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EFFECTS OF AN UNSEASONABLE SNOWSTORM ON RED-FACED WARBLER NESTING SUCCESS

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Abstract. Earlier initiation of nests by breeding birds may reflect an adaptive response to changes in food availability or warming of spring temperatures, but the consequences of initiating nests too early may be severe, particularly at high elevations. A rare snowstorm in late May 2008 resulted in nest abandonment by 68% of Red-faced Warblers (*Cardellina rubrifrons*) breeding in a high-elevation riparian ecosystem of southeastern Arizona. In addition, climate data from our study site from 1950 to 2008 revealed higher-than-average springtime temperatures during the past 10 years. If birds respond to this increase in springtime temperatures by nesting earlier their vulnerability to spring snowstorms may increase.

Key words: *Cardellina rubrifrons*, initiation date, nest abandonment, nest failure, Red-faced Warbler, snowstorm, weather.

Impacto de una Tormenta de Nieve Fuera de Temporada en el Éxito de Anidación de *Cardellina rubrifrons*

Resumen. La iniciación temprana de los nidos de las aves en reproducción puede reflejar una respuesta adaptativa ante los cambios en la disponibilidad de alimento y aumento de las

temperaturas en primavera, pero las consecuencias de iniciar los nidos muy tempranamente pueden ser severas, especialmente a elevaciones altas. Una tormenta de nieve rara que ocurrió a fines de mayo de 2008 produjo el abandono del 68% de los nidos de *Cardellina rubrifrons* que se encontraban reproduciéndose en un ecosistema ribereño de altitud en el sudeste de Arizona. Además, registros climáticos de nuestro sitio de estudio registrados entre 1950 y 2008 indicaron que las temperaturas de primavera de los últimos 10 años fueron mayores al promedio. Si las aves responden a este aumento de las temperaturas de primavera anidando más tempranamente, su vulnerabilidad ante las tormentas de primavera puede aumentar.

Recent studies have reported migratory birds arriving and laying earlier where spring conditions are shifting earlier in the year (Stevenson and Bryant 2000, Martin and Wiebe 2004, Both et al. 2005, Martin 2007). Earlier clutch initiation is often associated with an increase in clutch size (Klomp 1970), egg mass (Wheelwright and Schultz 1994, Nilsson 2000), or reproductive success (Perrins 1970, Daan et al. 1988, Hochachka 1990, Smith 1993). At high elevations, however, individuals that initiate clutches earlier likely face increased risks from spring snowstorms. Nest failure from spring snowstorms may be more costly than nest failure from predation because of the additional costs associated with maintaining the adults' body condition. Snowstorms often

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cause both the abundance and availability of food to decline, potentially for many days. This decline in food, in turn, can affect the adults' ability to renest and the survival of both adults and offspring (Eckhardt 1977, Arcese et al. 1992, Morton et al. 1993, Heltzel and Earnst 2006).

Nest failure caused by severe weather has been observed in other species (Sutton and Parmelee 1954, Jehl and Hussell 1966, Hendricks and Norment 1992, Morton et al. 1993, Heltzel and Earnst 2006, Martin and Wiebe 2006). All of these past studies took place north of 40° N, most in alpine or arctic environments where severe weather is not uncommon during the spring and summer (Barry et al. 1981). In this paper, we document the effects of a late spring snowstorm on a population of Red-faced Warblers (*Cardellina rubrifrons*) breeding in the Santa Catalina Mountains of southeastern Arizona (32° N). We assessed the severity of the observed storm and determined the frequency of spring snowstorms at this site by examining climate data over the past 58 years.

METHODS

In the Santa Catalina Mountains, spring weather commonly begins in early to mid-April and coincides with the Red-faced Warbler's arrival. The mountains receive occasional snowfall in early April, but temperatures consistently remain between 4.4° and 17.8° C. Red-faced Warblers typically begin nesting during the first week of May, with most nests initiated from 15 to 30 May. On 22 and 23 May 2008, 11.7 cm of snow fell in the Santa Catalina Mountains. We documented the fate of 19 nests that were active when the snowstorm began.

We located and monitored Red-faced Warbler nests (following Martin and Geupel 1993) from 2002 to 2008 on four 16- to 20-ha study plots (2300 to 2700m) near Summerhaven in the Coronado National Forest, Santa Catalina Mountains, Pima County, Arizona (32° 43' N, 110° 76' W). We visited nests every 2 to 3 days. On each visit we recorded whether each nest was still active, as part of an ongoing demographic study (Kirkpatrick and Conway 2005, 2008). To determine the severity of the storm, we compared the weather during the 2008 storm to previous years' weather. During the 7 years of our study, we had not observed a spring storm so late or so severe. Hence, we examined the frequency of spring snowstorms in past years by reviewing all of the available climate data for our study site from four sources: Pima County Regional Flood Control District (A. Wigg, unpubl. data), MesoWest-Mountain Meteorology Group (2008), Western Regional Climate Center (2008), and the National Oceanic and Atmospheric Administration (2008).

STATISTICAL ANALYSES

To determine the severity of the 2008 snowstorm, we used Pearson correlation analysis (SPSS version 12) to examine the relationship between Julian date and average daily temperatures throughout the 2002–2008 breeding seasons (Fig. 1). We also used Pearson correlation analysis to examine the relationship between year and the average daily temperatures during the Red-faced Warbler's typical egg-laying period (25 April–25 May) over the past 58 years (Fig. 2). All reported values are means \pm SE.

RESULTS

Nineteen pairs of Red-faced Warblers were actively nesting at the onset of the storm: seven building, four laying, and eight incubating. Five of the nests in the building stage were deserted;

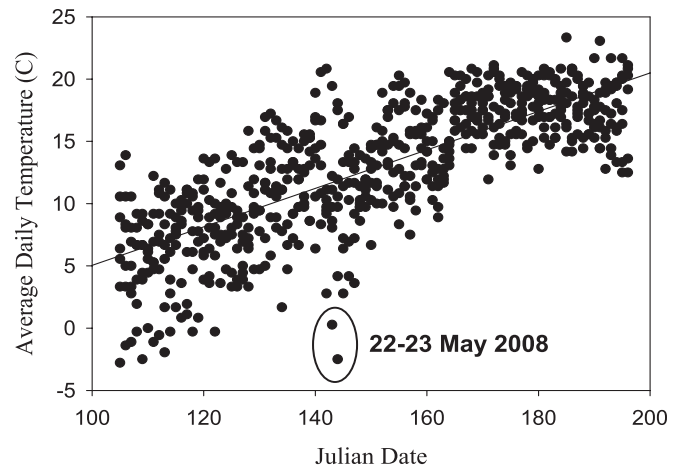


FIGURE 1. Average daily temperature increases as the Red-faced Warbler's breeding season progresses in the Santa Catalina Mountains of southeastern Arizona (Pearson correlation $r^2 = 0.60$, $df = 642$, $P < 0.001$). Data are from 2002–2008, and the two points circled are the days of the snowstorm (22 and 23 May 2008).

the birds completed the remaining two and laid four eggs in each, but the nests were depredated prior to hatching. Two of the four pairs that were still laying when the storm began abandoned their nests with incomplete clutches of one and two eggs, and the other two stopped laying and incubated clutches of two and three eggs (at our study site the average clutch size in late May of previous years was 4.39 ± 0.04 eggs; $n = 154$ nests). Six pairs abandoned complete clutches in the middle of incubation. The final two pairs continued incubating, and both hatched three of their four eggs. Overall, the snowstorm caused abandonment of 13 of the 19 (68%) nests that were active at the time of the storm. Nest abandonments during the storm accounted for 20% of the fates of all nests in 2008. During the 6 previous years (2002–2007) in our study area, 61% of nests active in late May failed, and we attributed virtually all nest failure to nest predation (Kirkpatrick and Conway, unpubl. data). Nine of the 13 pairs that abandoned nests began building a new nest immediately after the snowstorm (25 May) and laid the first egg by 30 May.

Since 1950, late-spring snowstorms have occurred six times, four of these since 1980. In addition, average daily spring (25 April–25 May) temperatures have increased since 1950, particularly during the past 10 years (Pearson correlation $r^2 = 0.29$, $df = 45$, $P < 0.001$; Fig. 2a), driven primarily by an increase in minimum temperatures (Pearson correlation $r^2 = 0.44$, $df = 45$, $P < 0.001$; Fig. 2b), not maximum temperatures (Pearson correlation $r^2 = 0.07$, $df = 45$, $P = 0.103$; Fig. 2c).

From 2002 to 2007, the earliest clutch-initiation date of the year ranged from 2 to 13 May ($\bar{x} = 5$ May). The average temperature (from 2002 to 2007) for 2 to 13 May was $9.3^\circ \pm 0.4^\circ$ C. In 2008, the first clutch initiated on 30 April, when the daily temperature averaged $8.9^\circ \pm 0.2^\circ$ C. Weather data show a consistent increase in average daily temperature as the breeding season progresses (Pearson correlation $r^2 = 0.60$, $df = 642$, $P < 0.001$; Fig. 1), indicating that temperatures during the snowstorm of 22–23 May 2008 were considerably lower than what breeding Red-faced Warblers normally experience at our study site. The storm produced 11.7 cm of snow, which remained on the ground for approximately 48 hr.

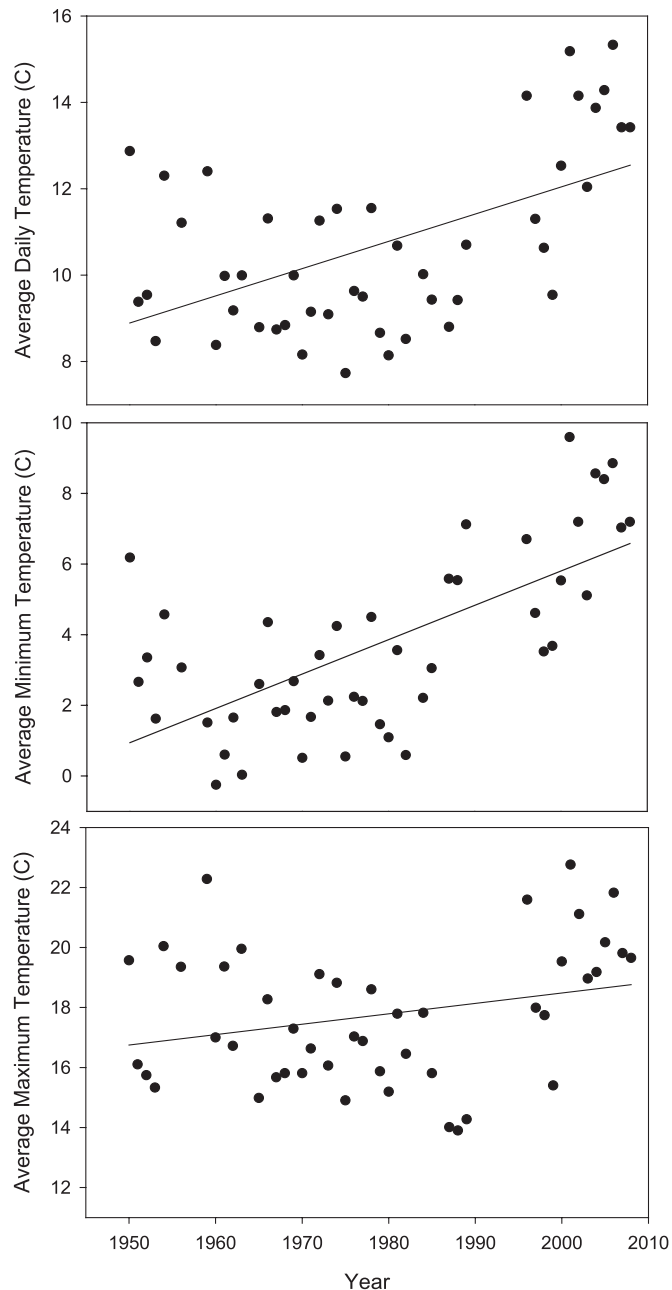


FIGURE 2. Mean daily average (a; Pearson correlation $r^2 = 0.29$, $df = 45$, $P < 0.001$), minimum (b; Pearson correlation $r^2 = 0.44$, $df = 45$, $P < 0.001$), and maximum (c; Pearson correlation $r^2 = 0.07$, $df = 45$, $P = 0.103$) temperatures during the peak of egg laying (25 April–25 May) by Red-faced Warblers from 1950 to 2008 in the Santa Catalina Mountains of southeastern Arizona (1990–1995 unavailable).

DISCUSSION

Nest failure due to severe weather is not rare in alpine or arctic environments in the northern latitudes of North America (Sutton and Parmelee 1954, Jehl and Hussell 1966, Hendricks and Norment 1992, Martin and Wiebe 2006). Neotropical migrants breeding in the mountains of southeastern Arizona, however, may be less able to cope with these events (Kirkpatrick et al. 2009). The available weather data show that the spring snowstorm in 2008

produced the lowest temperatures recorded in May since we began collecting nesting data in 2002 (Fig. 1). Birds in the Santa Catalina Mountains typically experience a consistent increase in temperature as the breeding season progresses; during extreme weather, many Red-faced Warblers are forced to abandon their nests. If individuals nest early in response to an increase in ambient temperatures (as seen at our study site; Fig. 2), they may decrease their nesting success by increasing their exposure to occasional and unpredictable extreme weather.

Previous studies addressing the effects of spring storms on birds have reported varying degrees of nest failure. Jehl and Hussell (1966) reported high rates of nest failure (87%), Morton et al. (1993) reported minimal nest failure (4%), and all other studies reported rates of nest failure ($\bar{x} = 64 \pm 5.02\%$) similar to those we observed. We might expect spring snowstorms to be less destructive in southern latitudes than in northern latitudes because the southern storms may be less severe. However, this does not seem to be the case; nest failure at our high-elevation study site in Arizona was equal to or greater than most nest failures reported as a result of late-spring storms in more northern latitudes. Our analyses of long-term climate data from our study site suggest increases in temperature over the past 58 years, particularly during the last 10 years. Because mountain ecosystems encompass several climatic zones, these environments may be among the most sensitive to climate change (Misserli and Ives 1997, Thompson 2000). Additional information on the predicted frequency (and severity) of late-spring snowstorms at high elevations of southern latitudes is required to more fully assess the effects of these storms on breeding birds. These data are needed to determine the effects of future climate change on persistence of bird populations in montane environments.

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