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Effects of local climate on nest cavity characteristics of a North African endemic woodpecker

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Abstract Levaillant's Woodpecker *Picus vaillantii* is a primary cavity nester, endemic to the forests of northern Africa, including the cedar forest in Aurès Mountains. This species, similar to all woodpeckers, is important for the integrity of ecosystems, especially as it provides nesting cavities and contributes to the availability of habitats for several secondary cavity nesters that cannot excavate their hollows. This work aim to characterise the Levaillant's Woodpecker's nest cavities and to test the effect of local climatic conditions on the size and orientation of these cavities. Surveys were carried out in the breeding seasons of 2018 and 2019 using the point count method to search for the nests. Based on nest measurements conducted on a total of 52 available nest cavities, our results reveal that entrances are dominated by round shapes (94.2%) as compared to oval shapes. The mean height and width values of the cavity entrances were found to be 7.26 ± 1.51 centimetres and 7.11 ± 1.44 centimetres. The depth of the internal chamber and its width were estimated to be 35.42 ± 7.82 centimetres and 17.95 ± 4.01 centimetres, respectively. Unlike the average values of the volumes of the internal chamber, those relating to the entrance area and orientation vary significantly according to altitude and climatic conditions. Indeed, when climbing towards the summits, the cavities widen and turn to the west-southwest. This behaviour of the Levaillant's Woodpecker seems to help it to benefit from maximum sunshine at high altitudes and to avoid predators and competitors more abundant at medium or low altitudes.

Keywords: *Picus vaillantii*, nest cavity, behaviour, bioclimatic level, cedar, Aurès

Összefoglalás Az Atlasz-küllő *(Picus vaillantii)* elsődleges odúköltő, azaz odúkészítő faj, amely Észak-Afrika erdeinek endemikus madárfaja. Elterjedési területe magában foglalja az Aurès-hegység cédruserdeit. A vizsgált faj, hasonlóképpen más harkályfajokhoz, fontos szerepet játszik az adott ökoszisztéma integritásának megőrzésében, mivel fészkelőodúkat készít, és így számos másodlagos odúköltő számára biztosít fészkelőhelyet. Észak-Kelet Algériában első alkalommal mértük föl az Atlasz-küllő költőodúk méreteit és tájolását a 2018–2019-es költési időszakban, különböző bioklimatikus zónákban. A terepmunka során pontszámlálást és odúkeresést alkalmaztunk. Az 52 odún végzett mérések eredményei alapján a bejárati nyílásoknál dominált a köralak (94.2%) az ovális alakkal szemben. A bejárati nyílások átlagos magassága és szélessége 7.26 ± 1.51 cm-es, valamint 7.11 ± 1.44 cm-es értékeket adott. A belső kamra mélysége és szélessége 35.42 ± 7.82 cm-esnek, valamint 17.95 ± 4.01 cm-esnek adódott. A belső kamra térfogatának átlagos értékeitől eltérően, a bejárat területe és orientációja szignifikáns kapcsolatban van a tengerszint feletti magassággal és klimatikus változókkal. A hegycsúcsok felé haladva az odúk egyre szélesebbek és egyre inkább nyugat-délnyugati irányba fordulnak. Az Atlasz-küllőnek ezen stratégiáját feltehetőleg az magyarázza, hogy nagy tengerszint feletti magasságokon előnyös számára a napfény maximális kihasználása, míg a ragadozók és kompetítorok kerülésének stratégiája gyakoribb közepes és alacsony tengerszint feletti magasságokon.

Kulcsszavak: *Picus vaillantii*, fészkelőodú, viselkedés, bioklimatikus kényszer, cédrus, Aurès

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Introduction

Mediterranean forests host many specialists in cavity-nesting birds (Devictor *et al.* 2010). Primary cavity nesters include woodpeckers which deploy considerable efforts, especially in terms of energy, to excavate their nest cavities. Secondary cavity nesters such as nuthatches (Sittidae) and tits (Paridae) exploit cavities previously created by primary nesters or those generated by the decaying of trees. (Martin & Li 1992, Blanc & Walters 2008).

Woodpeckers are important for the equilibrium of forest ecosystems (Drapeau *et al.* 2009, Damoc *et al.* 2014). They provide suitable habitats for the nesting of secondary cavity nesters. They provide the same resources with other bird species (Pakkala *et al.* 2006, Smith 2006), regulate the density of their prey, especially insects (Fayt *et al.* 2005), and participate in the transmission of wood-decaying fungi (Jackson & Jackson 2004). Owing to their highly selective ecological requirements, these species are frequently considered excellent bioindicators of the forest ecosystems' health (Angelstam & Mikusiński 1994, Mikusiński *et al.* 2001, Virkkala 2006).

The reproductive success of woodpecker populations is influenced by the nature and morphology of the cavities used mainly to protect the chicks against predation and the hostile conditions of their environment (Short 1979, Nilsson 1986, Li & Martin 1991, Newton 1994, Huhta *et al.* 1998, Ćiković *et al.* 2014). Key environmental drivers of nest cavities include the size of the interior chamber of the cavities, the type of bark, the thickness and density of the surrounding wood, the angle and the shape of the entrance, and the orientation of the cavities (Ricklefs & Hainsworth 1969, Austin 1974, Conner 1975, Inouye *et al.* 1981, Wachob 1996, Hooge *et al.* 1999). The number, size, and shape of cavities also influence the total number of cavity nesters in forest stands (Evans *et al.* 2002, Lõhmus & Remm 2005).

The cedar, oak and pine forests of the Maghreb countries are home to various associations of cavity-nesting birds dominated by the Levaillant's Woodpecker *Picus vaillantii* (Isenmann *et al.* 2005, Touihri *et al.* 2015, Badis & Hamdi 2022) a vicariant of the Green Woodpecker *Picus viridis* (Blondel 1999, Pons *et al.* 2010, Perktas *et al.* 2011). It is widespread in northwest Africa. In Tunisia, it frequents the forests of the central to the western parts of the country (Isenmann *et al.* 2005). In Algeria, its habitats extend from the sea to the high forests, reach the Saharan Atlas and the Aurès region (Isenmann & Moali 2000) southwards. However, in Morocco, it is found in forest areas at all altitudes (Heim de Balzac & Mayaud 1962). The diet of the Levaillant's Woodpecker is essentially based on adult ants and pupae, in particular those belonging to the genus *Formica* (Gillmen *et al.* 1998, Henine-Maouche *et al.* 2017). The study species is a sedentary breeder, whose egg-laying begins at the beginning of May. The clutch size amounts to 6–7, white, very shiny and quite pear-shaped eggs (Snow *et al.* 1998, Bougaham 2016). Literature resources show that on the North African scale, the characteristics of its cavities remain unknown. Only Bougaham (2016) studied briefly the dimensions of seven cavities located in the Babors Mountains in northern Algeria.

In this context, the main objective of this work is to provide new ornithological information, especially for the size and orientation of the cavities excavated by the Levaillant's Woodpecker, resident of the forest of Aurès Mountains in northeast Algeria. It is also a question of highlighting the potential relationships between the local climatic conditions and the entrance area, the chamber volume, and the cavity entrance orientation.

Material and Methods

Study area

This study was carried out in the eastern part of the Aurès Forest massifs in northeast Algeria *(Figure 1)*, precisely in the Ouled Yagoub natural cedar forests (35°19'N, 6°76'E at 35°45 'N, 7°01'E). These ecosystems have altitudes ranging from 1,400 m to 2,173 m and are formed of pure cedar forests on the summits and mixed cedar forests (Atlas cedar *Cedrus atlantica*, Holm oak *Quercus ilex*, Aleppo pine *Pinus halepensis*, and Dimorphic ash *Fraxinus dimorpha*) on medium and low altitudes (B.N.E.D.E.R. 2010), which span three bioclimatic levels: cold humid, cold subhumid, and cool subhumid level *(Table 1)*.

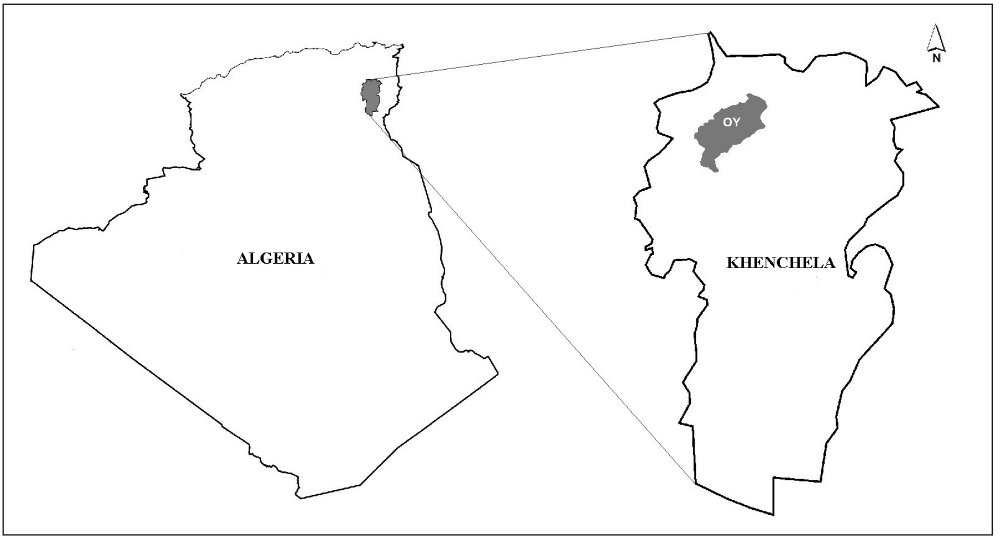

Figure 1. Location of Ouled Yagoub cedar forests in Khenchela – Algeria
1. ábra Az Ouled Yagoub cédrus erdő elhelyezkedése az algériai Khenchela tartományban

Table 1. Distribution of the bioclimatic levels of the study area according to altitude and local climatic conditions
1. táblázat A három különböző bioklimatikus zóna (hideg humid, hideg szubhumid, hűvös szubhumid) tengerszint feletti magasság, évi csapadékmennyiség és évi hőingás adatai

Bioclimatic level	Altitude (m)	Rainfall (ml)	T (°C min-max)
Cold humid	1950 – 2173	837	-1.22 – 32.08
Cold subhumid	1700 – 1950	777	-0.72 – 32.96
Cool subhumid	1450 – 1700	672	0.15 – 34.50

Nest cavity search and measurements

During two breeding seasons (March to July) of 2018 and 2019, using the point count method with playback (De Rosa *et al.* 2016), woodpeckers were searched in 75 stations, randomly chosen, and separated by at least 300 m to avoid double counting. Once the species was heard or seen, a systematic search for nests was launched within a radius of 150 m measured from the listening station. Identified nest cavities were located with a GPS.

Using a ladder, we were able to reach 52 cavities located at a height of less than 5.4 m, 44 in 2018 in the cedar forests and 8 in 2019 in the pine forests. The parameters we measured included: entrance height, entrance width, chamber diameter, chamber depth, using a tape measure in the reachable cavities. We measured the entrance orientation with a compass. Sizes of the interior chamber were taken for 20 reached nest cavities *(Table 2)*. All these measurements were recorded in the autumn to avoid disturbing the nesting process (Tamungang *et al.* 2016).

Entrance height and entrance width measures were used to calculate the entrance area for each cavity according to the formula defined by Kosinski and Ksit (2007):

Entrance Area = π ab (Where a and b were the half height and the half width of entrance). Similarly, chamber diameter and chamber depth measures were used to calculate the chamber volume according to the formula of Kosinski and Ksit (2007):

Chamber Volume = π (Chamber diameter/2)^2 Chamber depth.

The estimation of cavity entrance shape was based on the ratio between entrance height and entrance width (Baral *et al.* 2018) depending on the calculated proportions: round shape (proportion = 1–1.5); oval shape (1.6–3.5), and elongated shape (> 3.5).

Statistical analyses

To estimate the importance of the potential relationships established between the climatic conditions and the morphometric variables, we performed analysis of variance (ANOVA). The normality of these variables was verified by the Shapiro-Wilk test. The minimum level of probability allowed was treated as $P \leq 0.05$. The software used for the statistical calculations was IBM SPSS Statistics 23 (IBM 2015)

Based on circular statistics (Batschelet 1981), the Rayleigh uniformity test allowed us to identify the predictors of the cavities' entrances orientation. Indeed, a random distribution indicated the absence of preference, unlike the selective distribution which designated a predilection of the species for precise orientation. Circular orientation data was analysed by Oriana software version 4, Kovach Computing Services (Kovach 2011).

Results

Morphologic characteristics of nest cavities

The 52 available nest cavities of the Levaillant's Woodpecker detected in the Ouled Yagoub cedar forest in 2018 and 2019 were unevenly distributed over the different bioclimatic levels:

Table 2. Size and orientation of the Levaillant's Woodpecker cavities in the Ouled Yagoub cedar forest

2. táblázat A vizsgált odúparaméterek adatai. Az oszlopok: mintaszám, minimum-maximum, átlag, szórás. A vizsgált paraméterek fentről lefelé: a röpnyílás magassága, szélessége, területe, irányszöge, az odú belső átmérője, mélysége és űrtartalma

Parameter	N	Min – Max	Mean	SD
Entrance Height (cm)	52	4.2 – 11.7	7.26	1.51
Entrance Width (cm)	52	4.05 – 10.8	7.11	1.44
Entrance Area (cm^2)	52	13.35 – 78.5	41.93	15.27
Entrance Orientation (°)	52	0 – 320	263.65	117.54
Chamber Diameter (cm)	20	12 – 24.5	17.95	4.01
Chamber Depth (cm)	20	20.5 – 45.5	35.42	7.82
Chamber Volume (l)	20	2.71 – 18.53	9.98	5.64

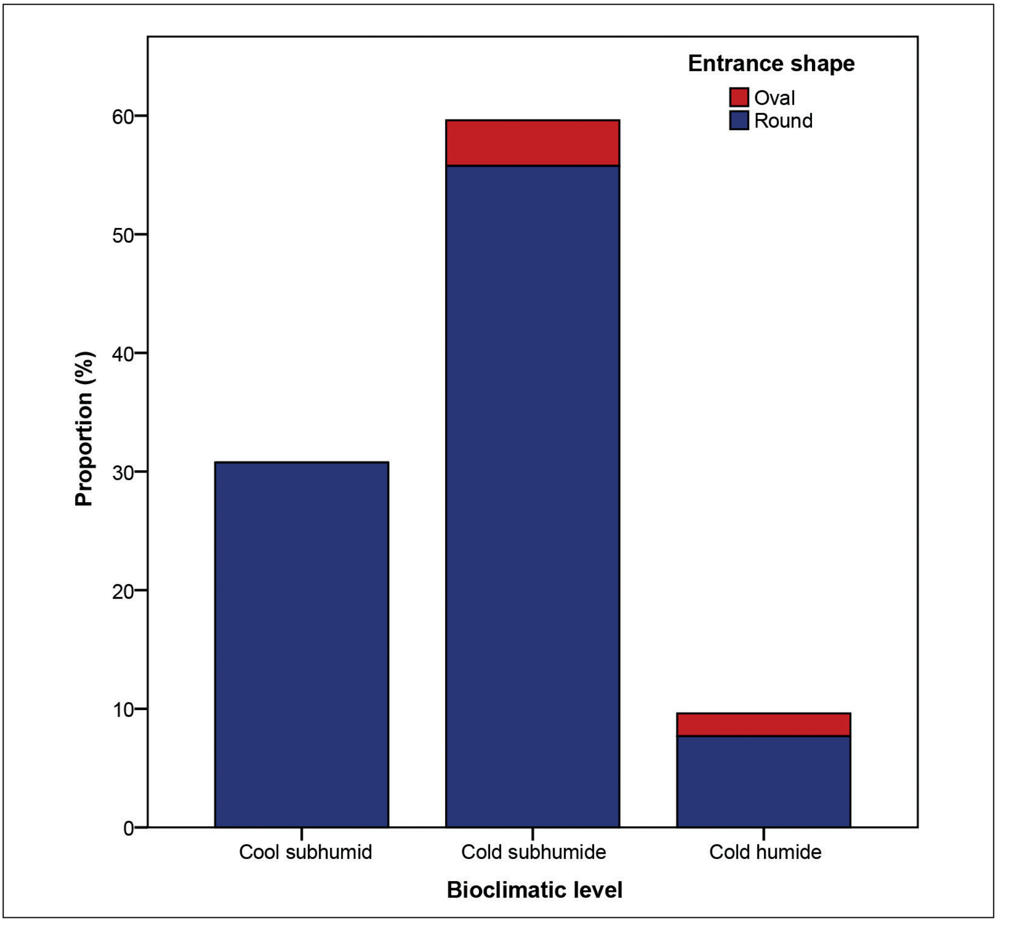

Figure 2. Distribution of the cavity entrances shapes over the three bioclimatic levels

2. ábra A röpnyílás alakok eloszlása a három bioklimatikus zónában (lásd *1. táblázat*)

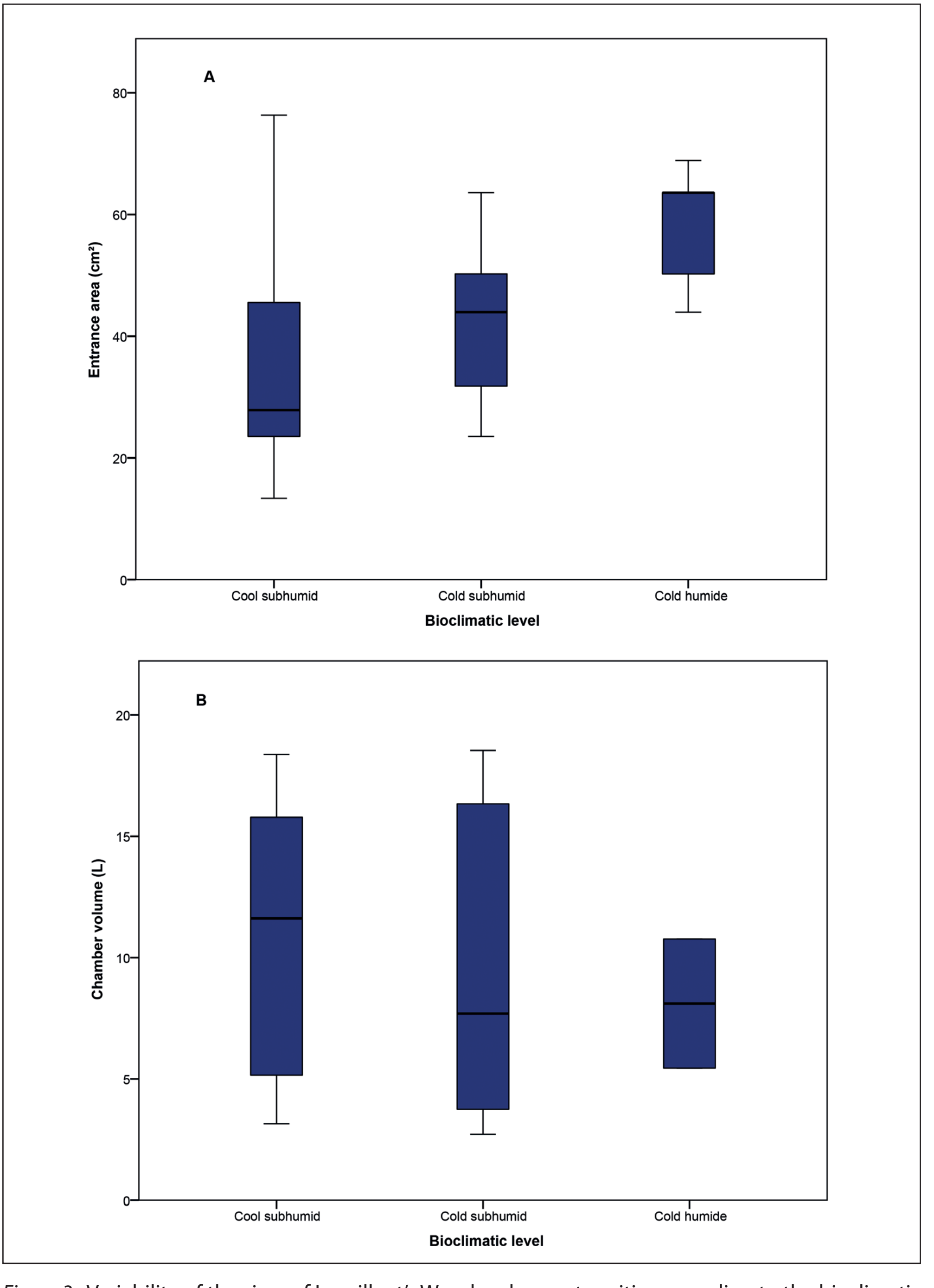

Figure 3. Variability of the sizes of Levaillant's Woodpecker nest cavities according to the bioclimatic levels: (A) cavity entrance area; (B) interior chamber volume

3. ábra Az odúméretek eloszlásai a három bioklimatikus zónában (lásd *1. táblázat*): (A) a röpnyílás területe; (B) az odú űrtartalma

5 at the cold humid level, 31 cavities at the cold subhumid level, and 16 cavities at the cool subhumid level.

Considering all bioclimatic levels combined, the values calculated for the cavity measurements were highly fluctuating *(Table 2)*. For example, the mean values recorded for cavity entrance height and width were 7.26 ± 1.51 cm and 7.11 ± 1.44 cm, respectively. The entrance area presented an average of 41.93 ± 15.27 cm² *(Table 2)*. In terms of cavity entrance, the ratio between the height and the width revealed a significant dominance of round shapes (94.2%) as compared to oval shapes (5.8%). No elongated entries have been found *(Figure 2)*.

The average diameter of the interior chamber was 17.95 ± 4.01 cm, whereas the depth of the chamber was found to be 35.42 ± 7.82cm. The calculated chamber volume was 9.98 ± 5.64 L.

Climate influence on cavity size and orientation

The ANOVA test revealed a significant effect of the bioclimatic level on the cavity entrance area (F = 4.64; df = 2; P = 0.01). Indeed, the Levaillant's Woodpecker decreased the entrance area from the cold humid level with 58.04 ± 10.46 cm² to the cool subhumid

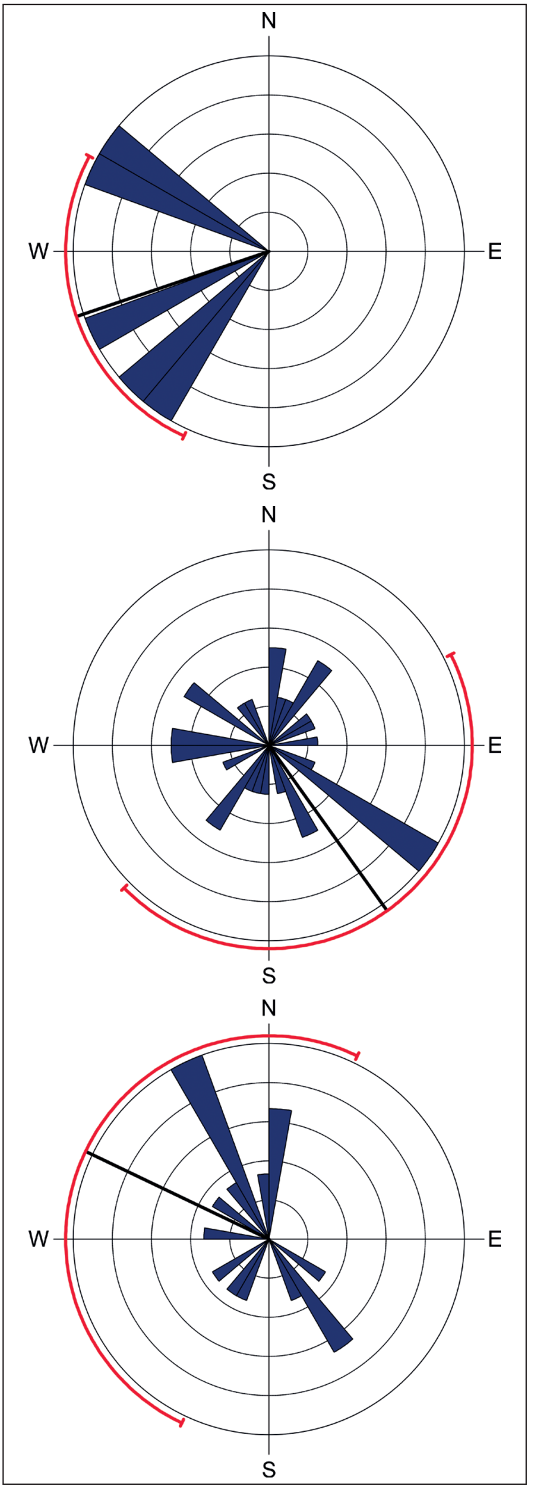

Figure 4. Orientation of entrances to Levaillant's Woodpecker nest cavities in three bioclimatic levels in the study area: (A) cold humid bioclimatic level; (B) cold subhumid bioclimatic level; (C) cool humid bioclimatic level

4. ábra A röpnyílások tájolása a három bioklimatikus zónában (a sorrendhez lásd *1. táblázat*) level with 35.873 ± 18.22 cm², passing by the cold subhumid level being 42.46 ± 12.35 cm² *(Figure 3A)*. The values of the chamber volume were independent of local climate variability ($F = 0.186$; $df = 2$; $P = 0.832$). Indeed, its mean values were found to be 8.1 ± 3.76 L at the cold humid level, 9.6 ± 6.5 L at the cold subhumid level, and finally 10.67 ± 5.6 L at the cool subhumid level *(Figure 3B)*.

The Rayleigh test of uniformity showed a preference for the west-southwest direction at high altitude characterised by a cold humid climate (Mean = 251.31° ± 37.7; Rayleigh test $z = 3.24$; $P = 0.03$) *(Figure 4A)*. In contrast, the species randomly chooses the direction of its cavities in the cold subhumid climate (Rayleigh test $z = 0.04$; $P = 0.96$) and in the cool subhumid level (Rayleigh test $z = 0.75$; $P = 0.47$) *(Figure 4B,C)*.

Discussion

The results of this work reveal that the mixed cedar forests of cold subhumid bioclimatic level represent a favourable environment for the survival of Levaillant's Woodpecker in the Aurès Mountains in Algeria. These ecosystems have a varied vegetation cover dominated by Atlas cedar and holm oak trees, which provides wooden structures to excavate nest cavities for Levaillant's Woodpecker (Badis & Hamdi 2022). They offer optimal and safe conditions for the implementation of cavities such as the low flammability and consistency of cedar woods, as well as its tolerance to various water and climatic stress (Valette 1990, Epron 1997, Ladjal *et al.* 2000, Brunetti *et al.* 2001, Moussouni & Boubaker 2015).

In woodpeckers, the dimensions, and shapes of the entrances to their nest cavities are adapted to body size (Kerpez & Smith 1990, Kosinski & Ksit 2007, Wan *et al.* 2008). This study showed that the cavity entrances of Levaillant's Woodpeckers in the Aurès Mountains are mostly round (94.2%). This observation is consistent with those specific to its European counterpart, the Green Woodpecker, while oval entrances remain reserved for exceptionally large individuals (Gorman 2015, Bütler *et al.* 2020). The absence of the elongated shape is consistent with the results of Baral *et al*. (2018), which linked this shape to non-excavated cavities resulting from mechanical damage and ageing structures of the tree.

Among our studied variables, only the cavity entrance area is significantly influenced by local climatic conditions. At the cold humid level, at a very high altitude, the cavities have larger average entrances compared to those of the cold subhumid and cool subhumid levels. Indeed, it seems that it is a response to the relatively hostile climatic conditions that prevail at high altitudes. This woodpecker adopts this choice to receive maximum solar radiation, reduce humidity and increase the temperature inside the cavities (Wiebe 2001). The reduction of entrance area at medium and low altitudes constitutes, in contrast, a mode of adaptation to avoid predators and competitors (Li & Martin 1991). In this context, various forestry studies confirm that cavity nester species occur in lower abundances with increasing altitude (Jansson & Andren 2003, Moussouni & Boubaker 2015, Bertuzzo *et al.* 2016).

The variability of the chamber volume of Levaillant's Woodpecker cavities in the Aurès Mountains is random and has no significant relationship with the local climate. Indeed, this parameter is most often determined by the number of chicks, which varies from five to seven

(Bougaham 2016), but probably by the body size of the parents and the consistency of the nesting tree.

In general, cavity-nesting birds have a preference for cavity entrance orientation (Mennill & Ratcliffe 2004). This choice is maintained to ensure optimal conditions, in particular a microclimate of the internal chamber favourable to the hatching and the viability of the chicks and therefore, to reproductive success (Conway & Martin 2000, Hartman & Oring 2003, Mainwaring *et al.* 2016). Concerning the present study, only at the cold humid bioclimatic level, at very high altitudes, the Levaillant's Woodpecker excavates cavities oriented in the west-southwest direction. This is a relatively effective strategy for receiving the most sunshine and warming the brood sufficiently. In addition, such an orientation promotes morning warming (Gorman 2021). This warming is associated with reproductive success as mentioned by Wiebe (2001) in a study on Northern Flicker *Colaptes auratus*. However, in the cool and cold subhumid levels, at low and medium altitudes, the orientation of the cavities is random. This observation is the same as concluded by previous studies on other forest and ecologically related species (Inouye *et al.* 1981, Ćiković *et al.* 2014). In this case, the Levaillant's Woodpecker seems to orient its cavities depending on the consistency of the wooden supports. It prefers to excavate in the decayed parts of the tree (Gorman 2021).

The results of this study represent the first scientific documentation of the nesting cavities measurements of this unknown endemic woodpecker species. The analysis of the influence of the local climate on the variability of the sizes and the orientation of the cavities of Levaillant's Woodpecker, endemic to northwest Africa, reveals an adaptive behaviour of the species towards local climatic conditions. Despite the reduced number of samples studied, especially on mountain peaks, these findings constitute an interesting database for understanding the ecology and reproduction of this woodpecker. It is an initiation to other studies that can form a basis for the development of strategies for the management and conservation of forest massifs in the Aurès Mountains.

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