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Eastern Bluebirds (*Sialia sialis*) rear four broods to apparent fledging in northeastern Arkansas

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ABSTRACT—Climate change has advanced the onset of spring and, subsequently, avian nesting activity. Although this advance can have negative consequences such as phenological mismatch, species may be able to increase the annual number of young fledged. Eastern Bluebirds (*Sialia sialis*) can rear 3 broods to fledging, but in this paper we report 3 pairs that reared 4 broods to apparent fledging in 2016 and 2020 in northeastern Arkansas. Nesting attempts began as early as 18 March with the first laid egg and concluded as late as 18 September with the last fledging event; brood sizes ranged from 2 to 5 chicks. Nests were checked daily 15–18 d post-hatching, increasing confidence in our determination of successful fledging. Unlike a previous report of 4 broods reared by a male that mated with 2 females at once, the pairs at our site all remained together through all 4 attempts. These pairs all consisted of after-second-year birds and we discuss why we believe these nests were successful, as well as factors that allowed these pairs to attempt to rear an additional brood. *Received 3 May 2021. Accepted 22 July 2021.*

Key words: climate change, multi-brooded, nest box, passerine, phenology.

Des merlebleus de l'Est (*Sialia sialis*) élèvent quatre nichées jusqu'à envol apparent dans le nord-est de l'Arkansas

RESUME (French)—Les changements climatiques a avancé le début du printemps et par conséquent celui de la saison de nidification des oiseaux. Bien que cette avancée des dates puisse avoir des conséquences négatives telles qu'une désynchronisation phénologique, les espèces aviaires pourraient être capable d'augmenter le nombre annuel de jeunes à l'envol. Les Merlebleus de l'Est (*Sialia sialis*) peuvent élever trois couvées jusqu'à l'envol, mais dans cet article, nous présentons trois paires de qui ont apparemment élevé quatre couvées jusqu'à l'envol en 2016 et 2020 dans le nord-est de l'Arkansas. Les tentatives de nidification ont commencé dès le 18 mars avec la ponte du premier œuf et se sont terminées le 18 septembre au plus tard avec le dernier envol; la taille des nichées variait de deux à cinq poussins. Les nids ont été suivis quotidiennement à partir de 15–18 jours après éclosion, augmentant ainsi le niveau de confiance dans notre détermination de la réussite des envols. Contrairement à un rapport précédent de quatre nichées élevées avec succès par un mâle qui s'est accouplé avec deux femelles à la fois, les couples de notre site sont tous restés ensemble au cours des quatre tentatives. Tous ces couples étaient composés d'individus qui s'étaient déjà reproduit pendant au moins une saison de nidification et nous discutons de ce pour quoi nous pensons que ces nichées ont réussi ainsi que des facteurs qui ont permis à ces couples de tenter d'élever une nichée supplémentaire.

Mots-clés: changements climatiques, espèce à plusieurs nichées par an, nichoir, passereau, phénologie.

For many passerine species, the number of breeding pairs and nesting attempts are limited by lack of suitable nesting sites and habitat (Cockle et al. 2010, Miller 2010), competition for mates (Møller 1991), inter- and intraspecific competition for nest sites (Strubbe and Matthysen 2009, Charter et al. 2016), and the length of the breeding season (Gurney et al. 2011). Generally, populations at high latitudes have shorter breeding seasons than those at middle latitudes (Wyndham 1986, Meier et al. 2020). However, as the onset of spring has advanced due to climate change

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(Monahan et al. 2016), so too have breeding birds advanced their first egg lay dates (Samplonius et al. 2018). This can negatively impact species in several ways, including phenological mismatch (Ross et al. 2017), reduced chick survival (Shipley et al. 2020), and an increase in agonistic interactions with competitive species (Samplonius and Both 2019). However, multi-brooded species may not only be able to breed earlier but also for longer, allowing increased fitness (Halupka and Halupka 2017).

Among species impacted by advancing spring and climate change, Eastern Bluebirds (*Sialia sialis*; hereinafter "bluebirds") have advanced their first egg dates (Torti and Dunn 2005) and shifted their breeding range northward (Zuckerberg et al. 2009). Bluebirds are widespread across eastern North America and range from Central America to southern Canada (Gowaty and Plissner 2020). Throughout this range, most pairs are double-brooded, although in the central regions, pairs may be triple-brooded (Peakall 1970, Gowaty 1980). Although it is not uncommon for pairs to attempt to rear more than 3 broods, this typically occurs after nest failure (Thomas 1946, Gowaty and Plissner 1997, Burtka and Grindstaff 2015). To our knowledge, there is only 1 recorded instance of a male bluebird successfully rearing 4 broods (Tucker 1990). However, this male was able to rear 4 broods by mating with 2 females at once. Here, we report 3 instances (2 in 2016 and 1 in 2020) of 3 distinct bluebird pairs rearing 4 broods to apparently successful fledging within 1 breeding season. For the purpose of this report, we define "successful fledging" as having at least 1 nestling leave the nest.

Methods

Our observations took place during a long-term nest box monitoring program, for which data have been collected since 2003. The field site consists of 150 nest boxes ~7.5 km north of Jonesboro, Arkansas. Boxes are located alongside roads, in pastures, and within residential yards. Approximately two-thirds of nest boxes are protected from predators by stovepipe baffles or axle grease on the mounting post. Nesting typically begins in mid-March and concludes in late August. Clutch size varies from 2 to 6 eggs, with the incubation period lasting 11–19 d (Gowaty and Plissner 2020). Fledging typically occurs 18 d post-hatching or later (Gowaty and Plissner 2020), but can occur as early as 16 d post-hatching (Pinkowski 1975). Within a season, bluebirds can successfully fledge up to 3 broods; on average, at our site, 45.3%, 33.6%, and 20.7% of pairs successfully fledge 1, 2, and 3 broods, respectively. Relative to the period 2013–2020, the mean minimum temperatures (T_{min}) for the first 2 weeks in March were highest in 2016 (7.78 °C ± 5.11 SD) and 2020 (7.10 °C ± 3.56 SD) (Fig. 1).

In 2013–2020, monitoring intensified, with nest visits every 1–6 d from initiation (i.e., nest building) to completion (i.e., fledging or failure), from mid-March to early September to span the entire nesting season. Parents were trapped in the nest box and banded 1–3 d after hatching (with the hatch day counted as day 1), and chicks were banded at day 13. Additionally, morphometric data (i.e., mass, wing chord, and tail length) were collected from all individuals, and adults were aged as second-year (SY; birds in their second calendar year of life) and after-second-year (ASY; birds at least in their third calendar year of life). Nests with banded chicks were checked daily starting 15–18 d post-hatching until fledging or failure to determine the nest fate. We determined that chicks had fledged or were depredated based on various criteria: presence/absence of fresh fecal sacs, uneaten food, and dander; condition of the nest (intact, disturbed, or pulled through the entrance hole); presence/absence of parents and fledglings near the box; and the overall body condition of chicks at day 13. For example, an undisturbed nest excluded mammalian mesopredator depredation (i.e., cats [*Felis catus*] and raccoons [*Procyon lotor*]). Fresh droppings indicated that chicks were present in the nest until recently. In some cases, fledglings were seen or heard with parents nearby, allowing for high confidence that at least 1 individual fledged. After each nesting attempt, we removed the nest so we could determine the start of the next attempt.

Results

Three pairs apparently successfully fledged 4 broods: 2 pairs in 2016 and another in 2020. All 3 pairs consisted of individuals already banded,

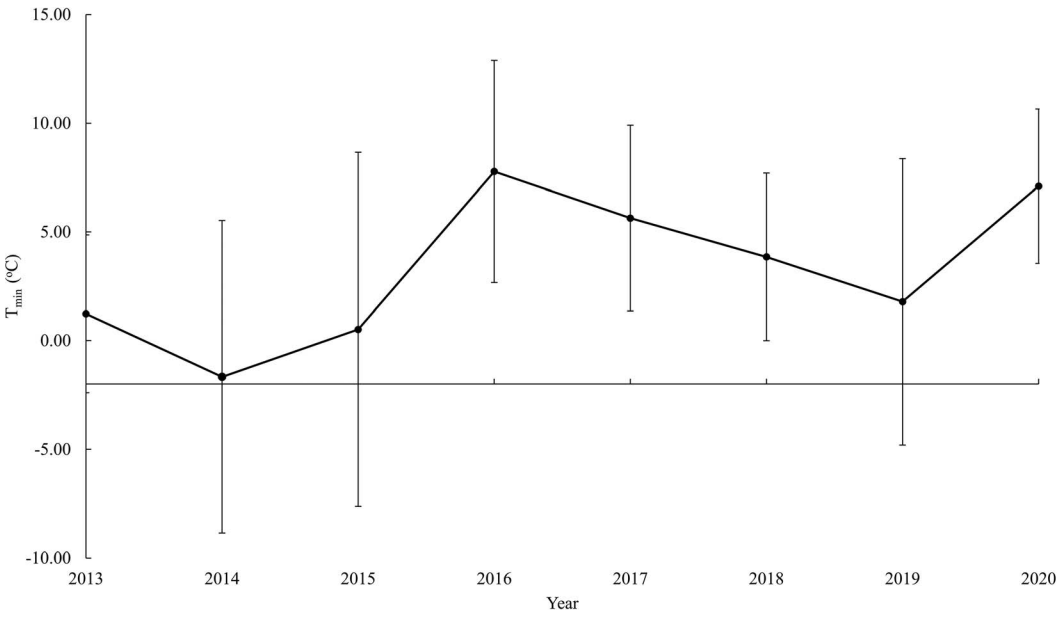

Figure 1. Mean minimum temperatures (T_{min}) ± SD at the field site in northeastern Arkansas for the first 2 weeks of March (1st–14th), 2013–2020.

indicating that they were all ASY birds. Their nesting phenology is summarized in Table 1. For comparison, the nesting phenology of pairs successfully fledging 3 broods is shown in Figure 2.

The first pair (Pair 1) nested in boxes 318 and 319 in 2016, which are 0.16 km apart and had no predator guards. After their first successful attempt in 318, Pair 1 initiated a second nest in box 319, which they abandoned, and a third nest in 318, which was also abandoned. The pair then moved back to box 319, where it successfully fledged 5 chicks. The pair switched to box 318 to raise its third 5-chick brood to fledging. Pair 1 stayed at box 318, where they built and abandoned a nest before beginning a final (fourth successful) attempt at box 319.

The second pair (Pair 2) remained in 1 nest box (86) for all 4 attempts in 2016. This box was equipped with a stovepipe baffle. Unlike Pair 1,

Table 1. Summary of nesting activity of Eastern Bluebird pairs with 4 successful broods in 2016 and 2020 in northeastern Arkansas. Assessment date is the nest check date at which chicks were no longer present in the nest box. Asterisks indicate the date at which fledging is believed to have occurred. Chick ages at assessment/fledging are noted in parentheses.

Pair	Box #	First egg date	Clutch size	Hatch date	Brood size on day 13	Assessment date	Days to next attempt
1	318	20 Mar 2016	5	7 Apr 2016	5	25 Apr 2016* (19)	19
1	319	14 May 2016	5	31 May 2016	5	17 Jun 2016 (18)	9
1	318	26 Jun 2016	5	13 Jul 2016	5	31 Jul 2016* (19)	9
1	319	9 Aug 2016	4	25 Aug 2016	3	11 Sep 2016 (18)	–
2	86	24 Mar 2016	4	10 Apr 2016	4	28 Apr 2016* (19)	20
2	86	18 May 2016	4	4 Jun 2016	4	22 Jun 2016* (19)	6
2	86	28 Jun 2016	3	15 Jul 2016	2	1 Aug 2016 (18)	13
2	86	14 Aug 2016	4	1 Sep 2016	2	18 Sep 2016 (18)	–
3	113	18 Mar 2020	5	6 Apr 2020	5	24 Apr 2020* (19)	12
3	113	6 May 2020	5	23 May 2020	4	11 Jun 2020* (20)	6
3	113	17 Jun 2020	4	4 Jul 2020	4	22 Jul 2020* (19)	3
3	114	25 Jul 2020	3	10 Aug 2020	3	28 Aug 2020* (19)	–

Table 2. Morphometric data collected from chicks of Eastern Bluebird pairs that successfully fledged 4 broods in 2016 and 2020 in northeastern Arkansas. Measurements were recorded at day 13 and are reported as mean ± 1 SD, with minimum and maximum values for each attempt in parentheses. For comparison, these values are also reported for all broods measured in 2016 and 2020.

Pair	Attempt #	Mass (g)	Wing chord (mm)	Tail length (mm)
Population 2016		27.0 ± 2.1 (17.5–33.0)	51.9 ± 3.3 (36.0–59.0)	14.0 ± 2.5 (3.00–20.0)
1	1	28.3 ± 0.6 (27.5–29.0)	52.0 ± 1.6 (50.0–54.0)	12.8 ± 1.1 (11.0–14.0)
1	2	28.0 ± 1.2 (26.5–29.0)	52.8 ± 2.8 (49.0–56.0)	14.6 ± 0.9 (13.0–15.0)
1	3	25.1 ± 0.7 (24.5–25.0)	53.6 ± 2.1 (50.0–55.0)	13.4 ± 1.5 (11.0–15.0
1	4	28.8 ± 1.3 (27.5–30.0)	55.0 ± 3.5 (51.0–57.0)	16.0 ± 4.0 (12.0–20.0)
2	1	26.6 ± 1.1 (25.0–27.5)	48.3 ± 1.5 (46.0–49.0)	9.8 ± 1.0 (9.0–11.0)
2	2	25.9 ± 1.2 (25.0–27.5)	48.0 ± 2.0 (45.0–49.0)	11.0 ± 0.8 (10.0–12.0)
2	3	25.5 ± 0.7 (25.0–26.0)	48.0 ± 1.8 (46.0–50.0)	11.5 ± 2.1 (10.0–13.0)
2	4	24.3 ± 1.1 (23.5–25.0)	53.5 ± 0.7 (53.0–54.0)	14.5 ± 0.7 (14.0–15.0)
Population 2020		27.1 ± 2.1 (19.5–32.5)	51.2 ± 4.3 (8.0–61.0)	14.0 ± 2.5 (2.0–21.0)
3	1	26.3 ± 0.9 (25.5–27.5)	53.2 ± 2.0 (51.0–55.0)	14.2 ± 2.2 (12.0–17.0)
3	2	24.0 ± 1.8 (22.0–25.5)	50.6 ± 3.1 (47.0–53.5)	12.8 ± 1.5 (11.0–14.0)
3	3	23.5 ± 1.6 (21.5–25.0)	54.5 ± 3.0 (51.0–57.0)	16.0 ± 1.8 (14.0–18.0)
3	4	25.3 ± 0.3 (25.0–25.5)	50.7 ± 0.6 (50.0–51.0)	13.7 ± 0.6 (13.0–14.0)

Pair 2 did not build nests that they abandoned in between their 4 successful attempts. The third pair (Pair 3) bred in 2020 and reared their first 3 broods in box 113 before switching to box 114 for the last brood. These nest boxes are 0.19 km apart and equipped with stovepipe baffles. Like Pair 2, Pair 3 did not build nests that they abandoned in between their 4 successful attempts. Although all 4 broods were reared to fledging, the second brood lost 1 chick between days 7 and 13.

Overall, regardless of brood, all nestlings when measured on day 13 appeared in normal condition (Table 2). Additionally, in 2016, the inter-brood interval (i.e., number of days elapsed between fledging and the first egg of the next nesting attempt) for Pairs 1 and 2 between the first and second broods (Table 1) was similar to the mean (± SE) inter-brood interval (19.6 ± 1.7 d) for pairs that fledged 3 broods. The inter-brood interval for Pairs 1 and 2 between broods 2 and 3 (Table 1) was also similar to other pairs (9.35 ± 1.4 d). However, in 2020, the inter-brood intervals for Pair 3 (Table 1) did not fall within the 95% CI for pairs that fledged 3 broods (between broods 1 and 2: 16.2–19.5 d; between broods 2 and 3: 8.6–10.4 d).

Additionally, in subsequent years we resighted 3 individuals belonging to 2 broods from Pair 1. Similarly, among the fatalities recorded after snowstorms that occurred in Jonesboro in February 2021, we found 2 individuals hatched from the third and last clutches of Pair 3, confirming that these two 2020 broods had successfully fledged. Of the parents captured and measured in early April, all appeared healthy and weighed 28.5–32.0 g ($\bar{x}_{\text{female}} = 29$–$32$ g, $\bar{x}_{\text{male}} = 28$–$31$ g; Gowaty and Plissner 2020).

Discussion

Eastern Bluebirds nesting in lower latitudes typically fledge up to 3 successful broods each nesting season (Peakall 1970, Gowaty and Plissner 2020). However, with climate change advancing the onset of spring (Monahan et al. 2016), many species are breeding earlier (Samplonius et al. 2018), and multi-brooded species are also lengthening their nesting seasons (Halupka and Halupka 2017). Here, we documented 3 bluebird pairs successfully fledging 4 broods within a single nesting season.

Although other records of bluebirds attempting more than 3 broods are recorded, these occurred after nesting failure (Thomas 1946, Burtka and Grindstaff 2015). The only recorded instance of a bluebird fledging 4 successful broods occurred in Alabama in 1987. However, this incident involved 1 male that alternatively mated with 2 females (Tucker 1990), whereas our pairs remained together through all 4 broods.

Because we checked for fledging beginning at day 15 in 2020 and observed fledging in real time

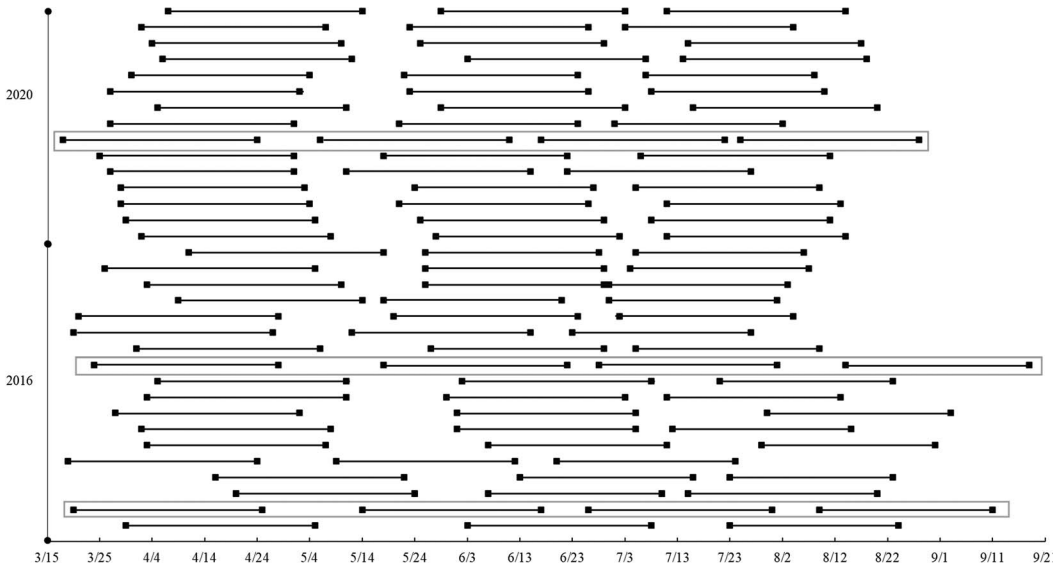

Figure 2. Timeline of nesting activity of Eastern Bluebird pairs with 3 and 4 successful broods in 2016 and 2020 in northeastern Arkansas. The beginning and end of nesting attempts are indicated by black squares. Pairs with 4 successful broods are outlined in gray.

for Pair 3's first attempt, we are confident that these broods successfully fledged. For Pairs 1 and 2, we checked for fledging beginning at day 18, at which point chicks may have already fledged or been depredated. However, we believe these broods were successful for several reasons. First, we evaluated the evidence left at the nest. None of these nests were disturbed, ruling out depredation by raccoons and cats. Although black rat snake (*Pantherophis obsoletus*) depredation often leaves no traces, we found uneaten food and fresh or semi-fresh droppings in the nest, indicating that chicks were present until recently. Additionally, for nests in which chicks were present on day 18 but absent on day 19, rat snake depredation is unlikely as snakes typically exhibit decreased activity levels in the days following large meals (Siers et al. 2018), and rat snakes often remained in the nest boxes for at least 1 d and up to 6 d after consuming chicks at this stage (SEH pers. obs.). Eastern fox squirrels (*Sciurus niger*) also depredate nests, although this typically occurs at the egg stage or when chicks are very young (Gowaty and Plissner 2020). Second, we considered the morphometric data from each brood. None of the chicks appeared underdeveloped or lethargic, and when compared to Pinkowski's (1975) measurements of mass (21.0–27.0 g), wing chord ($\bar{x} = 50.0 \pm 2.82$ SD mm), and tail length ($\bar{x} = 16.91 \pm 1.93$ SD mm) for chicks at day 13 (counted as day 12 by Pinkowski 1975), most individuals appeared in good condition (Table 2).

Third, the inter-brood intervals for the 3 pairs were similar to the intervals for pairs that successfully fledged 3 broods (Fig. 2). Fledglings stay with their family groups for up to 3 weeks, and the inter-brood interval is typically 2 weeks (Gowaty and Plissner 2020), although our results suggest that the first inter-brood interval (i.e., broods 1 and 2) seems to be longer than the second inter-brood interval (i.e., broods 2 and 3). Additionally, renesting can occur before the current brood fledges (Gowaty and Plissner 2020). Within the closely related Western (*Sialia mexicana*) and Mountain (*Sialia currucoides*) bluebirds, males assume sole feeding of fledglings if females initiate a second attempt soon after the first brood fledges (With and Balda 1990, Johnson et al. 2017). The shorter intervals for Pair 3 may have resulted from early fledgling mortality (i.e., before independence). One or more chicks dying post-fledging would have allowed the male to assume sole feeding duties of the remaining chicks (if any) while the female began renesting sooner. Fourth, although we checked for fledging at day 18

in 2016, chicks may fledge as early as day 17 (Pinkowski 1975). Therefore, chicks may have fledged before our nest checks. Finally, 3 chicks from Pair 1 returned to breed in 2017, 2018, and 2019. Because return rates for banded birds are low (Newton 2010), ~7% of fledglings return as SY breeders (SEH and VR, unpubl. data), and we did not have access to every nest box or natural cavity at the site, other chicks may have survived but were not recaptured.

It is difficult to determine why these pairs decided to initiate a fourth nesting attempt after successfully fledging 3 broods. We speculate that a number of environmental and intrinsic factors contributed to the productivity and success of these birds. First, environmental conditions in early March for 2016 and 2020 were conducive to breeding earlier in the season. Higher temperatures early in the breeding season can cue birds to begin breeding sooner (Wegge and Rolstad 2017, Shutt et al. 2019). Specifically, Lv et al. (2020) found that higher T_{min} in early spring were associated with Superb Fairywrens (*Malurus cyaneus*) breeding earlier and for a longer duration. For 2013–2020, the mean T_{min} for the first 2 weeks in March were highest in 2016 and 2020 (Fig. 2). Second, all pairs consisted of ASY birds, which are often more experienced and successful in rearing young (Nol and Smith 1987, Martin 1995, Plissner and Gowaty 1996) and frequently initiate their first attempts earlier (O'Brien and Dawson 2013). Third, we speculate that these birds may have been high-quality individuals. The 3 adults captured in April appeared in good condition, supporting this idea. However, we did not collect morphometric data at subsequent nesting attempts and can only speculate that they were able to maintain a healthy body condition throughout the breeding season. Finally, because these pairs started their first attempt early, they were able to start their fourth brood while other pairs were in the midst of or finishing their third attempt (Fig. 2), allowing just enough time for a fourth attempt. Due to the approach of autumn, there is likely a point at which it is disadvantageous for birds to initiate subsequent nesting attempts. Favorable environmental conditions, combined with experience, healthy body condition, early first attempts, and resident status, allowed these 3 pairs to complete an additional fourth attempt.

Although other pairs successfully fledged 3 broods in 2016 and 2020 (Fig. 2), these birds either started later in the season, or included 1 inexperienced (i.e., SY) individual. One or both members of these pairs may also have been in poorer shape and could not initiate a fourth attempt. However, because we only collected morphometric data once per individual during a season (typically during the first breeding attempt), we are unable to verify this.

In conclusion, we believe that 3 pairs of Eastern Bluebirds, 2 in 2016 and 1 in 2020, successfully fledged 4 broods within 1 breeding season due to environmental and intrinsic factors that favored the initiation of an additional attempt. Because initiating the first attempt early in the season was a critical component of these observations, and climate change is advancing the onset of spring, this may become a more common observation for bluebirds and other passerines (Møller et al. 2010, Carro et al. 2014). We therefore recommend that banding studies using multi-brooded passerines monitor and report the number of nesting attempts by pairs to further our understanding of the impact of climate change on passerine breeding phenology.

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Literature cited

Burtka JL, Grindstaff JL. 2015. Similar nest defence strategies within pairs increase reproductive success in the Eastern Bluebird, *Sialia sialis*. Animal Behaviour. 100:174–182.

Carro ME, Mermoz ME, Fernandez GJ. 2014. Factors affecting the probability of double brooding by Southern House Wrens. Journal of Field Ornithology. 85:227–236.

Charter M, Izhaki I, Mocha YB, Kark S. 2016. Nest-site competition between invasive and native cavity nesting birds and its implication for conservation. Journal of Environmental Management. 181:129–134.

Cockle KL, Martin K, Drever MC. 2010. Supply of tree-holes limits nest density of cavity-nesting birds in

primary and logged subtropical Atlantic forest. Biological Conservation. 143:2851–2857.

Gowaty PA. 1980. The origin of mating system variability and behavioral and demographic correlates of the mating system in Eastern Bluebirds (*Sialia sialis*) [dissertation]. Clemson (SC): Clemson University.

Gowaty PA, Plissner JH. 1997. Breeding dispersal of Eastern Bluebirds depends on nesting success but not on removal of old nests: An experimental study. Journal of Field Ornithology. 68:323–330.

Gowaty PA, Plissner JH. 2020. Eastern Bluebird (*Sialia sialis*). In: Poole A, editor. Birds of the world. Ithaca (NY): Cornell Lab of Ornithology. https://doi.org/10.2173/bow.easblu.01

Gurney KEB, Clark RG, Slattery SM, Smith-Downey NV, Walker J, et al. 2011. Time constraints in temperate-breeding species: Influence of growing season length on reproductive strategies. Ecography. 34:628–636.

Halupka L, Halupka K. 2017. The effect of climate change on the duration of avian breeding seasons: A meta-analysis. Proceedings of the Royal Society B. 284:20171710.

Johnson LS, Nguyen AV, Connor CL. 2017. Do parents play a role in the timing and process of fledging by nestling Mountain Bluebirds? Journal of Field Ornithology. 88:39–46.

Lv L, Liu Y, Osmond HL, Cockburn A, Kruuk LEB. 2020. When to start and when to stop: Effects of climate on breeding in a multi-brooded songbird. Global Change Biology. 26:443–457.

Martin K. 1995. Patterns and mechanisms for age-dependent reproduction and survival in birds. American Zoologist. 35:340–348.

Meier CM, Karaardıç H, Aymí R, Peev SG, Witvliet W, Liechti F. 2020. Population-specific adjustment of the annual cycle in a super-swift trans-Saharan migrant. Journal of Avian Biology. 51:e02515.

Miller KE. 2010. Nest-site limitation of secondary cavity-nesting birds in even-age southern pine forests. Wilson Journal of Ornithology. 122:126–134.

Møller A. 1991. Why mated songbirds sing so much: Mate guarding and male announcement of mate fertility status. American Naturalist. 138:994–1014.

Møller AP, Flensted-Jensen E, Klarborg K, Mardal W, Nielsen JT. 2010. Climate change affects the duration of the reproductive season in birds. Journal of Animal Ecology. 79:777–784.

Monahan WB, Rosemartin A, Gerst KL, Fisichelli NA, Ault T, et al. 2016. Climate change is advancing spring onset across the U.S. national park system. Ecosphere. 7:e01465.

Newton I. 2010. Methodology. In: Newton I, editor. The migration ecology of birds. Oxford (UK): Academic Press; p. 19–41.

Nol E, Smith JNM. 1987. Effects of age and breeding experience on seasonal reproductive success in the Song Sparrow. Journal of Animal Ecology. 56:301–313.

O'Brien EL, Dawson RD. 2013. Experimental dissociation of individual quality, food and timing of breeding effects on double-brooding in a migratory songbird. Oecologia. 172:689–699.

Peakall DB. 1970. The Eastern Bluebird: Its breeding season, clutch size, and nesting success. Living Bird. 9:239–256.

Pinkowski BC. 1975. Growth and development of Eastern Bluebirds. Bird-Banding. 46:273–289.

Plissner JH, Gowaty PA. 1996. Patterns of natal dispersal, turnover and dispersal costs in Eastern Bluebirds. Animal Behavior. 51:1307–1322.

Ross MV, Alisauskas RT, Douglas DC, Kellett DK. 2017. Decadal declines in avian herbivore reproduction: Density-dependent nutrition and phenological mismatch in the Arctic. Ecology. 98:1869–1883.

Samplonius JM, Bartosova L, Burgess MD, Bushuev AV, Eeva T, et al. 2018. Phenological sensitivity to climate change is higher in resident than in migrant bird populations among European cavity breeders. Global Change Biology. 24:3780–3790.

Samplonius JM, Both C. 2019. Climate change may affect fatal competition between two bird species. Current Biology. 29:327–331.

Shipley JR, Twining CW, Taff CC, Vitousek MN, Flack A, Winkler DW. 2020. Birds advancing lay dates with warming springs face greater risk of chick mortality. PNAS. 117:25590–25594.

Shutt JD, Cabello IB, Keogan K, Leech DI, Samplonius JM, et al. 2019. The environmental predictors of spatio-temporal variation in the breeding phenology of a passerine bird. Proceedings of the Royal Society B. 286:20190952.

Siers SR, Yackel Adams AA, Reed RN. 2018. Behavioral differences following ingestion of large meals and consequences for management of a harmful invasive snake: A field experiment. Ecology and Evolution. 8:10075–10093.

Strubbe D, Matthysen E. 2009. Experimental evidence for nest-site competition between invasive Ring-necked Parakeets (*Psittacula krameri*) and native nuthatches (*Sitta europaea*). Biological Conservation. 142:1588–1594.

Thomas RH. 1946. A study of Eastern Bluebirds in Arkansas. Wilson Bulletin. 58:143–183.

Torti VM, Dunn PO. 2005. Variable effects of climate change on six species of North American birds. Oecologia. 145:486–495.

Tucker JW. 1990. Male Eastern Bluebird rears four broods during one nesting season. Wilson Bulletin. 102:726–728.

Wegge P, Rolstad J. 2017. Climate change and bird reproduction: Warmer springs benefit breeding success in boreal forest grouse. Proceedings of the Royal Society B. 284:20171528.

With KA, Balda RP. 1990. Intersexual variation and factors affecting parental care in Western Bluebirds: A comparison of nestling and fledgling periods. Canadian Journal of Zoology. 68:733–742.

Wyndham E. 1986. Length of birds' breeding seasons. American Naturalist. 128:155–164.

Zuckerberg B, Woods AM, Porter WF. 2009. Poleward shifts in breeding bird distributions in New York State. Global Change Biology. 15:1866–1883.