TREE CAVITY-NESTING RECORDS OF THE AMERICAN KESTREL (*FALCO SPARVERIUS*) IN TWO ANDEAN FOREST SITES OF SOUTHERN CHILE

Registros de nidificación del cernícalo (*Falco sparverius*) en cavidades de árboles en dos sitios boscosos andinos del sur de Chile

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Resumen.- El cernícalo americano (*Falco sparverius*) nidifica en cavidades o pequeños agujeros protegidos, incluyendo oquedades de árboles (excavadas o producidas por descomposición), galerías en paredes rocosas o arenosas, entretechos de edificios y cajas nido. La biología reproductiva de esta especie es escasamente conocida en los ecosistemas templados de América del Sur. Entre 2015 y 2020, observamos siete eventos de nidificación del cernícalo en dos cavidades de árboles en un área boscosa del sur de Chile. El tamaño de puesta fue 4-5 huevos, la incubación duró 28-29 días, el tamaño de nidada fue 3-4 polluelos, los polluelos permanecieron 28-30 días en el nido y el número de volantones fue 2-4. Nuestras observaciones amplían la comprensión de la historia natural y biología reproductiva del cernícalo en áreas boscosas templadas del sur de Chile.

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INTRODUCTION

Tree cavities are an essential and reusable nesting resource for nearly 1900 avian species (≈ 18% of all birds; Van der Hoek *et al*. 2017). Cavity-nesting raptors interact with many other vertebrate species in "nest webs" (Martin & Eadie 1999). Tree cavities flow from trees to non-excavator species, such as cavity-nesting raptors, through a process facilitated by excavators (*e.g.,* woodpeckers) or tree-decay processes (Martin *et al*. 2004, Altamirano *et al.* 2017, Ibarra *et al*. 2020a). Therefore, the supply of excavated and non-excavated cavities may limit the population sizes of cavity-nesting raptors (Martin & Eadie 1999, Martin *et al*. 2004, Ibarra *et al*. 2020b). Cavity entrance size, volume, and depth are essential attributes for cavity selection because they influence reproductive success, competition, and predation (Aitken *et al*. 2002). Cavity-nesting raptors may reuse a cavity over searching for a new one due to the potential advantage of earlier laying dates, larger clutches and, in some cases, more renesting attempts (Wiebe *et al*. 2007).

The American Kestrel (*Falco sparverius*) inhabits diverse habitats (*i.e*., forests, meadows, grasslands, farmlands, orchards, and some urban or suburban areas) from Alaska and Canada to the Cape Horn archipelago in southern Chile (Smallwood & Bird 2002, Santillán *et al*. 2009). This falcon species nests in cavities available in open and semi-open habitats covered by short ground vegetation (Smallwood & Bird 2002, Smallwood *et al*. 2009). American Kestrels nest in a variety of cavities, including tree-holes (excavated or produced by decay), nest boxes, rocky crevices, sandy walls, and building nooks (Smallwood & Bird 2002, Salazar *et al*. 2011).

Current knowledge of the nesting biology of American Kestrels comes mainly from studies using nest boxes in North America (Bortolotti 1994, Wiebe & Bortolotti 1995, Breen & Parrish Jr. 1997, Smallwood *et al*. 2009). Indeed, the reported nesting records for American Kestrels in South America are anecdotal (Balgooyen 1989, De Lucca 1992, De Lucca & Saggese 1993, Liébana *et al*. 2009). Therefore, their nesting biology in the South American temperate ecoregion remains undocumented. Here, we report the nesting activity of American Kestrels in a temperate forest area in southern Chile. Although limited, our information contributes to filling the gap in the natural history of this falcon species.

MATERIALS AND METHODS

During five breeding seasons (2015-2020), we searched for nests of cavity-nesting birds at 20 sites within an Andean forested area of the La Araucanía region in southern Chile (39°16'S, 71°48'W; see Altamirano *et al*. 2017 for a complete description of the study area). At each site, we searched for nests for six hours per six days within an area of at least 20 ha. For detecting the kestrel nests, we inspected tree cavities or followed adult kestrels when they displayed some breeding behavior or carried prey. For cavities located up to 15 m high, we used a wireless video monitoring camera system with a telescopic pole (Altamirano *et al*. 2017). When a cavity was > 15 m high, we watched it from the ground to verify nesting events by observing adult kestrels hunting around or feeding nestlings (Gard & Bird 1990). When we confirmed an American Kestrel pair nesting, we monitored the nest every 4-7 days until we knew the nest fate (*e.g*., until chicks abandoned the nest).

After each nesting season, we quantified site characteristics at three scales: (a) *cavity-scale*: origin (*i.e*., excavated or non-excavated formed by tree decay processes), height, entrance orientation, cavity entrance width and height, vertical and horizontal depth; (b) *tree-scale*: tree species, diameter at breast height (DBH), diameter at cavity height (DCH), vine and epiphyte cover, decay of nest tree (decay classes: 1 = live, healthy tree; 2a = live tree with sign of boring arthropods and/or fungal decay; 2b = nearly dead tree with broken top and advanced levels of decay, with 20% live branches; 3 = standing dead tree in progressive states of decay; adapted from Thomas *et al*. 1979); (c) *site-scale*: habitat type (open farmland, secondary forest = 35-100 yr old, old-growth forest ≥ 100 yr old), canopy cover, understory cover, tree density (only trees with DBH > 12.5 cm) an signs of recent human activity (*e.g*., logging, grazing, or fire; for a review see Ibarra *et al*. 2014, Altamirano *et al*. 2017).

RESULTS

We located two American Kestrel pairs nesting in tree cavities. We considered that nests belonged to two different pairs because the distance between nest trees was > 40 km. Moreover, in some breeding seasons, the pairs nested simultaneously. Each pair nested during several breeding seasons in each tree cavity. Specifically, we found the first pair nesting on 24 November 2015 and the second on 17 December 2016. Each nest cavity was in an old-growth southern beech; one was in a roble pellín (*Nothofagus obliqua*), and the other in a coigüe (*N. dombeyi*). We presumed that each pair nested successively in the same cavity during several breeding seasons because the American Kestrel typically reuses the same nesting site for multiple years (Katzner *et al*. 2005).

Both cavities were originated from tree decay processes. In the case of the roble pellín, it was a remnant large-decaying tree located in farmland used for livestock grazing (Fig. 1A). The coigüe was in an old-growth mountain forest-stand composed of coigües and short-leave mañío (*Saxegothaea conspicua*), together with numerous large trees and some snags (Fig. 1B). Both nesting trees were among the largest in their respective sites (Table 1). We monitored over four and three years the reproductive activity of the kestrel pair that nested in the roble pellín and coigüe, respectively.

Both American Kestrel pairs began the nesting period in early November and ended in December-January. In one nesting event in the roble pellín, we recorded that the egg-laying lasted 6-7 days. In the same nest, the female laid three eggs at a 1-day interval (17-19 November 2019), but she laid a fourth egg three days later (22 November 2019; Fig. 1C). Clutch size ranged from 4-5 eggs (n = 3 nesting events). We recorded an incubation period of 28-29 days (n = 2 nesting events). The hatching success was four out of five eggs (80%) on 27-28 November 2017 and all four eggs (100%) on 18-19 December 2019 (n = 2 nesting events). Brood size was 3-4 nestlings (n = 3 nesting events; Fig. 1D). The nestling period for the two pairs was of 28-30 days. We recorded one to two dead nestlings in both cavities. These losses occurred during the first and second week after hatching. We recorded 2 to 4 fledglings for three nesting events. Each American Kestrel pair raised at least one fledgling in every reproductive season. In the nest cavity in the roble pellín, the fledging dates were 24-25 December 2017 and 16-17 January 2020 (n = 2 nesting events).

We recorded the remains of rodents inside the nesting cavity in the roble pellín. However, we could not identify them at the species level. In some visits to the nests during the incubation period, we observed a kestrel male outside the cavity perched on a branch of the same tree,

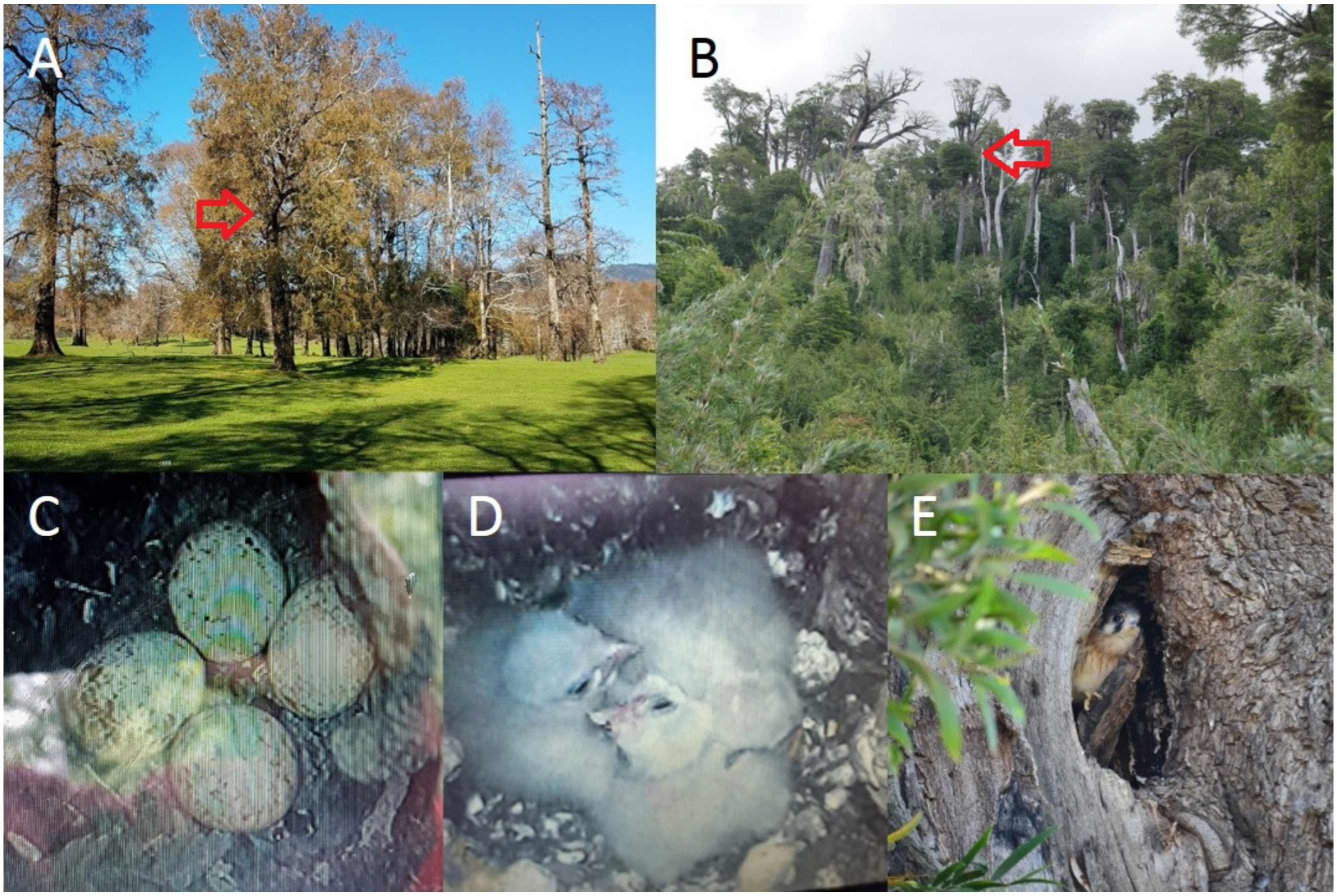

Figure 1. Nest trees, eggs, nestlings and nesting cavity of the American Kestrel (*Falco sparverius*) in Andean forest sites of southern Chile. **A**. Nest location in a roble pellín (*Nothofagus obliqua*) in a farmland used for livestock grazing. **B**. Nest Location in a coigüe (*N. dombeyi)* situated in an old-growth mountain forest-stand. **C**, **D**. Four eggs and two nestlings inside the non-excavated cavity in a roble pellín. **E**. An adult American Kestrel at the entrance of the non-excavated cavity in a roble pellín. Photographs: Gabriel Fuentes shared the photo of the American Kestrel inside the non-excavated cavity.

likely defending the nest from eventual predators or hunting. It attacked the telescopic pole when we checked the interior of the cavity.

DISCUSSION

Our observations expand our understanding of the natural history, breeding behavior, and life-history traits of the American Kestrel in southern Chile. The use of cavities in old southern beeches for nesting demonstrates the relevance of the scattered old-growth native trees for the reproduction of the American Kestrel. Like us, Figueroa & Corales (2004) also found an American Kestrel pair nesting successfully in an isolated old-growth roble pellín in an agricultural site in the La Araucanía region. Scattered old native trees are essential for the population persistence of cavity-nesting species, including the American kestrel, on agricultural lands in temperate ecoregion (Fischer *et al.* 2010, Carneiro *et al.* 2013, Jiménez *et al*. 2013, Ibarra *et al*. 2017, White & Jiménez 2017).

In general, the breeding phenology of the American Kestrel in our study area coincided with that reported for other localities. The incubation period we recorded for the American Kestrel was similar to that reported for nest boxes (28-30 days; Willoughby & Cade 1964, Balgooyen 1976). De Lucca & Saggese (1993) found that the nestling period for the American Kestrel was 30 days in basalt cliff holes in Argentine Patagonia. Clutch size, brood size, and the number of fledglings of American Kestrels in our study area were similar to those observed in nest boxes elsewhere (mean clutch size = 4.3-5.0 eggs; mean brood size = 2.7-3.9 nestlings; mean number of fledglings = 1.6-3.9; Balgooyen 1989, Varland & Loughin 1993, Bortolotti 1994, Wiebe & Bortolotti 1995, Breen & Parrish 1997, Smallwood & Collopy 2009, Liébana *et al*. 2009, 2013, Orozco-Valor & Grande 2020).

The American Kestrel's hatching success in our study area was higher than in pairs that nested in nest boxes. In North America, Varland & Loughin (1993) and Smallwood & Collopy (2009) observed that the mean hatching success in nest boxes reached almost 60% (mean

Table 1. Characteristics of nesting cavities and habitat used by two American Kestrel (*Falco sparverius*) pairs in an Andean forested area of southern Chile.

Variables[a]	Pair 1	Pair 2
At cavity-scale		
Origin	Non-excavated	Non-excavated
Cavity height (m)	29.5	10.4
Entrance orientation (°)	216	112
Entrance width (cm)	--	9
Entrance height (cm)	--	44
Vertical cavity depth (cm)	--	13
Horizontal cavity depth (cm)	--	33
At tree-scale		
Species	Coigüe (*Nothofagus dombeyi*)	Roble pellín (*Nothofagus obliqua*)
Diameter at cavity height (cm)	--	101
Diameter at breast height (cm)	196	99.8
Vine and epiphyte cover (%)	1	1
Decay class[b]	2B	2A
At site-scale		
Habitat type	Old-growth forest	Open farmland with remnant native trees
Canopy cover (%)	70	45
Understory cover (%)	100	0
Tree density (no./ha)	108.8	38
Signs of recent human activity disturbance	None	Logging-grazing

[a]Nest variables measured in a radius of 11,2 m. [--] No data
[b]Decay classes of nest tree: 1 = live, healthy tree; 2a = live tree with sign of boring arthropods and/or fungal decay; 2b = nearly dead tree with broken top and advanced levels of decay, with 20% live branches; 3 = standing dead tree in progressive states of decay (adapted from Thomas *et al.* 1979).

= 62.5-67.6 %). Possibly, the death of some nestlings in our study area was because of starvation. Starvation is a common cause of mortality in nestlings of this falcon species (Dawson & Bortolotti 2002). When food is scarce, kestrels may reduce their brood size by preferring to feed the oldest nestlings and letting the youngest chickens die (Wiebe & Bortolotti 1995). In addition, Sarasola *et al.* (2003) found that American Kestrel nestlings consume larger small mammal prey and more birds and reptiles than adults. That is consistent with the high energy demand of nestlings (Liebana *et al.* 2009).

Our finding of remains of rodents in cavities is consistent with the generalist food habit of the American Kestrel during the breeding season. Although breeding American kestrels prey mainly upon birds, insects, or reptiles, they also consume a proportion of rodents. (Sarasola *et al.* 2003, Figueroa & Corales 2004).

The American Kestrel is an obligate tree cavity nester in temperate forests of South America, which depends on tree cavities for nesting (Altamirano *et al.* 2017). In Argentine Patagonia, the American Kestrel nests in tree cavities produced both by woodpeckers and decay processes (De Lucca & Saggese 1993). In Mediterranean wooded areas of central Chile, some American Kestrel pairs nest in cavities excavated by Chilean Flickers.

In North America, cavities used by nesting American Kestrels include those made by Northern Flickers (*Colaptes auratus*), Pileated Woodpeckers (*Dryocopus pileatus*), and Red-headed Woodpeckers (*Melanerpes erythrocephalus*). These excavated cavities used by the American Kestrel were in living trees or snags (Toland & Elder 1987). In British Columbia, American Kestrels mostly used non-excavated cavities (Martin & Eadie 1999, Martin *et al.* 2004). Non-excavated cavities result over several decades because of fungal decay, insects, or physical damage due to fire and wind (Cockle *et al.* 2012, Ibarra *et al.* 2014). Furthermore, American Kestrels in Philadelphia select high cavities available in large trees (Brauning 1983).

We recommend additional studies to increase the knowledge of the breeding biology of the American Kestrel in southern Chile. These studies may consider evaluations of nest-site selection, breeding habitat, and life-history traits of this habitat generalist falcon species.

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LITERATURE CITED

Aitken, K.E.H., K.L. Wiebe & K. Martin. 2002. Nest-Site reuse patterns for a cavity-nesting bird community in interior British Columbia. *Auk* 119: 391-402.

Altamirano, T.A., J.T. Ibarra, K. Martin & C. Bonacic. 2017. The conservation value of tree decay processes as a key driver structuring tree cavity nest webs in South American temperate rainforests. *Biodiversity and Conservation* 26: 2453-2472.

Balgooyen, T.G. 1976. Behavior and ecology of the American Kestrel (*Falco sparverius*) in the Sierra Nevada of California. *University of California Publications in Zoology* 103: 1-83.

Balgooyen, T.G. 1989. Natural history of the American Kestrel in Venezuela. *Journal of Raptor Research* 23: 85-93.

Bortolotti, G.R. 1994. Effect of nest-box size on nest-site preference and reproduction in American Kestrels. *Journal of Raptor Research* 28: 127-133.

Brauning, D. 1983. Nest site selection of the American Kestrel (*Falco sparverius*). *Raptor Research* 17: 122.

Breen, T.F. & J.W. Parrish Jr. 1997. American Kestrel distribution and use of nest boxes in the coastal plains of Georgia. *Florida Field Naturalist* 25: 128-137.

Carneiro, A.P.B., J.E. Jiménez, P.M. Vergara & T.H. White Jr. 2013. Nest-site selection by Slender-billed Parakeets in a Chilean agricultural-forest mosaic. *Journal of Field Ornithology* 84: 13-22.

Cockle, K.L., K. Martin & G. Robledo. 2012. Linking fungi, trees, and hole-using birds in a neotropical tree-cavity network: pathways of cavity production and implications for conservation. *Forest Ecology and Management* 264: 210-219.

Dawson, R.D. & G.R. Bortolotti. 2002. Experimental evidence for food limitation and sex-specific strategies of American Kestrels (*Falco sparverius*) provisioning offspring. *Behavioral Ecology and Sociobiology* 52: 43-52.

De Lucca, E.R. 1992. Nidificación del halconcito colorado (*Falco sparverius*) en nidos de cotorra (*Myiopsitta monachus*). *Hornero* 13: 238-240.

De Lucca, E.R. & M. Saggese. 1993. Nidificación del halconcito colorado (*Falco sparverius*) en la Patagonia. *Hornero* 13: 302-305.

Figueroa, R.A. & E. Corales. 2004. Summer diet comparison between the American Kestrel (*Falco sparverius*) and Aplomado Falcon (*Falco femoralis*) in an agricultural area of Araucanía, southern Chile. *Hornero* 19: 53-60.

Fischer, J., J. Stott & B.S. Law. 2010. The disproportionate value of scattered trees. *Biological Conservation* 143: 1564-1567.

Gard, N.W. & D.M. Bird. 1990. Breeding behavior of American Kestrels raising manipulated brood sizes in years of varying prey abundance. *Wilson Bulletin* 102: 605-614.

Ibarra, J.T., T.A. Altamirano, K. Martin, F.H. Vargas & C. Bonacic. 2014. Tree–cavity nesting of Austral Pygmy-Owls (*Glaucidium nana*) in Andean temperate forests of Southern Chile. *Journal of Raptor Research* 48: 82-85.

Ibarra, J.T., M. Martin, K.L. Cockle & K. Martin. 2017. Maintaining ecosystem resilience: functional responses of tree cavity nesters to logging in temperate forests of the Americas. *Scientific Reports* 7: 1-9.

Ibarra, J.T., K.L. Cockle, T.A. Altamirano, Y. Van der Hoek, S. Simard, C. Bonacic & K. Martin. 2020a. Nurturing resilient forest biodiversity: nest webs as complex adaptive systems. *Ecology and Society* 25: 27.

Ibarra, J.T., F.J. Novoa, H. Jaillard & T.A. Altamirano. 2020b. Large trees and decay: suppliers of a keystone resource for cavity-using wildlife in old-growth and secondary Andean temperate forests. *Austral Ecology* 45: 1135-1144.

Katzner, T., S. Robertson, B. Robertson, J. Klucsarits, K. McCarty & K.L. Bildstein. 2005. Results from a long-term nest-box program for American Kestrels: implications for improved population monitoring and conservation. *Journal of Field Ornithology* 76: 217-226.

Liébana, M.S., J.H. Sarasola & M.S. Bó. 2009. Parental care and behavior of breeding American Kestrels (*Falco sparverius*) in central Argentina. *Journal of Raptor Research* 43: 338-344.

Liébana, M.S., J.H. Sarasola & M.Á. Santillán. 2013. Nest-box occupancy by neotropical raptors in a native forest of central Argentina. *Journal of Raptor Research* 47: 208-213.

Martin, K., K.E.H. Aitken & K.L. Wiebe. 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. *Condor* 106: 5-19.

Martin, K. & J.M. Eadie. 1999. Nest webs: a community-wide approach to the management and conservation of cavity-nesting forest birds. *Forest Ecology and Management* 115: 243-257.

Orozco-Valor, P.M. & J.M. Grande. 2020. Weather and agricultural intensification determine the breeding performance of a small generalist predator. *Scientific Reports* 10: 1-13.

Salazar, M.V., H.F. Cadena & E. Bonaccorso. 2011. Desarrollo de los polluelos y cuidado parental en el Quilico (*Falco sparverius*) en el suroeste de Ecuador. *Boletín SAO* 20: 61-66.

Santillán, M., A. Travaini, S.C. Zapata, A. Rodríguez, J. Donázar, D.E. Procopio & J.I. Zanón. 2009. Diet of the American Kestrel in Argentine Patagonia. *Journal of Raptor Research* 43: 377-381.

Sarasola, J.H., M.A. Santillán & M.A. Galmes. 2003. Food habits and foraging ecology of American Kestrels in the semiarid forests of central Argentina. *Journal of Raptor Research* 37: 236-243.

Smallwood, J.A. & D.M. Bird. 2002. American Kestrel (*Falco sparverius*). Pages 1-32, *in* Poole A. & F. Gill (eds.). *The birds of North America, No. 602.* The Academy of Natural Sciences, Philadelphia, PA and the American Ornithologists' Union, Washington, DC, U.S.A.

Smallwood, J.A. & M.W. Collopy. 2009. Southeastern American Kestrels respond to an increase in the availability of nest cavities in north-central Florida. *Journal of Raptor Research* 43: 291-300.

Smallwood, J.A., P. Winkler, G.I. Fowles & M.A. Craddock. 2009. American Kestrel breeding habitat: the importance of patch size. *Journal of Raptor Research* 43: 308-314.

Thomas, J.W., R.G. Anderson, C. Maser & E.L. Bull. 1979. Snags. Pp. 60-77, *in* Thomas J.W. (ed.) *Wildlife habitats in managed forests: the blue Mountains of Oregon and Washington*. Agriculture Handbook No. 553. USDA, Forest Service, Washington, DC, U.S.A.

Toland, B.R. & W.H. Elder. 1987. Influence of nest-box placement and density on abundance and productivity of American Kestrels in central Missouri. *Wilson Bulletin* 99: 712-717.

Van der Hoek, Y., G.V. Gaona & K. Martin. 2017. The diversity, distribution and conservation status of the tree-cavity-nesting birds of the world. *Diversity and Distributions* 23: 1120-1131.

Varland, D.E. & T.M. Loughin. 1993. Reproductive success of American Kestrels nesting along an interstate highway in central Iowa. *Wilson Bulletin* 105: 465-474.

White Jr, T.H. & J.E. Jiménez. 2017. *Lophozonia* tree cavities used for nesting by Slender-billed Parakeets (*Enicognathus leptorhynchus*) in the central valley of southern Chile: a potentially vanishing keystone resource. *Avian Research* 8: 3.

Wiebe, K.L. & G.R. Bortolotti. 1995. Food-dependent benefits of hatching asynchrony in American Kestrels *Falco sparverius*. *Behavioral Ecology and Sociobiology* 36: 49-57.

Wiebe, K.L., W.D. Koenig & K. Martin. 2007. Costs and benefits of nest reuse versus excavation in cavity-nesting birds. *Annales Zoologici Fennici* 44: 209-217.

Willoughby, E.J. & T.J. Cade. 1964. Breeding behavior of the American Kestrel. *Living Bird* 3: 75-96.