12-1-2024

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Recommended Citation

Miranda, K., Ringelman, K., & Bakner, D. (2024). Nest box-mounted PIT tag readers reveal cryptic recruits of cavity-nesting waterfowl in south Louisiana. *Scientific Reports, 14* (1) https://doi.org/10.1038/s41598-024-75460-8 scientific reports

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Nest box-mounted PIT tag readers reveal cryptic recruits of cavity-nesting waterfowl in south Louisiana

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Black-bellied Whistling-Ducks (*Dendrocygna autumnalis;* BBWD) are rapidly expanding northward into the core range of the eastern Wood Duck (*Aix sponsa*; WODU), yet little is known about BBWD nesting ecology. Typical field methods to study cavity-nesting waterfowl (i.e., weekly nest monitoring) preclude a full understanding of important breeding information, including nest prospecting and parasitic egg laying. To address this, we used subcutaneous passive integrated transponder (PIT) tags embedded in adults and PIT tag readers mounted on nest boxes with the objective to (1) identify individuals that used nest boxes but were not physically captured on a nest, (2) quantify box visitation, and (3) quantify BBWD pair and WODU hen behaviors during the prospecting, laying, and incubation periods. We deployed RFID readers on 40 nest boxes from March–December 2022 in Louisiana with the potential to detect BBWD and WODU marked with PIT tags in 2020–2022. We detected 48 (BBWD $n = 26$, WODU $n = 22$) adults of both species via RFID readers, and 33% ($n = 16$) of individuals (50% of BBWD, $n = 12$; 14% of WODU, $n = 3$) were never otherwise recaptured in 2022, meaning that traditional field methods for cavity-nesting waterfowl fail to document a substantial number of birds potentially contributing to the population via parasitism. We also used Bayesian generalized linear models to determine that both species visited a similar number of "new" (< 1 year old) and "old" (> 1 year old) nest boxes ($\beta = 0.66$, CI = -0.30, 1.64). However, BBWD preferentially visited (and subsequently nested in) old boxes at a significantly higher rate than WODU ($\beta = 1.32$, CI = 0.97, 1.66). Due to the generalist nature and rapid expansion of BBWD, an apparent aversion to newly installed boxes was unexpected, especially since there were several successful WODU nests in the new boxes before BBWD began nesting in 2022. Our study is one of the first to evaluate BBWD nesting behaviors within the core WODU breeding range, and the first to use nest box-mounted PIT tag readers to observe BBWD behavior.

North American ducks are a model system in avian ecology and conservation, and most species have benefitted from decades of careful research[1]. However, there is astonishingly little known about the ecology of Black-bellied Whistling-Ducks (*Dendrocygna autumnalis*; hereafter, BBWD), likely because they have only recently become abundant in some parts of the southern United States[2]. BBWD historically occurred throughout Central and South America, with the northernmost breeding population occurring in south Texas, and most published studies are from south Texas populations in the 1970s. However, BBWD began rapidly expanding their range northward in the late 20th century[2], with stable breeding populations now common throughout the southeast, extending as far north as Memphis, Tennessee[2] and wandering individuals observed as far north as Newfoundland[3]. Despite this range expansion, there has been very little research on BBWD ecology outside of south Texas[4,5].

As generalists, BBWD can thrive in a wide variety of environments, especially in urban and agricultural settings, which has certainly contributed to their range expansion[2]. BBWD are unusual among ducks in that both sexes incubate the nest, and they are facultative secondary cavity-nesters, with nests documented in natural cavities, manmade nest boxes, and on the ground[6–9]. As predominately cavity nesters, the expansion of BBWD into the core breeding range of Wood Ducks (*Aix sponsa*; hereafter, WODU) is potentially of management concern for myriad reasons, including competition for nest sites[10] in areas where breeding phenology of both species overlaps[4,11]. In addition, both conspecific[12–14] and interspecific[4,15,16] nest parasitism have been documented in

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BBWD, including parasitism of WODU nests[4,7], which has the potential to affect WODU reproductive success negatively by increasing nest abandonment and decreasing egg hatchability[17,18].

Traditional field methods used to study cavity-nesting waterfowl involve capturing and banding the incubating adult (both sexes in the case of BBWD) and collecting nest information such as clutch size, nest age, and apparent nest parasitism at regular (i.e., weekly) intervals. Because observations are only made at discrete intervals throughout the nesting period, these methods fail to capture potentially important breeding information, such as nest prospecting behavior, parasitic egg laying behavior, identification of nest attempts that fail before they are discovered (e.g., a predator removes all the eggs), and the presence of non-incubating individuals (i.e., individuals that visit nest boxes and/or lay eggs but do not incubate them) in the population. Crucially, non-incubating individuals may be more likely to be yearlings[19], and therefore failure to document those individuals returning as potentially breeding adults would bias estimates of duckling recruitment, which is the most important demographic parameter in estimating WODU population growth rates[20].

Here, we used radio frequency identification (RFID) readers mounted on nest boxes to quantify breeding behaviors of BBWD and WODU marked with passive integrated transponder (PIT) tags. These RFID readers continuously monitor and record each time a PIT-tagged individual enters or leaves the nest box, potentially capturing information not acquired by traditional periodic nest monitoring. Our objectives were to (1) identify individuals that used nest boxes but were not physically captured on a nest, (2) quantify box visitation, and (3) quantify and compare BBWD pair and WODU hen behaviors during the prospecting, laying, and incubation periods.

Methods

Study site

We monitored nest boxes installed by the Louisiana Department of Wildlife and Fisheries (LDWF) primarily for WODU use, although BBWD frequently nest in them. These nest boxes were located in Iberville Parish, Louisiana, on the Atchafalaya National Wildlife Refuge at two sections of Sherburne Wildlife Management Area known as “North Farm” (30.4642, -91.5717) and “South Farm” (30.4086, -91.5381), which are managed as moist soil impoundments for waterfowl (Fig. 1). South Farm is open to the public, while North Farm is a waterfowl refuge that is closed to the public except for youth lottery hunts (3 days per year). Nest boxes were located on the side of levees and accessed by all-terrain vehicles or trucks; nest box entrances were placed at an average height of 2.3 m (range 1.9 m to 2.7 m). Sherburne is one constituent site of a larger research project on cavity-nesting ducks; nests have been monitored weekly and ducks have been captured/marked in boxes since 2020.

Historically, all nest boxes at our site were single units mounted on a pole. To increase sample size and commensurate with other LDWF WODU monitoring sites, in February 2021 we converted all units to duplexes (two boxes on either side of the pole). Thus, for our study in 2022, we monitored 40 duplex-style nest boxes (20 at South Farm and 20 at North Farm). We categorized nest boxes erected in February 2021 as ‘new’ and nest boxes erected before 2021 as ‘old.’ New nest boxes were identical to the existing (old) boxes (Fig. 2) and installed on the opposite side of the pole; the orientation of old and new boxes was effectively random. All duplexes were outfitted with a conical baffle predator guard (Fig. 2).

Nest monitoring

We visited nest boxes at approximately seven-day intervals. We numbered new eggs sequentially with a permanent marker when we discovered them during nest checks[18], determined the species of each egg[4], and determined whether nests were active or inactive during each visit. We classified a nest as active if we observed a bird incubating, new eggs were laid since the previous visit, or incubation progressed[21]. We classified inactive nests as abandoned, depredated, or successful. We considered a nest abandoned if egg laying or incubation were discontinued without sign of depredation. We classified a nest as depredated if egg laying or incubation ceased and eggs were destroyed or missing. Successful nests survived to hatch ≥ 1 egg; we counted the number of unhatched eggs and egg membranes to determine the number of eggs that hatched. We also categorized each nest based on the apparent presence or absence of conspecific brood parasitism (CBP). CBP parasitized nests received a mean of > 1 egg per day during the laying stage[22] and/or additional eggs following day 4 of incubation, as our species initiate incubation about 3 days prior to laying the last egg[14]. We also identified interspecific brood parasitism (IBP); IBP nests received ≥ 1 egg of a different species.

During nest visits, we attempted to capture the incubating individual by covering the nest box entrance and removing the duck from the box through the side door. When caught, we checked the individual for any markers, including passive integrated transponder (PIT) tags and leg bands. We detected PIT tags in the hand with a handheld reader (Promag PCR120), running the device along the dorsal side of the bird several times. We banded individuals with the appropriate-sized federal band for their species and embedded 2 × 12 mm, 125 kHz PIT tags subcutaneously between the scapulae with a 12-gauge needle and implanter syringe; we closed the injection site with surgical adhesive.

As the hatch date approached, we checked each nest every 1–3 days to ensure we were there to process ducklings because they typically leave the nest within 24 h of hatching[1]. For each duckling, we determined their species by plumage and bill shape (Fig. 3) and marked them with PIT tags in the same way we marked adults. We marked all BBWD ducklings with PIT tags. As part of a concurrent study, half of WODU ducklings were marked with PIT tags, while the other half of WODU ducklings were marked with 6.4 mm Monel web tags (National Band and Tag Company, Style 1005-1). We fitted WODU ducklings with web tags by using modified needle-nose pliers to create two small incisions on the inner webbing of their feet, at the base of the toes[23].

We collected data under U.S. Fish and Wildlife Service banding permit #06669 and Special Use Permit 43612-20-04; LDWF state collecting permits WDP-20-037 and WDP-21-060, and Wildlife Management Area Permit WL-Research-2020-03; protocols were approved by the Louisiana State University Institutional Animal Care

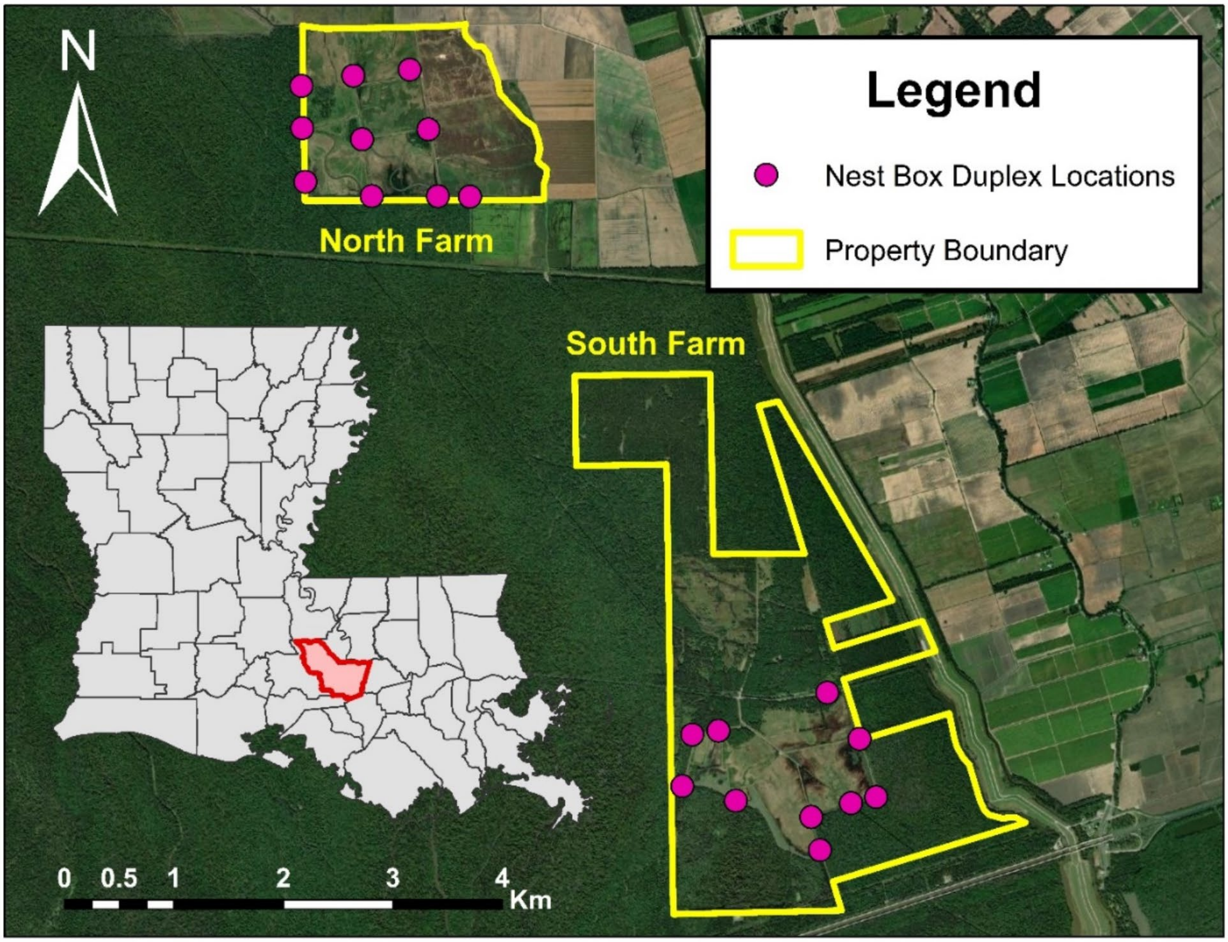

Fig. 1. Map of Louisiana with Iberville Parish highlighted in red and study sites within Sherburne Wildlife Area (North Farm and South Farm) outlined in yellow. Locations of nest box duplexes equipped with radio frequency identification (RFID) readers are represented by pink circles. Map created using ArcMap 10.8.2.

and Use Committee Protocol A2019-27. This study complies with the ARRIVE (Animal Research: Reporting of In Vivo Experiments) guidelines for observational research.

RFID readers

We created stationary PIT tag readers with a custom radio frequency identification (RFID) circuit board[24]; each unit was equipped with two loop-style antennas so one circuit board could be used on a duplex-style nest. We configured the units as a simple data logger that recorded the date, time, and alphanumeric ID of each individual's PIT tag as they entered or left the nest box.

We created the antennas with 26-gauge copper magnet wire and a circular jig to ensure the wire was wrapped in a uniform circle with an 11 cm diameter. PIT tags were particularly sensitive to antenna inductance, and a deviation of ~ 0.5 mH from optimal inductance resulted in failure of the antennas to detect PIT tags. We tuned each antenna to 1.2 mH with a digital inductance meter; each antenna required 67–68 turns of the copper wire to reach that inductance. We found that different brands of wire varied in the number of turns needed to achieve 1.2 mH, so each brand was tuned for the number of turns needed before creating a batch of antennas. Once the antenna wire was wound into a coil, we wrapped it snugly with electrical tape (this step was important to keep consistent, as the tightness of the wire coil can change the antenna's inductance) and coated it with Plasti-Dip, leaving the free ends (hereafter, leads) of the antenna exposed. Then, we used a fine-grit sandpaper to remove the insulation from the last ~ 1 cm of the antenna leads so that they could be tested for the optimal inductance and connected to the circuit board. We attached the antenna leads to the circuit board's screw clamps with a small flathead screwdriver and covered any exposed areas of the wire that remained with electrical tape to prevent them from touching one another. We marked "antenna 1" with a small piece of colored tape so the two could be easily distinguished when installing the readers in the field (Fig. 4).

After attaching the antennas to the circuit board, we installed a 3 V CR1025 battery to the back of the circuit board as a backup clock battery and loaded firmware to each board with the Arduino Integrated Development Environment (Arduino LLC, Scarmagno, Italy). While installing the firmware, we ran a PIT tag through the

Fig. 2. Duplex-style nest box consisting of one new (left) and one old (right) nest box on a singular pole with a conical baffle. The waterproof container housing electrical components is zip-tied below the nest boxes, while the solar panel is fastened to the top of a nest box with wood screws facing southward. The loop-style antennas are zip-tied around the nest box entrance through four drilled holes, with antenna 1 affixed to the new nest box and antenna 2 affixed to the old nest box.

center of each antenna several times to ensure they both worked and assigned each circuit board a numeric ID that is displayed as the filename of data recorded to the SD card. We discarded antennas that were unable to consistently detect a PIT tag in the center of the antenna.

To prepare each unit for the field, we first ran the solar panel cable through a waterproof container so that the circuit board was protected from water while the solar panel was mounted on top of the nest box (random between old and new boxes). We used dry boxes from Outdoor Products initially but switched to Ziploc Twist ‘n Loc containers due to cost and availability. For both container types, we drilled a hole to run the solar panel cable through and sealed it with waterproof epoxy putty. We then connected the cable to the battery pack (Voltaic V25 USB battery pack) with an adapter, connected the battery pack to the circuit board with a mini-USB cable, and inserted a FAT-formatted SD card into the circuit board. We ran the antenna lead wires through the lids without drilling a hole through the side of the container, as the wires were thin enough to pass through the threads/gaskets of the housing without affecting functionality of the lids (Fig. 4).

We installed each unit on duplex-style nest boxes in the field, using large zip ties to attach the waterproof container to the pole underneath the nest boxes. To attach the antennas, we drilled 4 holes around the next box entrance and zip tied the antenna around it (Fig. 2). We then attached the cable extending from the waterproof container to the solar panel (Voltaic 3.5-watt/6 volt) and attached it to the top of the nest box with wood screws. We installed each solar panel facing south for optimal sun exposure (Fig. 2). After installation, we turned on the circuit board and confirmed that it was working properly by running a PIT tag through each antenna several times. Units that worked properly would blink an LED light near the power switch on the circuit board (Fig. 4) each time a PIT tag was detected and recorded to the SD card. During weekly nest visits, we changed the SD cards in each unit (to retrieve data) and confirmed that the unit was still working properly.

Post-processing and analysis

The original dataset generated by the RFID readers had numerous duplicate scans generated from an individual sitting at the nest box entrance for an extended period of time. We removed consecutive scans within 15 s of one another, keeping the first one. We assigned each BBWD individual as “paired” or “unpaired,” with confirmed

Fig. 3. Physical comparison of Black-bellied Whistling-Duck (*Dendrocygna autumnalis* [BBWD]; left) and Wood Duck (*Aix sponsa* [WODU]; right) ducklings. BBWD ducklings have a larger, broader bill and different facial markings than WODU, and their darker-colored markings are a distinct dark black compared to WODU, which are more of a dusty brown color.

pairs defined as a male and female BBWD captured in the same nest box while the same nest was active. Since BBWD likely form long-term pair bonds[25,26] and we detected previously confirmed pairs visiting the same nest boxes from RFID data, our analyses include BBWD pairs that were confirmed as such when captured in 2020–2022. We assigned each BBWD pair an identification number for analysis. Since only WODU females incubate the nest, we identified individuals by their PIT tag identification number.

We categorized PIT tag detections into prospecting, laying, and incubation periods for each BBWD pair and WODU female. We defined each period based on empirical field data: the prospecting period is the time period when a pair/female lacks an active nest of their own (although they may be laying parasitically), the laying period is the interval between nest initiation and onset of incubation, and the incubation period is the time between onset of incubation and nest termination (i.e., hatching or being abandoned/depredated).

We conducted all analyses in R version 4.3.2[27] using a Bayesian framework and Poisson underlying distributions. We used a generalized linear model to predict BBWD and WODU preference for old vs. new nest boxes during the prospecting period:

$$\begin{aligned} &c_i \sim \ Poisson(\lambda_i), \\ &\log(\lambda_i) = \alpha + \beta_1 \cdot nest\ \ box\ \ age_i + \beta_2 \cdot species_i + \beta_3 \cdot (nest\ \ box\ \ age_i \cdot species_i)\ + \varepsilon_i \end{aligned}$$

where (c_i) is the estimate of the number of visits to nest box *i*. We used the log link function to evaluate the relationship between our fixed effects and the expected count (λ_i). Our fixed effects consisted of nest box age, species, an interaction between the two. We ran this model twice: once to predict the number of unique new and old nest boxes visited by BBWD and WODU, and once to predict the total number of visits to new and old boxes by both species during the prospecting period. Additionally, we used a second model:

$$\begin{aligned} &c_i \sim \ Poisson\left(\lambda_i\right), \\ &\log\left(\lambda_i\right) = \ \alpha \ + \ \beta_1 \cdot species_i + \varepsilon_{iyg} \end{aligned}$$

to evaluate the relationship between species and the total number of nest boxes visited throughout the entire breeding period, regardless of nest box age. We ran this model an additional two times: once to predict the duration of the prospecting period, and once to predict the number of nest boxes visited during the prospecting

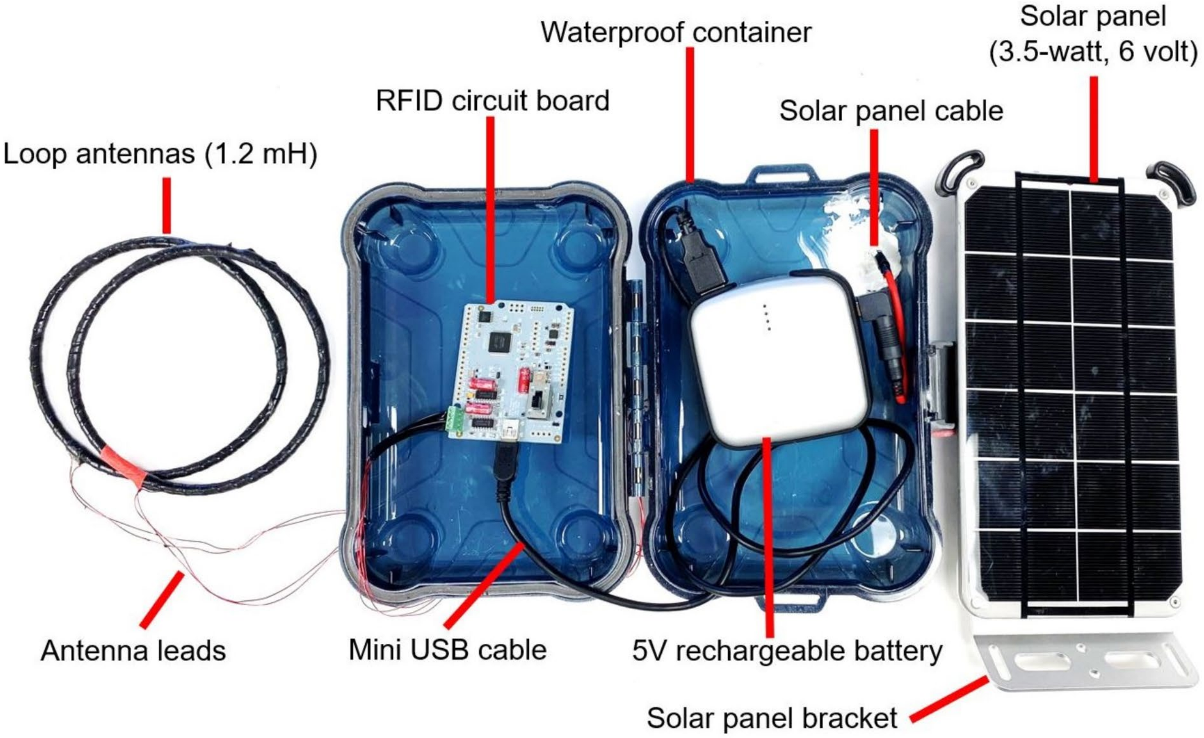

Fig. 4. Components of nest box-mounted radio frequency identification (RFID) readers. Note that the bulkier solar panel cable is run through a hole drilled into the container and sealed with epoxy putty, while the thinner antenna leads can be run through the lid or closure of the container without having to drill a hole.

period. For all models, we used WODU as the reference category for species and new nest boxes as the reference for nest box age; all comparisons were made relative to these categories. We fitted models with package brms in R[28] and used the default uninformative prior distributions for fixed effects. We ran 4 Markov Chain Monte Carlo (MCMC) chains of 5,000 iterations, discarding 2,500 iterations during the warm-up period; we did not use thinning or discard iterations[29]. We ensured that MCMC chains converged by examining trace plots and using the Gelman-Rubin statistic[30] ($\widehat{\mathrm{R}}$ value < 1.05). For all models, 95% credible intervals (CI) for the regression coefficient that did not overlap zero indicated significance. We confirmed model convergence by examining $\widehat{\mathrm{R}}$ values and trace plots.

Results

We deployed 20 RFID reader units with dual antennas on 40 duplex-style nest boxes from March to December 2022, achieving 8,040 active scanner-days and 22,615 detections of BBWD and WODU. After excluding consecutive detections within 15 s of each other and detections of ducklings leaving the nest box post-hatch, there were 2,335 BBWD detections and 1,908 WODU detections remaining for analysis. We detected 48 total adults via RFID readers (Table 1), including 9 confirmed BBWD pairs ($n = 18$ individuals).

We monitored nest boxes from 1 February until 28 July in 2022. We observed 17 BBWD and 29 WODU nest attempts via traditional nest monitoring during the time RFID readers were installed. RFID readers detected 38 (82%) of the 46 total nests we documented via typical field methods. Nests that were not detected by RFID readers were either abandoned early in (or prior to) incubation (9%, $n = 4$) or initiated late enough in the field season (9%, $n = 4$) that the nest hosts were not captured and PIT-tagged.

Nest box age

Our analyses suggest that BBWD have a strong preference for old nest boxes, while WODU do not. 82% ($n = 14$) of all BBWD nests were initiated in old nest boxes and 18% ($n = 3$) in new boxes, while 52% ($n = 15$) of WODU nests were in old boxes and 48% ($n = 14$) were in new boxes. Compared to WODU, BBWD pairs visited a similar number of old and new nest boxes (β = 0.66, CI = -0.30, 1.64; Fig. 5a5. However, BBWD visited old nest boxes significantly more often compared to WODU (β = 1.32, CI = 0.97, 1.68; Fig. 5b).

Prospecting, laying, and incubation periods

RFID readers documented all 9 BBWD pairs and 8 WODU females during the prospecting period. We observed that BBWD pairs prospect for significantly more pair-days days than WODU (β = 0.52, CI = 0.28, 0.77), and that BBWD pairs visited more nest boxes per day than WODU while prospecting (β = 0.26, CI = 0.02, 0.49). Across

			Not captured in 2022		
Species	**Total adults detected**	**Adults captured in 2022[a] (%)**	**Adults[b]**	**Duckling recruits[c]**	**Total not captured (%)**
WODU	22	19 (86%)	2	1	(14%)
BBWD	26	13 (50%)	12	1	(50%)
Both	48	32 (67%)	14	2	(33%)

Table 1. Total number of Wood Duck (*Aix sponsa*; WODU) and Black-bellied Whistling-Duck (*Dendrocygna autumnalis*; BBWD) adults detected by radio frequency identification (RFID) readers at Sherburne Wildlife Management Area (Iberville Parish, Louisiana) in 2022. Each species is categorized by whether individuals were captured by hand while physically monitoring nests in 2022. Note that a considerable portion of BBWD detected via RFID readers were not otherwise recaptured in 2022. [a]Adults captured in 2022 were captured by hand in a nest box but may have initially been marked with passive integrated transponder (PIT) tags in 2020 or 2021. [b] Individuals that were not captured by hand in 2022 but were previously captured and marked with PIT tags in 2020 or 2021. [c] Individuals that were marked with PIT tags as day-old ducklings in 2020 or 2021 but were never captured by hand as adults. Note that all BBWD ducklings were marked with PIT tags, but only half of WODU ducklings were marked with PIT tags.

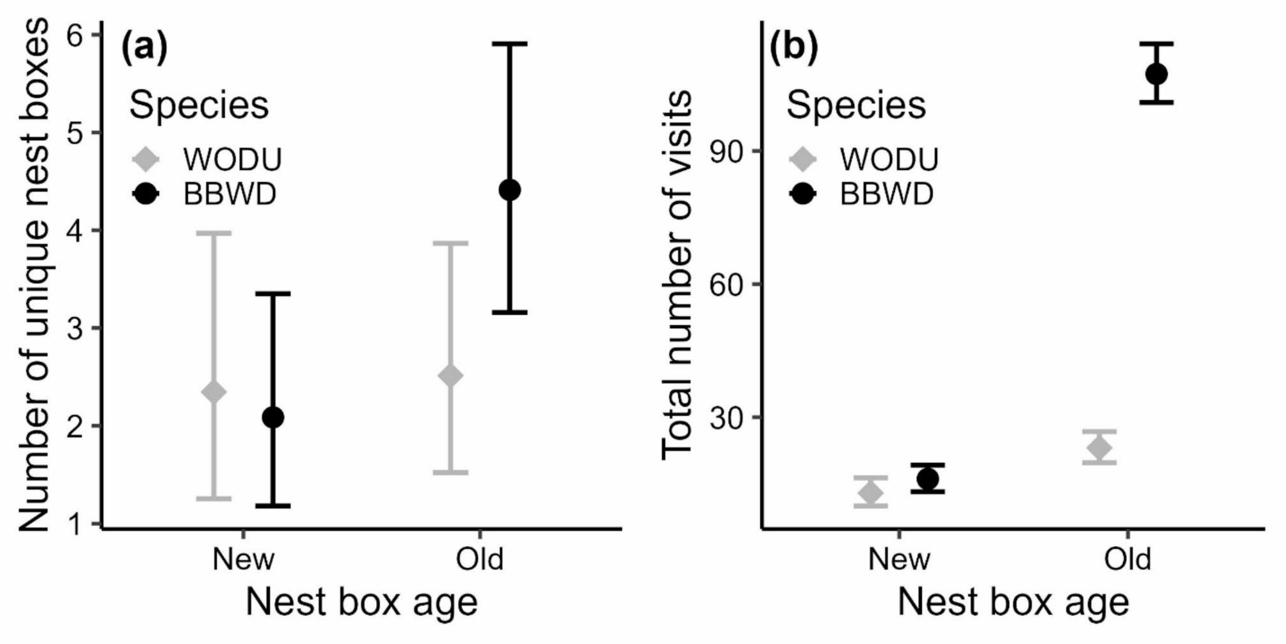

Fig. 5. Model predictions and 95% credible intervals for Black-bellied Whistling-Duck (*Dendrocygna autumnalis*; BBWD) pairs and Wood Duck (*Aix sponsa*; WODU) individuals during their respective prospecting periods in 2022, categorized by age of the nest box. **(a)** Total number of nest boxes visited by BBWD pairs and WODU individuals while prospecting in 2022. **(b)** Total number of visits to old and new nest boxes by BBWD pairs and WODU individuals.

the entire breeding period, BBWD visited a significantly higher number of nest boxes, regardless of nest box age ($\beta = 1.01$, CI = 0.63, 1.39).

RFID readers detected 5 BBWD pairs and 8 WODU individuals during their respective laying periods, and 8 BBWD pairs and 20 WODU individuals during their respective incubation periods. During the laying and incubation periods, BBWD pairs exclusively visited their own nest boxes, while WODU visited other nest boxes. We observed 11 instances where 5 WODU individuals visited other nest boxes during their own laying or incubation periods, consisting of 4 visits to empty boxes and 7 visits to active nests ($n = 4$). Three of these nests (75%) were parasitized by WODU, indicating that unlike BBWD, WODU may act as brood parasites while concurrently hosting their own nests.

Discussion

Our study used nest box-mounted RFID readers to reveal box-visitation behavior, box preferences, and the presence of cryptic recruits in WODU and BBWD in Louisiana. Most critically, one-third of all adults detected by RFID readers were never otherwise recaptured in 2022, meaning that traditional field methods for cavity nesting waterfowl would fail to document a substantial number of birds potentially contributing to the population via parasitism. Additionally, since only half of WODU ducklings were marked with PIT tags, the true number of WODU recruits that we never recaptured as adults is higher than we detected via RFID readers in Table 1. These cryptic individuals, especially those that were tagged as ducklings and never recaptured as adults, indicate that recruitment estimates from previous nest box studies may be biased low. Because recruitment rates are a major driver of duck populations, RFID readers could become critical tools for creating correction factors for future studies to accurately estimate recruitment in box-nesting populations.

We found that BBWD strongly preferred older nest boxes, while WODU did not. BBWD visited more old nest boxes than new ones, and they also visited them at a much higher frequency than WODU visited either nest box age. This was unexpected, given that both old and new nest boxes were identically constructed (Fig. 2), and new boxes were weathered enough to appear identical to old boxes by the end of the 2022 field season. Because each duplex consisted of one old and one new nest box mounted on the same pole, differential use cannot be attributed to new nest box sites not being discovered by BBWD. It also suggests that BBWD fidelity is associated with the specific nest box, and not box location because both boxes were mounted on the same pole.

Due to the generalist nature and rapid range expansion of BBWD, an apparent aversion to newly-installed nest boxes was unexpected[2]. These new nest boxes (installed in February 2021) had nearly two breeding seasons' worth of duck nests, and over half of the new nest boxes had ≥ 1 successful nests by the time that BBWD began nesting in 2022. The three BBWD nests that we observed in new boxes in 2022 occurred in 2 separate nest boxes, and both boxes had 2 successful WODU nests in each of them prior to BBWD nest initiation. Previous studies of Common Goldeneyes (*Bucephala clangula*) have demonstrated that nest boxes/cavities that previously held successful nests were more likely to be selected in the future[31,32], however, this is not true for WODU[33,34]. In the case of BBWD, more research is needed to determine why selection for older nest boxes occurs, and to explore the management implications of BBWD selection for older nest boxes.

We also found that unlike WODU, BBWD only visited their own nests during their laying and incubation periods. We documented several instances of WODU visiting other nests and seemingly parasitizing them during their own laying or incubation periods, but this behavior was never observed for BBWD. During the prospecting period, however, BBWD pairs visited more nest boxes than WODU (up to 11 total nest boxes), with ~ 1 nest box visited per day when pairs were actively prospecting. Additionally, we observed several BBWD pairs that seemingly parasitized nests (via RFID data) before initiating their own nests; however, we have not confirmed maternity of the additional eggs laid in these nests. Nevertheless, this suggests a dual nesting strategy similar to Redheads (*Aythya americana*) parasitizing Canvasback (*Aythya valisineria*)[35] nests before laying their own clutch. We found that BBWD may act as parasites by visiting multiple active nests before initiating their own nests, then ceasing visits to other nests. However, multiple years of data and genetic parentage are required to confirm this. In contrast to Sorenson's 1991 study[35], we did not observe BBWD pairs that acted as parasites-only in 2022, but this may change between years as resource availability varies.

Because BBWD remain in family groups for much longer periods of time compared to other duck species[36], future research should determine maternity of parasitic eggs and whether BBWD preferentially visit or lay in the nests of their kin[37]. Undoubtedly, there are abundant opportunities for further research into BBWD ecology as they continue to expand their range northward, and BBWD interactions with other cavity-nesters remains as a focal research priority.

Data availability

Data and code used for this study are available on the Open Science Framework: https://doi.org/10.17605/OSF.IO/A32JG.

Received: 7 March 2024; Accepted: 4 October 2024

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Acknowledgements

We gratefully acknowledge all lab members and technicians that assisted in field data collection and entry. This project was funded by the Louisiana State University (LSU) College of Agriculture, Louisiana Department of Wildlife and Fisheries, Nemours Wildlife Foundation, LSU Tiger Athletic Foundation, and the LSU Discover Undergraduate Research Program.

Author contributions

K.E.M. and K.M.R. secured project funding and designed the PIT tag reader component of the study. D.L.B. and K.M.R. secured project funding and designed the nest monitoring component of the study. K.E.M. created and installed PIT tag readers with assistance from D.L.B.; D.L.B. and K.E.M. collected and entered field data. D.L.B. and K.E.M. conceived the data analysis; K.E.M. performed the analyses. K.E.M. prepared figures and tables, and wrote the manuscript with edits from D.L.B. and K.M.R. All authors consent for publication.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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