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Ornithological Methods

A flood-resistant nest box for wetland-dependent secondary cavity-nesting birds

Una caja nido resistente a inundaciones para aves que anidan en cavidades secundarias y dependen de humedales

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ABSTRACT. Artificial nest boxes are an important tool for studying the breeding biology of birds. Additionally, they can provide valuable nest sites for secondary cavity-nesting birds when they are limited, but despite these potential benefits, if poorly constructed or placed, artificial cavities may act as ecological traps. The Prothonotary Warbler (*Protonotaria citrea*) is a wetland-dependent secondary cavity-nesting bird that prefers to nest over water and as a consequence, its nests are vulnerable to flooding. The Prothonotary Warbler has declined by 38% in the past 50 years and floods are becoming more frequent with the changing climate making this species more susceptible to nest loss from flooding. Nest boxes mounted at heights of 1.5 m to maximize ease of sampling by researchers are prone to inundation even in moderate flood conditions. Here, we describe a novel design for a flood-resistant nest box that provides both convenient access for researchers and a safe location for Prothonotary Warblers above most flood waters. Our nest box is made of polyvinyl chloride ("PVC") and is attached to a 3 m electrical conduit pole. The box is attached to the pole allowing it to be elevated with paracord safely above flood waters and then lowered to the check nest contents. We began using these nests boxes in 2018 and they remained above flood waters in 2018 and 2023, but they were submerged during the historic flood of the Mississippi River in 2019, which crested at a record high level. Our flood-resistant nest box is ideal for researchers studying the breeding biology of secondary cavity-nesting birds that nest near water.

RESUMEN. Las cajas nido artificiales son una herramienta importante para estudiar la biología reproductiva de las aves. Además, pueden proporcionar valiosos sitios de anidación para aves que anidan en cavidades secundarias cuando estos sitios son escasos. Sin embargo, a pesar de estos beneficios potenciales, si están mal construidas o ubicadas, las cavidades artificiales pueden actuar como trampas ecológicas. El chipe dorado (*Protonotaria citrea*) es un ave que anida en cavidades secundarias y depende de humedales, que prefiere anidar sobre el agua y, en consecuencia, sus nidos son vulnerables a las inundaciones. Sus poblaciones han disminuido un 38 % en los últimos 50 años, y las inundaciones son cada vez más frecuentes debido al cambio climático, lo que hace que esta especie sea más susceptible a la pérdida de nidos por inundaciones. Las cajas nido instaladas a una altura de 1,5 m para facilitar el muestreo por parte de los investigadores son propensas a inundarse incluso en condiciones de inundación moderadas. Aquí describimos un diseño novedoso para una caja nido resistente a inundaciones que proporciona un acceso conveniente para los investigadores y un lugar seguro para los chipes dorados por encima de la mayoría de los niveles de inundación. Nuestra caja nido está hecha de cloruro de polivinilo (PVC) y se fija a un poste de conducto eléctrico de 3 m. La caja se sujeta al poste, de manera que permite ser elevada mediante una cuerda de paracaidista de forma segura por encima de las aguas de inundación y luego bajarla para revisar el contenido del nido. Comenzamos a usar estas cajas nido en 2018 y permanecieron por encima de las aguas de inundación en 2018 y 2023, pero quedaron sumergidas durante la histórica crecida del río Misisipi en 2019, que alcanzó un nivel récord. Nuestra caja nido resistente a inundaciones es ideal para investigadores que estudian la biología reproductiva de aves que anidan en cavidades secundarias cerca del agua.

Key Words: *cavity nests; flood; nest box design; Prothonotary Warbler; Protonotaria citrea*

INTRODUCTION

Artificial nest boxes are valuable for researchers studying the breeding biology of birds because they are easily accessible and amenable to experimental manipulation (Hoover and Robinson 2007, Aitken and Martin 2008, Lambrechts et al. 2010, Sudyka et al. 2022). Nest boxes also allow mounting of equipment such as cameras and Radio Frequency Identification (RFID) readers to collect behavioral data that would otherwise be difficult to obtain (Zárybnická et al. 2015, Bridge et al. 2019). In addition to providing convenient sampling, nest boxes increase the availability of nest sites for secondary cavity-nesting birds, which unlike primary cavity-nesting species, cannot excavate their own nest cavities. These sites can be limited, which can lead to intense competition within species and between cavity-nesting species (Newton 1994, Potti et al. 2021, Scerbicke et al. 2024). The use of artificial nest boxes can help alleviate this competition and can benefit the populations of many species (Purcell et al. 1997, Lambrechts et al. 2010, Brazill-Boast et al. 2013, Gowaty and Plissner 2015, Raleigh et al. 2019). Overall, the use of nest boxes has significantly increased our knowledge of the breeding biology of secondary cavity-nesting birds (Lambrechts et al. 2010).

Despite the advantages of using nest boxes, there can also be negative effects (reviewed in Lambrechts et al. 2010, Zhang et al. 2023). Target species may not benefit from nest boxes (Stojanovic et al. 2021), and in some cases, they can serve as ecological traps.

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Fig. 1. A standard wooden nest box mounted on a 1.5-m pole at our study site in Scott County, Iowa.

For example, nest boxes placed in open habitats for Wood Ducks (*Aix sponsa*) had higher rates of conspecific brood parasitism than those in wooded areas (Semel and Sherman 2001). Although nest boxes increased the number of breeding Common Goldeneyes (*Bucephala clangula*), the number of fledglings in the population did not increase because of density-dependent effects (Pöysä and Pöysä 2002). Great Tits (*Parus major*) provided with a choice of cavities chose the largest, which resulted in lower fledging success (Demeyrier et al. 2016), and Blue Tits (*Cyanistes caeruleus*) had lower fledging rates in nest boxes compared to natural cavities (Sudyka et al. 2022). Great Tits also experienced reduced reproductive success when nest boxes increased breeding density beyond optimal levels (Mänd et al. 2005) and attracted birds to lower quality habitat (Krams et al. 2021).

Nest box placement is often designed for ease of access by researchers (Sudyka et al. 2022). However, some species prefer higher cavities likely because it provides greater safety from predators (Nilsson 1984, Svensson 1991, Serrano et al. 2017, Zhang et al. 2021). Researchers in Europe also tend to mount nest boxes higher than researchers in North America for this reason (range 1.5 to > 3 m, 1.5–2.5m, respectively; Lambrechts et al. 2010). Boxes mounted at heights optimized for convenience sampling (1.5 m) can be problematic for species that nest in habitat that is frequently flooded (Walkinshaw 1938, Diggs and Wood 2009) and may serve as an ecological trap because many species appear to prefer nest boxes over natural cavities (Drent 1984, Drilling and Thompson 1988).

The Prothonotary Warbler (*Protonotaria citrea*) is one of two New World warblers that nest inside of cavities. They prefer nests located over water (Petit et al. 1987, but see Mueller et al. 2019) and nest boxes to natural cavities (Petit and Petit 1996). Prothonotary Warbler nests located in natural cavities range from 0.5 m above water to 6.0 m above ground (Walkinshaw 1938, Brown 2001) and predation rates are lower when nests are located over deep water (Hoover 2006). Nest boxes for Prothonotary Warblers are typically mounted approximately 1.5 m above water and are consequently submerged during floods, a common occurrence in the floodplains and wetlands where this species breeds, resulting in the loss of all eggs and nestlings (Walkinshaw 1938, Flaspohler 1996).

Fig. 2. A flood resistant PVC nest box designed to be elevated above potential flood waters at our study site in Scott County, Iowa. It is mounted on a 3 m electrical conduit pole.

The Prothonotary Warbler was recently listed as a species of conservation concern because of a 38% decline in the past 50 years (Rosenberg et al. 2016); therefore, placement of nest boxes to benefit the population of this species should be done above potential floodwaters, otherwise these nest sites could become an ecological trap. Here, we describe a novel nest box design that resists flooding while maintaining easy access for researchers and report the flooding rates of standard versus modified boxes.

METHODS

Study site and nest monitoring

Our research on Prothonotary Warblers was conducted at the Princeton Wildlife Management Area north of Princeton, Iowa (41°72′46″ N, 90°34′59″ W) along the Mississippi and Wapsinicon River floodplains. The area consists of a wetland complex surrounded by oak-hickory forest with floodplain species including silver maple (*Acer saccharinum*) and eastern cottonwood (*Populus deltoides*). In 2017, we used standard wooden nest boxes mounted on 1.5 m electrical conduit (Fig. 1). In 2018, we developed the flood-resistant nest box and used this design from 2018 to 2023 (Fig. 2). In addition to Prothonotary Warblers, the nest boxes were occupied by Northern House Wrens (*Troglodytes aedon*) and Tree Swallows (*Tachycineta bicolor*; Scerbicke et al. 2024).

Fig. 3. A flood resistant PVC nest box showing the individual pieces before assembly. The body is a PVC sewer pipe that is approximately 18 cm long and 10.1 cm wide. A PVC cap is glued to the bottom and the top consists of a cleanout plug screwed into a cleanout adapter. The adapter is unscrewed to check the nest contents and for cleaning.

Fig. 4. A flood resistant PVC nest box attached to the electrical conduit pole showing the paracord attached to the screw-eye hook on top of the nest box. The nest box is raised above potential flood waters and then lowered to check the nest contents using the paracord.

Nests were monitored every 1–3 days during the breeding season (May–July), but Northern House Wren and Tree Swallow nests were not monitored with the same frequency because they were not our focal species. Nests were considered flooded when the water reached the level of the nest box and the contents became inundated. All nests that remained above water fledged young unless they were usurped by other species, which we have previously documented (Scerbicke et al. 2024). We only report data for years that our study site was flooded (2017–2019, and 2023) and for our focal species, the Prothonotary Warbler because the objective of the study was to determine whether the nest boxes remained above the water. Last, we compiled historical data from the U.S. Army Corps of Engineers (2024) on flooding rates by decade from 1880 to 2019 at the nearest monitoring station on the Mississippi River (Lock and Dam 15, Rock Island, Illinois).

Nest box design

The concept behind our flood-resistant nest box is one that allows researchers to easily check the nest contents and to position the nest box above potential flood waters. Our system was inspired by Purple Martin (*Progne subis*) houses mounted on telescoping poles that permit the houses to be lowered for cleaning (Ray 2012, Anderson and Hvenegaard 2021). The flood resistant nest box is cylindrical and made of polyvinyl chloride (hereafter PVC) sewer pipe and mounted on a 3-m piece of 1.27 cm wide electrical conduit (Fig. 2; see Table A1.1 in Appendix 1 for the components used in construction). The box is 10.1 cm wide and approximately 18 cm long. The area of the base is 80.1cm^2 and the volume of the box is 1442 cm^3. The bottom is a PVC cap secured to the box with PVC glue (Fig. 3). The top is a PVC cleanout plug screwed into a cleanout adapter with a female connector that is attached to the top of the box with PVC glue (Fig. 3). The cleanout plug can be unscrewed to check the nest contents and to clean the inside of the nest boxes.

A screw-eye hook is inserted into the top of the cleanout plug, and paracord is tied to the hook (Fig. 4) and passed through a ring attached to a conduit hanger mounted at the top of the conduit pole (Fig. 5). The conduit pole is inserted 15–25 cm into the ground. The box is secured to the electrical conduit pole using conduit straps loosely attached to the pole to allow free movement

Fig. 5. A conduit hangar is attached at the top of the electrical conduit pole and has a ring through which the paracord is pulled up and down to check the nest box contents and then to return it to its resting location at the top of the electrical conduit pole.

Fig. 6. The rear side of the flood resistant PVC nest box showing the nest box mounted onto the electrical conduit pole with conduit straps.

of the box up and down the pole (Fig. 6). If the straps are screwed too tightly, the box will not move freely. The box is raised to its elevated position by pulling the paracord down and it is secured to a screw drilled into the conduit. The nest box is lowered to check the contents and then returned to the top of the pole. The weight of the boxes is supported entirely by the paracord and we have never had to replace paracord because of wear since we began using this nest box design.

Both the PVC and wooden nest boxes were placed over water or in cases of deep water, placed immediately adjacent to the water. During drought conditions, some boxes were located above dry land as the water receded. Wooden boxes were mounted at the top of 1.5 m pieces of conduit and the PVC boxes were raised to the top of 3 m conduit. The distance between nest boxes and the water varied depending on the depth of the water in which they were placed.

RESULTS

Flooding affected most nests when standard wooden boxes were used but was largely prevented by flood-resistant PVC boxes except during the record flood of 2019 (Table 1). In 2017, when wooden boxes were mounted on 1.5-m conduit, 81.2% of Prothonotary Warbler nests were flooded during a late-May crest of the Mississippi River (Table 1). In contrast, none of the flood-resistant PVC boxes flooded in 2018 or 2023 despite major flood events (Table 1). However, during the record 2019 flood, when the Mississippi River reached its highest level on record at Lock and Dam 15, all accessible flood-resistant boxes were submerged.

DISCUSSION

Our flood-resistant nest box design provided a safe location above flood waters in most years for the Prothonotary Warbler. After we began using our nest boxes mounted on 3-m poles, they remained above flood waters in 2018 and 2023, the latter of which was 7th highest recorded crest of the Mississippi River at our study location. However, our nest boxes could not withstand the highest recorded crest of the Mississippi River in 2019. Thus, while our boxes are not "flood proof," they can withstand flooding to a much greater extent than standard nest boxes that are typically mounted at 1.5 m and were inundated during moderate flooding that occurred at our site in 2017 and 2018. Nest loss from flooding is a common occurrence in studies of Prothonotary Warblers (Walkinshaw 1938, Flaspohler 1996, Diggs and Wood 2009) and could create an ecological trap for birds in nest boxes that are not mounted high enough to withstand high water. The standard nest

Table 1. Flooding outcomes for nest boxes at our study site in Scott County, Iowa by year and box type, including the percentage of nests flooded (sample size in parentheses), maximum flood depth recorded for the Mississippi River at the Rock Island Lock and Dam 15, and the historical crest ranking for that flood event (U.S. Army Corps of Engineers 2024).

Year	Nest box type	Percent of nests flooded (n)	Maximum flood depth	Record crest level
2017	Standard wooden	81.2 (48)	5.2 m	34th highest
2018	Flood resistant PVC	0 (30)	5.3 m	28th highest
2019	Flood resistant PVC	100 (50)	6.92 m	1st highest
2023	Flood resistant PVC	0 (80)	6.6 m	7th highest

boxes used in North America are mounted low enough to maximize researcher access, whereas our modified pulley system provides researchers with sampling convenience in addition to a safe location for birds to nest above most floodwaters in our region. Prothonotary Warblers also appear to prefer nests that are higher than 1.5 m (Walkinshaw 1938, Brown 2001). Not only are our nest boxes beneficial for birds nesting near water, but they are also useful for species that prefer to nest higher than 1.5 m in habitats not inundated by water (Lambrechts et al. 2010).

Prothonotary Warblers have declined by 38% in the past 50 years and they were subsequently listed as a species of conservation concern in 2016 (Rosenberg et al. 2016). It is therefore critical for researchers and wildlife managers to mount nest boxes high enough to withstand potential flood waters, otherwise this could lead to significant nest losses. Moreover, Prothonotary Warblers are at a greater risk of nest failure from flooding caused by climate change. The warming climate appears to be associated with an increased frequency of flooding in some regions including portions of the Mississippi River (Chris and Luo 2017, but see Alifu et al. 2022) where much of the Prothonotary Warbler population is located in the northwestern periphery of its range (Flaspohler 1996, Fink et al. 2023, Scerbicke et al. 2024). Indeed, flooding at our study site along the Mississippi River has increased dramatically over the past three decades (Fig. A1.1). From 1880 to 2019, there were 1010 days in which the Mississippi River was at flood stage. Fifty-nine percent of those days occurred in the past three decades and the decade from 2010 to 2019 had the most at 356 days above flood stage. Providing Prothonotary Warblers with nest sites above floodwaters has never been more important and our novel nest box design can provide them and any other secondary cavity-nesting birds nesting near water with a safe nest location above floodwaters in most years. Future studies should evaluate the effectiveness of these flood resistant nest boxes by comparing occupancy rates and breeding success to traditional nest boxes.

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Data Availability:

All relevant data are contained within the manuscript.

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Appendix

Table. A1.1. Components used to construct the flood resistant nest box.

Item	Brand, part #	Price/ unit	Website
PVC sewer pipe (4” x 10’)	PVC 30040 0600HC	26.31	https://www.lowes.com/pd/4-in-x-10-ft-Sewer-Drain-PVC-Pipe/3133147
PVC sewer and drain cap (4”)	NDS 4P06	3.67	https://www.lowes.com/pd/PVC-4-in-dia-PVC-Cap-Fitting/3133139
PVC sewer and drain female cleanout adapter (4”)	NDS 4P11	7.88	https://www.lowes.com/pd/NDS-4-in-PVC-Sewer-and-Drain-Female-Adapter/3133119
PVC male plug (4”)	Charlotte Pipe, PVC 00106 1200	7.08	https://www.lowes.com/pd/Charlotte-Pipe-4-in-x-4-in-dia-PVC-Schedule-40-Male-Cleanout-Plug-Fitting/3132725
Clear PVC cement	Oatey 31018L	8.18	https://www.lowes.com/pd/Oatey-Medium-8-fl-oz-Clear-PVC-Cement/4750803
Silver EMT Conduit (1/2” x 10’)	101543	5.28	https://www.lowes.com/pd/Common-1-2-in-Actual-50-In-Metallic-Emt-10-ft-Conduit/3129551
Electrical (EMT) Zinc-plated steel conduit hangers (1/2”)	Sigma ProConnex 54100	0.60	https://www.lowes.com/pd/Sigma-Electric-ProConnex-1-2-in-Conduit-Hangers-Schedule-40-PVC-Compatible-Schedule-80-PVC-Compatible-Intermediate-Metal-Conduit-Compatible-Galvanized-Rigid-Conduit-Compatible-Electrical-Metal-Tubing-Compatible-Rigid-Metal-Conduit-Compatible-Conduit-Fitting/1001588532
Electrical (EMT) / Zinc-plated steel two-hole strap conduit fittings (3/4”)	Sigma ProConnex 42820	0.56	https://www.lowes.com/pd/Sigma-Electric-ProConnex-3-4-in-Two-hole-Strap-Electrical-Metal-Tubing-Compatible-Conduit-Fitting/1000152723
Zinc-plated screw eye hook (1/8” x 1.5”)	Everbilt	0.16	https://www.homedepot.com/p/Everbilt-Screw-Eye-1-8-in-x-1-1-2-in-Z-CP-813362/314745396
Self-tapping lath screws (8 x 1.25”)	ProTwistNMT1141	0.09	https://www.lowes.com/pd/Pro-Twist-8-x-1-1-4-in-Truss-Sharp-Lath-Screws-Pound-S/1000365329
Paracord (4mm x 200’)	Teceum B0BJHPJJ3D	15.19	https://www.amazon.com/dp/B0BJHPJJ3D/ref=dp_iou_view_item?ie=UTF8&th=1
O Rings (1.25”)	DGOL B094J3M9S4	0.48	https://www.amazon.com/dp/B094J3M9S4?ref_=ppx_hzsearch_conn_dt_b_fed_asin_title_1&th=1

Fig. A1.1. Days in which the Mississippi River was above flood stage (4.57 m) by decade from 1880 through 2019 at Lock and Dam 15, Rock Island, IL.