Title
A comprehensive monograph on the ecology and distribution of the House bunting (Emberiza sahari) in Algeria

Permalink
https://escholarship.org/uc/item/5hs9q97m

Journal
Frontiers of Biogeography, 13(1)

Authors
Chedad, Abdelwahab
Bendjoudi, Djamel
Beladis, Ibrahim
et al.

Publication Date
2021

DOI
10.21425/F5FBG47727

Supplemental Material
https://escholarship.org/uc/item/5hs9q97m#supplemental

Copyright Information
Copyright 2021 by the author(s). This work is made available under the terms of a Creative Commons Attribution License, available at https://creativecommons.org/licenses/by/4.0/

Peer reviewed
A comprehensive monograph on the ecology and distribution of the House bunting (*Emberiza sahari*) in Algeria

Abdelwahab Chedad, Djamel Bendjoudi, Brahim Beladis, Omar Guezoul, and Haroun Chenchouni

Abstract

The House bunting (*Emberiza sahari* Levillant, 1850) is a human commensal passerine bird species, characteristic of urban environments in the Sahara Desert of Algeria. Its distribution in Algeria, with particular emphasis in Ghardaïa, was investigated using two sampling methods: progressive frequency sampling and point abundance index, with ecological field data collected during 2017–2019. Morphological biometric measurements were carried out on free-living individuals for each sex. Reproduction phenology and success were surveyed through the breeding season (February–September) during 2018–2019. Trophic behavior was studied by direct observations of foraging individuals. Results showed that the species range in Algeria is larger than shown by data from the literature, with expansion northwards within the country. At a finer scale, in Saharan cities, the species prefers old and traditional urban environments, where its densities are higher than within modern urban habitats. At a national scale, we found that the species range is not restricted to desert climates, but extends towards the north of Algeria, including the semi-arid steppe rangelands of the Hauts-Plateaux region. Range changes are attributed to changes in building practices and climate change. Adult females were heavier and slightly larger than males, whose head plumage had different coloration patterns compared to females. Nests weighed 82.03 ± 20.77 g (mean ± standard deviation) and consisted of 72% plant materials, 19% animal-origin materials and 9% inert constituents. The nest cups were oval in form, top-lined and stuffed with diverse material. House buntings nest under the roofs of uninhabited houses, in stairwells, traditional water wells, and holes within walls. Nesting height averaged 2.14 ± 0.8 m. In Ghardaïa, courtship and pair formation began mid-February. Females can raise up to three successive broods (March–September), with 31–34 days/brood including 14–15 days for egg incubation. Clutch size is typically 2–3 eggs. The diet of the House bunting included seeds of annual grasses dominated by Poaceae species. The species also fed on anthropogenic food remains, and sometimes on insects, especially during the breeding period.

Keywords: Algeria, body biometrics, breeding biology, urban ornithology, *Emberiza sahari*, feeding ecology, House bunting, nesting, Sahara Desert, species distribution.
Introduction

The Sahara, the largest and most extreme of the deserts worldwide, is marked by edapho-climatic conditions that constrain the survival of spontaneous living beings (Chehma 2006). This ecoregion is characterized by low and uneven rainfall and pronounced thermal amplitudes between day and night and between seasons (Doumandji and Doumandji-Mitiche 1994). Regardless of its dryness, emptiness and severe environmental conditions, the Sahara contains a very particular diversity of flora and fauna, where some species have remarkable adaptations (Chehma 2006).

Birds are excellent indicators for studying the effects of urbanization because they react quickly to modifications in the landscape (Marzluff et al. 1998), and the trophic resources available present significant spatio-temporal variations that influence the functioning of populations and the expression of life history traits of individuals (Roff 1992). Among the birds of the Emberizidae family, two Bunting species characterize the Sahara Desert: House bunting (Emberiza sahari Levalliant, 1850) in Northwest Africa and Striolated bunting (Emberiza striolata Lichtenstein, 1823) in Northeast Africa and Asia. The latter includes three subspecies: E. s. saturiator, E. s. jebelmarrae and E. s. striolata (Kirwan and Shirihai 2007, Svensson et al. 2009, Sangster et al. 2013, Schweizer et al. 2017).

In Algeria, the House bunting has a narrow distribution range. The northern boundary includes the Saharan limits of the Aurès mountains and its oases (M’Chouneche, El Kantra, Ouitaya, Biskra, Tolga, Chetma) and the southern aspect of the Saharan Atlas (Bousâada, Messaad, Laghouat, Ain Sefra, Beni Ounif, Bechar). The southern boundary passes through Biskra, Ghardaïa, M’Zab, the oasis of Taghit and that of Beni Abbes south of Bechar. The distribution of this species also includes Hoggar, Tassili, Kalaa-Beni-Hammad (Setif), Belhiourt, Oued Abiod and Ghoufi (Aurès mountains) (Heim de Balsac and Mayaud 1926, Ledant et al. 1981, Isenmann and Moali 2000, Moulaï 2019). It is in this context that the current study aims to fill scientific gaps in several aspects of the species’ ecology and biogeography, by providing a comprehensive investigation including: (i) mapping and updating its range in Algeria with emphasis on the province of Ghardaïa and its neighboring regions in central Algeria; here the study focuses on how cultural shifts in building practices are changing the species’ distribution and abundance and assesses distribution shifts and expansion at a national scale. We investigated how urbanization intensity and building structure (considered as different urban habitats ranging from less urbanized and traditional habitats to modern and dense buildings) influence the occurrence and population abundance of this synanthropic species; (ii) determining biometric parameters and their variation between sexes; (iii) examining its breeding biology with analysis of the temporal variations of breeding parameters (clutch size, hatching and reproductive success) and egg-laying date for different broods, times of nesting and years of study; and (iv) exploring adult diet composition.

Materials and Methods

Study area

The present study was carried out in the region of Ghardaïa (32°28’N, 3°42’E), which is located in the central–northern part of the northern Sahara Desert. The City of Ghardaïa is located 600 km south of the capital city Algiers (Heim de Balsac and Mayaud 1926) and is described as a UNESCO World Heritage Site (https://whc.unesco.org/en/list/188/). The region has a Saharan bioclimate characterized by mild winters (mean temperature of the coldest month = 11.5 °C), very hot summers (mean temperature peaks in July with 35.5 °C) and low annual rainfall (~50–70 mm).

Mapping species distribution in Algeria

In order to establish a distribution map of the House bunting in Algeria, with a particular focus in Ghardaïa (central Algeria), species occurrence data during 2017–2019 were collected using the Progressive Frequency Sampling (Echantillonage Fréquentiel Progessif “EFP”) method, which is a point-sampling technique (see details in Blondel 1975, Bendjoudi et al. 2013). Using species occurrence data from the current study, complemented with additional occurrence data derived from eBird (www.ebird.org), we mapped and updated the geographic distribution of the House bunting in new locations detected outside its known range (BirdLife International 2016). Previous studies involving species range or occurrence reporting (Heim de Balsac and Mayaud 1962, Ledant et al. 1981, Isenmann and Moali 2000, Moulaï 2019) were also considered in updating the map of the House bunting range. ArcGIS (version 10.2.2 for Desktop: Esri®) was used to produce species distribution maps.
Population estimation

Population counts of the House bunting were conducted in the region of Ghardaia and surrounding areas using two sampling methods: progressive frequency sampling applied during the non-breeding season (October–early February) and a punctual abundance index (PAI) during the breeding season (mid-February–September), where the number of detected contacts, visual and/or auditory, were counted at four sampling points per habitat type (Blondel et al. 1970, Blondel 1975). Three different study sites were chosen and surveyed as representative of three types of urban environments in Ghardaia, considering construction material and building architecture and density: (i) traditional urban (Fig. 1A), often consisting of one-floor buildings, sparse (density≈4–5 dwellings/ha) and scattered within date palm trees and/or other trees such as pomegranates, orange trees, etc., and featuring traditional elements such as stone walls and floors with wood and clay; (ii) semi-modern urban (Fig. 1B), consisting of one-floor buildings, organized regularly in space (density=24 dwellings/ha), of the same area, height and distance from the street and/or other houses. While semi-modern urban buildings were constructed of modern materials (i.e. concrete), the architecture of traditional buildings, such as many small windows, arches and triangles, was preserved, but without green-spaces crisscrossing houses, and; (iii) a totally modern urban area (Fig. 1C), in the form of two-story buildings (density ≈ 92 dwellings/ha), with the same height, shape and area, and located adjacent to paved main roads. In each site, four sampling points were monitored in order to study the influence of the urban environment type on the fluctuations in the number of individuals.

The software R (R Core Team 2020) was employed for statistical analyses. Descriptive statistics, i.e. mean, standard deviation (SD) and range (min–max), were computed to summarize data on House bunting population counts across the different types of urban environments and also for data generated below. Normality was checked using Shapiro-Wilk tests before carrying out one-way ANOVA to test the variation of species count data between urban environments.

Body biometric measurements

Biometric measurements were obtained from free-living individuals captured either with an ornithological net (Japanese net) or by hand at roosting sites. Each captured individual (females = 4 and males = 7) was weighed using an electronic scale with 0.01 g precision, and the following morphometrics were measured using a digital Vernier caliper (precision = 0.01 mm): (i) total length (distance between the beak tip and the longest feathers of the tail), (ii) wingspan (distance between the wingtips with wings held outstretched), (iii) stretched wing (distance from the bend of the wing to the tip of the longest primary feathers), (iv) tail length (distance from the tip of the longest feathers to the base of the tail), (v) bill length (culmen: distance between the tip of the upper mandible and the first feathers of the skull), and (vi) length of tarsometatarsus (distance from the tibiotarsal articulation to the base of the toes; Eck et al. 2011). All individuals measured were captured from the semi-modern urban site of Ghardaia during the non-breeding season. Each individual was immediately released after obtaining these measurements. The variation of body biometric traits among sexes was tested using one-way ANOVA. Interrelationships between body morphometric variables were investigated using Pearson correlation tests at a significance threshold $\alpha = 0.05$. Correlations were mapped in an interactive plot displaying the correlation matrix using the package {corrplot} in R (Wei and Simko 2017).

Figure 1. Photos of different urban sites where populations of the House bunting (Emberiza sahari) were estimated in the region of Ghardaia (Sahara Desert of Algeria). A) traditional urban site inside an oasis of date palm (Phoenix dactylifera) trees; B) semi-modern urban environment; C) modern urban habitat. (Photographs by Abdelwahab Chedad)
Breeding ecology

From 2018 to 2019, nests of the House bunting were examined in all localities where the species’ presence was confirmed in the province of Ghardaïa. Nesting surveys started at an early stage of the breeding season and before egg laying. Field surveys were carried out regularly every 2–3 days. Once a nest was found, the following parameters were recorded: geographical coordinates, date, nest state (old or new), nest height above the ground, nest cup orientation, and other nest measurements (cup depth, nest outer and inner diameters).

For active nests, clutch size was recorded, and egg length (EL) and egg breadth (EB) were measured using a Vernier caliper (accuracy 0.01 mm). Egg weight (EW) was determined with an electronic scale (precision 0.01 g) during the first day after egg-laying. The shell index (IC) was subsequently calculated according to the formula of Ramade (1978): IC = EW1/EB, where EW1 is egg weight during the first day of laying. Egg volume (EV) was calculated following the formula of Hoyt (1979): EV = 0.51×EL×EB. Egg shape index (SI) was computed using the formula: SI = EB/ELx100 (Panda 1996). Represented as a correlation matrix, Pearson correlation tests were employed to analyze relationships between egg characteristics (EL, EB, EW, IC, EV and SI).

After hatching, the number of surviving hatchlings were monitored regularly every 3–4 days until all chicks fledged. Chicks were tagged with numbered and colored rings. During each nest visit, chicks were weighed to determine body mass, and total length was measured using the same methods described above.

For each nest, the following breeding parameters were obtained in each breeding year (2018–2019), for each brood and for all years and broods combined (Metallaoût et al. 2020): (i) the duration of incubation (from first egg laid to hatching of all eggs), (ii) the duration of brooding (from first egg laid to chick fledging), (iii) hatching success (%; calculated as the number of eggs hatched/clutch size × 100), (iv) fledgling success (%; calculated as the number of fledglings/nest × 100), and (v) breeding success (%; calculated as the number of fledglings/clutch size × 100).

The data used in the analysis of breeding biology of the House bunting were observed at the nest level. First, nests observed during the same brood (in total, there were three per year) were classified into two categories, i.e. ‘early’ and ‘late’ brood timing, based on the median of dates of egg-laying of the first egg per nest. The effects of breeding attributes (i.e. breeding year ‘2018-2019’, brood timing ‘early/late’, and number of broods ‘1-3’) on the variation of breeding parameters (i.e. clutch sizes, number of hatchlings and fledglings) were tested using generalized linear models (GLM). The first GLM included breeding year, brood timing, and number of broods as predictor variables of changes observed in clutch sizes. The second model included clutch size in addition to the previously described breeding attributes as explanatory variables of the variation in the number of hatchlings. The third GLM tested the variation in the number of chicks fledged per nest with the above-mentioned breeding attributes, clutch size and the number of hatchlings as predictor variables. Each GLM was simplified using the ‘backward/forward’ stepwise selection procedure in order to automatically obtain the model with the best fit, i.e. with the lowest Akaike Information Criterion (AIC) score. Based on the model selected, a likelihood ratio test was performed for each breeding parameter using the function ‘Anova()’ for GLM in order to determine the effects of each explanatory variable.

At the end of the breeding season in 2018, ten nests were carefully collected in cardboard bags and brought to the lab to analyze the composition of nest building materials. Each nest was weighed using an electronic scale (precision 0.01 g), and the nest building materials were separated and grouped into three categories, plant, animal and inert materials. Plant materials were compared with leaves and twigs of trees, shrubs and herbs in the environment surrounding the nest. Plant species used as nest material were determined using plant guides (e.g. Chehma 2006). ANOVA was used to test the variation of weights of nest building materials between the three material categories.

Diet composition analysis

The trophic behavior of the House bunting was studied using direct observations of birds when foraging (Blaguskónov 1987). Using a Nikon P-900 bridge camera (×83), the foraging birds were observed regularly all year round from 2017 to 2019 in several regions of the province of Ghardaïa. Observations took place mainly during the morning (07:00–12:00). In case of foraging activity on the ground, the individual (or the flock) was monitored for a while, and just after the bird left the site, the plant and/or animal species consumed were precisely described. Samples and photographs were considered in order to facilitate the identification of plant and insect species consumed. Plant species were determined using a plant guide (Chehma 2006), whereas insects were identified mainly based on Chinery (1988).

Results

Range of the House bunting in Algeria and Ghardaïa

During November 2017–December 2019, the presence of the House bunting was confirmed in several regions in Algeria (Fig. 2A), i.e. Bechar (Beni Ounif and Taghit), El Bayadh (El Abiod, Sidi Cheikh and Ain Larak), Laghouat (Laghouat city, Aflou, Sidi Makhlof and El Hadjeb), Djelfa city, Biskra (Biskra city and El Kantara), M’sila (Bousada), Batna (Ghoufi, T’kout, Gassira, Arris and M’doukal), Ouargla (Tougourt and Megarine), northern Ghardaïa, southern Tissensmilt, and the extreme south of the Algerian Sahara, Illizi (Djanet). The number of confirmed occurrence points used in updating and mapping species distribution was 425 (Fig. 2A), with 94% observed in 2017–2019 and 6% retrieved from ebird.org. In Ghardaïa, the
The distribution of *Emberiza sahari* densities among different urban environment types showed a significant difference (one-way ANOVA: $F_{(2,9)} = 34.03$, $P < 0.0001$). The traditional urban habitat had 18 pairs with a mean of $4.50 \pm 0.41$ pairs/ha for each sampling point, which was significantly greater than pair density in the semi-modern urban zone (mean = $3.0 \pm 0.41$ pairs/ha, total = 12 pairs) and the modern urban environment (mean = $1.63 \pm 0.63$ pairs/ha) (Table 1). During the breeding season, the density of pairs varied between 1 and 2 pairs/ha in the three urban sites.

**Body biometrics for both sexes**

In male House buntings, mass varied between 15.74 and 17.81 g, with a mean of 16.64 ± 0.72 g. The total length ranged between 13.1 and 13.3 cm (13.21 ± 0.09 cm). The wingspan was 20.7 ± 0.82 cm (range: 19.6–21.9 cm). The length of the tail fluctuated between 5.2 and 5.4 cm (5.3 ± 0.08 cm). The tarsometatarsus had a length of 1.68 ± 0.03 cm (range: 1.65–1.7 cm). The stretched wing fluctuated between 9.2 and 10.7 cm (10.08 ± 0.63 cm), whereas the length of the bill varied between 0.9 and 1.05 cm (0.98 ± 0.06 cm) (Table 2). The variation of body traits between sexes was not significant except for body mass (ANOVA: $F_{(1, 9)} = 12.83$, $P = 0.006$) and the length of the stretched wing (ANOVA: $F_{(1, 9)} = 8.083$, $P = 0.019$).

The Pearson correlation matrix (Supplementary Material - Figure S1) showed that out of 20 correlation tests between morphometric traits, none were significant ($|r| < 0.58$, $P > 0.05$). Length of wing was correlated positively with all morphometric traits except bill length, which was negatively correlated with all other traits, excluding body mass. The latter was negatively correlated with total length, tail length and wingspan, but correlated positively with length of the tarsometatarsus. This uneven pattern of correlations may be related to species-specific allometry or to the sample size analyzed.

**Sexual dimorphism in morphology and plumage**

With regard to the morphological description of the House bunting, the head, neck and chest are gray in color speckled with white. For both sexes, the bill is dark grayish for the upper mandible and yellowish for the lower mandible. The lower parts of the body are slightly brown. The wings have a rusty color with dark black wingtips. The tail is black with a heart-shaped
tip. Males are defined by more marked patterns on the head, with a more obvious dissimilarity between light and dark areas compared to females. On the other hand, females are characterized by a gray-brown color, and the patterns are less clear. The tibia and tarsus are russet with dark gray legs and black toes for both sexes (Fig. 3).

Breeding and nesting biology

Nest building materials

Nests of House buntings weighed on average 82.03 ± 20.77 g. They were constructed in three fractions, i.e. 72% plant materials (59.14 ± 14.25 g), 19% materials of animal origin (15.95 ± 3.82 g), and 9% inert materials (6.93 ± 6.62 g). The variation of nesting material weights among these three categories was highly significant (one-way ANOVA: \( F_{(2,27)} = 86.7, P < 0.0001 \)). The plant part was composed of 21 species belonging to 12 plant families. The Poaceae family was best represented with seven species: *Bromus* spp., *Cynodon dactylon*, *Setaria viridis*, *Polypogon monspeliensis*, *Hordeum murinum*, *Triticum* spp. and *Hordeum vulgare* (Table 3). The animal material fraction was composed of feathers, sheep wool, goat hair and human hair. The inert part was composed of several elements, including stone, mud, and small pieces of timber, tissue, foil, plastic fibers, fabric and soap. In the middle of the nests, several specimens of insects were found, including *Larinioides* spp., *Lepisma* spp., Myrmeleontidae spp. unidentified and larvae of Dermestidae.

Nests of the House bunting were built mainly from annual plants and dry medium-size branches (twigs) of trees (*Punica granatum*, *Citrus sinensis*, *Citrus limon*, *Ficus carica* and *Phoenix dactylifera*) collected from the environment surrounding the nesting site. Nests were garnished with stones, mud, seeds, tree barks and fruits. The cup of the nest, of oval shape, was composed of fine plant elements (small branches and blades of dry grass, roots, straws, etc.). Inside, it was lined and stuffed with palm hair, fibers, and feathers, and it was essentially characterized by the presence of sheep wool, human hair and goat hair.

Characteristics of nests and nest sites

In general, House buntings install their nests under a house roof or inside holes. The nests are always sheltered from direct sunlight. They build their nests above the shelves within houses (usually uninhabited), in stairwells (Fig. 4A), in holes of walls of traditional water wells, on bases of house windows, or in holes and cracks in fencing walls. The nesting height varied between 0.9 and 4.15 m (2.14 ± 0.795 m). The inner diameter averaged 5.8 ± 0.56 cm (range: 4.9–6.5 cm). The cup depth ranged between 5.01 and 6.2 cm (5.71 ± 0.39 cm). The outer diameter varied between 29 and 44 cm (34.77 ± 4 cm). Usually both partners participated in nest building (Fig. 4B, 4C), which lasted between 5 and 22 days. Nests were mainly installed with the cup oriented to the East, sometimes Northeast or Southeast.

Breeding chronology, egg traits and chick growth

The courtship and pair formation in the House bunting began in mid-February. The female can have three successive broods on the same nest over a period of seven months (March–September). Each brood lasted 31–34 days with 14–15 days spent in egg incubation. The first brood began in mid-March (mean laying date of the first egg = 5th April ± 14 days), the second occurred in mid-May (mean egg-laying date = 10th May ± 13 days) and the third brood was observed in early July (mean egg-laying date = 13th July ± 22 days).

Table 1. Numbers of the House bunting (*Emberiza sahari*) counted in different types of urban environments and counting-points during non-breeding season (using progressive frequency sampling technique) and breeding season (using punctual abundance index method) in the region of Ghardaia, Sahara Desert of Algeria.

| Variables                        | Traditional | Semi-modern | Modern |
|----------------------------------|-------------|-------------|--------|
| **Site characteristics**         |             |             |        |
| Latitude (North)                 | 32°30'17.75" | 32°23'58.68" | 32°21'49.84" |
| Longitude (East)                 | 03°38'51.58" | 03°45'39.29" | 03°47'49.95" |
| Elevation (m a.s.l.)             | 515         | 491         | 440    |
| Counting points                  | P1          | P2          | P3      |
|                                 | 13          | 12          | 11      |
| **Counts during non-breeding season** |             |             |        |
| Point-counts (pairs/ha)          | 4.5         | 1.5         | 1.5     |
| Total                            | 4.50 ± 0.41 | 1.50 ± 0.41 | 1.63 ± 0.63 |
| **Counts during breeding season** |             |             |        |
| Point-counts (pairs/ha)          | 1.5         | 2.5         | 1.5     |
| Total                            | 1.50 ± 0.48 | 2.50 ± 0.48 | 1.13 ± 0.25 |

Frontiers of Biogeography 2021, 13.1, e47727 © the authors, CC-BY 4.0 license
Table 2. Descriptive statistics of body morphometric traits for males (n = 7) and females (n = 4) of House buntings (Emberiza sahari) from the Sahara Desert of Algeria.

| Variables         | Mean    | SD     | IQR    | CV    | Min 25% | 50%  | 75%  | Max  | Skewness | Kurtosis | $F_{(1,9)}$ | P-value |
|-------------------|---------|--------|--------|-------|---------|------|------|------|----------|----------|------------|---------|
| **Body weight [g]** |         |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 17.98   | 0.12   | 0.09   | 0.006 | 17.8    | 18.0 | 18.0 | 18.0 | 18.1     | −1.63    | 2.88       |         |
| Male              | 16.64   | 0.72   | 0.91   | 0.043 | 15.7    | 16.1 | 16.8 | 17.0 | 17.8     | 0.43     | −0.62      |         |
| Overall           | 17.13   | 0.88   | 1.47   | 0.051 | 15.7    | 16.4 | 17.2 | 17.9 | 18.1     | −0.38    | −1.54      |         |
| **Total length [cm]** |        |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 13.23   | 0.05   | 0.03   | 0.004 | 13.2    | 13.2 | 13.2 | 13.2 | 13.3     | 2.00     | 4.00       |         |
| Male              | 13.21   | 0.09   | 0.15   | 0.007 | 13.1    | 13.2 | 13.2 | 13.2 | 13.3     | −0.35    | −1.82      |         |
| Overall           | 13.22   | 0.08   | 0.10   | 0.006 | 13.1    | 13.2 | 13.2 | 13.3 | 13.3     | −0.33    | −0.88      |         |
| **Wingspan [cm]** |         |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 21.15   | 0.13   | 0.15   | 0.006 | 21.0    | 21.1 | 21.2 | 21.2 | 21.2     | 0.00     | −1.20      |         |
| Male              | 20.70   | 0.82   | 1.15   | 0.040 | 19.6    | 20.1 | 20.9 | 21.2 | 21.2     | 0.04     | −1.25      |         |
| Overall           | 20.86   | 0.68   | 0.70   | 0.033 | 19.6    | 20.5 | 21.1 | 21.2 | 21.9     | −0.70    | −0.12      |         |
| **Stretched wing [cm]** |      |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 10.08   | 0.63   | 0.53   | 0.063 | 9.2     | 9.9  | 10.2 | 10.4 | 10.7     | −1.08    | 1.75       |         |
| Male              | 9.11    | 0.48   | 0.55   | 0.053 | 8.3     | 8.9  | 9.2  | 9.5  | 9.6      | −0.98    | −0.37      |         |
| Overall           | 9.46    | 0.70   | 0.65   | 0.074 | 8.3     | 9.2  | 9.4  | 9.9  | 10.7     | 0.16     | −0.16      |         |
| **Tail length [cm]** |        |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 5.30    | 0.08   | 0.05   | 0.015 | 5.2     | 5.3  | 5.3  | 5.3  | 5.4      | 0.00     | 1.50       |         |
| Male              | 5.39    | 0.22   | 0.30   | 0.041 | 5.1     | 5.3  | 5.3  | 5.3  | 5.7      | 0.25     | −1.37      |         |
| Overall           | 5.35    | 0.18   | 0.20   | 0.034 | 5.1     | 5.3  | 5.3  | 5.3  | 5.7      | 0.72     | −0.11      |         |
| **Bill length [cm]** |      |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 0.98    | 0.06   | 0.08   | 0.066 | 0.9     | 1.0  | 1.0  | 1.0  | 1.1      | 0.00     | −1.20      |         |
| Male              | 0.98    | 0.06   | 0.05   | 0.065 | 0.9     | 1.0  | 1.0  | 1.0  | 1.1      | 1.14     | 1.95       |         |
| Overall           | 0.98    | 0.06   | 0.05   | 0.062 | 0.9     | 1.0  | 1.0  | 1.0  | 1.1      | 0.69     | 0.29       |         |
| **Length of tarsometatarsus [cm]** |      |        |        |       |         |      |      |      |          |          |            |         |
| Female            | 1.68    | 0.03   | 0.05   | 0.017 | 1.7     | 1.7  | 1.7  | 1.7  | 1.7      | 0.00     | −6.00      |         |
| Male              | 1.61    | 0.06   | 0.05   | 0.039 | 1.5     | 1.6  | 1.6  | 1.7  | 1.7      | −0.74    | 1.49       |         |
| Overall           | 1.64    | 0.06   | 0.08   | 0.036 | 1.5     | 1.6  | 1.7  | 1.7  | 1.7      | −1.10    | 1.67       |         |

Clutch size varied between 2 and 3 eggs. Eggs were ivory–whitish colored, spotted with brown, and these spots were very dense at the end of the egg on the side of the air chamber. The weight of the eggs varied between 1.70 and 2.26 g (1.97 ± 0.15 g). Their length varied between 1.8–2.0 cm (1.87 ± 0.7 cm), and their breadth ranged between 1.3 and 1.5 cm (1.39 ± 0.05 cm). The values of the shell index fluctuated from one nest to another and from one egg to another (range: 0.13–0.16 g/cm, mean ± SD: 0.14 ± 0.008 g/cm). The mean of egg volume was 1.84 ± 0.19 cm³ and that of shape index was 74.33 ± 2.72% (Table 4).

Once hatched, 2-day–old chicks weighed 2.52 ± 0.41 g with a total length of 3.40 ± 0.20 cm. At the age of 7 days old, their average weight reached 9.4 ± 0.9 g and they measured 5.33 ± 0.89 cm long. Just before fledging, after 14 days, their average weight reached 14.94 ± 0.04 g, with a total length of 9.25 ± 0.07 cm.

The correlation matrix (Supplementary Material—Figure S2) showed that out of 15 Pearson correlation tests between egg characteristics, five were significant ($P < 0.05$). These correlations were all positive and observed between egg weight—breadth ($r = 0.75$, $P = 0.001$), weight—volume ($r = 0.59$, $P = 0.021$), weight—shell index ($r = 0.90$, $P < 0.001$), volume—length ($r = 0.87$, $P < 0.001$) and volume—breadth ($r = 0.87$, $P < 0.001$).

**Breeding parameters**

House bunting reproduction in Ghardaïa during 2018–2019 was monitored based on a total of 25 nests and 62 eggs, with 10 nests and 23 eggs surveyed in 2018 and 15 nests with 39 eggs monitored in 2019 (Table 5). The clutch size averaged overall 2.48 ± 0.51 eggs/nest (mean ± SD), with 2.30 ± 0.48 eggs/nest in 2018 and 2.60 ± 0.51 eggs/nest in 2019 (Fig. 5). GLM indicated that clutch size increased significantly in 2019 compared to 2018 (GLM: $\chi^2 = 7.35$, $P = 0.007$) (Table 6). Clutch size was
larger for the first brood in 2018 (2.67 ± 0.58 eggs/nest) compared to 2019 (2.60 ± 0.51 eggs/nest) and for the second and third broods in 2019 with 2.50 ± 0.58 and 3.00 ± 0.00 eggs/nest, respectively, compared with 2018, when we recorded 2.00 ± 0.00 and 2.33 ± 0.58 eggs/nest, respectively (Fig. 5). Statistically, the model did not reveal any significant difference between the three broods (P = 0.186), nor for brood timing for each brood (P > 0.05) (Table 6).

Hatchlings totaled 48 individuals, with an overall hatching success of 77.4%. Hatching success reached 100% (23 hatchlings) in 2018 and 64.1% (25 hatchlings) in 2019 (Table 5). Two-egg nests had higher hatching success (88.5%) than three-egg nests (69.4%). Fledglings totaled 43 individuals with a total fledging success of 89.6%, where 20 fledged in 2018 (fledging success = 87%) and 23 fledged in 2019 (fledging success = 92%). Nests with three eggs had a fledging success of 92%, higher than that in two-egg nests (87%). The overall reproductive success was 69.4% (87% in 2018 and 59% in 2019). Breeding success in two-egg nests (76.9%) was greater than that in three-egg nests (63.9%). In two-egg nests, reproductive success increased with the increase in the number of broods per year (72.2%, 83.3% and 100% for the first, second and third brood, respectively), but it decreased with the increase in the number of broods in three-egg nests (70.4%, 50.0% and 33.3% for the first, second and third brood, respectively).

Statistical analysis showed that the number of hatchlings varied significantly between the two breeding years (GLM: χ² = 5.61, P = 0.018). The number of hatchlings either in earlier or late broods did not vary significantly (P > 0.05) with brood timing, number of broods or brood order. However, the number of hatchlings increased significantly (GLM: χ² = 4.21, P = 0.040) with the increase in clutch size, but with a difference between years. Although hatching success was deemed to increase significantly with the increase in clutch size (χ² = 8.42, P = 0.004), no significant effects
Table 3. Nest building materials of the House bunting (*Emberiza sahari*) breeding in the Sahara Desert of Algeria.

| Type of material | Family | Species | Weight (g)/nest (n = 10) |
|------------------|--------|---------|--------------------------|
| Plant material   | Punicaceae | *Punica granatum* | 59.14 ± 14.25 30.80–78.61 |
|                  | Rutaceae  | *Citrus sinensis, Citrus limon* |           |
|                  | Rosaceae  | *Malus domestica* |           |
|                  | Moraceae  | *Ficus carica* |           |
|                  | Vitaceae  | *Vitis spp.* |           |
|                  | Arecaeae  | *Phoenix dactylifera* |           |
|                  | Casuarinaceae | *Casuarina equisetifolia* |           |
|                  | Cucurbitaceae | *Cucumis melo* |           |
|                  | Fabaceae  | *Arachis spp., Vicia faba* |           |
|                  | Poaceae   | *Bromus spp., Cynodon dactylon, Setaria viridis, Polypogon monspeliensis, Hordeum murinum, Triticum spp., Hordeum vulgare* |           |
|                  | Liliaceae | *Allium sativum, Allium cepa* |           |
|                  | Anacardiaceae | *Pistacia atlantica* |           |
| Animal material  | Feathers, sheep wool, goat hair, human hair | 15.95 ± 3.82 11.24–21.30 |
| Inert material   | Stone, dry mud, small piece of construction wood, tissue paper, aluminum foil, plastic fibers, cloth, pieces of soap | 6.93 ± 6.62 1.97–21.77 |
| Overall (n = 10) | | 82.03 ± 20.77 46.24–108.5 |
| One-way ANOVA   | | $F_{(2,27)} = 86.706$ |
|                 | | $P$-value = <0.0001 |

Figure 4. Photographs showing: (A) an overview of an active two-egg-nest of the House bunting *Emberiza sahari* built in an indoor stairwell of a house in Ghardaia region, Algeria. The nest is mainly built of plant materials, with the top of the nest lined with whitish-grey goat hair. Photographs of a (B) female and (C) male collecting nesting plant materials from the yard of a house in July 2018. The female is holding a dry branch of *Cynodon dactylon* in her bill, whereas the male is holding fresh uprooted twigs of *Cynodon dactylon*. (Photographs by Abdelwahab Chedad)
Table 4. Measurements of eggs and duration of breeding period in the House bunting (Emberiza sahari) nesting in the Sahara Desert of Algeria. Values are expressed as mean ± SD and range (min–max)

| Variables                  | Mean ± SD      | Range         |
|----------------------------|----------------|---------------|
| **Egg traits (n = 25)**    |                |               |
| Weight [g]                 | 1.97 ± 0.15    | 1.70–2.26     |
| Length [cm]                | 1.87 ± 0.70    | 1.80–2.00     |
| Breadth [cm]               | 1.39 ± 0.05    | 1.30–1.50     |
| Volume [cm³]               | 1.84 ± 0.19    | 1.55–2.30     |
| Shell index [g/mm]         | 0.14 ± 0.008   | 0.13–0.16     |
| Shape index [%]            | 74.33 ± 2.72   | 69.23–77.78   |
| **Breeding parameters (n = 25)** |            |               |
| Brooding time [days]       | 31.61 ± 1.20   | 31–34         |
| Incubation duration [days] | 14.26 ± 0.45   | 14–15         |

Table 5. Breeding parameters of the House bunting breeding at urban environments of the region of Ghardaia in the Sahara Desert of Algeria. Data were grouped for each clutch size per two breeding seasons (2018 and 2019) and number of brood.

| Breeding parameters | Breeding season and Number of broods | Clutch size | Overall |
|---------------------|--------------------------------------|-------------|---------|
| Number of nests     | Year 2018 7 3 10                     |             |         |
|                     | Year 2019 6 9 15                     |             |         |
|                     | 1st brood 9 9 18                     |             |         |
|                     | 2nd brood 3 2 5                      |             |         |
|                     | 3rd brood 1 1 2                      |             |         |
|                     | Overall 13 12 25                     |             |         |
| Sum of clutch sizes [eggs] | Year 2018 14 9 23                  |             |         |
|                     | Year 2019 12 27 39                   |             |         |
|                     | 1st brood 18 27 45                   |             |         |
|                     | 2nd brood 6 6 12                     |             |         |
|                     | 3rd brood 2 3 5                      |             |         |
|                     | Overall 26 36 62                     |             |         |
| Number of hatchlings | Year 2018 14 9 23                   |             |         |
|                     | Year 2019 9 16 25                    |             |         |
|                     | 1st brood 15 20 35                   |             |         |
|                     | 2nd brood 6 4 10                     |             |         |
|                     | 3rd brood 2 1 3                      |             |         |
|                     | Overall 23 25 48                     |             |         |
| Number of fledglings | Year 2018 11 9 20                   |             |         |
|                     | Year 2019 9 14 23                    |             |         |
|                     | 1st brood 13 19 32                   |             |         |
|                     | 2nd brood 5 3 8                      |             |         |
|                     | 3rd brood 2 1 3                      |             |         |
|                     | Overall 20 23 43                     |             |         |
| Hatching success [%]  | Year 2018 100 100 100                |             |         |
|                     | Year 2019 75 59.3 64.1               |             |         |
|                     | 1st brood 83.3 74.1 77.8             |             |         |
|                     | 2nd brood 100 66.7 83.3              |             |         |
|                     | 3rd brood 100 33.3 60                |             |         |
|                     | Overall 88.5 69.4 77.4               |             |         |
were observed for the number of eggs laid in terms of the number of hatchlings when combined with different brood timings ($\chi^2<0.01$, $P = 0.976$), number of broods ($\chi^2 = 2.79$, $P = 0.248$) and their interaction ‘clutch size × brood timing × number of broods’ ($\chi^2 = 3.26$, $P = 0.196$) (Table 6). The relationship of ‘clutch size—number of hatchlings’ was positive for the first brood. However, it was not significant for the second and third broods regardless of brood timing (Fig. 6). The third GLM (Table 6) demonstrated that the number of hatchlings ($\chi^2 = 54.87$, $P < 0.001$), but not clutch size ($\chi^2 = 2.82$, $P = 0.093$), influenced significantly the variation of chicks fledged per nest. Additionally, the number of fledglings varied significantly ($\chi^2 = 11.99$, $P = 0.002$)
between broods of the same breeding year. Although the number of fledglings was associated positively with the number of hatchlings, the effects of the number of hatchlings was the same when interrelated with brood timing, i.e. early/late brood ($P = 0.830$), or with number of broods ($P = 0.095$), which displayed the same variation patterns (Fig. 6). In addition, the GLM showed that the number of fledglings had no significant variation between years ($P = 0.294$) or brood timings ($P = 0.199$) (Table 6).

Diet composition
Using the visual method, it was possible to determine the diet of House buntings, which consisted mainly of annual weed seeds belonging to 13 species and 5 families. The Poaceae family was best represented with eight species, including *Cynodon dactylon*, *Polypogon monspeliensis* and *Phalaris paradoxa*. The House bunting also fed on food remains of plant origin, especially breadcrumbs, and sometimes on insects, including *Sarcophaga carnaria*, *Cadra* spp. and *Messor* spp. (Table 7).

Discussion
Species distribution and population size estimates
The presence of the House bunting was confirmed in the majority of the areas already mentioned in the literature (Heim de Balsac and Mayaud 1962, Ledant et al. 1981, Isenmann and Moali 2000), including El Kantra, Biskra, Bousâada, Beni Ounif, Ghardaïa, M’Zab, Taghit, Tassili, Ghoufi, and Laghouat. We have reported the presence of the species in new sites such as El Abiodh Sidi Cheikh and Ain Larak (El Bayadh), Aflou, El Hadjeb and Sidi Makhlouf (Laghouat), M’doukal, T’kout, Ghassira and Arris (Batna), Touggourt and Megarine (Ouargla), Djelfa city and Tissemsilt. In the present work, the expansion of House bunting distribution was observed more towards the North of Algeria. In

Table 6. Generalized linear models analyzing the effects of breeding attributes (i.e. breeding year, brood timing, and number of broods) on the variation of clutch sizes (GLM #1), breeding attributes and clutch size on the variation of number of hatchlings (GLM #2), and breeding attributes, clutch size and number of hatchlings on the variation of the number of fledglings (GLM #3) of House buntings (*Emberiza sahari*) nesting in the region of Ghardaïa (Sahara Desert of Algeria). Selection of model with best fit (lowest AIC score) was carried using the ‘backward/forward’ stepwise procedure. Sample size = 25 nests, 62 eggs, 48 hatchlings, and 43 fledglings.

| Variables                                      | $\chi^2$ | $P$-value | Sig. |
|-----------------------------------------------|----------|-----------|------|
| GLM #1: Clutch size (AIC = 43.292, $\Delta$AIC = 5.306) |           |           |      |
| Breed timing                                  | 2.71     | 0.100     | NS   |
| Number of broods                              | 3.36     | 0.186     | NS   |
| Year                                          | 7.35     | 0.007     | **   |
| Brood timing × Number of broods               | 4.63     | 0.099     | NS   |
| GLM #2: Number of hatchlings (AIC = 41.657, $\Delta$AIC = 0) |           |           |      |
| Clutch size                                   | 8.42     | 0.004     | **   |
| Brood timing                                  | 0.06     | 0.807     | NS   |
| Number of broods                              | 4.63     | 0.099     | NS   |
| Year                                          | 5.61     | 0.018     | *    |
| Clutch size × Brood timing                    | 0.00     | 0.976     | NS   |
| Clutch size × Number of broods                | 2.79     | 0.248     | NS   |
| Brood timing × Number of broods               | 1.05     | 0.593     | NS   |
| Clutch size × Year                            | 4.21     | 0.040     | *    |
| Clutch size × Brood timing × Number of broods | 3.26     | 0.196     | NS   |
| GLM #3: Number of fledglings (AIC = 15.856, $\Delta$AIC = 72.643) |           |           |      |
| Hatchlings                                    | 54.87    | <0.001    | ***  |
| Brood timing                                  | 1.65     | 0.199     | NS   |
| Clutch size                                   | 2.82     | 0.093     | NS   |
| Number of broods                              | 11.99    | 0.002     | **   |
| Year                                          | 1.10     | 0.294     | NS   |
| Hatchlings × Brood timing                     | 0.05     | 0.830     | NS   |
| Hatchlings × Number of broods                 | 4.72     | 0.095     | NS   |

($\chi^2$: Chi-square value of the likelihood ratio test, AIC = Akaike information criterion of the current selected GLM, $\Delta$AIC = AIC difference between the initial GLM and the simplified one with the lowest AIC, Sig.: probability significance codes, ***: $P<0.001$, **: $P<0.01$, *: $P\leq0.05$, NS: $P>0.05$)
2017, the species was already observed in northern Algeria, at the capital city Algiers, Tissemsilt and Bordj Bou-Arreridj (Moulaï 2019). In Morocco, the same expansion trend in species range was reported northward, but also southward (Amezian et al. 2006, Azaouaghe et al. 2020).

Since the 1960s, *Emberiza sahari*, which was mainly observed in the south of the country at that time (Heim de Balsac and Mayaud 1962), has spread progressively to the north. We consider it likely that the species will continue to increase its range in the north of Algeria, first in the Northwest of the country and then in the highlands of both the East and West regions that are characterized by arid and semi-arid climates (Fatmi et al. 2020). The range of the House bunting in Ghardaia includes mainly the northern regions where the species occupies urban habitats and the surrounding areas, in particular the regions

![Figure 6](image-url)

**Figure 6.** Scatterplots showing relationships between clutch size—number of hatchlings (top plots), clutch size—number of fledglings (middle plots) and number of hatchlings—number of fledglings (bottom plots) during early (symbol: red circles) and late (symbol: blue triangles) brooding timing for the 1st, 2nd and 3rd broods of House buntings (*Emberiza sahari*) nesting in the region of Ghardaia (Sahara Desert of Algeria). The solid lines represent linear regressions obtained by Poisson GLM fit with confidence intervals in dark grey.
of the M’Zab Valley, Zelfana, Berriane, Metlili, Sebseb and Mansoura. The species was absent in the rest of the region of Ghardaia, such as in Guerrara, Hassi El F’Hel, Hassi El Gara and El Menea. The change in building practices combined with the expansion of modern urban environments in hot drylands have a negative influence on species distribution and populations dynamics of the House bunting. For this synanthropic species, traditional dwellings offer more favorable conditions, such as roosting and nesting sites, as this type of urban habitat is characterized by arcades, small windows, ventilation and lighting holes within walls that facilitate entry and exit. In addition, traditional dwellings are distinguished by the abundance of food resources (weeds) around orchards and palm groves and characterized by less disturbance to their behavior (low human density and less light, sound and soil pollution). This is supported by several studies that investigated the harmful impact of urbanization on biodiversity, demography and stress physiology of passerines and other bird species (Bonier 2012, Meillère 2015, Ferland 2015, Chenchouni 2017a, Marzluff 2017). Yet, urban habitats present some advantages to birds, including more food resources, good nesting sites, and stable and high-quality foraging habitats. Thus, they allow species to settle in areas close to favorable foraging and breeding habitats, and sometimes offer secure nests against natural predators (Møller 2010, Seress and Liker 2015, Marzluff 2017).

During the non-breeding season, the number of pairs recorded in traditional urban habitats of Ghardaia was 4.5 pairs/ha, whereas it was 3 pairs/ha in semi-modern urban environments and 1.5–2 pairs/ha in modern urban environments. During the breeding season, the density of breeding pairs varied between 1 and 2 pairs/ha in the three urban habitats. Abundance of the House bunting varied from one region to another and from one period to another. House bunting density was higher in traditional urban habitats and during the non-breeding period compared to modern urban environments and during the breeding season. This decrease during the breeding season was due to the territoriality of this species, which is reflected by its conspecific antagonism and intra-specific competition between pairs (Roux et al. 1990). Guezoul et al. (2013) reported 0.75 pairs/ha in Biskra oasis and 0.25 pairs/ha in Ghardaia oasis during the breeding season, whereas the density of breeding pairs in Marrakech (Morocco) was 2 pairs/ha (Roux et al. 1990).

*Morphological sexual dimorphism*

According to Kirwan and Shirihai (2007), *Emberiza sahari* and *E. striolata* are similar to each other in terms of plumage patterns, the structure of the bird’s silhouette and behaviors (foraging, flying, etc.). We found that adult males of *E. sahari* differed partially from adult females in the plumage pattern and coloring of their eyebrows. Although only body mass and stretched wing were significantly different, females were slightly larger than males, based on body mass, tarsometatarsus length, total length, stretched wing and wingspan. In *E. striolata*, Ali and Ripley (1974) reported that males were larger than females. When comparing the biometric measurements of *E. sahari* obtained in the current study with those of Ali and Ripley (1974), the House bunting’s biometrics were larger than those of the Striolated bunting, especially the total length and length of the tarsometatarsus. These findings agree with the data obtained by Kirwan and Shirihai (2007).

*Nests and nesting characteristics*

The nest of the House bunting was built mainly from dry plant material such as twigs, barks, fibers and roots, which are collected around the nesting site. The top layer of the nest was covered with animal materials, especially goat hair and sheep wool. Pande et al. (2006) indicated that sometimes nests are lined with inflorescences of soft herbs and one or two feathers. We observed the presence of small stone, dry mud blocks, tissue paper, aluminum foil, plastic fibers, and cloth tissues. In some nests, we found insects such as *Larinioides* spp. (*Araneae*), *Lepisma* spp. (*Zygentoma*), *Myrmelontidae* spp. (*Neuroptera*) and larvae of *Dermestidae* (Coleoptera). These inquillin
species likely use *E. sahari* nests either to feed on plant building materials and/or nesting food scraps, or to lay their eggs.

According to Joshi and Bhatnagar (2016), *E. striolata* nests in southern Rajasthan are placed at 120 cm height, facing north where direct sunlight never reaches. The same observation was made in Ghardaia in the present study concerning the installation of House bunting nests, but with the nest cup oriented toward the East (sometimes Northeast or Southeast) and nesting height on average 214 cm above the ground. Pande et al. (2006) indicated that Striolated bunting nests measured 12 cm × 9 cm (outer diameter × inner diameter) in Maharashtra, India, and were 2.3 cm deep. However, in this study, we found larger nest sizes, where outer diameter of the nest averaged 34.77 cm, inner diameter was 5.8 cm, and the cup depth was 5.71 cm. These dimensions varied depending on the nest location where they were installed. During nest construction, we observed that both partners participated in collecting nesting materials (Fig. 4B–4C) and the construction of the nest, similar to observations of Pande et al. (2006), but different from Roux et al. (1990) who stated that only the female was responsible for building the nest.

**Breeding biology**

Our findings indicated that the courtship and pair bond formation in the House bunting begins in mid-February. According to Chakir (1986), copulation behavior is often associated with antagonistic contacts between parents, while during mating, parents rapidly vibrate their half-stretched wings with the female beneath the male. This is a common courtship behavior in many sparrow species (Guezoul et al. 2011). Roux et al. (1990) noted that the courtship period lasts approximately 5–10 days prior to nest construction. In addition, we demonstrated in the present study that the female House bunting can produce up to three broods between March and September, with an incubation of 14–15 days/brood, which is consistent with incubation periods documented in previous studies, i.e. 14–16 days in Morocco (Roux et al. 1990) and 14 days in Maharashtra, India (Pande et al. 2006). The breeding time (from first egg laid to chick fledging) of the house bunting in Ghardaia lasts 31–34 days, including 14–15 days of egg incubation and 17–19 days of chick rearing. Roux et al. (1990) reported observing parents feeding their fledglings for an additional week outside the nest after rearing them for 17–18 days.

According to Heim de Balsac and Mayaud (1962), two successful broods per reproduction season are common in *E. sahari* in the Tassili n’Ajjer (Sahara Desert of Algeria). Exceptionally, some pairs can rear four broods during the same season (Robin 1971). The number of broods per year is species-specific and depends on (i) extrinsic factors: ecological conditions of the region and the quality of climatic conditions during the breeding season (especially precipitation which influences food resources), quality of the nesting site, etc.; and (ii) intrinsic factors: age and breeding experience of parents, fertility of the female, etc. (Reynolds et al. 2019, Metallaoui et al. 2020).

According to Behidj-Benyounes et al. (2013), the synchronization of reproduction depends on climatic conditions, which influence the abundance, quality and availability of food and thus affect breeding success and population demographics (Bendjoudi et al. 2015, Chenchouni et al. 2015). Subsequently, Bradai et al. (2015) indicated that both the amount of rainfall and its temporal distribution have an important influence on habitat productivity. Precipitation exerts many effects at different levels of the biology of animal species, influencing fertility, longevity and thus population dynamics (Idler-Ighili et al. 2015, Bezzalla et al. 2019).

Slight differences exist between the different egg measurements of the House bunting and the Striolated bunting. In Ghardaia, House bunting eggs weighed on average 1.97 g and were 1.87 cm in length and 1.39 cm in width. These egg measurements are similar to those reported in Ali and Ripley (1974) (length = 2 cm, width = 1.5 cm), Pande et al. (2006) (weight = 2 g, length = 1.8 cm, width = 1.35 cm), and Roux et al. (1990) (length = 1.985 cm, width = 1.41 cm).

According to Pande et al. (2006), only the female Striolated bunting incubated eggs. This is also what we observed with female House buntings in Ghardaia. The male was often observed standing next to the nest while the female incubated the eggs, but when she was absent for short feeding periods, the male turned the eggs. In general, hatching of eggs in the same nest was relatively synchronized, with just a few hours between the first and the last hatching of the House bunting (Roux et al. 1990). In the present study, 2-day–old chicks weighed on average 2.52 g, they increased 2-fold on the fifth day, 4-fold on the seventh day, 5-fold on the tenth day and then 6-fold on the fifteenth day, which denotes a weight gain of about 0.996 g/day during the first 15 days. Pande et al. (2006) stated that 4-day-old chicks of the Striolated bunting weighed 2.5 g, reached only 4 g at the eighth day, 11.83 g on the twelfth day and 12.5 g on the fourteenth day. Growth curves in bird chicks indicate a rapid increase at an early age, then a plateau at the premature stage or fledging. This trend of body growth, in both length and body mass of offspring of most vertebrate species, follows a non-linear regression most often fitted to a three- or four-parameter logistic function, such as Richards, Gompertz, Von Bertalanffy, Weibull and Baranyi models (Chenchouni 2017b).

**Feeding ecology**

The method of direct visual observation used to study the trophic behavior of birds is a very flexible and efficient practice that provides a rapid qualitative assessment of the diet of the observed species (Blagosklonov 1987). This technique facilitates the identification of consumed species/matter/items when studying diet composition compared to other diet analysis methods, such as the analysis of fecal sacs, droppings and/or regurgitate pellets. The House bunting usually competes for food with other grain-eating species such as House Sparrows (*Passer domesticus* Linnaeus, 1758), Spanish sparrows (*Passer hispaniolensis* (Temminck, 1820)) and their hybrids (*Passer domesticus × P. hispaniolensis*), Rock Doves...
(Columbia livia Gmelin, 1789) and Trumpeter Finches (Bucanetes githagineus (Lichtenstein, 1823)) (Chedad, pers. obs.). The House bunting is a granivorous species, feeding mainly on seeds of annual weeds found near its roosting or nesting site (Pasteur 1956, Pande et al. 2006). According to Grzegorz and Czarnecka (2007), the diet of the House bunting resembles that of the Common Reed bunting (Emberiza schoeniclus). Our study indicated that the House bunting preferred feeding on certain plant species such as Chenopodium murale, Cynodon dactylon and Schismus barbatus. The species often picks up the remains of food of plant origin (crumbs of dried bread, seeds) inside houses (Pasteur 1956). Sometimes it feeds on insects (Sarcophaga carnaria, Cadra spp., Messor spp.), especially when rearing and feeding chicks. In Ghardaia, we observed that it ingests fine stones and grains of sand, probably to facilitate food processing, especially in chicks.

Conclusion
The House bunting is a human commensal bird that characterizes the desertic regions of Algeria where it frequents, breeds and forages in urban and anthropogenic environments. It cohabits with humans and has lived alongside them for a long time. The House bunting range in Algeria is larger than described in previous works. Locally, it is distributed mainly in northern Ghardaia. This study showed that the species range has extended towards the north of Algeria through the semi-arid steppe rangelands of the Hauts-Plateaux region. The present study provides a baseline for future comparisons, as climate and building practices continue to change across the Saharan landscape. The individuals examined showed a slight morphological difference between the two sexes. The species prefers nesting indoors in traditional urban habitats, at an average height of 2.14 m, on different structures, which influences nest dimensions and construction materials used. Accordingly, the duration of nest building, involving both parents, varies from 5 to 22 days. In Ghardaia, courtship and pair-formation displays begin in mid-February. Females can raise up to three successive broods of 2–3 eggs/clutch (31–34 days from egg-laying to chicks fledging) over seven months (March-September), with 14–15 days for egg incubation. Being a granivore, the species feeds on annual weeds, mainly Poaceae, exploits other resources in human buildings such as leftover food and sometimes eats insects. Due to the widespread range of Emberiza sahari in Algeria, which is distinct from the range of Emberiza striolata, it is recommended to investigate the spatial genetic variability of both species through phylogenetic analysis based on 16S rRNA mitochondrial DNA sequences involving populations from northern regions of the Maghreb countries (including Algeria) and from the Sahara.

Acknowledgments
We thank the farmers of the traditional palm grove at Ghardaia for their help during field visits, and for allowing us to access their private lands for nest tracking. We are grateful to the Directorate of Forest Conservation of Ghardaia and the members of the National Network of Algerian Ornithologist Watchers “R.N.O.O.A.” for their support and accompaniment during the study. Dr. Sharon A. Poessel (Forest & Rangeland Ecosystem Science Center, U.S. Geological Survey) provided edits and comments on an earlier version of the manuscript. Comments from the editor, Robert J. Whittaker, and the two anonymous reviewers improved the manuscript.

Author Contributions
OG and AC conceived the study, AC and BB conducted fieldwork and collected data. AC and OG carried out laboratory work and compiled data. AC, DB, and HC analyzed data. AC, DB, OG and HC wrote the original manuscript. AC, DB, OG and HC revised the final article. All authors read and approved the final paper.

Data Accessibility
The datasets used and/or analyzed during the study are available from the first author on reasonable request.

Supplementary Materials
The following materials are available as part of the online article from https://escholarship.org/uc/fb

References
Ababsa, L., Sekour, M., Souttou, K., Guezoul, O. & Doumandji, S. (2013) Quelques aspects sur l’avifaune dans deux palmeraies du Sahara septentrional (Algérie). Algerian Journal of Arid Environments, 3, 59–67.
Ababsa, L., Souttou, K., Sekour, M., Beddada, A., Guezoul, O. & Doumandji, S. (2011) Ecologie trophique du cratérope fauve Turdoides fulvus (Desfontaines, 1787) dans deux régions du Sahara Septentrional en Algérie. Lebanese Science Journal, 12, 83–90.
Ali, S. & Ripley, S.D. (1974) Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. Flowerpeckers to Buntings. Oxford University Press, Bombay.
Amezian, M., Bensusan, K., Perez, C. & Thompson, I. (2006) Is House buntings about to colonise Europe? Birding World, 19, 263.
Azaouaghe, S., Thevenot, M. & Bergier, P. (2020) Première mention du Bruant du Sahara à Nador et compléments sur l'historique de l'expansion au Maroc. Go-South Bulletin, 17, 16–19.

Behidj-Benyounes, N., Bissaad, F.Z., Behidj, K.K., Chebouti, N. & Doumandji, S. (2013) Le suivi de la reproduction chez le moineau hybride Passer domesticus × P. hispaniolensis dans un milieu agricole de la partie extrême-orientale de la Mitidja. Bulletin de la Société Zoologique de France, 138, 331–343.

Belkacem, M., Marniche, F., Berrabah, D.E., Medina, F.M., Daoudi-Hacini, S. & Doumandji, S. (2017) Scavenging diet of Brown-necked raven Corvus ruficollis Lesson, 1830 (Aves: Corvidae) in a hyper-arid region of central Algerian Sahara. Acta Zoologica Bulgarica, 69, 239–248.

Bendjoudi, D., Chenchouni, H., Doumandji, S. & Voisin, J.F. (2013) Bird species diversity of the Mitidja Plain (Northern Algeria) with emphasis on the dynamics of invasive and expanding species. Acrocephalus, 34, 13–26.

Bendjoudi, D., Voisin, J.F., Doumandji, S., Merabet, A., Benyounes, N. & Chenchouni, H. (2015) Rapid increase in numbers and change of land-use in two expanding Columbidae species (Columba palumbus and Streptopelia decaocto) in Algeria. Avian Research, 6, 18. doi.org/10.1186/s40657-015-0027-9

Bezzalla, A., Houhamdi, M., Maazi, M.C. & Chenchouni, H. (2019) Modelling climate influences on population dynamics and diurnal time budget of the Shelduck (Tadorna tadorna) wintering in Ramsar wetlands of Algeria. Avian Biology Research, 12, 77–95.

BirdLife International (2016) Emberiza sahari. The IUCN red list of threatened species 2016: e.t22734808a104265494. https://dx.doi.org/10.2305/iucn.uk.2016-3.rlts.t22734808a104265494.en.

Blagosklonov, K. (1987) Guide de la protection des oiseaux. Mir, Moscow.

Blondel, J. (1975) L'analyse des peuplements d'oiseaux - éléments d'un diagnostic écologique. La méthode des échantillonnages fréquentiels progressifs (E.F.P). Revue d'Ecologie (Terre et Vie), 29, 533–589.

Blondel, J., Ferry, C. & Frochot, B. (1970) La méthode des I.P.A. ou des relevés d'avifaunas par «station d'écoute». Alauda, 39, 55–71.

Bonier, F. (2012) Hormones in the city: endocrine ecology of urban birds. Hormones and Behavior, 61, 763–772.

Bounaceur, F., Bissaad, F.Z., Marniche, F., Boutheldja, H., Abaiter, N., Khellil, K. & Saad, A. (2016) Ecologie trophique du Hibou Grand-duc du désert Bubo ascalaphus (Savigny, 1809) dans la région de l'Ahaggar Sud Algérien. Revue Ivoirienne des Sciences et Technologie, 27, 175–189.

Bradai, L., Bissati, S., Chenchouni, H. & Amrani, K. (2015) Effects of climate on the productivity of desert truffles beneath hyper-arid conditions. International Journal of Biometeorology, 59, 907–915.

Chakir, N. (1986) Ecologie du Bruant striolé (Emberiza striolata). Contribution à la biologie et à la dynamique des populations à Marrakech (Maroc). Dissertation, Faculty of Sciences, Marrakech, Morocco.

Chehma, A. (2006) Catalogue des plantes spontanées du Sahara septentrional algériens. Laboratoire Protection des Ecosystèmes, University of Ouargla, Algeria.

Chenchouni, H. (2010) Statuts de protection et de conservation des oiseaux recensés dans les Aurès et ses alentours (nord-est algérien). Proceedings of the International Conference “SIBFA”. University of Ouargla, pp. 56–75.

Chenchouni, H. (2012) Diversity assessment of vertebrate fauna in a wetland of hot hyperarid lands. Arid Ecosystems, 2, 253–263.

Chenchouni, H. (2017a) Variation in White Stork (Ciconia ciconia) diet along a climatic gradient and across rural-to-urban landscapes in North Africa. International Journal of Biometeorology, 61, 549–564.

Chenchouni, H. (2017b) Contribution à l'étude de la bio-écologie de la Cigogne blanche (Ciconia ciconia) dans la région de Batna (Nord-est algérien). Doctoral dissertation, University of Batna, Algeria.

Chenchouni, H., Si Bachir, A. & Alrashidi, M. (2015) Trophic niche and feeding strategy of the White Stork (Ciconia ciconia) during different phases of the breeding season. Avian Biology Research, 8, 1–13.

Chinery, M. (1988) Insectes d'Europe occidentale. Les éditions Arthaud, Paris.

Djilali, K., Sekour, M. & Bissati, S. (2012) Étude du régime alimentaire du hibou des marais, Asio
flammeus (Pontoppidan, 1763) dans la région d’El-Golea. Revue des Biressources, 2, 29–36.

Doumandji, S. & Doumandji-Mitiche, B. (1994) Ornithologie appliquée à l’agronomie et à la sylviculture. Office National des Publications Universitaires, Algiers.

Dupuy, A. (1969) Catalogue ornithologique du Sahara algérien. L’Oiseau et la Revue Française d’Ornithologie, 39, 225–241.

Eck, S., Fiebig, J., Fiedler, W., Heymen, I., Nicolai, B., Töpfer, T., et al. (2011) Vögel vermessen/measuring birds. Deutsche Ornithologen-Gesellschaft, Christ Media Natur, Minden.

Farhi, Y. & Belhamra, M. (2012) Typologie et structure de l’avifaune des Ziban (Biskra, Algérie). Courrier du Savoir 13, 127–136.

Fatmi, H., Mâalem, S., Harsa, B., Dekak, A. & Chenchouni, H. (2020) Pollen morphological variability correlates with a large-scale gradient of aridity. Web Ecology, 20, 19–32.

Ferland, A. (2015) La conservation de la biodiversité en milieu urbain: comment aménager les villes du monde?. Doctoral thesis, Univ. Sherbrooke, Québec, Canada.

Grzegorz, G. & Czarnecka, J. (2007) Winter diet of Reed bunting Emberiza schoeniclus in fallow and stubble fields. Agriculture Ecosystems & Environment, 118, 244–248.

Guezoul, O., Ababsa, L., Souttou, K. & Sekour, M. (2017) Répartition des oiseaux dans quelques oasis de la partie septentrionale du Sahara). Courrier du Savoir, 23, 129–136.

Guezoul, O., Chenchouni, H. & Doumandji, S. (2011) Breeding biology in hybrid Sparraow (Passer domesticus × P. hispaniolensis) in northern Algerian Sahara: case study of Biskra date palm-grove. Journal Advanced Laboratory Research in Biology, 1, 15–21.

Guezoul, O., Chenchouni, H., Sekour, M., Ababsa, L., Souttou, K. & Doumandji, S.E. (2013) An avifaunal survey of mesic manmade ecosystems “Oases” in Algerian hot-hyperarid lands. Saudi Journal of Biological Sciences, 20, 37–43.

Heim de Balsac, H. & Mayaud, N. (1926) Contribution à l’ornithologie du Sahara central et du Sud algérien. Imprimerie Le Typo-litho, Algiers, Algeria.

Heim de Balsac, H. & Mayaud, N. (1962) Les oiseaux du Nord-Ouest de l’Afrique. Le chevalier P, Paris.

Hoyt, D.F. (1979) Practical methods of estimating volume of fresh weights of birds eggs. The Auk, 96, 73–77.

Idder-Ighili, H., Idder, M.A., Doumandji-Mitiche, B. & Chenchouni, H. (2015) Modeling the effects of climate on date palm scale (Parlatoria blanchardi) population dynamics during different phenological stages of life history under hot arid conditions. International Journal of Biometeorology, 59, 1425–1436.

Ishemmann, P. & Moali, A. (2000) Oiseaux d’Algérie – Birds of Algeria. SEOF, Paris.

Joshi, A.K. (2016) Nesting record of Striolated bunting (Emberiza striolata, Lichtenstein) in mid and southern Rajasthan. Zoo’s Print, 31, 5–6.

Kirwan, G.M. & Shirihai, H. (2007) Species limits in the House bunting complex. Dutch Birding, 29, 1–19.

Ledant, J.P., Jacob, J.P., Malher, F., Ochando, B. & Roche J. (1981) Mise à jour de l’avifaune Algérienne. Le Gerfaut, 71, 295–398.

Marzluff, J., Gahlbach, F.R. & Manuwal, D. (1998) Urban communities: influences on avifauna and challenges for the avian conservationist. In: Avian conservation: research and management (ed. by Marzluff, J.M. & Sallabanks, R.), pp 283-299. Island Press.

Marzluff, J.M. (2017) A decadal review of urban ornithology and a prospectus for the future. Ibis, 159, 1–13.

Meillère, A. (2015) Influence de l’environnement urbain sur les passerelles: une approche éco-physiologique et éco-toxicologique. Doctoral thesis, University of Rochelle, France.

Metalläoui, S., Dziri, H., Bousseheba, A., Heddam, S. & Chenchouni, H. (2020) Breeding ecology of the Cattle Egret (Bubulcus ibis) in Guerbes-Sanhadjia wetlands of Algeria. Regional Studies in Marine Science, 33, 100979.

Møller, A.P. (2010). The fitness benefit of association with humans: elevated success of birds breeding indoors. Behavioral Ecology, 21, 913–918.

Moulaï, R. (2019) Expansion du Bruant du Sahara Emberiza sahari dans le nord de l’Algérie. Alauda, 87, 170–171.

Pande, S., Pawashe, A. & Joshi, V. (2006) Note on the breeding of Striolated bunting Emberiza striolata near Pune, Maharashtra (India). Indian Birds, 2, 153–156.

Pasteur, G. (1956) Premières observations sur le Traquet, le Bruant et l’Ammomane du poste
d'Aouinet Torkoz (Bas Draa). Bulletin de la Société des Sciences Naturelles du Maroc, 36, 165–183.

R Core Team (2020) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.R-project.org/

Ramade, F. (1978) Elément d'écologie: écologie appliquée. McGraw-Hill, Paris.

Reynolds, R.T., Lambert, J.S., Kay, S.L., Sanderlin, J.S. & Bird, B.J. (2019) Factors affecting lifetime reproduction, long-term territory-specific reproduction, and estimation of habitat quality in northern goshawks. Plos One, 14, e0215841.

Robin, P. (1971) Les oiseaux du sud marocain. Bulletin de la Société des Sciences Naturelles et Physiques du Maroc, 37, 7–14.

Roff, D.A. (1992) The evolution of life histories: theory and analysis. Chapman & Hall, New York.

Roux, P., Chakir, N. & Lesne, L. (1990) Étude comparée de la reproduction du Bruant striolé - Emberiza striolata sahari Levaillant - dans deux types d'environnement urbain à Marrakech (Maroc). Bièvre, 11, 13–20.

Sangster, G., Collinson, J.M., Crochet, P.A., Knox, A.G., Parkin, D.T. & Votier, S.C. (2013) Taxonomic recommendations for Western Palearctic birds: ninth report. Ibis, 155, 898–907.

Schweizer, M., Shirihai, H., Schmaljohann, H. & Kirwan, G.M. (2018) Phylogeography of the House bunting complex: discordance between species limits and genetic markers. Journal of Ornithology, 159, 47–61.

Seress, G. & Liker, A. (2015) Habitat urbanization and its effects on birds. Acta Zoologica Academiae Scientiarum Hungaricae, 61, 373-408.

Svensson, L., Mularney, K. & Zetterstrom, D. (2009) Collins bird guide, 2nd edn. Harper Collins, London.

Taibi, A., Aabasa, L., Bendjoudi, D., Doumandji, S., Guezoul, O. & Lephy, M. (2009) Régimes alimentaires de deux sous-espèces de la pie-grièche méridionale Lanius meridionalis au Maghreb. Alauda, 77, 281–285.

Wei, T. & Simko, V. (2017) R package “corrplot”: visualization of a correlation matrix (Version 0.84). Available from: https://github.com/taiyun/corrplot

Submitted: 16 April 2020
First decision: 24 May 2020
Accepted: 9 November 2020

Edited by Robert J. Whittaker