Prothonotary Warbler (*Protonotaria citrea*) Post-Flood Response at Tishomingo National Wildlife Refuge, Oklahoma

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In 2008, we studied Prothonotary Warbler (*Protonotaria citrea*) site fidelity and reproductive success following a 20-year flood event at the Tishomingo National Wildlife Refuge in south-central Oklahoma. We established an array of 77 nest boxes to determine if Prothonotary Warblers returned to previous nest sites or dispersed one year post-flood. Prothonotary Warblers demonstrated lower site fidelity than in previous years and dispersed an average of 697 m from previous years' nest sites. Post-flood reproductive success was comparable to pre-flood years. We concluded that Prothonotary Warblers demonstrated lower site fidelity due to flood damage, although some warblers did return within one km of their previous nest sites. Flood impacts on the landscape did not appear to negatively affect Prothonotary Warbler reproductive success.

INTRODUCTION

Prothonotary Warblers (*Protonotaria citrea)* are a Nearctic-Neotropical migrant that inhabit bottomland hardwood forest, riparian forest, and other wetland habitats (Petit 1999). Migration from their wintering grounds in Central and South America begins in March and they arrive in Oklahoma in early April (Dunn and Garrett 1997). Prothonotary Warblers use abandoned cavities excavated by primary cavity nesters such as Downy Woodpeckers (*Picoides pubescens*; Walkinshaw 1953) and are the only secondary-cavity nesting warbler in the east-central United States. Prothonotary Warblers also use nest boxes indicated by results in northern Virginia (Cartwright 1997), Tennessee (Petit 1989), Wisconsin (Flaspohler 1996), and Oklahoma (Wood 2004). Male Prothonotary Warblers arrive first on the nesting grounds to establish territories. Females arrive seven days after the males arrive and pair bonds are formed (Walkinshaw 1938). Once a pair bond is established, the nest is built by the female (Petit 1999). Nesting material consists of moss that fills the cavity space and a cup constructed from dead leaves and grasses nestled on top of the moss layer (Blem and Blem 1994). Once the nest is constructed, a clutch is initiated with one egg laid per day. Mean clutch size is three to seven eggs, although eight-egg clutches have been recorded (Wood 2007a). Eggs are then incubated for 12 to 14 days (Petit 1999). Once nestlings hatch, the parents remove shell fragments from the nest and begin feeding young (Petit 1999).

Extensive research was conducted in the eastern (Blem and Blem 1991), northern (Flaspohler 1996) and central (Petit 1989) regions of this species' range; however, limited research has been conducted in the western areas of the Prothonotary Warblers' range.

Wood (2004) investigated Prothonotary Warbler reproductive success in relation to microhabitat characteristics of nesting sites at the Tishomingo National Wildlife Refuge in Oklahoma. From 2003 to 2005, Prothonotary Warbler reproductive success was high. The mean fledgling rate per nesting season was 8.8 fledglings per female (Wood and Reasor 2006), whereas previous studies showed a slightly lower mean fledgling rate of 7.8 fledglings per female over a four-year period in the eastern United States (Petit and Petit 1996). Prothonotary Warbler site fidelity, recapture rates, recruitment and morphometrics (Wood and Reasor 2006; Wood 2007b) also were investigated. Female Prothonotary Warblers demonstrated nest site fidelity as shown by a 32% adult recapture rate (Wood and Reasor 2006). Prothonotary Warblers demonstrated a 3% recruitment rate of juveniles (Wood and Reasor 2006).

Prothonotary Warblers occupy habitats characterized by forests with shallow standing water, where major flooding events can occur (Blem and Blem 1991). We studied the impacts of a major flood event on a population of Prothonotary Warblers in south-central Oklahoma. Our research objectives included: 1) determine if Prothonotary Warblers returned to previous nest sites after a major flood event, 2) determine how far Prothonotary Warblers dispersed away from nest sites flooded in 2007, 3) determine how flooding affected inter- and intra-seasonal movements, and 4) determine if Prothonotary Warbler post-flood reproductive success in 2008 was different from pre-flood reproductive success from 2003 to 2006.

METHODS

Study Site

Tishomingo National Wildlife Refuge (TNWR) is a 6700-ha landscape composed of bottomland hardwoods, upland hardwoods, agricultural fields, and the 1821-ha Cumberland Pool of Lake Texoma. Due to sedimentation from the Washita River, the Cumberland Pool is now isolated from the main body of the lake except during flood events, making flood control its main purpose (Chappell and Fisher 2005). From May to July 2007, 96 cm of rain fell on southern Oklahoma, which raised the Cumberland Pool water level 7.3 m from a starting elevation of 188 m to 195.3 m. The resulting flood inundated and damaged nest boxes used in previous years.

Nest Box Placement

From 2003 to 2007, 40 nest boxes were used by Prothonotary Warblers at TNWR (Wood 2004). Beginning in mid–March, we replaced nest boxes that were destroyed by the 2007 flood. In some cases, nest boxes could not be replaced in the same location from previous years due flood debris. In these cases, nest boxes were placed as close to the original box location as possible. We added 37 new nest boxes throughout suitable habitat at TNWR to increase the probability of detecting dispersal as a post-flood response by Prothonotary Warblers.

Monitoring

Starting 1 April 2008, box checks were conducted every three to seven days to determine nesting activity (Martin and Geupel 1993). Boxes with nest starts (i.e., small amounts of nesting material in the bottom of the box) were checked more regularly to determine if the box was going to be used for egg laying or if it was a dummy nest. When eggs were laid, the box was checked every one to three days until clutch completion. Ten days after the final egg was laid, the box was checked daily to determine the number of eggs hatched.

Once hatching occurred, boxes were checked every one to three days until fledging, which was typically 11 days post–hatching. We recorded the number of successful fledglings and if any un-hatched eggs remained. Un-hatched eggs were removed from the nest after fledging and broken to determine whether they were infertile, or if incomplete incubation occurred (Wood and Reasor 2006).

Banding

Adult females were target captured at the nest box while incubating (Wood and Reasor 2006). Females were banded with a uniquely numbered size 0 band and then classified as either Second Year (SY) or After Second Year (ASY) based on plumage characteristics (Pyle 1997). Banding males was de-emphasized compared to previous years because of time constraints and low capture rates (Wood and Reasor 2006). If the bird was a recapture, we recorded the band number, nest box number, age, and morphometric measurements. Nestlings were banded and weighed approximately eight to ten days post hatching.

Georeferencing and GIS

We used a Garmin etrex global positioning system unit to mark all box locations in Universal Transverse Mercator units. We transferred this data into ArcMap Version 9.3 (ESRI, Redlands, California). We ground-truthed all box locations once they were projected and used ArcMap to accurately map inter- and intra-seasonal movement patterns and distance for new and recaptured Prothonotary Warblers.

Statistical Analysis

SPSS15.0 (SPSS Inc., Chicago, Illinois) software was used to obtain descriptive statistics (mean ± standard deviation [SD]) for reproductive success parameters such as clutch size, number hatched, and number of nests that fledged ≥1 young of SY and ASY females. Non-parametric Kruskal–Wallis H tests ($\alpha = 0.05$) were used because reproductive success data had small sample sizes and did not follow a normal distribution.

RESULTS

Banding

From 3rd May to 17th July 2008, we banded 23 new adult and 156 nestling Prothonotary Warblers. We banded 10 SY females and 11 ASY females using the hat trick method and two ASY males were captured in mist nets during nestling provisioning. The 156 nestlings were banded from 37 successful and one un-successful nest attempts. We recorded 42 total adult Prothonotary Warbler capture events in 2008. Nineteen ASY females of which eight were recaptured intra-seasonally, 10 SY females of which two were recaptured intra-seasonally, and three ASY males of which two were banded and one was an inter-seasonal recapture.

From 2003 to 2008, the overall recapture rate was 10% (73/725) for all Prothonotary Warblers banded at TNWR. The adult recapture rate was 36% (57/159) and the nestling recapture rate was 3% (16/566). In 2008, we documented 18 total Prothonotary Warbler recapture events, 14 ASY females including one which was caught on a third nest attempt, two SY females, and one ASY male. Eight of the recaptures (i.e., one seventh–year female, three fifth–year females, two fourth–year females, one after second–year female, and one after second–year male) were returning Prothonotary Warblers from previous years.

Inter-Seasonal Movement and Site Fidelity

We recorded eight inter-seasonal movements of seven ASY females and one ASY male. No female re-nested in the same nest box as pre-flood years. The average distance females relocated between pre- and post-flood years was 697 m (range = 99–2773 m). The ASY male returned to the same territory surrounding a nest box between pre- and post-flood years. Two ASY females recaptured in 2008 showed recruitment by returning to their natal site and successfully fledging young.

Intra-Seasonal Movement and Site Fidelity

We recorded 10 intra-seasonal recaptures of which eight re-nested in the same nest box as their first nest attempt. One of the eight females that re-nested made a third nest attempt, but was unsuccessful. The tenth recapture was a female that relocated

318 m to another box and successfully re-nested. The mean number of fledglings in first nest attempts for females that re-nested in the same box (4.3 ± 2.1 SD) was greater, but not statistically significant compared to the mean number of fledglings in second nest attempts in the same nest box (3.4 ± 1.5 SD; $\chi_1^2 = 2.79$, $P = 0.10$).

Nest Initiation

We observed two peaks in clutch initiation from 20th April to 31st May and from 1st June to 28th June. The first peak of 25 nest attempts was from 20th April to 31st May. During this time, the majority of nest attempts (n =16) in the first peak of the nesting season was during the two-week period of 20th April to 3rd May. The second peak of 21 nest attempts was from 1st June to 28th June. The majority of nest attempts (n = 10) in the second peak of the nesting season were during the week of 1st June to 7th June.

Reproductive Success

We monitored 77 Prothonotary Warbler nest boxes in 2008. Forty–two percent (32/77) of nest boxes were used for ≥1 nest attempt, whereas 58% (45/77) of nest boxes were not used by Prothonotary Warblers. Eighty percent (37/46) of Prothonotary Warbler nest attempts produced ≥1 fledgling per nest. For first nest attempts, 77% (24/31) were successful at fledging ≥1 nestling, whereas 93% (13/14) of second nest attempts produced ≥1 fledgling. One female attempted a third nest, but it failed due to raccoon (*Procyon lotor*) predation.

We calculated partial brood loss at hatching (PBLH= mean clutch size – mean number hatched) and at fledging (PBLF= mean number hatched – mean number fledged) for Prothonotary Warblers in 2008. $PBLH_{2008}$ (0.43) was greater than previous years, whereas $PBLF_{2008}$ (0.08) was lower than previous years (Table 1).

Un-hatched Eggs and Nest Loss

Ten infertile eggs and nine incompletely incubated eggs were recovered from 10 nests. Seven nests contained infertile eggs ranging from one to three eggs per nest and three nests contained incompletely incubated eggs ranging from one to four eggs per nest. A total of three nestlings died in two separate nest attempts by two different sets of parents. In one nest, cause specific mortality for one nestling appeared to be from inexperienced parenting, (i.e., fecal sacs were not removed from the nest) but the four remaining young successfully fledged. In a separate nesting attempt with five nestlings, two nestlings possibly died from a fungal infection from the attending male Prothonotary Warbler. Two nestlings from that same nest also possibly died from the fungal infection from the male but were removed from the nest box by the parents. The fifth nestling successfully fledged.

Table 1. Partial brood loss from clutch size to hatching (PBLH) and hatching to fledging (PBLF).

Year	*n*	PBLH	PBLF
2003	41	0.30	0.40
2004	60	0.15	0.20
2005	79	0.35	0.28
2006	67	0.17	0.28
2008	37	0.43	0.08

Age-related Reproductive Success Parameters

We compared SY and ASY female mean clutch size, number hatched and number fledged for all nest attempts with ≥1 fledgling. We were unable to capture nine females due to nest failure; therefore we excluded those nine in the comparison for all nest attempts between SY and ASY females for clutch size, number hatched, and number fledged. Of the 37 nest attempts by known age females, ASY mean clutch size (4.6 ± 0.8 SD) was not significantly greater than SY females (4.6 ± 0.9 SD; n = 38; $\chi_1^2 = 0.005$, P = 0.95). ASY female mean number hatched (4.4 ± 0.9 SD) was greater, but was not significantly greater than SY females (3.8 ± 1.5

SD; $n = 36$; $\chi_1^2 = 1.56$, $P = 0.2$). ASY mean number fledged (4.4 ± 0.9 SD) was greater, but not significantly greater than SY females (3.8 ± 1.5 SD; $n = 35$; $\chi_1^2 = 1.2$, $P = 0.3$).

Pre- and Post-Flood Reproductive Success

In 2008, Prothonotary Warblers had the second highest mean clutch size (4.7 ± 0.85 SD), second lowest mean number hatched (4.3 ± 1.20 SD), and second highest mean number fledged (4.19 ± 1.20 SD; Table 2) compared to 2003–2006 reproductive success parameters.

Nest Loss

During the 2008 nesting season, 20% (9/46) of all nest attempts failed. One nest with six nestlings was lost to Western Rat Snake (*Scotophis obsoletus*) predation. Floodwaters inundated two nest boxes, one with five nestlings and one with five eggs. Three nests, all with four eggs, were lost to raccoon predation. Two nests failed, one with four intact eggs and one with three intact eggs, due to the nest box falling and parental abandonment. One nest with four eggs was abandoned for unknown reasons.

Inter-specific Nest Box Kleptoparasitism

After the nest lost to Western Rat Snake predation, a female Carolina Wren (*Thryothorus ludovicianus*) added new nest material and laid four eggs. This nest also was unsuccessful due to Western Rat Snake predation. In a different box, a Tufted Titmouse (*Baeolophus bicolor*) laid three eggs and successfully fledged two young. This is the first documented successful nest attempt by a Tufted Titmouse in a Prothonotary Warbler nest box at TNWR.

DISCUSSION

Banding

Compared to previous years, the total number of adults banded (23) was the fifth lowest, but the number of nestlings banded was the second highest since the research began in 2003 (Table 3). Altogether, 179 total Prothonotary Warblers were banded which was the second highest number since research began in 2003. The decrease in number of adults banded could be an indicator of post-flood dispersal in that Prothonotary Warblers were avoiding nesting sites that were inundated in 2007 because the habitat quality surrounding previous nest sites was degraded. In 2008, one female Prothonotary Warbler moved 3 km from her previous nest site to nest. We also suggest that the lower number of adult Prothonotary Warblers banded in 2007 was because nest sites were destroyed and displaced adults. As adults became floaters (birds without territories that move through the landscape looking for open territories), they may have been more vulnerable to predation.

The increased number of nestlings in 2008 could be due to an increased number of nest boxes available to females. Another reason for the increased number of nestlings could be the increased insect availability for nestling provisioning. Increased piles of

Table 2. Comparison of Prothonotary Warbler pre- and post-flood reproductive success parameters (mean ± SD) for nests that fledged ≥1 young.

Year	*n*	Clutch Size	Number Hatched	Number Fledged
2003	41	4.50 ± 0.12	4.20 ± 0.14	3.80 ± 0.18
2004	60	4.65 ± 0.12	4.50 ± 0.17	4.30 ± 0.21
2005	79	4.75 ± 0.09	4.40 ± 0.13	4.12 ± 0.16
2006	67	4.45 ± 0.13	4.28 ± 0.20	4.00 ± 0.26
2008	37	4.70 ± 0.85	4.27 ± 1.20	4.19 ± 1.20

Table 3. Number of adult and nestling Prothonotary Warblers banded annually at Tishomingo National Wildlife Refuge.

Year	Adults	Nestlings	Total
2003	36	132	168
2004	39	137	176
2005	57	197	254
2006	25	100	125
2007	2	0	2
2008	23	156	179
Total	180	722	902

driftwood and isolated pools of water provided increased breeding ground for insects which may have increased prey availability for Prothonotary Warblers.

Seventy–three percent of all SY females were captured and banded in the new study sites included in our research. This could be an indicator that SY females are inexperienced or not as physically competitive with ASY females for prime nesting sites. Or SY females may have followed ASY females that dispersed to new areas in 2008.

Recapture Rates

From 2003 to 2008, the overall recapture rate for Prothonotary Warblers at TNWR was 10%. The adult recapture rate was 36%, which was comparable to other documented recapture rates. In Virginia, a 47.9% recapture rate of female Prothonotary Warblers was documented (Blem and others 1999). Kowalski (1985) reported a 57% recapture rate of male Prothonotary Warblers in Indiana and Kleen (1973) reported a 93% male recapture rate in Illinois.

In the 2008 nesting season, we had 19 recapture events. We recaptured eight returning adult Prothonotary Warblers during the 2008 nesting season. This was the second lowest returning adult recapture rate, the lowest being in 2003 during the first year of study (Wood and Reasor 2006). In 2008, numbers could be low because returning Prothonotary Warblers dispersed into areas outside the study site or used natural cavities unable to be monitored. We concluded that the lower recapture rate was due to post-flood dispersal and avoidance of the study site. Some females did return to their pre-flood sites, but not as precisely as in previous years (Wood and Reasor 2006). The remaining 10 recapture events were intra-seasonal captures of females attempting a second nest and the last recapture event was a female attempting a third nest. This was the second lowest recapture rate since 2003.

Inter- and Intra-Seasonal Movement

From 2003 to 2006, both male and female Prothonotary Warblers moved an average of 300 m between seasons (Wood and Reasor 2006). Petit (1999) reported a mean distance of 203 m moved by females and 48 m moved by males between subsequent years. Post-flood, female Prothonotary Warblers moved an average of 697 m. The mean distance moved was two times greater than between pre- and post-flood years, indicating an aversion response by Prothonotary Warblers to the previous years' nest sites.

In 2008, no Prothonotary Warbler females re-nested in the same nest box as previous years; whereas from 2003 to 2006, 35% of female Prothonotary Warblers returned to the same nest box between years (Wood and Reasor 2006). Because no Prothonotary Warblers returned to the same nest box in 2008 at TNWR, this showed a negative post-flood response by Prothonotary Warblers.

From 2003 to 2006, most intra-seasonal movements were made by female Prothonotary Warblers after their first nest attempt had failed due to raccoon or snake predation (Wood and Reasor 2006). In 2008, only one female made an intra-seasonal move between successive nest attempts at TNWR. She moved had a successful first nest and fledged four young, but she moved 318 m for her second nest attempt where she fledged three young. This distance is greater than the average of 271 m intra-seasonal movements by female Prothonotary Warblers at TNWR from 2003 to 2006 (Wood and Reasor 2006). Petit (1999) reported an

average distance moved between successive nest attempts in Tennessee of 40 m with the longest move being 300 m.

Site Fidelity and Dispersal

Floodwaters in 2007 inundated all previous Prothonotary Warbler nest sites at TNWR. Prothonotary Warblers are known from previous studies to show strong site fidelity (Petit 1999) and at TNWR 76%, of all female Prothonotary Warblers banded have been recaptured (Wood and Reasor 2006). Although no female re-nested in the same nest box as a pre-flood location, six females returned within an average of 351 m (range 99–612 m) to nest post-flood. This is comparable to previous years' distance of approximately 300 m (Wood and Reasor 2006). One male returned to the same territory between pre- and post-flood years. He was captured in 2006 in a mist nest and was recaptured in 2008 within 50 m of the original 2006 location. This coincides with Petit (1999) where 71% of males returned within 50 m of their previous years' territories in Tennessee. This indicates general site fidelity with some females returning for a seventh nesting season.

The longest inter-seasonal move at TNWR in pre-flood years was 1000 m (Wood and Reasor 2006). In 2008, one female dispersed 3 km from her pre-flood nest site. In combination with low recapture rates, this indicated the 2007 flood negatively influenced Prothonotary Warbler site fidelity post-flood. Other banded Prothonotary Warblers may have returned to the general area, but were not captured because they nested outside the study area.

Reproductive Success

In 2008, 42% of all nest boxes were used for $\geq$1 nesting attempt and 80% of all Prothonotary Warbler nest attempts produced fledglings. Peak nesting activity during mid to late April at TNWR for first broods was the same as that described by Walkinshaw (1941) and Petit (1989) in Tennessee and Blem and Blem (1992) in Virginia. Peak nesting activity for second nests at TNWR was during the first week of June, which was earlier than those described by Walkinshaw (1941) and Petit (1999). Infertile eggs and chick mortality created partial brood loss, but PBLF was lower than previous years. Forty–five percent of females attempted a second nest after a successful first nest and 93% of those successfully raised two broods. Petit (1999) reported that 45–77% of female Prothonotary Warblers in Tennessee attempted a second nest after a successful first nest and approximately 50% of those successfully raised two broods.

Mean clutch size was the second highest since research was initiated in 2003 (Wood and Reasor 2006). This is similar to mean clutch sizes (range 4.3–5.0 eggs) in Wisconsin (Flaspohler 1996), Virginia (Blem and Blem 1992), Michigan (Walkinshaw 1941) and Tennessee (Petit 1989). The mean number hatched was the second lowest since research began in 2003 (Wood and Reasor 2006). This is similar to the 4.3 mean number of Prothonotary Warblers hatched in Tennessee (Petit 1989).

From 2003 to 2006, female Prothonotary Warblers attempted an average of 2.7 nests and the mean fledgling rate per nesting season was 8.8 per female (Wood and Reasor 2006). For 2008, the mean fledgling rate was 4.2 per female with an average of 1.4 nesting attempts. This is less than the pre-flood fledgling rate, but greater than the 7.8 young per female in Tennessee reported by Petit and Petit (1996).

Age Related Reproductive Success and Nest Loss

Comparisons between SY and ASY female reproductive success showed that ASY females had a greater clutch size, number hatched and number fledged than SY females, but were not statistically significantly different. In 2008, predation events by a Western Rat Snake, raccoons, inundation of two nest boxes and boxes falling resulted in a 20% nest loss rate at TNWR. This is relatively low with only nine nests lost during

the 2008 nesting season. This is lower than other reported nests loss rates such as 21% in Tennessee (Petit 1989) and 28% in Wisconsin (Flaspohler 1996). Predation of eggs and nestlings by rat snakes and raccoons were also common in Wisconsin (Walkinshaw 1938, 1953), Iowa (Brush 1994), and Tennessee (Petit 1989).

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