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Use of Nest Boxes by Eastern Bluebirds in Rural South-Central Florida

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Abstract - Nest boxes are widely used for *Sialia sialis* (Eastern Bluebird), yet the influence of box design on occupancy and reproductive success remains contested. We monitored 60 nest boxes in rural south-central Florida to compare 3 common designs constructed from wood and plastic. Bluebirds showed a strong preference for wooden boxes, in contrast to previous findings from urban sites. This discrepancy may reflect differences in prior experience, with urban populations more accustomed to nesting in plastic tubes on buildings, whereas rural populations more often use natural tree cavities and wooden fence posts. Only 2 of 20 plastic boxes were occupied, limiting our ability to evaluate their effects on reproductive performance. Nevertheless, our results align with prior studies indicating that common nest-box materials do not significantly affect reproductive success.

Introduction

Nest boxes are widely used for *Sialia sialis* (L.) (Eastern Bluebird, hereafter Bluebird) both by researchers and birdwatchers (Hvenegaard and Perkins 2019, Plummer et al. 2021). Over time, different box-design variations have been suggested to optimize reproductive success and reduce the costs of building and maintenance (North American Bluebird Society 2024). Because Bluebirds have experienced population declines in the past due to habitat loss and competition for cavities, effective nest-box programs remain essential for their long-term conservation. Furthermore, as secondary cavity nesters that rely on limited natural cavities, they serve as a model species for understanding how artificial structures can offset habitat limitations for wildlife (Jones et al. 2014). Nevertheless, the species' preference for individual box designs and their impact on its reproductive success have only recently been empirically tested, and studies have produced inconsistent results and conflicting recommendations.

A 3-year study in Virginia by Burkart et al. (2013, 2014) compared Bluebird use of traditional rectangular wooden boxes with pyramid-shaped wooden Peterson boxes. Preferences varied annually: traditional boxes were favored in the first year, Peterson boxes in the second, and no clear preference was observed in the third. In northern Florida, Perreau and Sieving (2015) conducted a similar experiment at an urban site, testing Peterson wooden boxes against cylindrical PVC Gilbertson boxes. Contrary to expectations that wood would be preferred, Bluebirds selected

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both designs at similar rates. Although PVC was expected to create warmer interiors, forming conditions linked to reduced reproductive success in Bluebirds (Cooper et al. 2006), Perreau and Sieving (2015) reported higher hatching success, faster nestling growth, and greater fledging rates in Gilbertson boxes compared to Peterson boxes. Further, Jackson (2015) repurposed metal containers and used them as nest boxes in the species' southern range in Mississippi and despite the measured higher internal temperatures, the study did not report a negative impact on hatching and fledging rates.

Here, we investigated Bluebird preferences for 3 commonly used nest-box models: the model formerly recommended by the North America Bluebird Society (NABS), the model formerly recommended by the Florida Bluebird Society (FBS), and the Gilbertson nest box (Fig. 1, Table 1). It is important to note that neither NABS nor FBS currently endorse specific nest-box designs. NABS now presents plans for several different options on its website (North American Bluebird Society 2024), while the FBS website no longer provides any box-design recommendations (Florida Bluebird Society 2024). However, we have based our box nomenclature on their former recommendations to facilitate communication in this paper.

Our study was carried out at a rural site in south-central Florida, where Bluebirds breed under high temperatures near the southern limit of their range. The reproductive success of the Bluebird has been shown to negatively correlate with increases in temperature across its range (Cooper et al. 2006). Single-wall plastic nest boxes are more susceptible than wooden boxes to variation in ambient temperatures, recording higher maximums and averages (Callan et al. 2023, Howard et al 2022).

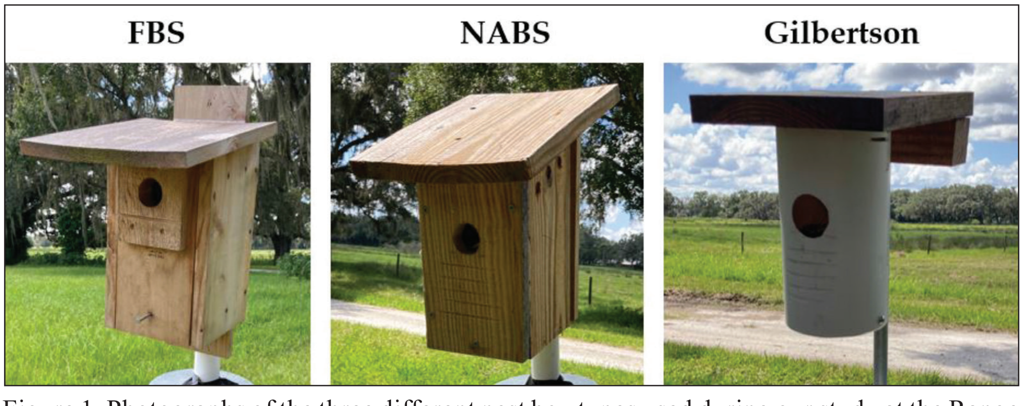

Figure 1. Photographs of the three different nest box types used during our study at the Range Cattle Research and Education Center in Ona, FL, from 15 January to 15 August 2021.

Table 1. Characteristics of Bluebird nest boxes deployed at the Range Cattle Research and Education Center in Ona, FL, from 15 January to 15 August 2021.

Nest-box type	Material	Shape	Volume (liters)	Floor area (cm^2)
NABS	Pine	Rectangular	4.00	195
FBS	Cedar	Rectangular	4.00	195
Gilbertson	Plastic (PVC)	Cylindrical	1.85	90

If temperatures do impact Bluebird reproductive success, we predicted birds nesting in Gilbertson plastic nest boxes would have lower hatching and fledging rates. Based on reports of low use of a novel nest-box design (Burkart et al. 2013), we also hypothesized that if familiarity with box appearance was a main component in the Bluebird's nest-box use, then the cylindrical plastic nest boxes should be the less selected at our rural study site.

Study site

We conducted our study at the University of Florida Range Cattle Research and Education Center (REC) in Hardee County, FL (27°24'N, 81°56'W; Fig. 2). The Range Cattle REC covers 1150 ha, at the time of our study comprised of improved pasture (dominated by *Paspalum notatum* Flüggé [Bahia Grass]), semi-native rangeland, upland hardwood hammocks, and *Pinus* (pine) flatwoods with ~1200 head of *Bos taurus* L. (Cattle). Wire and fence posts were widespread in the area to ensure partitioning of pastureland for Cattle-management purposes. Our study was the first to deploy nest boxes in the site. The main Bluebird nest competitors in the region are *Sturnus vulgaris* L. (European Starling) and *Passer domesticus* (L.) (House Sparrow) (Bailey et al. 2020), but neither species is locally common, and none have been recorded at our nest boxes. The climate is humid-subtropical. Precipitation and temperature are highest in August, averaging 269 mm and 27 °C

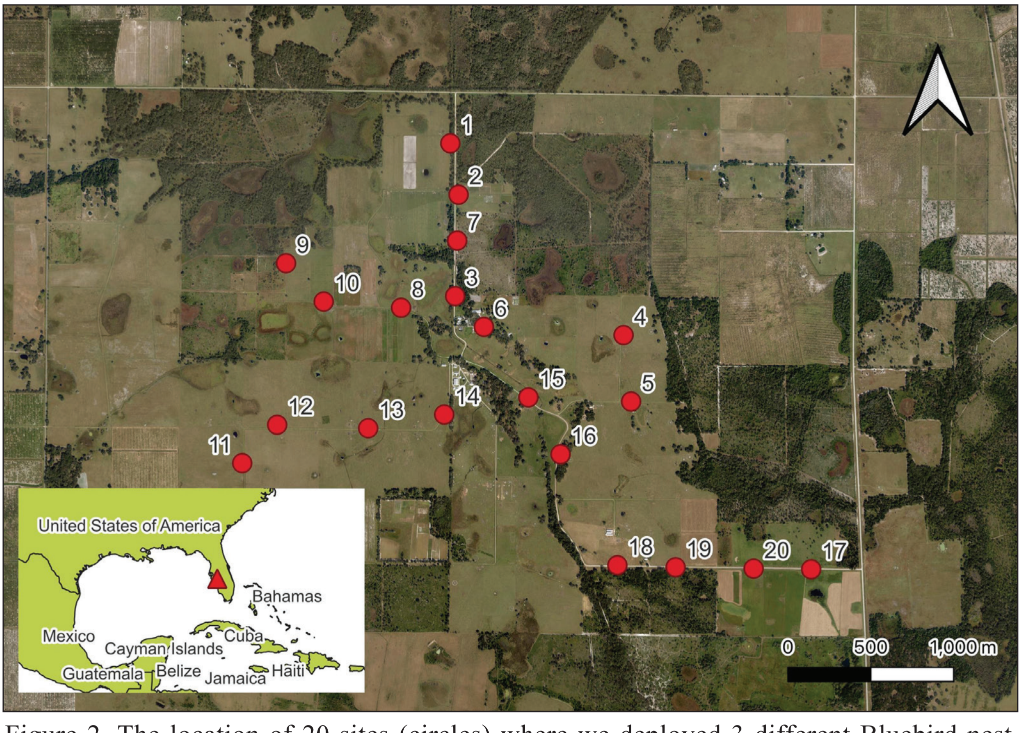

Figure 2. The location of 20 sites (circles) where we deployed 3 different Bluebird nest-box types during our study at the Range Cattle Research and Education Center in Ona, FL (triangle), from 15 January to 15 August 2021.

respectively. January is the coldest and driest month with 16.4 °C mean temperature and 15 mm average precipitation (2020– 2023 data; Florida Automated Weather Network 2024).

Material and Methods

Experimental design

We monitored nest boxes at 20 sites across the Range Cattle REC's pastures between 15 January 2021 and 15 August 2021 (Fig. 2). Each site contained 3 nest boxes, 1 of each design (NABS, FBS, and Gilbertson), placed 30 m away from one another and at least 200 m from other sites to minimize negative territorial interactions and their potential effect on nest-box selection. We fixed nest boxes on poles at ~1.5 m in height to ensure favorable Bluebird-nesting conditions (Jackson et al. 2013). To reduce predation risk, we equipped the poles with stovepipe baffles as nest-box guards and spread grease at the pole's base to deter fire ants and smaller climbers from reaching the nest.

We monitored sites weekly using a borescope camera to non-invasively investigate whether Bluebirds had begun building a nest. We approximated the final laying date and counted the number of eggs once incubation began. We continued monitoring during incubation and recorded hatching rates. We did not perform hatchling measurements to reduce the risk of nest abandonment. However, we continued to regularly monitor nests after hatching to evaluate fledging rates. After fledging, we did not remove used nests and continued monitoring boxes to allow second or third nesting attempts. We carried out the protocol described above when we detected new nests.

Analysis

We used conditional logistic regression stratified by site to determine factors linked with nest-box selection. We modeled box type, distance to fence, and distance to road as explanatory variables. We used AICc to compare model performance and reported models that had more support than the null model. All analyses and data visualization were carried out in program R 4.3.2 (R Core Team 2023). We ran models using the 'survival' package v. 3.2-3 (Therneau 2020) and comparisons using the 'AICcmodavg' package v. 2.3.2 (Mazerolle 2023).

Results

During our study, we recorded Bluebird nests at 14 of 20 sites, with no site supporting more than 1 occupied box at a time. The earliest 2 nests were recorded on February 25. Seven sites were used for the first time in March, 4 in April, and 1 in June. Twelve sites were reused for a second clutch, and 6 for a third clutch (Table 2). Across the 32 Bluebird nests observed during our study, 17 occurred in NABS boxes, 13 in FBS boxes, and only 2 in Gilbertson boxes. Differences in selection rates were not statistically significant between NABS and FBS boxes (P = 0.47). However, Bluebirds exhibited a significantly lower use of the Gilbertson design ($P < 0.01$). Conditional logistic regression showed that nest-box type is the only significant feature linked to box use within sites and supported that Gilbertson boxes were used less compared to the other designs (β = -2.25, SE = 0.11, $P < 0.01$).

Across all nests, 142 Bluebird eggs were laid, of which 116 hatched (81.7%) and 112 of those fledged (96.5%) (Table 3). Hatching rate was highest for the Gilbertson boxes, followed by the FBS then the NABS designs. While sample size limitations did not allow a statistical assessment for the Gilbertson box, the FBS boxes had higher hatching rates compared to the NABS design (Mann–Whitney $U = 62$, $Z = -2.253$, $P < 0.05$). Average clutch size was 4.44 (SD = 0.98), with values varying from 4.23 in FBS boxes to 5.5 in Gilbertson boxes (Table 3). Across all nests, the average number of days from first egg to hatch was 17 (SD = 1.8). The shortest observed period was 13 days in a FBS box, and the longest observed period was 22 days in a NABS box. Across all nests, the average number of days from hatch to fledge was 17.7 (SD = 1.3). The shortest observed period was 14 days in a NABS

Table 2. Nesting start dates and nest box types used by Bluebirds during our study at the Range Cattle Research and Education Center in Ona, FL, from 15 January to 15 August 2021. Sites where nesting did not occur have no data shown.

	First nesting attempt		Second nesting attempt		Third nesting attempt	
Site	Date	Nest-box type	Date	Nest-box type	Date	Nest-box type
1						
2	25 Feb 2021	NABS	20 Apr 2021	NABS	4 Jun 2021	NABS
3	15 Jun 2021	Gilbertson				
4	13 Mar 2021	FBS	26 Apr 2021	FBS	6 Jun 2021	NABS
5	20 Apr 2021	NABS				
6	25 Feb 2021	NABS	1 Apr 2021	Gilbertson	19 May 2021	FBS
7						
8						
9	17 Mar 2021	FBS	7 May 2021	NABS		
10	27 Apr 2021	NABS	23 Jun 2021	FBS		
11	1 Apr 2021	NABS	21 Apr 2021	FBS		
12	2 Apr 2021	NABS	17 May 2021	FBS		
13	25 Mar 2021	FBS	10 May 2021	NABS	30 Jun 2021	FBS
14	19 Mar 2021	NABS	10 May 2021	FBS		
15	6 Mar 2021	NABS	4 May 2021	NABS	14 Jun 2021	NABS
16						
17						
18	20 Mar 2021	FBS	8 May 2021	NABS	22 Jun 2021	FBS
19	25 Mar 2021	FBS	12 May 2021	NABS		
20						

Table 3. Reproductive performance of Bluebirds by nest-box type during our study at the Range Cattle Research and Education Center in Ona, FL, from 15 January to 15 August 2021.

Nest-box type	Eggs laid	Hatched (%)	Fledged (%)	Average clutch size (SD)
NABS	76	54 (71.1%)	53 (98.2%)	4.47 (1.07)
FBS	55	51 (92.7%)	49 (96.1%)	4.23 (0.83)
Gilbertson	11	11 (100%)	10 (91.0%)	5.50 (0.71)
Total	142	116 (81.7%)	112 (96.5%)	4.44 (0.98)

box, and the longest observed period was 20 days, which occurred in both a NABS and a FBS box.

Discussion

Our results indicate that Bluebirds strongly preferred wooden designs (NABS and FBS) over the plastic Gilbertson box. Hatching rates were lower in the 2 wooden designs, but the limited use of Gilbertson boxes (n = 2) prevented a meaningful assessment of their reproductive consequences. Hatching success in Bluebirds is known to vary geographically, with lower rates at lower latitudes where higher ambient temperatures elevate nest-box temperatures and reduce egg viability (Cooper et al. 2006). To mitigate these risks, females in southern populations often lay smaller clutches and initiate incubation earlier in the season (Cooper et al. 2005). Cooper et al. (2006) reported an average unhatched-egg rate of 7.8% across their sample, increasing to 8.9% at lower latitudes and for extreme clutch sizes (small clutches defined as having 3 eggs and large clutches as having 6). In contrast, we observed intermediate clutch sizes (mean = 4.4 eggs), yet our unhatched-egg rate was considerably higher, averaging 18.3%. Cooper et al.'s (2006) study only covered samples from northwestern Florida where proximity to the ocean could reduce the impact of the heat. Therefore, the elevated failure rate recorded here, may reflect the harsh conditions at our study site in south-central Florida, which could amplify embryo mortality despite moderate clutch sizes.

According to the egg-viability hypothesis, our study and others across the literature should have noted lower hatching rates in hotter nest boxes (Cooper et al. 2005). In contrast to this prediction, Perreau and Sieving (2015) found that Gilbertson nest boxes in northern Florida had higher hatching rates than the cooler wooden Peterson boxes. Jackson (2015) found that metal nest boxes did not show lower hatching and fledging rates compared to wooden boxes despite higher internal temperatures. Whilst the use of the plastic Gilbertson boxes in our study was limited (n = 2), the low hatching failure (0 %) recorded in them seems to support results from Perreau and Sieving (2015) and Jackson (2015) indicating the low impact of internal nest-box temperature on Bluebird hatching rates.

We propose that the higher temperatures in the species' southern range impose costs that affect the species' reproduction in ways that go beyond the simple increase in internal nest temperature and its potential effect on egg viability. The higher environmental temperature increases overall costs of foraging (Pattinson et al. 2020, Van de Ven et al. 2019) and mating (Aronov and Fee 2012, Gudka et al. 2019), mandates earlier incubation (Cooper et al. 2005), and increases energy spent on thermoregulation (Weathers 1997) that in turn reduce the energy that the bird can allocate to incubation, nest building, and care of offspring, which in consequence likely affects overall reproductive success in the Bluebird's southern range.

Although plastic nest boxes did not appear to reduce reproductive performance, Bluebirds in our study showed a strong preference for wooden designs. This contrasts with Perreau and Sieving (2015), who found equal use of wooden and plastic boxes by Bluebirds on the University of Florida campus in Gainesville. A long-term study in Virginia also revealed variable preferences across years: Bluebirds favored rectangular wooden boxes in the first year, Peterson pyramidal wooden boxes in the second, and showed no preference in the third (Burkart et al. 2013, 2014). Together, these studies suggest that habituation and prior exposure to nesting substrates influence Bluebird nest-box selection. For instance, urban populations may be more accustomed to PVC structures common on buildings, while rural populations are more familiar with wooden cavities. The Virginia study supports this interpretation: Peterson boxes were introduced for the first time in year 1, when Bluebirds primarily selected traditional rectangular boxes. By the second year, however, use of Peterson boxes increased, likely reflecting greater familiarity with the novel design (Burkart et al. 2013). Moreover, our rural study area likely contains more natural cavities than urban settings, where tree density and management can limit cavity availability. In urban contexts, birds may exhibit reduced selectivity and use a wider range of artificial boxes, including PVC designs (e.g., Perreau and Sieving 2015).

This hypothesis suggests that in the first year of deployment, a familiar nest-box design should be selected to favor immediate high nest use. In the long term, however, appearance and building material do not seem to be decisive factors in the reproductive performance or use of nest boxes by Bluebirds (Burkart et al. 2013, Perreau and Sieving 2015).

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