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SHORT NOTE

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PATTERNS OF NEST ORIENTATION IN THE GOLDEN BILLED SALTATOR (*SALTATOR AURANTIIROSTRIS*) IN CENTRAL ARGENTINA

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Abstract · In birds, nest location defines the microclimatic conditions for the development of eggs and nestlings. In general, direct solar radiation and wind are the main determinants of bird nest orientation patterns. In this study, we analyzed the orientation pattern of nests of the Golden-billed Saltator (*Saltator aurantiirostris*) in central Argentina. The nests were mainly oriented towards the north side of the substrate plant, with greater concealment from the south and west. Nest mean orientation in the species matches the conditions of higher solar radiation in the plant, although the vegetation concealment from above and west may compensate for the high exposure to solar radiation in the species. Nests were also placed in sites further from the foliage edge and were supported by more branches, variables that may be associated with reduced risk of nest predation. Overall our results show that the selection of nesting sites in the Golden-billed Saltator may involve a number of decisions to maximize microclimatic conditions that may aid the thermoregulation of eggs and nestlings, while minimizing the risk of nest predation.

Resumen · Patrón de orientación de los nidos de Pepitero de collar (*Saltator aurantiirostris*) en el centro de Argentina
En las aves la ubicación del nido define las condiciones microclimáticas para el desarrollo de los huevos y los pichones. En general, la radiación solar directa y el viento son los principales determinantes de los patrones de orientación del nido de las aves. En este estudio analizamos el patrón de orientación de los nidos de Pepitero de Collar (*Saltator aurantirostris*) en el centro de Argentina. Encontramos que los nidos naturales estaban orientados hacia el lado norte de la planta soporte, con un alto porcentaje de cobertura superior y del oeste. La orientación media de los nidos coincide con las condiciones de mayor radiación solar dentro de la planta, sin embargo la cubierta vegetal ayuda a compensar la alta exposición solar. Los nidos estaban colocados en sitios más alejados del borde foliar de la planta y sostenidos por más ramas, variables que pueden asociarse con un menor riesgo de depredación de nidos. En general, nuestros resultados muestran que la selección de sitios de anidación en el Pepitero de Collar puede implicar una serie de decisiones para maximizar las condiciones microclimáticas que ayuden a la termorregulación de huevos y pichones, al mismo tiempo que se minimiza el riesgo de depredación de nidos.

Key words: Argentina · Microclimate · Neotropic · Nest orientation · Nest protection · *Saltator aurantirostris* · Solar radiation

Birds show an enormous diversity in terms of nest architecture and nesting habits, which usually respond to local climatic conditions and the risk of nest predation (Hansell 2000, Deeming 2002, Eggers et al. 2005, Gill 2007, Peluc et al. 2008). Nest composition (e.g., nest material; Mainwaring et al. 2014) and nesting site might both be related to reproductive success, since birds attempt to maintain an optimal temperature for the development of the eggs and nestlings (Gloutney & Clark 1997, Conway & Martin 2000, Deeming 2002). Higher breeding success would thus be expected in microsites capable of alleviating the negative effects of factors, such as excessive solar radiation, wind, humidity or rainfall (Webb 1987, Zwartjes & Nordell 1998, Thogmartin

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1999, Mezquida 2004, Mainwaring et al. 2014). For example, many species build their nests in places well concealed by vegetation which reduces their exposure to direct solar radiation, and regulates nests microclimate, enhancing reproductive success (Viñuela & Sunyer 1992, Burton 2006).

Nest orientation (i.e., the location of the nest regarding the central axis of the substrate) is another variable that birds may select in order to maximize regulation of nest microclimate (With & Webb 1993, Norment 1993, Souza & Santos 2007, Van der Hoek 2017). Moreover, nest orientation may vary within a species across its latitudinal or altitudinal range of distribution in accordance to changes in insolation (Rauter et al. 2002, Burton 2007, Landler et al. 2014). For example, at high latitudes in the Northern hemisphere nests are usually oriented towards the equator, taking advantage of solar radiation to reduce cold temperatures (Landler et al. 2014). In environments close to the equator, species are expected to orient their nests to maximize shade during the middle of the day, when the sun is highest and therefore daily temperatures are at their maximum(Greeney 2009, Van der Hoek 2017). At mid-latitudes, nest location may result from the compromise of having enough shading from above and from the western side (against midday and/or afternoon sun), and possibly facing east to warm more rapidly in the morning (Nelson & Martin 1999, Burton 2007). At high southern latitudes, we would expect patterns that mirror those of northern latitudes with nests oriented toward the equator to take advantage of greater insolation and warmth from that direction to ameliorate the effects of a cold climate (Hussell & Montgomerie 2002, Landler et al. 2014).

Here, we analyze the orientation pattern in nests of the Golden-billed Saltator (*Saltator aurantiirostris*) in central Argentina, at a latitude of 31°10´S. We expect them to be located on the northern side of the substrate plant to optimize solar radiation (Mezquida 2004), yet to be well concealed from above and from the west to avoid overheating during the hours of highest temperature (Hartman & Oring 2003, Burton 2007).

METHODS

The study was conducted in a 100 ha native forest fragment in the locality of Rio Ceballos (31°10´S, 64°15´O; 500–600 m a.s.l.), Córdoba, Argentina. The climate is semiarid, with a mean annual temperature of 18.9°C (range 18–39°C during the breeding season), and 650 mm annual precipitation, concentrated in the summer. During the reproductive period (October-February) prevailing winds are warm and blow from the north and northeast. However, precipitations characteristic of the summer usually occur in the form of a storms accompanied by winds from the south, (data obtained from the closest meteorological station - 20 km - to the study site, Capitanelli 1979). The study site consists of an open to semi-closed forest with canopy cover varying from 30 to 70% (Cabido et al. 1998) Predominant vegetation include shrubs of *Condalia microphylla* (Rhamnaceae) and *Schinus fasciculate* (Anacardiaceeae) and trees of C*eltis ehrenbergiana* (Celtidaceae), *Aspidosperma quebracho-blanco* (Apocynaceae), *Prosopis alba* (Fabaceae), *Acacia caven* (Fabaceae), and *Acacia praecox* (Fabaceae). The fragment is part of the Chaco Serrano forest district, in the Great Chaco region (Cabrera 1971, Cabido et al. 1998).

From October 2011 to February 2012, we searched for Golden-billed Saltator nests, open cups that are usually placed on shrubs and trees, at heights between 1–4 m (de la Peña 2005, Luczywo 2013). Each nest site was characterized by means of 11 microsite variables (percentage nest concealment from above, west, south, east, and north, distance of nest from foliage edge, number of supporting branches, mean diameter of supporting branches, nest height, nest orientation, and substrate height). More specifically, nest concealment was visually estimated (estimate % cover); distance of nest from foliage edge, number of supporting branches, mean diameter of supporting branches, and nest height were measured directly (using measuring tape); and nest orientation was recorded as a cardinal deviation of nests from the tree central axis (using a compass), following the methods described by Martin et al. (1997) and Mezquida (2004).

To determine if nest orientation or other characteristics of the nesting microsite were selected by the species, we compared microhabitat variables between natural (41) and random (40) nesting sites. We used a digital grid of the entire sampling area (satellite image of the Google Earth ©) with assigned grid numbers, to randomly select 40 GPS coordinates, constituting random sampling points. At each random point, we located the nearest tree/shrub (random nest substrate), and used tables with a range of 1–4 m and a range of 0–360° to assign a random height and random nest orientation to the random nest site. At random nests we measured the same variables as for the real nests.

Data analysis. We estimated mean-nest orientation (± SD) using circular statistics. We used the Watson's U^2 test to determine if orientation was randomly distributed or directed (Zar 1999). This analysis was performed using Oriana software (Kovach Computing Services 2004).

We used the non-parametric Mann-Whitney *U* test (W) (because data did not to meet normality assumptions) to compare mean vegetation concealment from above between nests oriented toward the northern quadrants (between 270–0 and 0–90 degrees) and those facing the southern quadrants (90–180 and 180–270 degrees). We run a principal component analysis (PCA) on the 11 microsite variables at natural and random nesting sites in order to identify nesting site variables selected by Golden-billed Saltator. Mann-Whitney *U* tests and PCA were

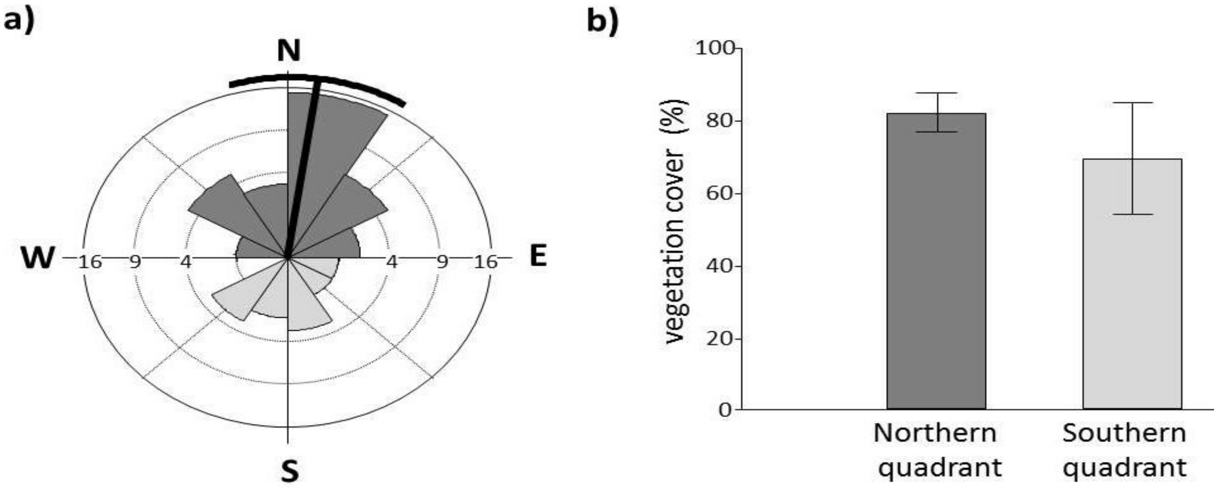

Figure 1. a) Mean orientation (± SD) (black line) and distribution of orientation values for 41 nests of the Golden-billed Saltator (*Saltator aurantiirostris*) during the reproductive period October 2011−February 2012, in Cordoba, Argentina. Most nests appeared to be oriented towards the north. b) Percentage of vegetation concealment from above for nests located on the northern and southern quadrants of the substrate plant.

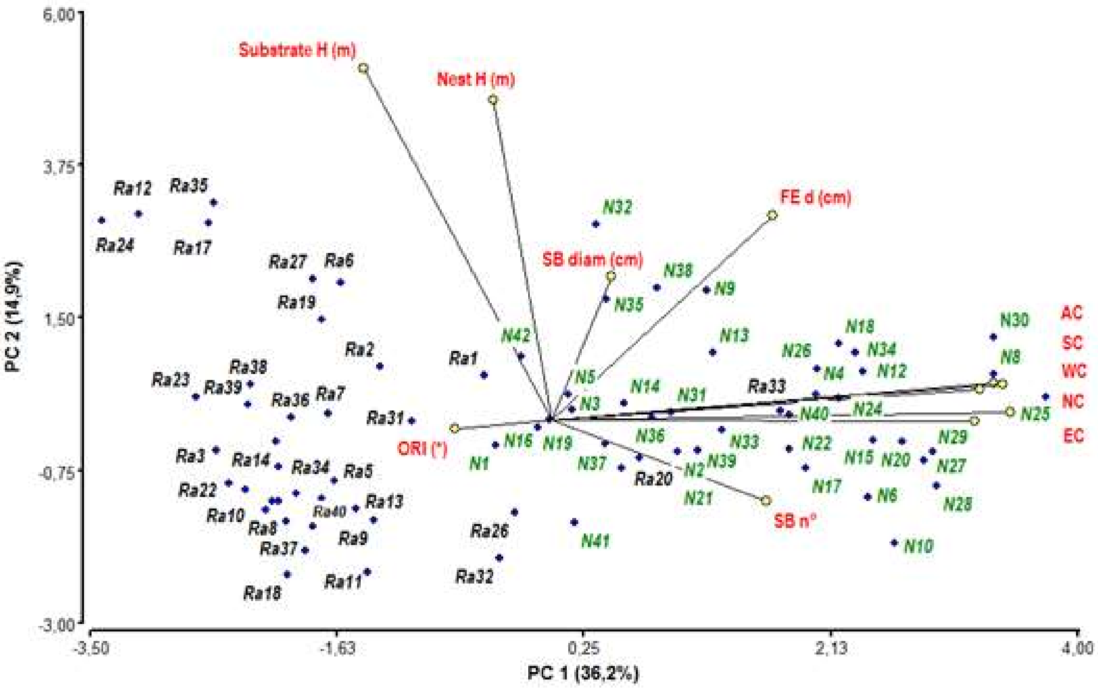

Figure 2. Principal component analysis for 11 microsite variables measured for nests (N green dots; n = 41) of the Golden-billed Saltator (*Saltator aurantiirostris*) found during the 2012–2013 breeding season in Cordoba, Argentina and for random nest sites (Ra black dots; n = 40). Loadings of variables are represented as black lines of different size and directions. Variable names are abbreviated as follows: Substrate H: substrate height; Nest H: nest height; SB diam: diameter of support branches; FE d: distance from nest tofoliar edge; AC: above coverage; SC: south coverage; WC: west coverage; NC: north coverage; EC: east coverage; SB n°: number of support branches; N orient (*): nest orientation. Note that natural and random nest sites are segregated along PC1 axis. The 3 microsite variables that contribute most to this pattern are WC, SC, and AC, indicating that nest sites have in general higher vegetative cover than random nest sites.

run using the software InfoStat (Di Rienzo et al. 2002).

RESULTS AND DISCUSSION

The main substrates for Golden-billed Saltator nests (n = 41) were *Schinus fasciculata* (42%) and *Celtis ehrenbergiana* (34%). Other species used for nesting included *Aspidosperma quebracho-blanco* (10%), *Acacia caven* (5%), and *Condalia microphylla* (5%), all of which are native in the study area.

The mean orientation of nest was 8.23° ± 13.35 and Watson's U^2 test indicated a non-random pattern facing north ($U^2 = 0.548$; $p < 0.005$). Thirty-two nests

Table 1. Eigenvector and accumulated eigenvalues from a Principal Component Analysis that includes 11 microsite variables measured at 41 nest of Golden-billed Saltator (*Saltator aurantiirostris*), in Cordoba, Argentina. In order to facilitate interpretation and visualization, in this Table we only listed Natural nest eigenvectors and eigenvalues. Also, since the four most important variables separating natural from random nests are distributed along the PC1 axis, we limited the information solely to PC1.

	Variable	Eigenvectors	Eigenvalues
Natural nest	Percent concealment from the West	0.43	0.36
	Percent concealment from the South	0.43	0.51
	Percent concealment from above	0.42	0.61
	Percent concealment from the East	0.4	0.71
	Percent concealment from the North	0.4	0.79
	Distance from the foliage edge	0.21	0.85
	Number of supporting branches	0.2	0.89
	Diameter of supporting branches	0.06	0.92
	Nest height	-0.06	0.95
	Nest orientation	-0.09	0.98
	Substrate height	-0.18	1

were placed in the northern quadrants of the substrate plant (between 270–0 and 0–90 degrees), whereas only 9 were located on the south facing quadrants (90–180 and 180–270 degrees; Figure 1a).

Mean nest concealment from above of natural nests was 82.22% ± 15.75 and 69.44% ± 23.51, for north and south facing quadrants respectively (Figure 1b). Although nests in the northern quadrants showed higher values of concealment from above, differences were not statistically significant between both locations (W = 134; $p = 0.0794$). The PCA on the 11 nesting microsite variables shows that individuals place their nests non-randomly, selecting particular characteristics of the site. Natural nests tended to be located at sites with greater superior concealment as well as more coverage from the west and south than random nests (Table 1; Figure 2). This suggests that individuals of Golden-billed Saltator select nest sites with greater coverage, especially from above, south and west. Sites with such vegetation concealment may be more effective at avoiding direct insolation during midday and afternoon, hours of highest temperature in the summer months, as well as being more protective from humid winds blowing from the south (Capitanelli 1979). In addition, two other microsite variables, distance to the foliage edge and number of branches that support the nest, contributed to the differences between random and real nest sites in the PCA (Table 1; figure 2), suggesting nest site selection. These variables are associated with the structure of the nesting site, and could be involved in reducing the probability that the nest is perceived by visual predators (Nalwanga et al. 2004, Latif et al. 2012, Fogarty et al. 2017).

Our results show that the Golden-billed Saltator locates more nests on the northern quadrants of the plant than the southern quadrants. This in agreement with the results reported by Mezquida (2004), who found similar tendencies for open cup nests in species of Tyrannidae and Emberizidae in the southern hemisphere. Unfortunately, high nest predation rates (70% of predated nests) in the system prevented us from evaluating the influence of nest orientation on overall nest success, egg development, or nestling growth. Overall our results suggest that nest site selection in this species may involve a number of decisions to maximize microclimatic conditions that may aid the thermoregulation of eggs and nestlings (Thogmartin 1999, Collias 1997, Mainwaring et al. 2014) while at the same time minimizing the risk of nest predation (Fogarty et al. 2017).

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REFERENCES

Burton, NH (2006) Nest orientation and hatching success in the Tree Pipit *Anthus trivialis*. *Journal of Avian Biology* 37: 312–317.

Burton, NH (2007) Intraspecific latitudinal variation in nest orientation among ground-nesting passerines: a study using published data. *The Condor* 109: 441–446.

Cabido, M, G Funes, E Pucheta, F Vendramini & S Díaz (1998) A chorological analysis of the mountains from Central Argentina. Is all what we call Sierra Chaco really Chaco? *Candollea* 53: 321–331.

Cabrera, AL (1971) Fitogeografía de la República Argentina. *Boletín de la Sociedad Argentina de Botánica* 14: 1–42.

Capitanelli, R (1979). III Clima. Pp 45–138 *in* Vázquez, JV, RA Miatello & ME Roqué (dirs), Geografía física de la provincia de Córdoba. Ed. Boldt, Buenos Aires, Argentina.

Collias, NE (1997) On the origin and evolution of nest building by passerine birds. *The Condor* 99: 253–270.

Conway, C.J & TE Martin (2000) Evolution of passerine incubation behavior: influence of food, temperature, and nest predation. *Evolution* 54: 670–685.

Deeming, DC (2002) *Avian incubation behaviour, environment, and evolution*. Oxford Univ. Press, Oxford, UK.

de la Peña, MR (2005) *Reproducción de las aves argentinas (con descripción de pichones)*. Monografía 20. Editorial L.O.L.A., Buenos Aires, Argentina.

Di Rienzo, J, M Balzarini, I González, M Tablada, W Guzmán, C Robledo & F Casanoves (2002) *Software INFOSTAT Versión 1.1.* FCA, Univ. Nacional de Córdoba, Córdoba, Argentina.

Eggers, S, M Griesser, T Andersson & J Ekman (2005) Nest predation and habitat change interact to influence Siberian Jay numbers. *Oikos* 111: 150–158.

Facemire, CF, ME Facemire & MC Facemire (1990) Wind as a factor in the orientation of entrances of Cactus Wren nests. *The Condor* 92: 1073–1075.

Fogarty, DT, RD Elmore, SD Fuhlendorf & SR Loss (2017) Influence of olfactory and visual cover on nest site selection and nest success for grassland-nesting birds. *Ecology and Evolution 7*: 6247–6258.

Gill, FB (2007) *Ornithology*. 3rd ed. W. H. Freeman and Company, New York, New York, USA.

Gloutney, ML & RG Clark (1997) Nest-site selection by Mallards and Blue-winged Teal in relation to microclimate. *The Auk* 114: 381–395.

Greeney, HF (2009) Nest orientation of the Spotted Barbtail, *Premnoplex brunnescens*, is strongly correlated with stream flow. *Journal of Ethology* 27: 203–208.

Hansell, M (2000) *Bird nests and construction behaviour*. Cambridge Univ.Press, Cambridge, UK.

Hartman, CA & LW Oring (2003) Orientation and microclimate of Horned Lark nests: the importance of shade. *The Condor* 105: 158–163.

Hussell, DJT & R Montgomerie (2002) Lapland Longspur (*Calcarius lapponicus*). *In* Poole, A & F Gill (eds). *The birds of North America, No. 656*. The birds of North America, Inc., Philadelphia, Pennsylvania, USA.

Kovach, W (2004) *Oriana v. 2.02 a.* Kovach Computing Services, Anglesey, Wales, UK.

Landler, L, MA Jusino, J Skelton & JR Walters (2014) Global trends in woodpecker cavity entrance orientation: latitudinal and continental effects suggest regional climate influence. *Acta Ornithologica* 49: 257–266.

Latif, QS, SK Heath & JT Rotenberry (2012). How avian nest site selection responds to predation risk: testing an ‘adaptive peak hypothesis’. *Journal of Animal Ecology* 81: 127–138.

Luczywo, A (2013) *Disponibilidad de alimento y plasticidad fenotípica en relación a diversas estrategias de nidificación, en paseriformes del Chaco Serrano, Córdoba.* Tesis de grado, FCEFyN. Universidad Nacional de Córdoba, Córdoba, Argentina.

Mainwaring, MC, IR Hartley, MM Lambrechts & DC Deeming (2014) The design and function of birds' nests. *Ecology and Evolution* 4: 3909–3928.

Martin, T, C Paine, C Conway, W Hochachka, P Allen & W Jenkins (1997) *BBIRD field protocol.* Montana Cooperative Wildlife Research Unit, Univ. of Montana, Missoula, Montana, USA.

Mezquida, ET (2004) Patrones de orientación de los nidos de Passeriformes en una zona árida del centro-oeste de Argentina. *Ornitología Neotropical* 15:145–153.

Nalwanga, D, P Lloyd, MA du Plessis & TE Martin (2004) The influence of nest-site characteristics on the nesting success of the Karoo Prinia (*Prinia maculosa*). *Ostrich* 75: 269–274.

Nelson, KJ & K Martin (1999) Thermal aspects of nest-site location for Vesper Sparrows and Horned Larks in British Columbia. *Studies in Avian Biology* 19: 137–143.

Norment, CJ (1993) Nest-site characteristics and nest predation in Harris' Sparrows and White-crowned Sparrows in the Northwest Territories, Canada. *The Auk* 110: 769–777.

Peluc, SI, TS Sillett, JT Rotenberry & CK Ghalambor (2008) Adaptive phenotypic plasticity in an island songbird exposed to a novel predation risk. *Behavioral Ecology* 19: 830–835.

Rauter, CM, Reyer, HU & K Bollmann (2002) Selection through predation, snowfall and microclimate on nest-site preferences in the Water Pipit *Anthus spinoletta*. *Ibis* 144: 433–444.

Souza, FL & CA Santos (2007) Climate and nest opening orientation in *Furnarius rufus* (Furnariidae). *Iheringia*, *Série Zoologia* 97: 293–295.

Thogmartin, WE (1999) Landscape attributes and nest-site selection in wild turkeys. *The Auk* 116: 912–923.

Van der Hoek, Y (2017) Southeastern orientation in entrances of Yellow-tufted Woodpecker (*Melanerpes cruentatus*) cavities on the equator. *Acta Ornithologica* 52: 233–238.

Viñuela, J & C Sunyer (1992) Nest orientation and hatching success of Black Kites *Milvus migrans* in Spain. *Ibis* 134: 340–345.

Webb, DR (1987) Thermal tolerance of avian embryos: a review. *Condor* 89: 874–898.

With, KA & DR Webb (1993) Microclimate of ground nests: the relative importance of radiative cover and wind breaks for three grassland species. *The Condor* 95: 401–413.

Zar, JH (1999) *Biostatistical analysis.* Prentice-Hall Inc., Englewood Cliffs, New Jersey, USA.

Zwartjes, PW & SE Nordell (1998) Patterns of cavity-entrance orientation by Gilded Flickers (*Colaptes chrysoides*) in cardon cactus. *The Auk* 115: 119–126.