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Breeding ecology of the endangered Algerian Nuthatch *(Sitta ledanti)* endemic to the Babors′ Kabylia (Northeastern Algeria): Implications of conservation

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Abstract The endemic Algerian Nuthatch *Sitta ledanti*, is classified as an endangered species by the IUCN and protected species by Algerian law. Available information on its nesting and breeding biology is sporadic and incomplete, the purpose of which is to provide additional data on the different aspects of multi-site nesting of the species. 22 nests are monitored across five forests, during the nesting season of 2021. An endoscopic camera was used to monitor eggs and nestlings in the nests during the whole study. Most of the nests (n = 20) were constructed in different parts of the dead trees such as trunks or branches of the Atlas cedar *Cedrus atlantica*, the Algerian oak *Quercus canariensis*, the African oak *Quercus afares* or Cork oak *Quercus suber*. The laying dates were from early April to the end of May when April 28 (± 13 days) is the laying season's median start date. The average clutch size was 4.6 (n = 21). The mean hatching success was 89.2%, while mean fledging success was 88.2%. The nestling sex ratio was 14 males versus 18 females. Data on clutch dates and fecundity of breeding pairs should be considered in any conservation approach and strategy in the context of habitat management and preservation.

Keywords: Algeria, Babors' Kabylia, Algerian Nuthatch, conservation, fecundity, breeding

Összefoglalás Az IUCN szerint az endemikus atlasz-csuszka, *Sitta ledanti* veszélyeztetett faj, melyet az algériai törvények is védettnek tekintenek. A szaporodásbiológiájáról hiányosak a rendelkezésre álló információk. Öt erdei élőhelyen összesen 22 fészket figyeltek meg a 2021-es költési időszakban. Az odúk vizsgálatát endoszkópos kamerával végezték. A legtöbb fészket (n = 20) elhalt fák, például az Atlas-cédrus *Cedrus atlantica*, a Kanári-tölgy *Quercus canariensis*, az afrikai tölgy *Quercus afares* vagy a paratölgy *Quercus suber* törzseiben vagy ágaiban találták. Az első tojás lerakása április elejétől május végéig történt, a medián költéskezdés április 28. volt. Az átlagos fészekaljnagyság 4,6 tojás volt (n = 21). A kelési siker 89,2%, míg a kirepülési siker 88,2% volt (±13). A fiókák esetében az ivarok aránya: 14 hím és 18 tojó volt. A vizsgálat fontos, eddig még nem ismert szaporodásbiológiai adatokat szolgáltatott az algériai csuszkáról, amelyek segíthetik a faj élőhelyeinek megőrzését.

Kulcsszavak: Algéria, Babors Kabila, atlasz-csuszka, természetvédelem, költésbiológia, fekunditás, szaporodási siker

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Introduction

Monitoring and knowledge of the nesting period, laying dates, brood sizes, and breeding success are important in bird population studies. These kinds of data are very important to determine conservation strategies for threatened species since they might be ancestral features in species adaptation and could also help analyse the viability of passerine populations (Sutherland *et al.* 2004).

There is no complete nesting data for more than 30% of bird species, and most have incomplete or unknown information (Xiao *et al.* 2016). Also, this aspect is well-studied in other groups of birds than in passerines (Xiao *et al.* 2016). The breeding biology of birds can be influenced by environmental conditions, climate change, predation, habitat fragmentation and food resource availability (Crick 2004, Norris *et al.* 2004, Lampila *et al.* 2005, Dunn *et al.* 2010). This is the case for the mesogenic nuthatches group where the nesting is influenced by habitat loss and forest fires (Thibault 2002, 2004), human activities, deforestation, overgrazing, altitude (Ledant *et al.* 1985), and changes in spring temperatures (Albayrak & Erdogan 2005, Thibault & Villard 2005).

In the nuthatches group, studies about the breeding biology of various species in the *Canadensis* and mesogenic group are frequent (Löhrl 1960, Albayrak & Erdogan 2005, Thibault & Villard 2005, Bougaham *et al.* 2017, Ghalambor & Martin 2020). Clutch sizes of the Algerian Nuthatch *(Sitta ledanti)* and Krueper's Nuthatch *(Sitta krueperi)* range from four to seven eggs (Albayrak & Erdogan 2005, Bougaham *et al.* 2017). The incubation period varies between 14 and 15 days in *S. ledanti* (Bougaham *et al.* 2017), from 12 to 15 days for *S. krueperi* (Albayrak & Erdogan 2005) and from 14 to 17 days in Corsican nuthatch *(S. whiteheadi)* populations (Villiard & Thibault 2001). Hatching success ranges from four to seven eggs hatched and fledging success from zero to six chicks fledged for both *S. ledanti* and *S. krueperi* and from three to six chicks fledged for *S. whiteheadi* (Albayrak & Erdogan 2005, Thibault & Villard 2005, Bougaham *et al.* 2017).

The Algerian Nuthatch is a rare and endemic forest bird of Algeria (Hamitouche & Bougaham 2021). It is classified as Endangered species (BirdLife International 2021) and protected forest bird in Algeria since 1983 (JORA 1983, 2012). This species is frequent both in deciduous and evergreen forests in the Babors' Kabylia biogeographical region (Northeastern Algeria), which is distributed in 13 separated habitats (Vielliard 1976, Ledant 1977, Chalabi 1989, Bellatrèche & Chalabi 1990, Moulai & Mayache 2018, Haddad & Afoutni 2019, Bougaham *et al.* 2020, 2021, 2022, Mayache *et al.* 2021). It has been the subject of several studies analysing population densities (Bellatrèche & Chalabi 1990, Bougaham *et al.* 2018, Hamitouche *et al.* 2020, 2021, Hamitouche & Bougaham 2021, Zemouri & Bougaham 2022), the description of habitats (Ledant 1977, Ledant & Jacobs 1977, Vielliard 1978, 1980, Ledant *et al.* 1985, Chalabi 1989, Bellatrèche 1990, Bougaham *et al.* 2017, 2018, Moulai *et al.* 2017, Moulai & Mayache 2018, Hamitouche *et al.* 2020), ecological preferences (Ledant & Jacobs 1977, Vielliard 1978, Ledant *et al.* 1985, Chalabi 1989, Bellatrèche & Boubaker 1995, Bougaham *et al.* 2018, Hamitouche *et al.* 2020) and its diet (Zemouri *et al.* 2021, 2023). However, studies on the Algerian Nuthatch breeding biology remain incomplete by studying only the populations of the Jebel Babor (Vieilliard 1978, Gatter & Mattes 1979, Ledant & Jacobs 1979, Harrap

& Quinn 1996, Monticelli & Legrand 2009) and Guerrouch forest (Bellatrèche & Boubaker 1995, Moulai *et al.* 2017, Bougaham *et al.* 2017).

Our study is conducted on a multi-site scale to provide comprehensive and detailed information on the breeding parameters of the Algerian Nuthatch. We tried to highlight the multifunctional role of this information in the context of the implications of habitat preservation and species conservation.

Material and Methods

Study area

The monitoring of Algerian Nuthatch breeding was conducted in five forests, where the population density of the species was high (Hamitouche & Bougaham 2021) *(Figure 1)*. The monitored populations were found in deciduous forests, aside of Jebel Babor forest. Only the Guerrouch and Babor forests benefit from a protection status (JORA 1984, 2019). Babor forest has an area of 1,268 hectares (Ledant *et al.* 1985) and peaks at 2,004 m. It is dominated by the presence of the Atlas cedar *(Cedrus atlantica)*. However, we also observe the presence of mixed plant formations with Atlas cedar, Algerian oak *(Quercus canariensis)*, Numidia fir *(Abies numidica)* and Aspen popular *(Populus tremula)* (Zemouri & Bougaham 2022). Tamentout forest has an area of 9,688 hectares (Boudy 1955 in Bellatrèche 1999) and reaches altitudes of 1,660 m in Jebel Sidi Salah. The tree stratum of this forest is essentially represented by Algerian oak, African oak *(Quercus afares),* and Blunt-leaved Maple *(Acer obtusatum)* (Hamitouche *et al.* 2022). However, the Guerrouch forest's plant cover is typified by the Algerian oak, African oak, obtuse-leaved maple, and the Cork oak *(Quercus suber)*. This forest covers 10,860 hectares and attains its highest point in M'cid Echta summit at 1,534 m (Bellatrèche 1994). The Algerian oak dominates the vegetation of the Djimla forest while the African oak dominates in the Larbâa forest (Bougaham *et al*. 2018, Hamitouche *et al.* 2021). The areas of these latter forests are 1,000 hectares (Bellatrèche 1994) and 700 hectares (Hamitouche *et al.* 2021), respectively.

Data collection

Preliminary trips began in March 2021. The Algerian Nuthatch's nesting territories were identified by the males' responses to a recording of the species' song (Bougaham *et al.* 2017). Once the nesting territories demarcated, we remotely monitor the nesting behaviour through the observation of the digging activity of the nest cavity, the transport of nest-building materials, and the provision of food to the female who incubates the eggs.

In each forest, the position of the nests found was indicated by GPS points (Garmin map 76 CSx model) *(Figure 1)*. Nesting monitoring was done during the same breeding season in 2021 to prevent bias in the results and to enable data comparisons across the five populations studied.

We were able to locate 22 nests of the species: five nests in the Babor forest, five in the Tamentout forest, four in the Guerrouch forest, four nests in the Djimla forest, and also

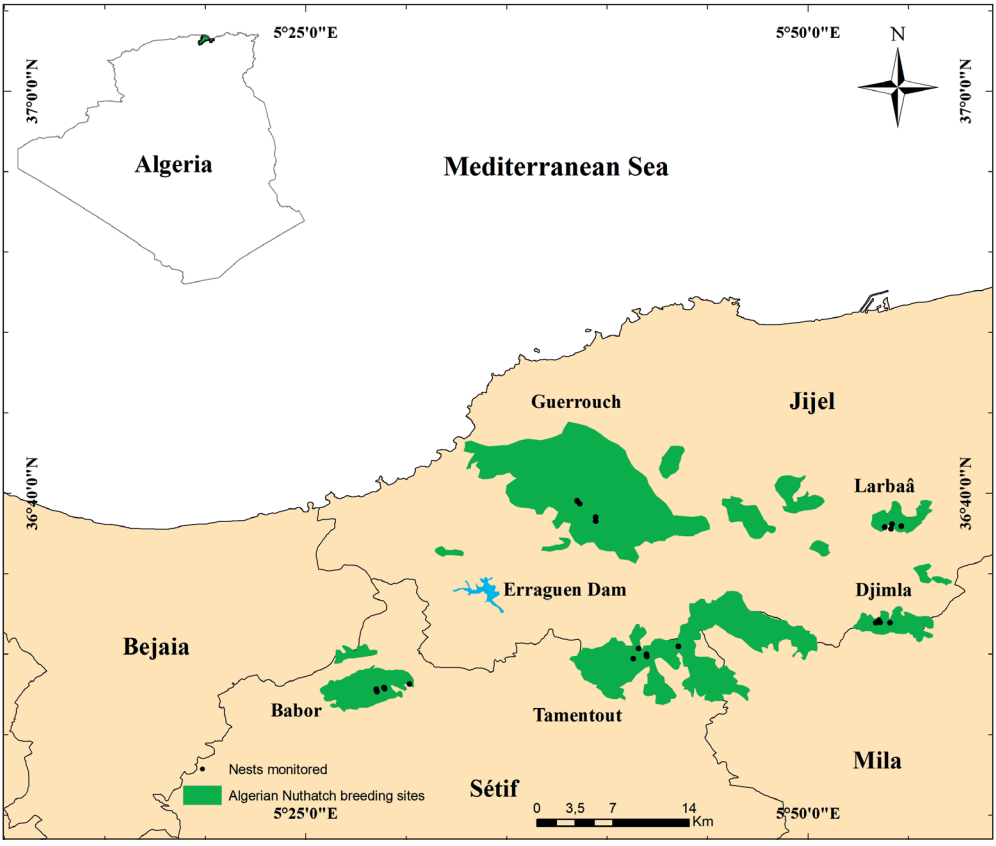

Figure 1. Algerian Nuthatch's nesting sites (green patches) and location of monitored nests
1. ábra Az atlasz-csuszka fészkelőhelyei (zöld foltok) és a megfigyelt fészkek elhelyezkedése

four nests in the Larbâa forest. These nests were monitored from the beginning of April until the end of May using an endoscopic camera (Bougaham *et al.* 2017). In the case of nests inaccessible by the endoscopic camera, we created an opening in the bark and trunk of the tree behind the nesting hole (Pravosudov 1993, Villard & Thibault 2001) to be able to observe the eggs and chicks hidden in the nest out of our field of vision. At the end of each check, we put the extracted piece of wood and bark back in its place using wood glue to avoid all kinds of nesting disturbance.

Nest characteristics

The vertical distance between the ground and the entrance to the nest hole was measured using a tape measure. The purpose of this operation was to calculate in meters the height of the nest hole on the plant support. Our attention sprang from the tree portion (trunk or branch) that the species chose to build its nest. We were also interested in the condition of the plant support alive or dead that was utilised to determine the species' requirements for nesting (Hamitouche & Bougaham 2021).

Nesting season

The dates of the first eggs laid were generally observed directly by inspections of the nests. When the nest was detected with more than one egg laid, the date of the first egg was deduced by the back-calculation method (Norris 2014, Bougaham *et al.* 2017), considering that the Algerian Nuthatch lays one egg every day.

When the nest was discovered at the nestling stage, the date of the first egg laid was determined by estimating their ages using the Norris method (2014) applied for the Red-breasted Nuthatch *(Sitta canadensis)*, where 14.5 days correspond to the duration of eggs incubation in the Algerian Nuthatch (Bougaham *et al.* 2017). The extreme dates of laying was expressed in days of the year where time is expressed as five-day intervals: pentade 1 = 1–5 April (*sensu* Berthold 1973).

Clutch size and breeding success

Clutch size is defined once the number of eggs in a nest has not changed after two consecutive visits. We also calculated the hatching success which corresponds to the percentages of eggs hatched compared to the total number of eggs laid.

$$\text{Hatching succes} = \frac{\text{number of eggs hatched}}{\text{total number of eggs laid}} \times 100$$

Whereas fledging success corresponds to the number of young fledged divided by the number of eggs hatched.

$$\text{Fledging success} = \frac{\text{number of young fledged}}{\text{total number of eggs hatched}} \times 100$$

Thus, total breeding success is calculated by dividing the number of fledglings by the number of eggs laid (Bougaham 2021).

$$\text{Breeding success} = \frac{\text{number of young fledged}}{\text{total number of eggs laid}} \times 100$$

Sex ratio of nestlings

The sex ratio was observed for each brood just before fledging dates, where morphological differences between male and female nestlings were observable. We noticed sexual dimorphism in the Algerian Nuthatch nestlings, including a black cap that starts from the edge of the beak towards the back of the head, thus extending beyond the males' eyes (Bougaham *et al.* 2017). However, this cap was not observed in young females.

Statistical analysis

The R software (2021) was used to check if there was any variation between dates and clutch sizes, and reproductive success at hatching and fledging. We opted for the non-parametric Kruskal-Wallis test when the raw statistical series are not normal and/or its variances are not equal, it was applied three times, one time to verify whether there was a difference between clutch sizes, second time to verify if there was a difference between hatching success and third time to check the relationship between fledging success in the five forests. We compared between the proportion of males and females by a parametric Chi-square test (χ^2). We also checked if there was a correlation between altitude and laying dates. While in every analysis, statistical tests were considered significant at the $P < 0.05$ level.

Results

Heights and altitudes of nests

The height of the nests ranged between 2 m and 12.4 m with an average of 6.6 m, the altitude varied between 1,054 m and 1,993 m with an average of 1,335.7 m *(Table 1)*.

Table1. Nests height (m) and nests altitude (m) of Algerian Nuthatch
1. táblázat Az atlasz-csuszka fészkek magassága (m) és tengerszint feletti magassága (m)

	Babor	Tamentout	Guerrouch	Djimla	Larbâa	Total
Number of nests	**5**	**5**	**4**	**4**	**4**	**22**
Nests height (range)	2.6–8.7	2–12.3	3.2–8	4.2–8	5.2–11	**2–12.3**
Nests height (mean ± SD)	5.4±2.2	7.9±5.3	6.1±2.5	6.3±1.6	7.7±2.7	**6.6±2.8**
Nests altitude (range)	1421–1993	1290–1401	1054–1198	1103–1227	1068–1087	**1054–1993**
Nests altitude (mean±SD)	1837.8±235.3	1341±48.9	1080.2±37	1148.2±39.9	1077±9.5	**1335.7±323.9**

Nest supports

The nests were located on different types of trees depending on the habitat type of the forests studied. In the Babor forest, all the nests were built on the Atlas cedar, in the Tamentout forest the nests were located on the Algerian oak and the African oak, in the Guerrouch forest they were on the Algerian oak, African and cork oak, in the Djimla forest all the nests were located on the Algerian oak and lastly, in Larbâa forest, we found the nests on the Algerian and African oak, and one nest on a new species the hybrid oak (African oak × cork oak) *(Table 2)*. The Algerian Nuthatch chose dead wood for the construction of its nesting cavities; in this study, 20 nests were located either on a branch or a dead trunk and 2 were located on living wood *(Table 2)*.

Table 2. Nest support of the Algerian Nuthatch. n: number of monitored nests.
2. táblázat Az atlasz-csuszka fészkek fafajonkénti eloszlása. n: a megfigyelt fészkek száma

Forest	n	Tree	Support types		Dead	Alive
			Trunk	Branch		
Babor	5	*Cedrus atlantica*	3	2	3	2
Tamentout	5	*Quercus canariensis* *Quercus afares*	1	4	5	0
Guerrouch	4	*Quercus afares* *Quercus suber* *Quercus canariensis*	1	3	4	0
Djimla	4	*Quercus canariensis*	0	4	4	0
Larbâa	4	*Quercus afares*	0	4	4	0

Breeding period

The nesting season of the Algerian Nuthatch in the Babor's Kabylia region was characterised by a large spread over time *(Figure 2)*. Most nuthatches of the five habitats studied were laid in April, the average laying date for all forests was April 28. The Djimla forest' nuthatches were the earliest and that of Babor were the latest. There was a positive, but non-significant association between laying dates and the position of the nest in altitude ($t = 1.9786$, $df = 19$, $p = 0.06254$).

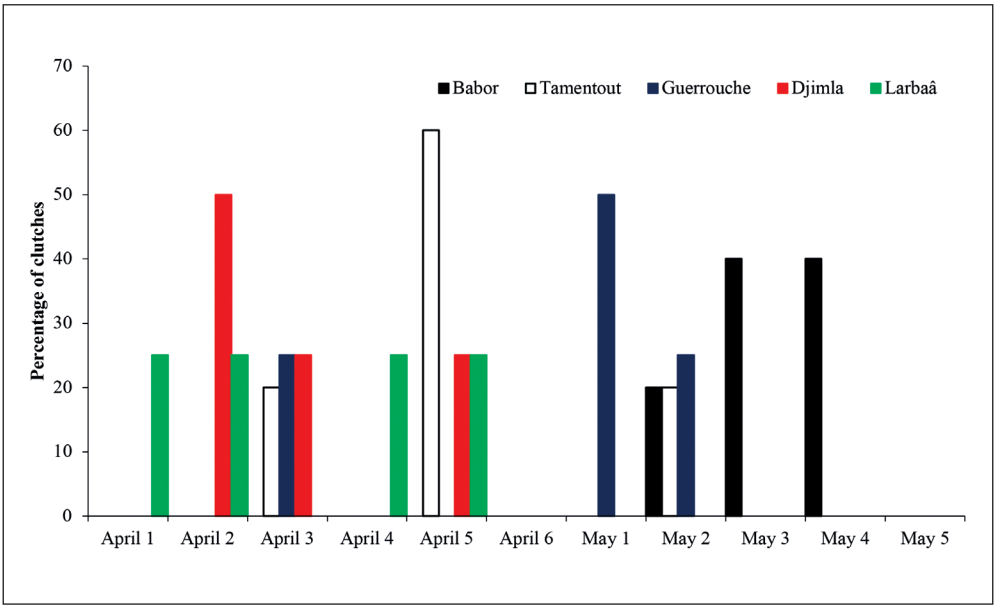

Figure 2. Changes in the first-egg laying pattern of the Algerian Nuthatch clutches in the five forests. Laying time in consecutive five-day periods is presented
2. ábra Változások az atlasz-csuszka felső tojás lerakásának mintázatában az öt erdőben, ötnapos periódusonként

Table 3. The first egg-laying date, clutch size, number of hatchlings and fledglings, hatching success, breeding success at fledging, and sex ratio (male/female) of the Algerian Nuthatch. N: Number of nests found. n: Number of nests monitored. Data is presented as a mean ± SD, with the range in brackets

3. táblázat Az atlasz-csuszka első tojásának lerakási időpontja, a fészekalj mérete, a kikelt fiókák és kirepült fiókák száma, a kelési siker, a költési siker a kirepüléskor és az ivararány (hím/tojó). N: A talált fészkek száma. n: A megfigyelt fészkek száma. Az adatok átlaga ± SD, a tartomány zárójelben

	N	Laying date	Clutch size	Number of hatchlings	Number of fledglings	Hatching success (%)	Fledging success (%)	Ratio Male/female
Babor	5	15 May±3 days (10 May–18 May)	5±0 (5–5)	4.5±0.5 (4–5)	4.4±0.5 (4–5)	88	88	2/3 (n = 1)
Tamentout	5	24 April ±9 days (11 April–7 May)	4.2±0.8 (4–5)	3.6±0.5 (3–4)	3.6±0.5 (3–4)	88.2	88.2	5/6 (n = 3)
Guerrouch	4	28 April ±12 days (11 April–8 May)	4.25±0.5 (4–5)	3.7±0.9 (3–5)	3.7±0.9 (3–5)	85.7	85.7	2/5 (n = 2)
Djimla	4	14 April±7 days (8 April–23 April)	4.5±2.4 (3–7)	4.7±1.2 (3–6)	4.7±1.2 (3–6)	86.4	86.4	3/2 (n = 1)
Larbâa	4	28 April ± 10 days (16 April–8 May)	4.25±0.9 (3–5)	4.2±0.9 (3–5)	4±1.1 (3–5)	100	94.1	2/2 (n = 1)
All forests	**22**	**28 April ± 13 days**	**4.6±1**	**4.1±0.9**	**4.1±0.9**	**89.2**	**88.2**	**14/18 (n = 8)**

Fecundity of the Algerian Nuthatch

An average clutch of 4.6 (SD = 1, range: 3–7, n = 21) eggs were noted. There was no significant difference between clutch sizes in the five forests (Kruskal-Wallis = 6.0549, df = 4, p = 0.1951). The average number of eggs hatched per nest was equal to 4.1 (89.2%) (SD = 0.88, range: 3–6, n = 21). The number of hatchlings did not differ between habitats (Kruskal-Wallis = 4.8375, df = 4, p = 0.3044). Fledging success varied between three and six chicks per nest, with an average of 4.1 (SD = 0.92, n = 21) and a percentage of 88.2%. We did not note a significant difference between fledging success in the different forests (Kruskal-Wallis = 4.3533, df = 4, p = 0.3603). The sex ratio of the fledglings was 14 males versus 18 females (n = 8 nests), where the Chi-square test (χ^2) between the proportion of males and females showed no significant difference in all the forests (χ^2 = 6.6667, df = 6, p = 0.3528) *(Table 3)*.

Table 4. Number of Algerian Nuthatch broods that failed in each location

4. táblázat Az egyes helyeken sikertelenül költő atlasz-csuszkák száma

	Number of monitored nests	Type of brood failures	
		Number of nests with sterile eggs	Number of nests with dead nestlings
Babor	5	3	–
Tamentout	5	3	–
Guerrouch	4	2	–
Djimla	4	3	–
Larbâa	4	–	1
Total	**22**	**11**	**1**

Nesting failure of the Algerian Nuthatch

Among the causes of breeding failure in the Algerian Nuthatch we noted predation for one nest in the Larbâa forest, another cause was the sterility of the eggs *(Table 4)*.

Discussion

The nest heights noted in our study were lower than those noted in the Guerrouch forest (Bougaham *et al.* 2017) which was between 7 and 15 meters. In the Jebel Babor, the height of the nests was between 5 m and 15 m according to Ledant and Jacobs (1979) and was from 4 to 15 m according to Vieilliard (1978), but they were close to those cited by Gatter and Mattes (1979) which varied between 3 and 13 meters. These results are probably linked to variations in population densities of the species in each forest, which means that the height of the nest location decreases with increasing species density. Indeed, Nilson (1984) showed a negative correlation between nest density and nest height in the European Nuthatch, the Common Starling *(Sturnus vulgaris)* and the Blue Tit *(Cyanistes caeruleus)*. The nest sites of the Algerian Nuthatch reach altitudes of 2,004 meters on the Babor forest (Ledant & Jacobs 1977). Bougaham *et al.* (2017), studied nests located between 707 and 878 meters above sea level in the Guerrouch forest. However, in our study, nests are found between 1,054 and 1,993 meters. The lowest altitudinal position of the nests was noted in the Guerrouch forest and the highest in the Babor forest. In the other nuthatch species, *S. krueperi* the nest sites location reach an altitude of 1,700 m (Albayrak & Erdogan 2005) and those of *S. whiteheadi* at an altitude ranging from 1,000 to 1,600 m (Thibault & Villard 2005).

The nest supports of the Algerian Nuthatch vary between the forests studied depending on the dominant tree type. In the Babor forest, the nests are located on the Atlas cedar, the Numidian fir and the Algerian oak (Vielliard 1978, Gatter & Mattes 1979, Ledant & Jacobs1979). In other deciduous forests, the nests are located on the Algerian oak, African oak and Cork oak (Bougaham *et al.* 2017, Moulai *et al.* 2017). However, the *S. ledanti* had no preference for the dominant tree types, where in the Guerrouch forest nests were also found on the common eucalyptus*(Eucalyptus globules)* (Bougaham *et al.* 2017), the wild cherry *(Prunus avium)* (Mostfai 1990) and the strawberry tree *(Arbutus unedo)* (Kisserli 1992). The nuthatches nests are generally placed on dead wood; only two nests are located on living wood in Babor forest. All previous studies showed the same result (Ledant & Jacobs 1977, Bougaham *et al.* 2017, Moulai *et al.* 2017). These results confirm the importance of dead wood for the nesting of the species (Ledant & Jacobs 1977, Bougaham *et al.* 2017, Moulai *et al.* 2017, Bougaham *et al.* 2018, Hamitouche & Bougaham 2021, Zemouri & Bougaham 2022).

The breeding period of the Algerian Nuthatch extends from April 8 to May 28; April 28 is the average date of the first egg laid. The Algerian Nuthatch in Djimla forest is the earliest during the 2021breeding season. This result was different with the results obtained by Bougaham *et al.* (2017) which give April 5 as the average date of the first egg laid.

The Babor forest's nuthatches remain the latest to lay eggs in our study. The same results were found in the study of Ledant and Jacobs (1977). This differences probably due to the effect of altitude which correlates with the laying dates. Indeed, at higher altitudes the Algerian Nuthatch tends to lay eggs later than other populations of the species living at lower altitudes; this may be linked to temperature variations in Babor's Kabylia which vary from 0 °C to 9 °C in winter and from 28 °C to 31 °C in summer (Seltzer 1946, Ledant & Jacobs 1977, Bellatrèche 1999) such as the case of the Corsican Nuthatch where the effect of altitude was not clear but there was a correlation between the average temperatures of April and the laying dates (Thibault & Villard 2005). The availability of food supply can be another parameter that influences the laying dates of the Algerian Nuthatch (Bougaham *et al.* 2017, Mayache *et al.* 2020) like the case of Corsican Nuthatch (Thibault & Villard 2005).

Clutch sizes described in our study are within the range of results obtained in previous studies, where clutches was varied between 5 and 6 eggs in the Guerrouch forest (Bougaham *et al.* 2017), in the Babor forest, it was between 6 and 10 eggs according to Ledant and Jacobs (1979) and between 3and 4 eggs according to Veilliard (1978). Studies carried out on birds have shown an effect of latitude and length of day on the clutch sizes (Lack 1947, Jetz *et al.* 2008). Also, the Red-breasted Nuthatch *(S. canadensis)* clutch sizes was varied according to food availability, during years when beetles were less available the clutch size decreases with the increase in the laying date (Norris & Martin 2014). Predation can be another factor acting on the clutch size variation (Doligez & Clobert 2003).

The hatching success and fledging success in the five forests were less important than those noted at Guerrouch forest by Bougaham *et al.* (2017). Predation of the nests by the Great Spotted Woodpecker *(Dendrocopos major)* and the frequency of sterile eggs were the main causes of breeding failure in the Algerian Nuthatch (Bougaham *et al.* 2017, Moulai *et al.* 2017).

In this study, we noted a sex ratio in favour of females for the five forests. Several parameters can influence the variation of the sex ratio in birds. Some studies have shown that food availability was a determining factor; parents tend to produce the less expensive sex during the feeding period (Sheldon 1998). Climate variations and the synchronisation of reproduction affected the variation in the sex of the offspring in certain species of birds; pairs that bred early in the season produced more males than females (Dijkstra *et al.* 1990). The age of the parents also contribute to the imbalance in the sex ratio (Daan *et al.* 1996).

Threats and conservation measures for the Algerian Nuthatch

Our study on the breeding ecology of the Algerian Nuthatch provided us with useful information that could help natural area managers and decision-makers in future protection and conservation projects for the species and habitats. The creation of two national parks of Taza and Babor-Tababort (JORA 1983, 2012, 2019) is a less effective protection measure, especially since they only represent a small area compared to the extent of its distribution area which includes 13 isolated forests (Bougaham *et al.* 2022). It would be imperative to create new protected forest areas and to extend, for example, the current limits of

the Taza National Park towards other forest cantons of the Guerrouch forest because the current protected area is insufficient for the effective protection of the species, and also the creation of ecological corridors between the different forests, particularly between Djimla and Tamentout and also between Babor and Tababort (Bellatrèche & Chalabi 1990, Bougaham *et al.* 2021). As a result, it would be feasible to increase the size of some populations and to facilitate individual exchanges, which will benefit all populations through genetic exchange. Like the Corsican Nuthatch (Thibault *et al.* 2004), even within these protected areas, the populations of the Algerian Nuthatch remain threatened by the loss of habitat caused by repeated forest fires which remain major threat factors for the species (Ledant 1977, 1981, Ledant *et al.* 1985, Bougaham *et al.* 2018, Hamitouche *et al.* 2021). In addition to forest fires, illegal logging and the recovery of dead wood will reduce the availability of nesting supports (Ledant & Jacobs 1977, Vielliard 1978, Gatter & Mattes 1979, Ledant 1981, Bougaham *et al.* 2017) and food research (Bellatrèche & Boubaker 1995, Zemouri *et al.* 2021, 2023) of which the maintenance of dead trees standing and the control of all silvicultural activities is essential for the protection of this species (Ledant & Jacobs 1977, Bougaham *et al.* 2017, Moulai *et al.* 2017, Bougaham *et al.* 2018, Hamitouche & Bougaham 2021, Zemouri & Bougaham 2022). The opening of passable forest tracks will allow the installation of humans and the fragmentation of forests which causes the disturbance of breeding pairs during the breeding period (Moulai *et al.* 2017, Mayache *et al.* 2018, Hamitouche *et al.* 2021), just like eco-tourists activities such as the creation of the Djimla recreational forest (Bougaham *et al.* 2018). The limitation of access to forests during the breeding season and the development of other forest tracks to avoid nesting territories and all contact with breeding pairs and promote all eco-tourism activities outside the breeding and feeding period may be conservation recommendations that decrease the causes of nesting failure and further improve the breeding success of the Algerian Nuthatch. It would be helpful to map the current climatic vulnerabilities of Algerian Nuthatch's distribution area and include the areas most affected by the factors endangering the species, this could help to develop management plans and actions for the protection and conservation of the Algerian Nuthatch, notably advanced fire-fighting systems, planning for the opening of tracks and roads and the management of tourist activities, etc. (Lipka 2017).

Conclusions

The study on the different parameters of the Algerian Nuthatch breeding biology, which was carried out on five important populations, allowed us to provide complete and precise information on the laying dates, the clutches size, and the breeding success of the species. This information obtained is similar between the different local populations studied and does not record any significant differences. This observation could be linked to the overall bioclimatic conditions of Babor Kabylia, whose local populations of the species are located close to each other in the same biogeographic sector. Like other studies carried out on other groups of nuthatches, our study confirms the importance of the availability of dead wood

resources for the nesting of the Algerian Nuthatch, which is a component to consider in any protection and conservation project of the species. The combination of the different threats listed and the information collected on nesting and fertility of this endemic species will help managers of natural environments make appropriate decisions on conservation strategies for the species.

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