

Nest-site selection by Slender-billed Parakeets in a Chilean agricultural-forest mosaic

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Received 26 December 2011; accepted 9 November 2012

ABSTRACT. Species in the family Psittacidae may be particularly vulnerable to anthropogenic habitat transformations that reduce availability of suitable breeding sites at different spatial scales. In southern Chile, loss of native forest cover due to agricultural conversion may impact populations of Slender-billed Parakeets (*Enicognathus leptorhynchus*), endemic secondary cavity-nesting psittacids. Our objective was to assess nest-site selection by Slender-billed Parakeets in an agricultural-forest mosaic of southern Chile at two spatial scales: nest trees and the habitat surrounding those trees. During the 2008–2009 breeding seasons, we identified nest sites ($N = 31$) by observing parakeet behavior and using information provided by local residents. Most (29/31) nests were in mature *Nothofagus obliqua* trees. By comparing trees used for nesting with randomly selected, unused trees, we found that the probability of a tree being selected as a nest site was positively related to the number of cavity entrances, less dead crown, and more basal injuries (e.g., fire scars). At the nesting-habitat scale, nest site selection was positively associated with the extent of basal injuries and number of cavity entrances in trees within 50 m of nest trees. These variables are likely important because they allow nesting parakeets to minimize cavity search times in potential nesting areas, thereby reducing energetic demands and potential exposure to predators. Slender-billed Parakeets may thus use a hierarchical process to select nest sites; after a habitat patch is chosen, parakeets may then inspect individual trees in search of a suitable nest site. Effective strategies to ensure persistence of Slender-billed Parakeets in agricultural-forest mosaics should include preservation of both individual and groups of scattered mature trees.

RESUMEN. Selección de lugares de anidación por *Enicognathus leptorhynchus* en un mosaico Chileno de agricultura y bosque

Especies de la familia Psittacidae pueden ser particularmente vulnerables a transformaciones antropogénicas del hábitat, lo cual reduce la disponibilidad de lugares adecuados para reproducirse a diferentes escalas espaciales. En el sur de Chile, la pérdida de cobertura boscosa debido a la conversión agrícola puede afectar las poblaciones de *Enicognathus leptorhynchus*, un psittacido endémico que anida en cavidades existentes (anidador secundario en cavidades). Nuestro objetivo fue evaluar la selección de lugares de anidación por *Enicognathus leptorhynchus* en un mosaico de agricultura y bosque en el sur de Chile en dos escalas espaciales: árboles para anidar y el hábitat que rodea a estos árboles. Durante la temporada reproductiva del 2008–2009, identificamos lugares de anidación ($N = 31$) mediante la observación del comportamiento del perico e información proporcionada por los residentes locales. La mayoría de los nidos (29/31) se localizaron en árboles maduros de *Nothofagus obliqua*. Mediante la comparación de árboles usados para anidar con árboles seleccionados de manera aleatoria, encontramos que la probabilidad de que un árbol sea seleccionado como un lugar de anidación se relaciona positivamente con el número de entradas a la cavidad, menor número de copas muertas, y más heridas basales (e.g., cicatrices por fuegos). A la escala de anidación de hábitat, la selección de lugares de anidación se asocia positivamente con el grado de heridas basales y número de entradas a la cavidad en árboles localizados a menos de 50 m del árbol donde estaba el nido. Estas variables probablemente son importantes porque permiten que los pericos que están anidando minimicen el tiempo de búsqueda de cavidades en potenciales áreas de anidación, de este modo reduciendo las demandas energéticas y la exposición potencial a depredadores. El perico (*E. leptorhynchus*) puede así usar un proceso jerárquico de selección de lugares de anidación; después que un parche de hábitat es elegido, los pericos pueden entonces inspeccionar árboles de manera individual en búsqueda de lugares

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adecuados para anidar. Estrategias efectivas para asegurar la persistencia del perico (*E. leptorhynchus*) en mosaicos de agricultura y bosque deberían incluir la preservación tanto de individuos como de grupos de árboles maduros dispersos.

Key words: *Enicognathus leptorhynchus*, forest fragmentation, habitat use, Psittacidae, scattered trees, secondary cavity nesters, spatial scales

The family Psittacidae is the world's most threatened group of birds, with at least 28% of the species in this family facing some risk of extinction (Collar 1997, 2000, Snyder et al. 2000, Cockle et al. 2007). Slender-billed Parakeets (*Enicognathus leptorhynchus*; locally known as choroy) are endemic secondary cavity nesters of the south-temperate forests of Chile and little is known about their natural history (e.g., Peña-Foxon et al. 2011). Early reports indicated that the species was widely distributed throughout the lowland *Nothofagus* forests of southern Chile (Philippi 1864, Hellmayr 1932, Goodall et al. 1957), which have been fragmented and degraded by humans for agriculture and livestock grazing during the past 150 yr (Echeverría et al. 2006). Currently, most lowland forest remains as small scattered fragments of second-growth forest consisting of small trees that do not provide suitable nest cavities for Slender-billed Parakeets (Donoso 1993, Carneiro 2010).

In agricultural forest mosaics, Slender-billed Parakeets use mature trees, remnants of the original forest cover that are scattered throughout agricultural fields and pastures, for foraging and nesting (Díaz et al. 2005, Díaz and Kitzberger 2012). Farmland and pastures with high densities of scattered mature trees have been reported as the main habitats selected by Slender-billed Parakeets at multiple spatial scales (Carneiro et al. 2012), lending support to the results of previous studies that have shown that even agricultural areas can provide important habitat for wildlife, including breeding habitat for cavity-nesting birds (Fischer and Lindenmayer 2002, Manning et al. 2006, Gibbons et al. 2008, Koch et al. 2009, Cockle et al. 2011a).

Although Slender-billed Parakeets are categorized as a species of least concern by IUCN (IUCN 2011), the Chilean government considers them vulnerable in southern Chile because they are experiencing a steady numerical decline (SAG 1998). An important initial strategy for the conservation of Slender-billed Parakeets in fragmented agricultural landscapes is to identify characteristics of scattered trees and

forest patches important in nest-site selection. However, nest-site selection can be affected by factors other than availability of trees, such as proximity to foraging sites or predation risk (e.g., Hessel and Quinney 1987, Finch 1989, Brightsmith 2005, White et al. 2006). Therefore, understanding the spatial scale at which Slender-billed Parakeets select nest sites may provide valuable insights for developing conservation programs in fragmented agricultural landscapes of southern Chile. Our objective was to examine nest-site selection by Slender-billed Parakeets in an agricultural-forest mosaic in southern Chile. We determined habitat features that are selected by Slender-billed Parakeets at two spatial scales: nest trees and the habitat surrounding nest trees.

METHODS

Study area. Our study was conducted in a fragmented agricultural landscape in the central valley of the Lakes Region of southern Chile, 12 km south of the city of Osorno (40°42' S, 73°10' W; Fig. 1). The climate is wet-temperate, with yearly average precipitation of 1383 mm and an average temperature of 11.4°C (Luebert and Plissock 2006). Rainfall is distributed throughout the year, with a slight reduction in the summer (December–March). The original vegetation in this area was continuous deciduous lowland forest dominated by *Nothofagus obliqua*, *Laurelia sempervirens*, and *Persea lingue* trees (Donoso 1993, Luebert and Plissock 2006). The current landscape consists of an agricultural matrix with crops of wheat, oats, and barley, cattle pastures, scattered mature trees, exotic plantations of *Pinus radiata*, and small fragments of native second-growth forest (Echeverría et al. 2006, Carneiro 2010).

Nest sampling. We searched for Slender-billed Parakeet nest sites from October to mid-January 2008–2009. Nest trees were identified by direct observation through intensive searching in the study area and using information about nest locations supplied by local residents,

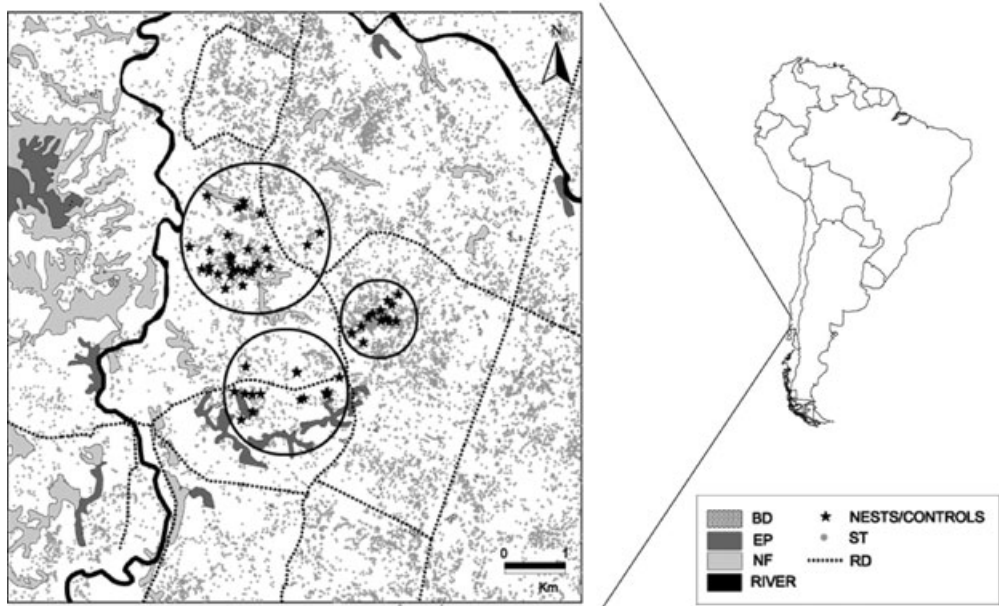


Fig. 1. Map of the study area. Landscape variables were measured using an existing GIS database (CONAF-CONAMA-UACH 2008) derived from recent aerial photographs and LANDSAT images (taken in 2005). Land use practices (BD: area occupied by buildings, NF: area occupied by native forest, RD: roads, EP: area occupied by exotic plantations) and scattered trees (ST) are indicated. Circles represent the three distinguishable nesting clusters separated by local roads.

some of whom were former nest poachers. Nest trees were visited at least once every week throughout the breeding season. A nest was considered active if a parakeet entered a cavity and stayed inside for >30 min. Most active nests (80%) were also accessed by climbing and the status of nest cavities verified directly or using a digital camera. We considered such nests active if we detected either eggs or chicks inside the cavity. We did not observe use of cavities for roosting by non-breeding parakeets, so birds entering cavities were assumed to be breeders.

Random tree selection. Nest site selection was assessed using a case-control design, where trees used for nesting were compared to available, but unused, trees (e.g., Agresti 1996). Each time a nest was found, a control tree was selected by taking a random compass bearing and moving a distance of 500 m (measured with a hand-held GPS) from the nest tree. This threshold distance allows structural characteristics of the habitat (e.g., species composition, tree density) to vary while controlling for pos-

sible confounding variables such as distance to foraging sites (Cameron 2006). When a control site was located in unsuitable habitat (e.g., near buildings or inside a fragment of second-growth forest), we moved in the opposite direction from the nest tree to select the control site. Trees < 0.6-m diameter at breast height (dbh) were excluded because this was the minimum dbh of trees used for nesting by parakeets (Carneiro 2010). Further, only *N. obliqua* trees were selected as controls because most nests (29/31, 93.5%) were in this species of tree. After moving 500 m, the nearest tree that met all these conditions was selected as the control tree.

Study design. We delineated a 130-km² study area (Fig. 1) based on available information about the locations of parakeet nests and the estimated size of home ranges of fledgling parakeets (mean = 4402.0 ± 1116.0 [SE] ha, *N* = 8, Carneiro et al. 2012). A hierarchically nested design was used to characterize the site and habitat characteristics of Slender-billed Parakeet nests at two spatial scales: (1) nest trees, and (2) habitat surrounding nest trees (hereafter



Fig. 2. Typical example of a cluster of scattered, mature *Nothofagus obliqua* trees in an agricultural landscape near Osorno, Chile. Arrows indicate nest trees used by Slender-billed Parakeets.

nesting habitat). Nesting habitat was defined as the area within a radius of 50 m around nest trees.

Parakeet nests were distributed in three distinguishable clusters separated by local roads (Fig. 1). Based on Euclidean Distance Nearest Neighbor analysis in ArcGIS, nest trees were not randomly distributed ($Z = -3.1$, $P = 0.002$) and the mean nearest neighbor distance between nests was 244.4 m. Because parakeet nests were spatially grouped, we were unable to estimate habitat variables at the landscape scale. Indeed, $\sim 65\%$ of nest-trees included in our analysis had another nest tree < 200 m away, and $< 35\%$ had another nest trees ≤ 100 m away (Fig. 2). Therefore, 50-m-radius plots for quantifying nesting habitat minimized the similarities between neighbor nest-trees while including important ecological attributes of the habitat around nests. In addition, adult parakeets tend to perch in trees located within 50 m of nest trees to scan the landscape before entering nest cavities (Carneiro 2010). Although such a clustered nest distribution could result from conspecific attraction, the lack of information about the total number of nests across the entire study area prevented us from assessing this effect.

Nest variables. We chose variables that have frequently been cited as important in selection of nest sites by secondary cavity nesters (Gibbons et al. 2002, Gibbons and Lindenmayer 2002, Manning et al. 2004, Cameron 2006,

White et al. 2006, Koch et al. 2008). These included: (1) diameter at breast height (dbh), (2) tree height (measured with a clinometer), (3) dead crown, or an estimate of the percentage of the tree crown whose main branches were dead, (4) basal injuries (e.g., fire scars) to the lower meter of the trunk, or the percent cambium killed calculated by dividing the scar width by the tree circumference (only injuries associated with heartwood decay were included), (5) crown area measured as the ellipsoid of the maximum diameter of the projection of the crown on the ground and its perpendicular value, and (6) the number of cavity entrances in the trunk visible from the ground using binoculars (10×42) and with a suitable size (diameter of the entrance $\sim \geq 10$ cm) for parakeets. The number of cavity entrances was always verified by at least by two observers and was used as an index of the number of cavities that potentially might serve as nests.

At the nest-habitat scale, the same variables described above were collected for all *N. obliqua* trees with dbh > 0.6 m within a 50-m radius of nest trees. For analysis, each variable was averaged over all trees. In addition to these variables, the number of trees with dbh > 0.6 m within 50 m of nest trees was also recorded. The number of cavity entrances was summed over all trees. Only *N. obliqua* trees were used to obtain mean values and the sum of all cavity entrances for the immediate surroundings because parakeets predominately used this tree species for nesting (Carneiro et al. 2012). However, the number of trees recorded within the 50-m radius around nest and control trees included all observed species.

Data analyses. We compared the characteristics of nest trees and control trees using paired t -tests. All variables were tested for normality and, when necessary, arcsin and logarithmic transformations were applied. For this analysis, a P value < 0.05 was considered significant. Nest-site selection by Slender-billed Parakeets was evaluated using conditional logistic regression models implemented with the clogit command in the survival package in R version 2.15 (R Development Core Team 2009). Conditional logistic regression is a suitable tool for assessing case-control data because the ratio of controls to cases in the sample is not the same as the ratio of controls to cases in the population (Keating and Cherry 2004).

An information-theoretical approach based on the Akaike's information criterion modified for small sample sizes (AIC_c) was used to identify the most important variables influencing nest-site selection by parakeets at the two spatial scales. First, for each spatial level, we developed a subset of "single-scale" candidate models including the effects of variables measured at each scale. These models were ranked from most to least supported given the data based on ΔAIC_c (the difference in AIC_c between the model with the smallest AIC_c value and the current model) and Akaike weights (w_i). Based on this rank and on Burnham and Anderson's (2002) criteria, models with $\Delta AIC_c \leq 2$ and representing $\geq 90\%$ of the w_i were considered as evidence for supporting the hypotheses. Second, we developed and compared "two-scale models" in an attempt to determine the spatial scale most important in nest-site selection by parakeets. For this analysis, models were built using variables of the best single-scale models and comparisons were made using the same approach as explained above.

Model accuracy was assessed using the ROCR package (Sing et al. 2005) to calculate the Area Under the Curve of the receiver operating characteristic Curve (AUC), a measure of binary classifier performance (proportion of true positives and false positives) independent of cutoff values (Cockle et al. 2011a). AUC values > 0.7 indicate high model accuracy or an acceptable discrimination (Swets 1988). To reduce bias and increase precision in parameter estimation, we computed model-averaged regression coefficients (Burnham and Anderson 2002). Odds ratio for model-averaged regression coefficients and the proportion of change in odds ratio were used to assess the strength of each model parameter estimate (Hosmer and Lemeshow 2000). Variables with odds ratio equal to 1.0 were not considered as useful predictors in the conditional logistic model (Hosmer and Lemeshow 2000).

RESULTS

We located 31 nest trees in our study area. Most nests ($N = 29$) were in *N. obliqua* trees, with one each in *L. sempervirens* and *Eucryphia cordifolia* trees. We only found one active nest cavity per tree, and all were located in the trunk. One nest cavity was located in a dead tree; the rest were in live trees.

Nest tree selection. Characteristics of nest and control trees were similar, except for the number of cavity entrances ($P < 0.001$, Table 1). The mean number of cavity entrances in nest trees was more than twice that of control trees (Table 1). The probability of a *N. obliqua* tree being selected as a nest site was negatively affected by the percentage of dead crown and positively affected by the percentage of basal injuries in the tree and the total number of cavity entrances (Tables 2 and 3). One model including these variables was well supported by the data based on ΔAIC_c values, model weights, and AUC (Table 2). Odds ratio for model-averaged regression coefficients indicated that the probability of a tree being selected by a parakeet for nesting increased 3.5 times for each cavity entrance present. The probability of being selected as a nest site also increased by 9% for each percentage of basal injuries, and decreased by 12% for each percent of dead crown (Table 3).

Nesting habitat. Comparisons of the mean dbh, height, percent dead crown, and crown area between trees surrounding nests and control trees revealed no significant differences (Table 1). However, mean basal injuries and number of cavity entrances in trees around nest trees were more than three times higher than for trees around control trees (Table 1). The mean number of trees around nest trees was also higher than the number of trees surrounding control trees ($P = 0.031$, Table 1).

The probability of a tree being selected as a nest site by a parakeet increased 50 and 60% for every unit increase in the percentage of basal injuries and for each cavity entrance present in trees around nest trees, respectively (Table 3). The AUC value of the model indicated very high model accuracy (Table 2).

Two-scale selection. When using the best variables from single-scale models in two-scale models, we found a slightly improvement in model accuracy (larger AUC values, Table 2). The best two-scale model indicated that the probability that a *N. obliqua* tree being selected as a nest site was dependent on the number of cavity entrances in the nest tree as well as on the percentage of basal injuries and number of cavities entrances in the trees around the nest tree. The best model alone presented strong evidence to support the data in accordance with ΔAIC_c values, model weights, and AUC (Table 2).

Table 1. Comparison of the mean characteristics (SE) of nest trees used by Slender-billed Parakeets, control (unused) trees, and trees within 50 m of nest and control trees.

	Nest trees ($N = 31$)		Control trees ($N = 31$)		Paired t -test	
	Mean	SE	Mean	SE	t	P
(a) Nest trees						
DBH (cm)	140.3	5.2	140.7	4.7	0.1	0.96
Height (m)	30.7	1.2	30.9	1.2	0.1	0.94
Dead crown ^a (%)	5.4	1.6	8.6	1.8	1.5	0.14
Basal injuries ^a (%)	10.7	2.5	4.7	1.2	2.0	0.065
Crown area (m ²)	211.0	16.0	228.2	14.9	0.9	0.44
Number of cavities	2.5	0.3	1.1	0.2	4.2	<0.001
(b) Nesting habitat ^b						
DBH (cm)	133.6	4.6	133.5	5.0	0.01	0.99
Height (m)	30.8	0.9	28.8	1.1	1.5	0.14
Dead crown (%) ^c	9.6	1.7	7.8	1.7	1.3	0.19
Basal injuries (%) ^c	7.9	1.1	2.2	0.6	4.2	<0.001
Crown area (m ²) ^c	220.7	17.2	233.7	18.0	0.7	0.48
Number of cavities ^c	6.3	0.9	1.8	0.4	3.9	<0.001
Number of trees ^c	7.1	1.1	3.1	0.5	2.2	0.031

^a Arcsin transformed.

^b Trees within a 50-m radius of nest trees. Means of all nesting habitat variables, with the exception of the number of trees, were for *Nothofagus obliqua* trees only.

^c Log transformed.

Table 2. Conditional logistic regression models for nest-site selection by Slender-billed Parakeets measured at two spatial scales and in a two-scale model. Within each scale, models were ranked based on AIC_c. For each model, the number of estimating parameters, change in AIC_c (Δ AIC_c), AIC_c weights (w_i), and AUC are also shown.

Model/scale ^a	K	AIC _c	Δ AIC _c ^b	w_i	AUC
(a) Nest tree					
Dead crown + basal injuries + cavities	3	50.08	0.00	0.89	0.88
(b) Habitat					
Basal injuries-50 + cavities-50	2	32.86	0.00	1.00	0.90
(c) Two-scales					
Cavities + basal injuries-50 + cavities-50	3	25.35	0.00	0.97	0.93

^a50 after a variable indicates it represents means for *Nothofagus obliqua* trees within 50 m of nest sites.

^bOnly models with Δ AIC_c ≤ 2 are shown.

For the best-supported model, the probability of a site being selected by a parakeet increased by almost three times for each additional cavity entrance in the nest tree (Table 3). The probability also increased by 58 and 75% with each percent increase of basal injuries and number of cavity entrances in the trees around the nest tree, respectively (Table 3).

DISCUSSION

Nest tree selection. Slender-billed Parakeets in our study selected nest trees with more cavity

entrances in the trunk, a greater percentage of basal injury, and less dead crown. Peña-Foxon et al. (2011) also described Slender-billed Parakeet nest sites, but their data were limited to the specific characteristics of two nests, thereby precluding a more rigorous assessment of nest site selection at multiple scales.

The number of cavities has previously been recognized as an important determinant in nest-site selection by secondary cavity-nesting birds (Marsden and Pilgrim 2003, Berkunsky and Reboresda 2009, Politi et al. 2009). Although ground-based surveys like those in our study can

Table 3. Model-average estimates, standard errors (SE), odds ratios, and 95% confidence intervals (CI) from the best supported models, including predictors of the nest-site selection by Slender-billed Parakeets measured at the nest-tree scale, nest-habitat scale, and both scales (two scales).

Model/scale ^a	Estimate	SE	Odds ratios	Odds ratio lower CI	Odds ratio upper CI
(a) Nest tree					
Dead crown	-0.12	0.05	0.88	0.80	0.98
Basal injuries	0.09	0.04	1.09	1.02	1.17
Cavities	1.26	0.38	3.51	1.68	7.33
(b) Habitat					
Basal injuries-50	0.39	0.15	1.48	1.10	1.98
Cavities-50	0.47	0.16	1.60	1.17	2.20
(c) Two-scales					
Cavities	1.07	0.42	2.93	1.29	6.67
Basal injuries-50	0.45	0.18	1.58	1.10	2.26
Cavities-50	0.56	0.22	1.75	1.13	2.72

^a50 after a variable indicates it represents means for *Nothofagus obliqua* trees within 50 m of nest sites.

potentially misidentify or not detect all cavities in a given tree, they are useful in providing an indication of relative cavity abundance (Koch 2008). In a study conducted in a *Eucalyptus obliqua* forest in Australia, Koch (2008) found that few trunk cavities were missed in trees smaller than 140 cm in diameter (mean dbh in the present study was 140 cm, Table 1). Trees with several cavity entrances are likely more obvious to birds, may increase the probability of finding suitable cavities, and may provide more than one exit for escaping from predators (Hardy and Morrison 2001, Gibbons and Lindenmayer 2002, Gibbons et al. 2002, Koch et al. 2008). Indeed, during nest inspections, we sometimes observed parakeets exiting through openings that were not the primary nest entrance. The presence of multiple cavities in trees may also reduce interspecific competition for cavities, as reported for Elf Owls (*Micranthene whitneyi*) and Gila Woodpeckers (*Melanerpes uropygialis*) in Arizona (Hardy and Morrison 2001). Indeed, evidence exists of potential competition between Slender-billed Parakeets and Speckled Teal (*Anas flavirostris*) for *Nothofagus* cavities in our study area (Jimenez and White 2011).

Advanced wood decay is a necessary precursor for hollow formation in eucalypts and *Nothofagus* trees (Gibbons and Lindenmayer 2002, Ojeda et al. 2007). Branch stubs and basal injuries are typical areas where decay gains access to heartwood (Gibbons and Lindenmayer 2002). Although crown dieback was considered a key process for creating cavities for Magel-

lanic Woodpeckers (*Campephilus magellanicus*) in *Nothofagus* trees (Ojeda et al. 2007), we found that an increasing percentage of dead crown slightly reduced the chances of a tree being selected as a nest site by Slender-billed Parakeets. However, because the mean percent dead crown of nest and control trees did not differ, and the chances of a tree being selected as a nest site was only 12% higher for trees with a smaller percentage of dead crown, we believe this result should be interpreted with caution. The results of several studies suggest an association between dead wood in the canopy and a greater probability of trees having suitable cavities (Gibbons and Lindenmayer 2002, Gibbons et al. 2002, Ojeda et al. 2007, Koch et al. 2008). Associations between the presence of fire scars at the base of trees and the occurrence of cavities in the crown have been reported for eucalypts in Australia (Gibbons and Lindenmayer 2002). Repeated burning of scarred tissue either exposes, or leads to the formation of, a cavity in the main stem (Gibbons and Lindenmayer 2002). Although the probability increased by a small percentage, the extent of basal injury differed between nest and control trees, contributing to the importance of this effect.

Nesting habitat. Nesting Slender-billed Parakeets selected sites containing scattered trees that had more basal injuries and cavities than control sites. Basal injuries of neighboring nest trees may be an important environmental cue to the presence of suitable cavities because nest-site searching could be a costly process for parakeets

in terms of energy, time, or predation risk. Therefore, a greater percentage of basal injuries in these trees could increase the probability of parakeets finding a suitable cavity in at least one of the visited trees, thereby maximizing efficiency of search efforts within a given area.

Although the number of trees surrounding nest trees was significantly greater than for control trees in the univariate analysis (Table 1), this variable did not emerge in any of the regression models. However, trees surrounding nests were used by most adults as perch sites and foraging sites (Carneiro et al. 2012). Nearby and abundant perch sites may aid nesting parakeets in detecting potential predators before approaching and entering nest cavities, a factor reported by White et al. (2006) as important for nesting Puerto Rican Parrots (*Amazona vittata*). Li and Martin (1991) also demonstrated that nests in cavities near perches that allowed breeding adults to more effectively survey their surroundings for potential threats were more likely to be successful. Indeed, proximity to an array of necessary resources has been found to influence nest site selection in other species. For instance, White et al. (2006) found that proximity (i.e., <30 m) to abundant food sources influenced nest site selection by Puerto Rican Parrots by maximizing foraging efficiency near nest sites and thereby reducing exposure to predators. During our nest observations, we frequently observed nesting parakeets feeding on *Nothofagus* seeds and an associated arboreal fungus (*Cyttaria* sp; locally known as llaolao) as well as probing for and consuming unidentified items in bark fissures in both nest trees and adjacent *Nothofagus* trees. Austral Parakeets (*Enicognathus ferrugineus*) also engage in similar feeding behavior in *Nothofagus* forests (Diaz and Kitzberger 2006).

Management considerations. Our results indicate that conservation plans for Slender-billed Parakeets will require maintenance of individual nest trees as well as the conservation or improvement of nesting opportunities at the patch level. Additional studies to determine other habitat requirements, for example, roost sites and foraging areas included within the home ranges of breeding Slender-billed Parakeets, are needed, and our results need to be validated with replicated data at the landscape level. Nevertheless, a logical and potentially beneficial strategy would be to conserve numerous patches (i.e., dense clusters of varying size) of mature

trees throughout the agricultural landscapes of southern Chile (Vergara and Armesto 2009), as also recommended for Thick-billed Parrots (*Rhynchopsita pachyrhyncha*) in commercially logged areas of Mexico (Lanning and Shiflett 1983), as well as for cavity-nesting species in general (Cockle et al. 2011b, Martin and Eadie 1999). Such clusters (Fig. 2) may also provide additional trees for future nesting attempts via natural senescence (Giese and Cuthbert 2003), as well as perching and foraging sites. The continued decline in the number of mature trees in these landscapes over coming decades will likely create a critical resource bottleneck due to a diminished number of nest trees for this hollow-dependent species (Willson et al. 1994, Echeverría et al. 2006, 2007, Cornelius et al. 2008), as also documented in Australia (Manning and Lindenmayer 2009), with a concomitant increase in interspecific competition for remaining nest sites (Pell and Tidemann 1997, Pinho and Nogueira 2003, Jiménez and White 2011). Our results provide additional evidence for the importance of maintaining scattered mature trees for the persistence of numerous species, including psittacids. The success of any conservation efforts for Slender-billed Parakeets will depend to a great extent on timely development of a comprehensive management plan that effectively addresses this critical aspect of the species ecology.

ACKNOWLEDGMENTS

This study was supported by the Laboratorio de Vida Silvestre at Universidad de Los Lagos, the United States Fish and Wildlife Service–Puerto Rican Parrot Recovery Program, Parrots International, Amigos de las Aves–USA Parrot Conservation Fund, International Conure Association, GEF SIRAP, FONDECYT 11080085, and Tony Pittman. G. Ritchison and three anonymous reviewers provided comments that helped improve the manuscript. We thank all the landowners who allowed us to access parakeet nests on their property and the several volunteers that helped us to monitor nests. Chile's Forest Service provided digital vegetation maps.

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