NEST SUCCESS OF OPEN-CUP NESTING BIRDS IN CHILEAN RAINFOREST

ÉXITO REPRODUCTIVO DE AVES CON NIDO ABIERTO EN EL BOSQUE TEMPLADO LLUVIOSO CHILENO

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ABSTRACT

Between 1993 and 1999, we monitored nest success of open-cup nesting species in fragmented and unfragmented temperate rainforest and in associated shrubby vegetation of fencerows, roadsides, and pastures, on Isla Grande de Chiloé in south-central Chile. Daily nest survival rate in forest was estimated to be 0.964 by the Mayfield method, marginally higher than in shrub habitat (0.945). Predation accounted for most nest losses in forest, but both predation and parasitism by *Molothrus bonariensis* led to failure of nests in shrub habitat. Nest success of three common species was low (20-30%). Negative effects of forest edge on apparent nest success were small for *Turdus falcklandii* and *Sephanoides sephanoides*, but apparently more marked for *Elaenia albiceps*. Levels of predation during the nestling and incubation phases were similar in forest fragments, but higher during incubation in continuous forest. Low rates of reproductive success in fragmented forests could pose problems for maintenance of these ecologically important species in this forest ecosystem.

KEY WORDS

forest fragmentation, nest success, edge effect, nest predation, brood parasitism, south-temperate rainforest, *Elaenia*, *Turdus*, *Sephanoides*

RESUMEN

Entre 1993 y 1999, estudiamos el éxito de los nidos de las especies de nido abierto en bosques fragmentados y continuo del bosque lluvioso templado y en la vegetación arbustiva asociada a cercos, bordes de caminos, y pastos, en Isla Grande de Chiloé en el centro sur de Chile. La tasa diaria de la sobrevivencia de los nidos en el bosque fue estimada en 0.964 por el método de Mayfield, marginalmente superior que en el habitat del matorral (0.945). La depredación explicó la mayoría de las pérdidas de los nidos en bosques, pero la depredación y el parasitismo por *Molothrus bonariensis* contribuyó al fracaso de los nidos en el habitat del matorral. El éxito de los nidos de tres especies comunes fue bajo (20 - 30 %). Los efectos negativos del borde

del bosque en el éxito de los nidos fueron pequeños para *Turdus falcklandii* y *Sephanoides sephanoides*, pero al parecer más marcado para *Elaenia albiceps*. Los niveles de depredación durante las fases de nidaje e incubación fueron similares en fragmentos de bosque, pero más altos durante la incubación en bosques continuos. Las bajas tasas del éxito reproductivo en bosques fragmentados podrían causar problemas para la mantención de estas especies ecológicamente importantes en este ecosistema del bosque.

PALABRAS CLAVES

Fragmentación del bosque, éxito de los nidos, efecto borde, depredación de los nidos, parasitismo de la cría, bosque lluvioso templado del sur, *Elaenia, Turdus, Sephanoides.*

INTRODUCTION

The avifauna of the temperate rainforest of southern South America is characterized by a high level of endemism (Johnson 1967, Vuilleumier 1985) and the geographic ranges of many species are small (Fjeldså and Krabbe 1990, Ridgely and Tudor 1994). Because of these two factors, many of the native species are potentially at risk of extinction (Balmford and Long 1994), as the habitat continues to be deforested and the remnants become more fragmented (Willson and Armesto 1996; Lara et al. 2002). Many studies in the northern hemisphere have identified negative impacts of habitat fragmentation on forest-dwelling songbirds, including population declines and lower nesting success as a result of increased levels of nest predation and brood parasitism in fragments and at habitat interfaces, often especially between forest and agricultural lands (Askins 1995), although there are exceptions to this common pattern (Trine 1998, Friesen *et al*. 1999, Morse and Robinson 1999). Effects of forest patch size and edges have only recently been studied in south-temperate rainforests of Chile (Willson *et al*. 1994, 1996a, Estades and Temple 1999, Cornelius *et al*. 2000, De Santo *et al*. 2002). Several species native to these

forests migrate relatively long distances (Fjeldså and Krabbe 1990, Ridgely and Tudor 1994), adding yet another risk factor (Greenberg 1980, Hussell *et al*. 1992, Böhning-Gaese *et al*. 2000). The avifauna in this region includes pollinators and seed dispersers, mutualists that are important for reproduction of many forest plants and thus to the perpetuation of this narrowly distributed forest ecosystem (Smith-Ramírez 1993, Armesto *et al*. 1996, Willson *et al*. 1996b). Consequently, there is concern for the status of the avifauna in this landscape increasingly dominated by agriculture and plantation forestry.

Populations of several species of birds in the Chilean rainforest are sensitive to habitat fragmentation (Willson *et al*. 1994, 2004), but population density alone can be a poor indicator of the status of a species (Van Horne 1983, Vickery *et al*. 1992). In order to allow a more accurate assessment of the conservation status of forest birds in this increasingly fragmented forest, we estimated nest success of several species in fragmented and continuous forest and tested whether reproductive success of open-cup nesters was affected by forest patch size or proximity to forest edges (see De Santo *et al*. 2002 for effects on cavity-nesting tapaculos).

METHODS

Study area. Our study was conducted on Isla Grande de Chiloé, Region X, south-central Chile (41°55'S, 73°35'W), in the austral spring and summer (late October-early February) of six years (1993-1994 through 1998-1999). Chiloé is a large continental island that lies within 10 km of the Chilean mainland and supports similar communities of birds (Johnson 1967, Fjeldså and Krabbe 1990, Ridgely and Tudor 1994).

Study sites included a 25-ha area in the 43,000-ha continuous forest of the Parque Nacional Chiloé on the west coast of Chiloé near the settlement of Cole-Cole, and 19 forest fragments within 15 km of each other on northeastern Chiloé, where agriculture was the predominant land use. Fragments are defined as discrete patches of mature forest bordered by pastureland on most sides; many of them have been selectively logged and are used as winter shelter for livestock. We measured fragment area from aerial photographs (1:20 000 scale), using a 10 x 10 mm gridded transparency placed over the photo. Large fragments ranged in size from 108-136 ha (mean $\pm$ SE = 121 $\pm$ 5, n = 3) and small fragments were from 3–33 ha (10 $\pm$ 1 ha, n = 16) in size. We

also monitored nests in the vegetation of fencerows, roadsides, and pastures near the forest study sites.

The native old growth rainforest in the forest fragments was characterized by emergent *Nothofagus nitida* and *Eucryphia cordifolia,* with a canopy of *Drimys winteri*, *Weinmannia trichosperma*, several myrtaceous species, and the conifer *Podocarpus nubigena* (Armesto and Figueroa 1987, Veblen *et al.* 1996). The understory included dense *Chusquea* spp. (bamboo) thickets and tree saplings. The tree composition of the forest in the national park was characterized by more *Aextoxicon punctatum* and myrtaceous species (including *Luma apiculata* and *Myrceugenia ovata* var. *ovata)* and less *P. nubigena*, and epiphytic bromeliads were common. Unlike most forest fragments, the disturbance within the forest of the national park was very low, with human activity limited to one hiking trail.

The vegetation of roadsides and fencerows typically consisted of small *D. winteri*, *Berberis* spp., *Raphithamnus spinosus*, *Buddleja globosa*, *Fuchsia magellanica*, *Ulex europaeus* (introduced), and various other shrubs or small trees. Pastures had some scattered stands of myrtaceous and *D. winteri* saplings, and the same shrubs as those found in fencerows.

Nest success. We recorded nesting data for the austral springs of 1993-1999. All the observed species had begun nesting in October except the fío-fío (*Elaenia albiceps*), which began in November. Nests were found by watching the behavior of adults carrying nesting material or food to consistent locations or sometimes by accidentally flushing a bird from a nest. Nests were monitored every 1-3 days until the young fledged or the nest failed. A nest was considered to be (1) active, if there was evidence that eggs or young were being tended; (2) depredated, if the nest showed obvious signs of depredation (egg shell fragments or torn nesting material) or if nest contents were missing before possible fledging age (based on plumage development and compared to known-age birds); (3) failed due to weather, if the nest showed obvious signs of disturbance from wind, rain, or flooding; (4) abandoned, if the nest was not tended but cause of failure was unknown; or (5) successful, if adults were observed feeding ε 1 nestling near fledging. Nests abandoned during nest building or not used for reproduction were excluded from analyses.

Nest success was calculated using the Mayfield method (1961, 1975) as detailed by Hensler and Nichols (1981), including nests with uncertain fate (Manolis *et al.* 2000), for samples of sufficient

minimum size. We used average values for clutch sizes, incubation periods, and nestling periods, appropriate for each species, to determine observation days in each period of the nesting cycle (Johnson 1967, our unpubl. data) to calculate overall Mayfield percent nesting success for species with adequate sample sizes. For calculations of percent nest success, we included the period of egg laying as part of the incubation period. For selected cases with small sample sizes, we perforce report 'apparent nest success' as a simple percent of total nests found. Although this value is subject to some bias, especially in comparisons with other studies (e.g., Jehle *et al.* 2004), it is sufficient to indicate relative levels of success **within** this study.

Statistical analyses. Daily survival rates for samples of sufficient size for the Mayfield method were compared with computer program CONTRAST, which uses a Chi-square analysis with multiple comparisons (Hines and Sauer 1989, Sauer and Williams 1989). Preliminary analyses indicated no annual differences among the years for which sample sizes were adequate, so subsequent analyses pooled data from all years. We tested for differences in nest characteristics of successful and depredated forest nests using nonparametric univariate statistics (Wilcoxon two-sample test, SAS Institute Inc. 2000). To examine nest success near forest edges, we assigned nests to distance categories and found that daily mortality rates were highest within 20m of the edge, so we then used that distance for comparisons of edge vs. interior nest success. All percent data were angular-transformed before analysis. For post-hoc multiple pairwise comparisons, we used an adjusted alpha value to control for experiment-wise error (Zar 1999).

RESULTS

Habitat distribution. Three common species (see Table 1) nested in forest fragments and the national park (*E. albiceps*, n = 61 nests; *S. sephanoides,* n = 122; *T. falcklandii*, n = 51), and occasionally (n = 1, 6, and 4 respectively) in shrubby habitats. Cachuditos (*Anairetes parulus*, n = 14) nested within forest fragments and at the forest edge of the national park but were not observed in the forest interior of the national park. The viudita (*Coloramphus parvirostris*, n = 9) nested in both small and large forest fragments that were relatively undisturbed by foot traffic or

selective logging but was not observed in the national park. Nests of diuca (*Diuca diuca*, 6), rara (*Phytotoma rara*, 10), diucón (*Xolmis pyrope*, 6), and chincol (*Zonotrichia capensis*, 13) were found only in shrubby habitat or near forest edges; nests of cometocino (*Phrygilus patagonicus*, 10) and tordo (*Curaeus curaeus*, n = 3) occurred in both shrub and forest fragments.

Nest survival in forest and shrub habitats. Daily nest survival of all nests in forest (0.964 ± 0.003, *n* = 256, 3363 exposure days) was marginally higher ($c^2_2 = 3.72$, $P < 0.06$) than in the shrub habitat of roadsides, fencerows, and pastures (0.945 ± 0.009, *n* = 60, 604 exposure days). Estimated nest success (Mayfield) in forest habitat was 21% for *S. sephanoides* (1919 exposure days), 20% for *T. falcklandii* (444 exposure days), and 27% for *E. albiceps* (658 exposure days). Predation accounted for 71% of 122 known nest failures in forest, but just 42% of 33 failed nests in fencerows, roadsides, and pastures, where brood parasitism accounted for 39% of failures.

Brood parasites (mirlo, *Molothrus bonariensis*) affected three species in shrubby habitats. Parasitism rates for host species were fairly high (46% of 13 *Z. capensis* nests, 50% of 6 *D. diuca* nests, 57% of 7 *P. patagonicus* nests). Brood parasitism often decreased the probability of nest success: one nest fledged the cowbird young, but the host (*Z. capensis)* eggs did not hatch; eleven nests were abandoned by hosts (3 nests of *D. diuca*; 3 nests of *P. patagonicus*; 5 nests of *Z. capensis*) after being parasitized, and one nest was depredated after hatching both the cowbird and host (*P. patagonicus)* eggs; the remaining nests fledged at least one chick. Although *X. pyrope* is a documented cowbird host (Johnson 1967, Mason 1985, Johnsgard 1997), none of the nests we found was affected.

Nest survival in fragments and edges. Apparent nest success of *S. sephanoides* and *T. falcklandii* differed only slightly between edge and interior or between fragments and the national park (Table 1). In contrast, apparent nest success of *E. albiceps* was markedly lower in fragments (21% of 24 nests) than in the park (39% of 13 nests) and lower in forest edges than interior (Table 1).

Nest survival and nesting phase. Considering all forest nests (with known outcome and placement relative to edges), only 5% (of 40

nests) in the national park were depredated during the nestling period, compared with 33% during the incubation period. In contrast, predation during the egg and nestling stages was similar in forest edges (25% of 64 nests during incubation, 27% during nestling stage) and the interior forest of fragments (22% of 92 nests during incubation, 20% during nestling stage).

DISCUSSION

We found marked edge effects only for some open-cup nesting species (and none for natural cavity nests; De Santo *et al.* 2002), confirming that case-by-case data are necessary to obtain information usable for conservation and management purposes (Flaspohler et al. 2000). Nest success of open-cup nests was far lower than that of cavity nests in this rainforest (De Santo *et al.* 2002), a result that is commonly recorded but seldom based on studies conducted in the same time and place (Martin and Li 1992). We also noted lower predation of nestlings than eggs in the interior forest of the national park, but not within forest edges or the interior forest of fragments. The observed differences in patterns of nest predation may be related to the behavior and abundance of predators or to inherent vulnerability of nests in each habitat. Although several nest predators have been documented in our study area (Willson et al. 2001), relatively little is known about their habits or behaviors.

Molothrus bonariensis has been reported to parasitize the nests of several species (Johnson 1967, Mason 1985, Johnsgard 1997); this brood parasite occurs on Chiloé despite its common omission from distribution maps (Ridgely and Tudor 1994, Johnsgard 1997, Peña and Rumboll 2001) and depresses the nest success of its hosts. We found cowbird eggs in the nests of two of the three previously documented species (*D. diuca* and *Z. capensis*, but not *X. pyrope*) as well as in nests of *P. patagonicus*, a species not previously reported to be a host. As more and more forest is cleared for agriculture, however, an increase in suitable habitat is expected to lead to increased populations of potential hosts and of this brood parasite, and brood parasitism may even expand to additional species and habitats.

The three most common species in our sample (*E. albiceps*, *S. sephanoides, T. falcklandii*)

are all important mutualists with plants in our study area (Armesto *et al.* 1987, 1996; Smith-Ramírez 1993; Willson *et al.* 1994, 1996b). Previous work showed that population densities of all three are relatively high in forest fragments; indeed, *E. albiceps* was the most frequently detected bird in many study sites (Willson *et al.* 1994, Rozzi *et al.* 1996). The low nest success (20-30%), together with a small clutch size (usually 2 or 3 eggs), suggests that populations might have difficulty maintaining current levels (in the absence of immigration to fragments), and interactions with native plants may ultimately be impaired. However, additional information on demographic traits (e.g., juvenile and adult survival, number of nesting attempts per year) of these birds is needed in order to assess this risk properly.

It is becoming clear that general rules about the effects of habitat fragment size and edge effects are difficult to formulate. Many factors contribute to the observed variation, including landscape context (degree of fragmentation, structure of the matrix, Castellón and Sieving 2006, Tewksbury et al. 2006), regional differences in abundance, distribution, and identity of predators and brood parasites, and differing responses of the nesting birds themselves (e.g., Friesen *et al.* 1999, Morse and Robinson 1999, De Santo and Willson 2001). Achievement of conservation goals for at-risk breeding birds therefore requires knowledge of local risk patterns and will commonly require examination on a case-by-case basis.

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Table 1: Apparent nest success of three common species in the study sites on Isla Grande de Chiloé. Only nests of known outcome are included.

Family	Scientific name	Chilean name	English name	Apparent nest success		
				fragment edge	fragment interior	national park
Trochilidae	*Sephanoides sephanoides*	picaflor	green-backed firecrown	35% n = 20	45% n = 64	41% n = 17
Tyrannidae	*Elaenia albiceps*	fío- fío	white-crested elaenia	9% n = 11	31% n = 13	39% n = 13
Turdidae (or Muscicapidae)	*Turdus falcklandii*	zorzal	austral thrush	42% n = 24	44% n = 9	50% n = 6