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Trumpeter finches (*Bucanetes githagineus*) breeding at highlands have higher breeding success but a shorter breeding season

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ABSTRACT

One of the responses of arid-land birds to ongoing climate warming is to shift their ranges towards higher altitudes to track species climatic optima. As this can influence their life history traits, more information is needed on breeding output from these border populations. We studied the breeding biology of the Trumpeter finch (*Bucanetes githagineus*) during three years in the center of the Saharan Atlas (ca. 1400 m a.s.l). Compared to lowland populations, breeding season was shorter and egg hatchability lower, but breeding success higher, as the main difference regarding previous studies was the lack of predation in the 23 nests we monitored. This is an advantage for this arid-land species breeding at the limit of its altitudinal range. However, in the face on future climate warming, predator ranges are also expected to shift towards higher altitudes, thus minimizing this current advantage, while breeding limitations due to harsh weather could prevail, what could compromise population viability.

1. Introduction

One observed consequence of the ongoing climate warming is the massive shifts in species distribution ranges towards higher altitudes, in order to track species climatic optima (e.g., see Auer and King, 2014 for North American passerines). These shifts can imply important changes on species life history traits and, in turn, on their population dynamics. For instance, finches breeding at high elevations have smaller clutches and fewer broods per season, as well as longer incubation periods than their counterparts breeding at lowlands (Badyaev, 1997). Whereas the breeding biology of bird faunas from North America and Europe are well known, allowing for future projections, basic information on bird fauna from northern Africa is limited. A rich bird fauna dwells the Maghreb region, which is the southernmost border for several Palaearctic species and, in turn, it is the northernmost limit for other Afro-tropical species (Cramp and Perrins, 1994). The mountain ranges in this region, like the Saharan Atlas, are characterized by a sharp transition from the Mediterranean to an arid climate, offering traits, like diverse environmental structure, landscape heterogeneity, as well as its geographic proximity to the Iberian peninsula, that create an ideal framework for the study of biogeographical patterns (Tellería et al., 2014). This potential has been demonstrated with a recent study on two passerines, in which the authors found that winter climatic suitability for these species in the region will shift from lowlands to highlands by 2050 and 2070 (Tellería et al., 2016). However, little is known on the breeding biology of species dwelling the region beyond some classical works that offer valuable but limited data (typically only clutch size) on bird faunas from the region (Heim de Balsac and Mayaud, 1962; Etchécopar and Hüe, 1964).

One of the most characteristic birds from this semi-arid region is the trumpeter finch (*Bucanetes githagineus*, Lichtenstein, 1823), a small passerine distributed from the Canary Islands to the Middle East (Barrientos et al., 2009a, 2014). It has been recorded that

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populations in the northernmost limit of its range undergo annual fluctuations both in their range limits and in their breeding densities (Isenmann and Moali, 2000; Barrientos et al., 2009a, 2014), but nothing is known on their potential fluctuations in central populations breeding at the highest limit of its altitudinal range. Likewise, whereas breeding biology of this species has been studied in lowlands (220–260 m a.s.l) populations from South-eastern Iberian Peninsula or the Canary Islands (Barrientos et al., 2007, 2009b,c), little is known on populations located in the highlands from the center of its range (Barrientos, 2015). We aim to investigate the breeding biology of a population of trumpeter finch breeding at high altitude (1330–1400 m a.s.l.), including timing of breeding, clutch size, hatching and fledging rates as well as breeding success. Additionally, we report data on egg dimensions, traits that were not studied in detail in previous works on this species (Cramp and Perrins, 1994). We expect that this new data on life history traits can contribute to improve forecasting on the consequences of arid-land birds breeding at higher altitudes as a response to global warming.

2. Material and methods

Our study was conducted in region of Ed-Dokhlia, in the northeastern region of Djebel Amour (Aflou), Algeria (2° 10′ E; 34° 17′ N) during 2007–2009. This zone ranged from 1330 to 1400 m a.s.l.

Mean annual temperature was 11 °C, with a maximum in July (24 °C) and a minimum in January (2 °C), and annual rainfall around 350 mm. The dominant ecosystem is the steppe of alfa *Stipa tenacissima* L. (Poaceae) with presence of some scattered Phoenician juniper *Juniperus phoenicea* L. (Cupressaceae) and prickly juniper *J. Oxycedrus* L. (Cupressaceae) shrubs. The average slope of the study area is of 17°. The community of potential predators is relatively poor compared to other continental areas (see Supplementary Material).

We monitored trumpeter finch nests from March to June during 2007–2009 breeding seasons. This time of year is the expected breeding season for the species (Barrientos, 2015). Trumpeter finch nests were located by searching the vegetation. We also accidentally found a few of them by flushing an adult from the nest while walking. Females were not ringed, but nests were found during the same period, so we treated them as different females. Once found, we monitored nests every 2–5 days to determine clutch size. We waited for parents to leave the nest before checking nest content. Laying date was only established for those nests found during building or laying period, and was defined as the day when the first egg was laid (1 = 1st March). Population mean laying date was thus the average of the laying dates of the first egg in every nest. The clutch was considered complete when there was no increase in clutch size between two consecutive visits, under the assumption that trumpeter finches lay one egg per day (Barrientos et al., 2009c). To assess the date of clutch completion, we added to the penultimate visit the difference in the number of eggs between penultimate and ultimate visits. Once the clutch was completed, nest and length (L) and breadth (B) of every egg were measured with a sliding calliper to the nearest 0.1 mm. Egg volume (V) was calculated according to Hoyt's (1979) formula: $V = 0.51 * L * B^2$. We assumed that incubation began on the date of clutch completion, and that it finished with the hatching of the first egg (Barrientos et al., 2009c), being this lag the incubation period. We calculated the hatching rate as the proportion of eggs hatched to the number of eggs laid. Eggs failing to hatch were those that were still present in the nest four days after hatching. Hence, if the brood size was lower than clutch size on these first days, missing eggs were assumed to have hatched, and the chicks concerned were assumed to have died, and to have been removed by the parents. Fledging rate is the proportion of chicks fledging to the number of chicks hatched, and was only calculated for broods in which at least one chick fledged. Finally, we defined breeding success as the proportion of chicks fledging to the number of eggs laid. Nest predation is easily distinguished from other causes of failure like nest abandonment, egg hatching failure or chick death by starvation because eggs are broken or disappear, and chick corpses are found in the nest cup or disappear before the expected fledging date (Barrientos et al., 2009c).

We used Kruskal-Wallis tests to investigate the influence of the study year in the laying date, the clutch size, the incubation period, the hatching and fledging rates and the breeding success, as these were not normally distributed, and they have a single value per nest. When appropriate, post-hoc comparisons of mean ranks of all pairs of groups were computed as implemented by default in Statistica v.10 (Statsoft, Tulsa, OK, USA). We used Generalized Linear Mixed Models (GLMMs) to examine the role of year in egg traits (length, breath and volume) as these datasets had normal distribution. Nest was included as random factor to control for the lack of independence among eggs within the same nest. Post-hoc Tukey Honestly Significant Difference (HSD) tests were used to explore the differences among years when appropriate. Statistical analyses were performed with Statistica v.10 (Statsoft, Tulsa, OK, USA). Data are expressed as mean ± standard error (SE).

3. Results

A total of 23 nests were monitored during the three breeding seasons. The nests were open-cups all of them built at the base of clumps of alfa on a rough ground, in slopes averaging 37°. This shrub was the only species used for nesting. Nests showed an outer diameter of 9.2 ± 3.4 cm, an inner diameter of 5.8 ± 2.1 cm and depth of 4.2 ± 1.2 cm.

The first clutches were recorded in the third week of March (Fig. 1), and total laying season extended for 43 days. The mean laying date was 33 ± 2, with a peak in the last week of March, and a second, lower, one at the end of April. There were no differences in laying date among years (Kruskal-Wallis test, $H_{2,23} = 0.24$, $P = 0.89$). Most (56%) of clutches consisted of 5 eggs, being those with 4 and 6 also frequent (22% in both cases). Clutch size differed among years (Kruskal-Wallis test, $H_{2,23} = 10.54$, $P < 0.01$; Table 1). Regarding egg traits, the length varied both with year ($F_{2,\ 92} = 7.36$; $P < 0.01$; Table 1) and female identity ($F_{20,\ 92} = 3.68$; $P < 0.0001$). The year did not influence egg breadth ($F_{2,\ 92} = 0.21$; $P = 0.81$), but

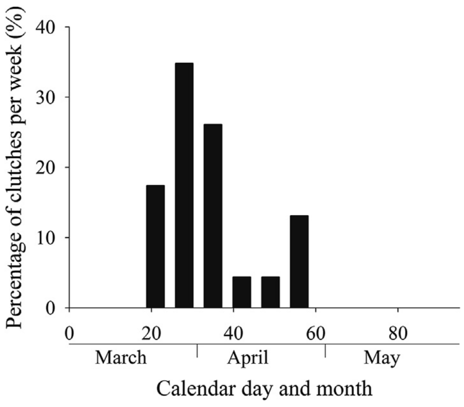

Fig. 1. Laying phenology of the trumpeter finch in Ed-Dokhlia area during 2007–2009. The percentage of clutches per week is obtained by dividing the total number of clutches in a certain week during the three years by the total number of clutches. Calendar day (1 = 1 March) and the corresponding months are shown.

Table 1
Annual differences in clutch size (mean number of eggs) and egg length (cm). Mean values ± SE are shown in the diagonal, and p-values for 2x2 post-hoc tests above the diagonal.

Variable	Year	Mean (n)		
Clutch size		2007	2008	2009
	2007	5.3 ± 0.2	$P = 0.03$	$P = 1.00$
	2008		4.4 ± 0.2	$P = 0.06$
	2009			5.3 ± 0.2
Egg length	**Year**	**2007**	**2008**	**2009**
	2007	1.83 ± 0.01	$P = 0.85$	$P < 0.01$
	2008		1.82 ± 0.01	$P = 0.01$
	2009			1.77 ± 0.02

the female identity did ($F_{20,\ 92} = 6.12$; $P < 0.0001$). Mean egg breadth was 1.26 ± 0.00 cm. Similarly, the year did not influence egg volume ($F_{2,\ 92} = 0.15$; $P = 0.86$), but the female identity did ($F_{20,\ 92} = 4.54$; $P < 0.0001$). Mean volume was 1.46 ± 0.01 cm^3.

Incubation period lasted 12.7 ± 0.2 days (range 12–14), and there were no differences among years (Kruskal-Wallis test, $H_{2,23} = 0.35$, $P = 0.84$). The mean hatching rate was 77 ± 4% (range 40–100%), and did not differ among years (Kruskal-Wallis test, $H_{2,23} = 5.43$, $P = 0.07$). The mean fledging rate was 89 ± 3% (range 60–100%), not differing among years (Kruskal-Wallis test, $H_{2,23} = 2.37$, $P = 0.31$). Notably, no losses due to predation were observed. Thus, breeding success was high (67 ± 3%, range 40–100%), irrespective of the year (Kruskal-Wallis test, $H_{2,23} = 1.00$, $P = 0.61$).

4. Discussion

The Trumpeter Finch is a steppe-land species that in our study area placed their nests under alfa clumps on steep slopes. Despite nesting in cliffs can be advantageous against predation (Barrientos et al., 2009b), we found no nests above the ground, which is a notable difference regarding previous studies (Barrientos et al., 2009b). However, the main singularity of our work was that we recorded no nest predation in our trumpeter finch population, whereas in other populations it reached 54–63% (Barrientos et al., 2009b).

The breeding onset in our study area was delayed with respect to other populations (Heim de Balsac and Mayaud, 1962; Cramp and Perrins, 1994; Barrientos et al., 2007). Breeding season starting and, consequently, its duration can markedly vary between cold and warm years in relation with the germination of annual *Cruciferae* species that represent the bulk of both adult and nestling diets, which are completely based on vegetative material (Barrientos et al., 2007; Barrientos, 2015). However, we did not detect phenological differences in our three study years in this highland population. What we found was a shorter (from mid-March to the end of June) breeding season in the Saharan Atlas compared to those previously reported in lowlands like the Iberian Peninsula (from mid-February to the end of July; Barrientos et al., 2007). In this sense, the typically shorter period of food abundance in highlands likely constrains the length of breeding season (Badyaev, 1997; Johnson et al., 2006; Kouidri et al., 2012). We found a second peak of clutches in April. This second peak, already found in Spanish populations, could correspond to second or replacement clutches (Barrientos et al., 2007). The absence of predation events in our study suggests a low influence of replacement clutches in our case, although we cannot discard other less common causes of clutch failure like those related to adverse weather events.

The clutch size we recorded was within the species' range (Heim de Balsac and Mayaud, 1962; Etchécopar and Hüe, 1964; Cramp and Perrins, 1994; Isenmann and Moali, 2000; Barrientos et al., 2009c). The smaller clutch size in 2008 and the fact that eggs were shorter in 2009 are hard to explain with our data. Egg dimensions were relatively smaller compared to other populations (Etchécopar and Hüe, 1964; Cramp and Perrins, 1994). Female identity influenced on all egg traits, as several female-related factors like age and weight (Christians, 2002) or body condition, mediated by food availability (Meijer and Drent, 1999), influence egg formation.

The incubation period length in Algeria was similar to that found in other populations located at similar latitudes like Tabernas Desert, Iberian Peninsula (37° 2′ N, 02° 30′ W) or La Oliva, Canary Islands (28° 35′ N, 13° 58′ W), but lower altitudes (Barrientos et al., 2009c), despite population at higher altitudes like ours are expected to have longer incubation periods due to temperature constrains (Badyaev, 1997). The hatching rate was lower than in lowland populations (Barrientos et al., 2009c), perhaps conditioned by harsher climatic conditions. On the contrary, breeding success was higher compared to other populations (Cramp and Perrins, 1994; Barrientos et al., 2009c; Barrientos, 2015) as there were no brood losses due to predation. This result mirrors the general pattern in carduelines, as nest predation decreases with elevation in this subfamily (Badyaev, 1997). The differences in predator faunas can influence predation rates (Barrientos et al., 2009b), and despite we recorded predation events on other finch species, even in those breeding above the ground like the linnet *Linaria cannabina* or the greenfinch *Chloris chloris* (authors, unpublished data; see also Kouidri et al., 2012), it is possible that predator activity (very specially that of reptiles) is lower in our highland study area (see Supplementary Material). Other non-mutually-exclusive explanation is that nest dispersion as a consequence of low nest density reduces the probability of a particular nest to be predated. This high breeding success in our central population seems to support the hypothesis pointed out by Barrientos et al. (2009a, 2014) that suggests that current range expansion of trumpeter finch in peripheral populations is been supported by other populations in the core of the range, as no genetic differences were found based on microsatellites between European and North African populations (Barrientos et al., 2009a, 2014). Central populations like the Algerian one could be fuelling the expansion in a source-sink dynamic, although still more research is need to confirm this point.

To summarize, it is not clear whether breeding at higher altitudes is advantageous for arid-land birds. On one hand, the harsher weather conditions seem to limit breeding output, as the shorter breeding season reduces the chances of re-nesting, and egg hatchability seems reduced compared to lowlands. But, on the contrary, breeding success in highland populations seems to be higher due to the reduced predation. However, in the face on future climate warming, it is expected that predator ranges are also shifted towards higher altitudes, thus reducing the advantages that currently have arid-land species breeding at the limit of their altitudinal ranges. Thus, more research is need, especially regarding fledgling survival and return rates in these populations living on the edge.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jaridenv.2017.05.003.

References

Auer, S.K., King, D.I., 2014. Ecological and life-history traits explain recent boundary shifts in elevation and latitude of western North American songbirds. Glob. Ecol. Biogeogr. 23, 867–875.

Badyaev, A.V., 1997. Avian life history variation along altitudinal gradients: an example with cardueline finches. Oecologia 111, 365–374.

Barrientos, R., Barbosa, A., Valera, F., Moreno, E., 2007. Temperature but not rainfall influences timing of breeding in a desert bird, the trumpeter finch (*Bucanetes githagineus*). J. Ornithol. 148, 411–416.

Barrientos, R., Kvist, L., Barbosa, A., López-Iborra, G.M., Moreno, E., 2009a. Colonization patterns and genetic structure of peripheral populations of the trumpeter finch (*Bucanetes githagineus*) from Northwest Africa, the Canary Islands and the Iberian Peninsula. J. Biogeogr. 36, 210–219.

Barrientos, R., Valera, F., Barbosa, A., Carrillo, C.M., Moreno, E., 2009b. Plasticity of nest-site selection in the trumpeter finch: a comparison between two different habitats. Acta Oecol. 35, 499–506.

Barrientos, R., Barbosa, A., Valera, F., Moreno, E., 2009c. Breeding parameters of the trumpeter finch at the periphery of its range: a case study with mainland expanding and island populations. J. Arid Environ. 73, 1177–1180.

Barrientos, R., Kvist, L., Barbosa, A., Valera, F., Khoury, F., Varela, S., Moreno, E., 2014. Refugia, colonization and diversification of an arid adapted bird: coincident patterns between genetic data and ecological niche modelling. Mol. Ecol. 23, 390–407.

Barrientos, R., 2015. Camachuelo trompetero – *Bucanetes githagineus*. In: Salvador, A., Morales, M.B. (Eds.), Enciclopedia Virtual de los Vertebrados Españoles. Museo Nacional de Ciencias Naturales, Madrid. http://www.vertebradosibericos.org/.

Christians, J.K., 2002. Avian egg size: variation within species and inflexibility within individuals. Biol. Rev. 77, 1–26.

Cramp, S., Perrins, C.M., 1994. Handbook of the Birds of Europe, the Middle East and North Africa. The Birds of the Western Paleartic. In: Crows to Finches, vol. 8. Oxford University Press, London, p. 899.

Etchécopar, R.D., Hüe, F., 1964. In: Cie, Boubée et (Ed.), Les oiseaux du Nord de l'Afrique, p. 606. Paris.

Heim de Balsac, H., Mayaud, N., 1962. Les Oiseaux du Nord-Ouest de l'Afrique. Lechevalier, Paris, p. 487.

Hoyt, D.F., 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96, 73–77.

Isenmann, P., Moali, A., 2000. The Birds of Algeria (Les oiseaux d'Algérie). SEOF, Paris, p. 332.

Johnson, L.S., Ostlind, E., Brubaker, J.L., Balenger, S.L., Johnson, B.G.P., Golden, H., 2006. Changes in egg size and clutch size with elevation in a Wyoming population of mountain bluebirds. Condor 108, 591–600.

Kouidri, M., Ouakid, M.-L., Houhamdi, M., 2012. Biologie de la reproduction de la Linotte mélodieuse (*Carduelis cannabina* L. 1758) dans la région de Djebel Amour (Aflou, Algérie). Alauda 80, 117–124.

Meijer, T., Drent, R., 1999. Re-examination of the capital and income dichotomy in breeding birds. Ibis 141, 399–414.

Tellería, J.L., Fandos, G., Fernández-López, J., Onrubia, A., Refoyo, P., 2014. Winter distribution of passerine richness in the Maghreb (North Africa): a conservation assessment. Ardeola 61, 335–350.

Tellería, J.L., Fernández-López, J., Fandos, G., 2016. Effect of climate change on Mediterranean winter ranges of two migratory passerines. PLoS One 11, e0146958.