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NEST SITE SELECTION AND NESTING SUCCESS OF THE YELLOW-KNOBBED CURASSOW (*CRAX DAUBENTONI*) IN A FRAGMENTED LANDSCAPE IN THE VENEZUELAN LLANOS

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Resumen. – Selección del sitio de anidación y éxito de nidada del Paují de Copete (*Crax daubentoni*) en un paisaje fragmentado de los llanos de Venezuela. – El estudio de las características del sitio de anidación asociadas con el éxito de ésta en lugares con presión de depredación puede ser útil para entender el proceso de selección del sitio del nido. Los objetivos de este estudio fueron: 1) Identificar las características del hábitat que influencian la selección del sitio de anidación, y 2) Estimar el éxito de nidada y los factores que lo determinan. Para ello, se hizo el seguimiento semanal de 21 nidos desde Mayo hasta Agosto 2002 en el Hato Piñero, Estado Cojedes, Venezuela. Dependiendo de la localización, los nidos se catalogaron como "aislados" (en fragmentos de bosque < 2 ha) o "no aislados" (en fragmentos grandes >100 ha, o bosque continuo). Investigamos las preferencias por el sitio de anidación midiendo variables de vegetación en parcelas de 10 x 10 m (n = 21) y en un número similar de parcelas en localidades escogidas al azar dentro del bosque. En cada nido se registró el número de huevos, número de huevos que eclosionaron, y número de huevos perdidos (por causas desconocidas o depredación). Los paujíes seleccionaron nidos en sitios con alta densidad de plantas leñosas con un DAP 11–30 cm, alta cobertura del sotobosque y sin árboles de tronco grueso (DAP > 30 cm). Todos los nidos fueron encontrados dentro de una franja dentro del bosque a no más de 20 m del borde. Aunque el número de huevos eclosionados no mostró diferencias entre nidos "aislados" (n = 15) y "no aislados" (n = 4), el número de huevos perdidos fue mayor en el bosque que en fragmentos aislados (M-W Test, $U = 12{,}00$, $P < 0{,}05$). El Paují de Copete ha sido considerado una especie de bosque pero nuestros resultados podrían indicar que la depredación de nidos estaría forzando a dichas aves a nidificar en fragmentos aislados para evadir dicha depredación.

Abstract. – Studying nesting site features associated with successful nesting in areas with substantial nest predation may be useful in understanding the process of nest site selection. The aims of this study were: 1) to identify habitat features influencing nest-site selection, and 2) to estimate the nesting success and their determining factors. To do so, we monitored 21 nests weekly from May to August 2002 in Hato Piñero, State of Cojedes, Venezuela. Depending on location, nests were classified as "isolated nests" (in fragmented forest < 2 ha) or "non- isolated nests" (in larger fragments < 100 ha, or continuous forest). We investigated nesting site preference by measuring vegetation variables in nest-centred 10 x 10 m plots (n = 21) and the same number of plots at randomly chosen locations in the forest. For each nest we recorded the number of eggs laid, eggs hatched, and eggs lost (from unknown reasons or from predation). Curassows selected nest sites with high density of wooded plants with DBH 11–30 cm, high understory cover, and lacking thick stemmed trees (DBH > 30 cm). All nests were found within 20 m from borders between forest and open habitat. Although the number of hatched eggs did not show a significant difference

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between "non-isolated nests" (n = 4) and "isolated nests" (n = 15), number of lost eggs was higher in the forest than in isolated fragments of forest (M-W Test, $U = 12.00$, $P < 0.05$). The Yellow-knobbed Curassow has been considered a forest-species, but our results might indicate that nest-predation is forcing them to nest in isolated forest fragments in order to evade nest predation. *Accepted 9 November 2007.*

Key words: Yellow-knobbed Curassow, *Crax daubentoni*, cracids, nest selection, nesting success, fragmented landscape, Venezuela.

INTRODUCTION

Nest site selection can be very important for the future of a population, because it may influence nesting success, and thus be a decisive factor for the survival of endangered species (Badyaev 1995, Lau *et al.* 1997). Nest predation is generally a very important factor reducing the reproductive success, thus nest location affects predation risk of both eggs and chicks (Martin 1993, Söderström *et al.* 1998). Processes such as habitat fragmentation and a subsequent creation of edges (Murcia 1995) can cause spatial variations in predation risk, such that predation increases 1) on nests located on edges with respect to homogeneous inner areas of habitat, and 2) when forest fragment size diminishes (Andren & Angelstam 1988, Small & Hunter 1988, Paton 1994, Keyser 2002, Pangav-Adam *et al.* 2006).

When studying nest site selection in a species it is important to consider different factors such as vegetation structure and characteristics adjacent to the nest site. These features can in turn influence predation risk e.g., providing cover in the line of vision and increasing the potential number of nest sites can reduce predator success (Badyaev 1995).

The Yellow-knobbed Curassow (*Crax daubentoni*) population has been said to be in decline due to hunting and destruction of its habitat (Silva & Strahl 1991, Silva & Strahl 1997, Begazo & Bodmer 1998). The Yellow-knobbed Curassow is characterized by delayed sexual maturity together with one of the lowest existing reproductive potentials among Galliformes (Estudillo-López 1997, Vié 1999), making it especially vulnerable to factors such as nest predation. Little is known about basic biology, not to mention nest site selection and nesting success, and doubts have even arisen about its mating system (Schäefer 1953, Strahl *et al.* 1997). The Yellow-knobbed Curassow represents the only endangered cracid species in Venezuela that does not inhabit humid forest but rather gallery and lowland dry forests, an ecosystem largely threatened throughout its distribution. Thus, it is interesting and important to study the reproductive features of a threatened game species susceptible to suffer the consequences of habitat encroachment. The objectives of this work were, to 1) find out what habitat requirements the curassow might have for nest selection, and 2) determine nesting success and factors influencing it, in a fragmented landscape.

METHODS

This study was carried out in Hato Piñero, a 75,000 ha private cattle ranch located in Cojedes State, Venezuela (08°56'N, 68°05'W). The climate of the area is strongly seasonal with a dry season from November to April and a rainy season from May to October. Average rainfall is 1470 mm and annual average temperature is 27.5 °C. In Hato Piñero, the Yellow-knobbed Curassow has been protected from hunting and the habitat (dry semidecidous forest) has been more or less stable during the last decades. The field part of this study was done from April to August

TABLE 1. Vegetation variables used for comparing plots with and without nests.

No of variables	Variables
1	Presence of nest (0/1)
2	Number of wooded plants with DBH < 3 cm
3	Number of trees with DBH 3-10 cm
4	Number of lianas with DBH 3-10 cm
5	Number of trees with DBH 11-30 cm
6	Number of lianas with DBH 11-30 cm
7	Number of wooded plants with DBH > 30 cm
8	Canopy cover (%)
9	Understorey cover (%)
10	Canopy height (m)

2002 in a 10,000 ha area in the centre of the ranch. The habitat is a mixture of small pockets of forest surrounded by open areas devoted to pastures on one hand, and large fragments to big, extensive forests, on the other. Field work period coincides with the breeding season of curassows which begins with the onset of the rainy season (Buchholz 1995).

We localized curassow nests by walking the study area following roads and footpaths we made through the area. Once localized, we determined exact position with a GPS. A nest was considered active when a female was observed over the nest on more than one occasion. We sampled the vegetation structure and composition in 10 x 10 m nest-centered plots (n = 21), and the same number of randomly selected plots. The vegetation measures were conducted during one week in order to avoid temporal differences in leaf cover. We used four percentage ranges: 0–25, 25–50, 50–75, and 75–100% (Schmutz *et al.* 1989). Trunk diameter at breast height (DBH) was measured on all wooded plants (lianas and trees or bushes) and categorized as: < 3, 3–10, 11–30, 31–50, and > 51 cm (Badyaev & Faust 1996). We collected vegetation data to find out potential differences between plots with- and without nest. For this analysis we used 10 variables in a multiple logistic regression aimed at identifying potential determinants of nest site selection by curassows (Table 1). The goodness-of-fit of the model was assessed using both maximum likelihood criteria and a Wald test (Aitkin *et al.* 1989). The Wald test compares the estimates with their asymptotic standard error. The ratio of estimate/error can be treated as having, approximately, a t-distribution.

As chicks abandon the nest as soon as they are hatched (Delacour & Amadon 2004), it is very dificult to observe when they actually leave the nest. Consequently, it was considered as evidence of successful reproductive activity when large pieces of eggshells and foetus membrane were found in the nest (Sermeño 1997).

In order to compare the number of hatched and lost eggs (as variables indicating nesting success) with nest location (classified as "isolated" and "non-isolated"), we used a Mann-Whitney *U*-test. The "isolated" nests were found in forest fragments smaller than 2 ha, while "non isolated" nests were found in continuous forest or fragments larger than 100 ha. Statistical analyses were performed by using Statistica v 5.0 package.

RESULTS

Altogether 21 nests were found in the study area of which 19 were active, including 15 in "isolated" and 4 in "non-isolated" locations. Nests were found mainly in May and June which corresponds to the first half of the breeding season of the curassows. All nests were found within 20 m from the edge between forest and open habitat, normally pastures but also roads. Several nests were found close to each other with the shortest distance being 31 m between two nests.

TABLE 2. Significant vegetation variables from multiple logistic regressions.

Constant	Coefficient	SE	t	*P*
Constant	-1.748	1.1059	-1.5809	< 0.05
Trees and bush with 11–30 cm DBH	0.3387	0.1824	1.8571	< 0.25
Understory cover	0.0467	0.0197	2.3653	< 0.05
Trees with > 30 cm DBH	-0.2208	0.1098	-2.0118	< 0.05

Deviation = 55.05, Residual deviation = 40.89, $\chi^2 = 14.15$; $P < 0.05$.

Curassows selected nest sites with high density of trees and bushes (DBH 11–30 cm), a dense undergrowth and a lack of thick-stemmed trees (DBH > 30 cm) (see Table 2). The model assigned correctly 78% of the plots. These significant variables are associated with disturbed vegetation along forest borders or in small fragments.

The number of hatched eggs, which equals the nesting success in precocial species as the curassow because nestlings leave the nest immediately after hatching, did not differ significantly between isolated (Average = 0.73, SD = 0.80, n = 11 eggs) and non-isolated (Average = 0.25, SD = 0.5, n = 1 egg) nests (Mann-Whitney, $U = 9.00$, $P = 0.07$). On the other hand, number of lost eggs was significantly higher in non-isolated nest (Mann-Whitney, $U = 12.00$, $P < 0.05$) (Fig. 1).

DISCUSSION AND CONCLUSIONS

Curassows nests were located near edges of small forest fragments and in smaller proportion, near edges of continuous forest. Distance to edge was on average 4 m, indicating that nests were found close to the border between habitats. Nest site was significantly

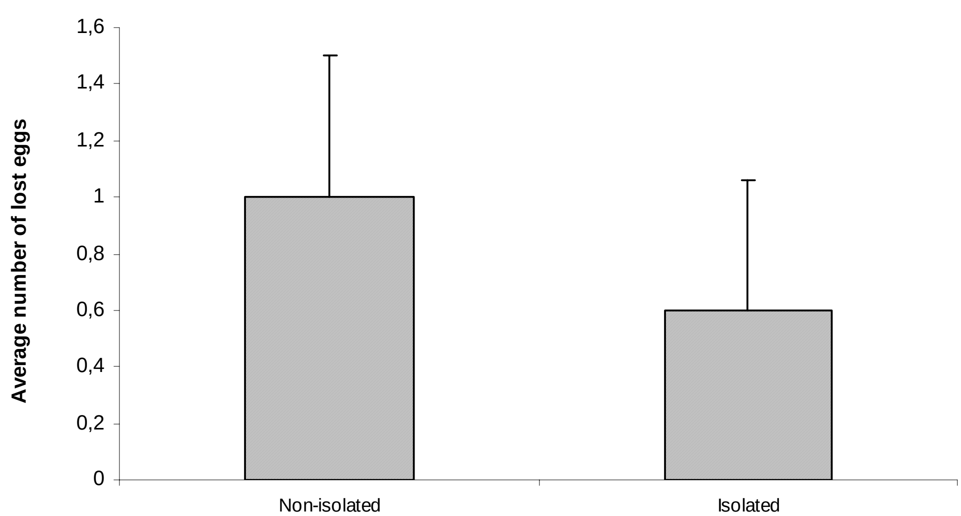

FIG. 1. Lost eggs in nests located in isolated vs non-isolated plots. The number of eggs lost in isolated plots was significantly lower than those in non-isolated plots.

related to high density of thin-stemmed trees, dense undergrowth and a lack of thick-stemmed trees. Although not significant in the final model, the higher abundance of lianas in the nest plots compared with the randomly selected non-nest plots was often significant during the modeling process. These features coincide with what is expected due to edge effects (Laurance & Bierregaard 1997, Putz *et al.* 2001). That all nests were found in or near forest borders can possibly be explained by higher plant density, thus better possibility of hiding the nest from avian predators from above and in some cases also from climbing mammals.

Our results suggest that, although the Yellow-knobbed Curassow has traditionally been considered as an exclusive forest species (Schäefer 1953, Delacour & Amadon 2004), it appears to be able to use forest borders and small forest fragment to breed in when predation risk is too high. In our study area, predation may have affected curassow nesting success in non isolated nests, forcing the birds to nest in isolated sites. The biggest threat surely comes from capuchin monkeys (*Cebus olivaceus*), the fiercest egg predator in this ecosystem (Lau *et al.* 1997). In order to evade them, curassows might be forced to breed in isolated forest fragments surrounded by open areas rarely traversed by the monkeys. Perhaps also some snakes, rats, and opossums are discouraged by an open surrounding.

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