trees		4.4 ± 8.3	1.3 ± 1.5	4.4 ± 5.5
Total number				
of trees >5 cm dbh	19.7 ± 17.4	18.0 ± 15.2	21.1 ± 15.2	
	# 5–25 cm dbh	16.6 ± 16.7	15.8 ± 13.6	17.5 ± 14.5
	# >25 cm dbh	3.1 ± 3.3	2.3 ± 1.9	3.6 ± 3.4

contained ants throughout the summer. Carolina chickadees (*Poecile carolinensis*) fledged five young from a nest box that prothonotary warblers never used.

Vegetation characteristics were similar in sampling plots around successful and unsuccessful prothonotary warbler nest boxes (Table 2). Stepwise model selection entered five variables (midstory height, overstory canopy cover, percent ground cover [water], and total number of trees) into a reduced model, but failed to produce a successful model ($F_{1,4}$ = 1.33, P = 0.86, R^2 = 0.033). The model was able to correctly classify 100% of successful prothonotary warbler nests; however, 0% of unsuccessful nests were correctly classified by the model.

Vegetation characteristics for successful nest boxes and random points were different in structure and composition (Table 2). Successful nest boxes had greater understory vegetation density and percent ground cover (water), whereas random points had greater percent ground cover (forbs, woody), number of trees, midstory height, and overstory height (Table 2). Stepwise model selection entered seven variables (overstory height, midstory height, overstory canopy cover, understory vegetation density 1.5–1.8 m, percent ground cover [water], number of dead trees, and number of trees) into the reduced model, which was moderately successful ($F_{1,6}$ = 17.01, P = 0.02, R^2 = 0.21). The model correctly classified

64% of successful nests and 67% of random points. Nest success was positively associated with increased percent ground cover (water) (Coefficient = 0.05, SE = 0.02), understory vegetation density (1.5–1.8 m; Coefficient = 0.04, SE = 0.02), and overstory canopy cover (Coefficient = 0.37, SE = 0.02).

DISCUSSION

Prothonotary warbler nest box use was high and 88% of all nests produced fledglings. Clutch size ($\bar{x}$ = 4.4) at Tishomingo NWR was similar to other clutch sizes throughout the species range (Flaspohler 1996, Petit 1999). Although partial brood loss occurred due to infertile eggs and mortality, prothonotary warblers fledged almost four juvenile warblers for each successful nesting attempt. Two nestlings and 16 adults banded in 2003 at Tishomingo NWR were recaptured in spring 2004 at the same sites, which corresponded to site fidelity documented for this species in other areas (Kowalski 1985). Prothonotary warbler nest boxes occurred in small landscape fragments (4–12 ha), but exhibited nest success comparable to sites with larger habitat fragments (Petit 1989, Flaspohler 1996). Kahl et al (1985) suggested that prothonotary warblers needed >100 ha to successfully nest and were an area-sensitive species. However, at Tishomingo NWR, they nested successfully and recapture rates indicate site fidelity by successfully nesting warblers. Thus, this species does not appear to be area-sensitive in the landscape context of Tishomingo NWR.

Vegetation characteristics at prothonotary warbler nest sites had high canopy height (13–15 m) with low midstory canopy height (2–4 m). Moderate canopy cover (56–62%), understory vegetation density (26–71%), forb density (29–37%) and standing water (20–35%) ground cover also typified most warbler nest sites. Kahl et al (1985) reported that prothonotary warblers used stands with a canopy height of 16-20 m with extensive canopy cover (50–75%) and sparse understory cover due to standing water. Nest sites at Tishomingo NWR had an overstory canopy height of 13–15 m and overstory canopy cover of 56–62%, which is similar to Kahl et al (1985). However, understory vegetation density and ground cover were denser at Tishomingo NWR than the sparse undercover story documented by Kahl et al (1985) in Missouri.

A logistic regression model failed to predict successful and unsuccessful nest outcomes based on vegetation characteristics. The model was able to predict successful nests (100%); however, it was unable to predict unsuccessful nests (0%). The small sample size of unsuccessful nests (n = 4) contributed to the deficiency of the model. A moderately successful model was developed that differentiated between successful nest sites and random points within the same stands: the model correctly predicted successful nests (64%) and random points (67%) based on a seven-variable model. Nest success was positively associated with increased percent ground cover (water), understory vegetation density (1.5–1.8 m), and overstory canopy cover. The presence of standing water and overstory canopy cover were important variables in determining prothonotary warbler nest success in this study, which was similar to Kahl et al (1985). However, at Tishomingo NWR, water levels fluctuated frequently throughout the breeding season due to increased water depth of the Cumberland Pool of Lake Texoma. This hydrology allowed dense understory vegetation to grow quickly that would not have occurred if standing water were present throughout the breeding season.

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