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SHORT NOTE

WOODPECKER CAVITY-TREE SELECTION IN THE ECUADOREAN AMAZON REGION

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Abstract · Tree cavities are important as sites for nesting and roosting, but their availability or use has been little studied in the Neotropics. We studied woodpecker (Picidae) cavity-tree selection in disturbed and undisturbed landscapes in the Amazonian region. We found that woodpeckers excavated predominantly in large dead trees (mean diameter 44 cm). We highlight the importance of dead trees as substrates for cavities in the Ecuadorean Amazon region. We propose that woodpeckers in our study region are potentially important cavity formation agents for other cavity-nesters, especially in disturbed landscapes.

Resumen · Selección de árboles para excavar cavidades por pájaros carpinteros en la región Amazónica Ecuatoriana
Las cavidades en árboles son importantes para animales como sitios para anidar y dormir, pero su disponibilidad o uso han sido poco estudiados en el Neotrópico. Estudiamos la selección de árboles como sustratos para cavidades hechos por pájaros carpinteros (Picidae) en paisajes perturbados y no perturbados. Encontramos que los pájaros carpinteros excavaban predominantemente en árboles muertos grandes (diámetro medio de 44 cm). Destacamos la importancia de los árboles muertos como sustratos para las cavidades en la región amazónica ecuatoriana. Proponemos que los pájaros carpinteros son potencialmente importantes para la formación de cavidades para otras aves en la región de estudio.

Key words: Cavity-nesting birds ·Chakras · Excavated cavities · Forest disturbance · Wood decay · Snags

INTRODUCTION

The richness of woodpecker species (Picidae), the most diverse and abundant group of cavity-excavating birds, is determined globally primarily by tree cover (Ilsøe et al. 2017). Locally, however, it is affected by a preference for specific tree species or characteristics, and the availability of such habitat elements in the landscape (Aubry & Raley 2002, Drever & Martin 2010; Cockle et al. 2011b, 2012). Consequently, studies of woodpecker ecology, such as understanding of the size, condition or species of trees required to ensure availability of suitable nesting or roosting substrates, will provide crucial information to guide forest policy and management for biodiversity (Cornelius et al. 2008, Cockle et al. 2012, Ruggera et al. 2016, Altamirano et al. 2017).

We know that the availability of suitable cavity substrates (for excavators) or decay-formed cavities (for non-excavators) differs substantially across regions (see e.g., Cockle et al. 2008), but we currently have no detailed information on cavity-availability near the equator. On the one hand, there should be fewer dead trees in the tropical Neotropics than in temperate forests of North America, because high rates of decay imply that dead trees persist for a relatively brief time in the Neotropics (Gibbs et al. 1993, Boyle et al. 2008, Vázquez & Renton 2015). In contrast, high decay rates may also lead to accelerated formation of decay-formed cavities, implying that decay-formed cavities could be relatively abundant in the subtropical Neotropics (Cornelius et al. 2008, Pereira et al. 2009; Cockle et al. 2011a, 2011b; Altamirano et al. 2017).

At local scales, the availability of potential cavity substrates and decay-formed cavities, as well as habitat and tree selection by woodpeckers, is influenced by vegetation type, community composition, climatic conditions,

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and the amount of human disturbance (Monterrubio-Rico & Escalante-Pliego 2006, Cornelius et al. 2008; Cockle et al. 2010, 2011b; Vázquez & Renton 2015). For example, in the Atlantic forest of Argentina, primary forests contained significantly more suitable cavities than logged forests (Cockle et al. 2008). In addition, excavators were hypothesized to be more important in producing cavities for non-excavating cavity-users in farmlands than in primary forest, given the higher rate of cavity formation by excavators compared to decay-forming processes in farmlands (Cockle et al. 2012).

The Amazon rainforest is a hotspot of cavity-nester richness (van der Hoek et al. 2017), yet there are few ecological studies of cavity nesters for the region (Cornelius et al. 2008). We aim to enhance our understanding of cavity nester ecology in eastern Ecuador, a part of this vast Amazon region. We provide information on cavity-tree selection by woodpeckers in an area consisting of lowland and piedmont forest, interspersed with gardens, farmland, and terrain dedicated to a traditional agroforestry system known as 'chakras', a cultivation of a variety of crops (e.g., plantain, yucca, lemon) at relatively low-intensity, often without clearing all native trees (Torres et al. 2015). As a reference, we also provide a list of the cavity-nesting bird species observed in our study area.

METHODS

From August 2015 to May 2017, we conducted fieldwork in the province of Napo, Ecuador, across an altitudinal range, from ~ 300–1200 m a.s.l., in a region formerly comprised of lowland and foothill evergreen forest, but currently dominated by disturbed types of land cover, a mix of secondary forests, monoculture agroforestry (e.g., cacao), gardens, cattle pasture, and chakras. For our analyses, we created two broad landscape categories, pooling various land cover types with similar degrees of habitat modification together. One category comprises a landscape with a mix of primary and secondary forests with some history of selective logging but a canopy cover of > 90% (hereafter 'undisturbed landscape'). The other category includes a mix of highly disturbed habitats, such as gardens, farmland, and chakras with < 30% canopy cover of native vegetation (hereafter 'disturbed landscape'). These landscapes are found within 20 km of the city of Tena (0°59'S, 77°48'W; Figure 1), and include the external buffer zone of the Biological Reserve Colonso-Chalupas and the first 3 km inside this reserve. Average annual rainfall in the area exceeds 4500 mm and temperatures range from 19.3°C to 28.7°C year-round, with no defined seasons and occasional peaks over 32°C (meteorological station of Universidad Regional Amazónica Ikiam, 0°56'S, 77°51'W, unpubl. data). Little is known of breeding seasons for most tree-cavity-nester species in the region, but timing likely differs across species (Greeney & Gelis 2008).

We searched for excavated tree cavities by walking four existing trails (2–5 km in length) located in an undisturbed forest landscape (three of which were located partially inside the Biological Reserve Colonso-Chalupas), at least once every month, for a total of > 150 survey hours. We searched for tree-cavities along the trail, carefully screening all trees up to a distance of about 20 m on either side of the trail, covering a total area of approximately 0.5–0.8 km^2 of undisturbed forest landscape. We supplemented these data by conducting opportunistic surveys in disturbed landscape by car, foot or bike, and by responding to reports of cavities or woodpecker activity from colleagues, field assistants, and other acquaintances, ensuring we secured comparable total numbers of cavity-bearing trees in undisturbed and disturbed landscapes. We only considered cavities that were likely to be suitable for use by cavity-nesting birds, (i.e., cavities that appeared to allow a bird to enter entirely so that it is not visible from the outside and that were at least ~ 3 cm in diameter, which is the approximate size of the cavity entrances of Lafresnaye's Piculet (*Picumnus lafresnayi*), the smallest woodpecker found in the study area), and that were likely to be excavated by woodpeckers. This implied that cavity entrances had to be regularly circular or oval-rectangular in shape.

For each cavity-bearing tree we recorded the diameter at breast height (DBH, cm), tree height (estimated with a digital clinometer, m), tree condition (1. alive with no decay, 2. alive with decaying branches, 3. dead with top 1/3 of tree missing, 4. dead with top 2/3 of tree missing), cavity height from the ground (estimated with a digital clinometer, m), and when possible tree species. To provide absence data for subsequent logistic regression models (i.e., trees with no excavated cavity), we also counted and measured tree characteristics and the presence of excavated cavities, for all trees with a DBH ≥ 12.5 cm and ≥ 1 m height found in a 0.04-ha circular plot (11.3 m radius) surrounding 35 cavity-bearing trees (midpoint of circle) as well as all trees found in 52 plots (0.04-ha each) located at a randomly chosen compass direction at 25 m from the midpoint of a cavity-bearing tree. A total of 66 of these plots were located in disturbed landscape and the remaining 21 plots in undisturbed landscape. Our field protocols were based on those outlined by Aitken et al. (2002) for studies in the Nearctic region, as we are unaware of previous studies of this kind near the equator in the Neotropics after which we could model our methodology.

Although plots in undisturbed landscapes were more commonly located at higher altitudes and plots in disturbed landscapes at lower altitudes, we found no significant difference between the distribution of plots in disturbed versus undisturbed landscapes across elevation (Mann-Whitney *U* test, W = 382, $P < 0.016$), and thus continued to test for differences in the characteristics of cavity-bearing trees in these two different landscape types. First, we calculated mean DBH (cm) and heights (m) of trees with at least

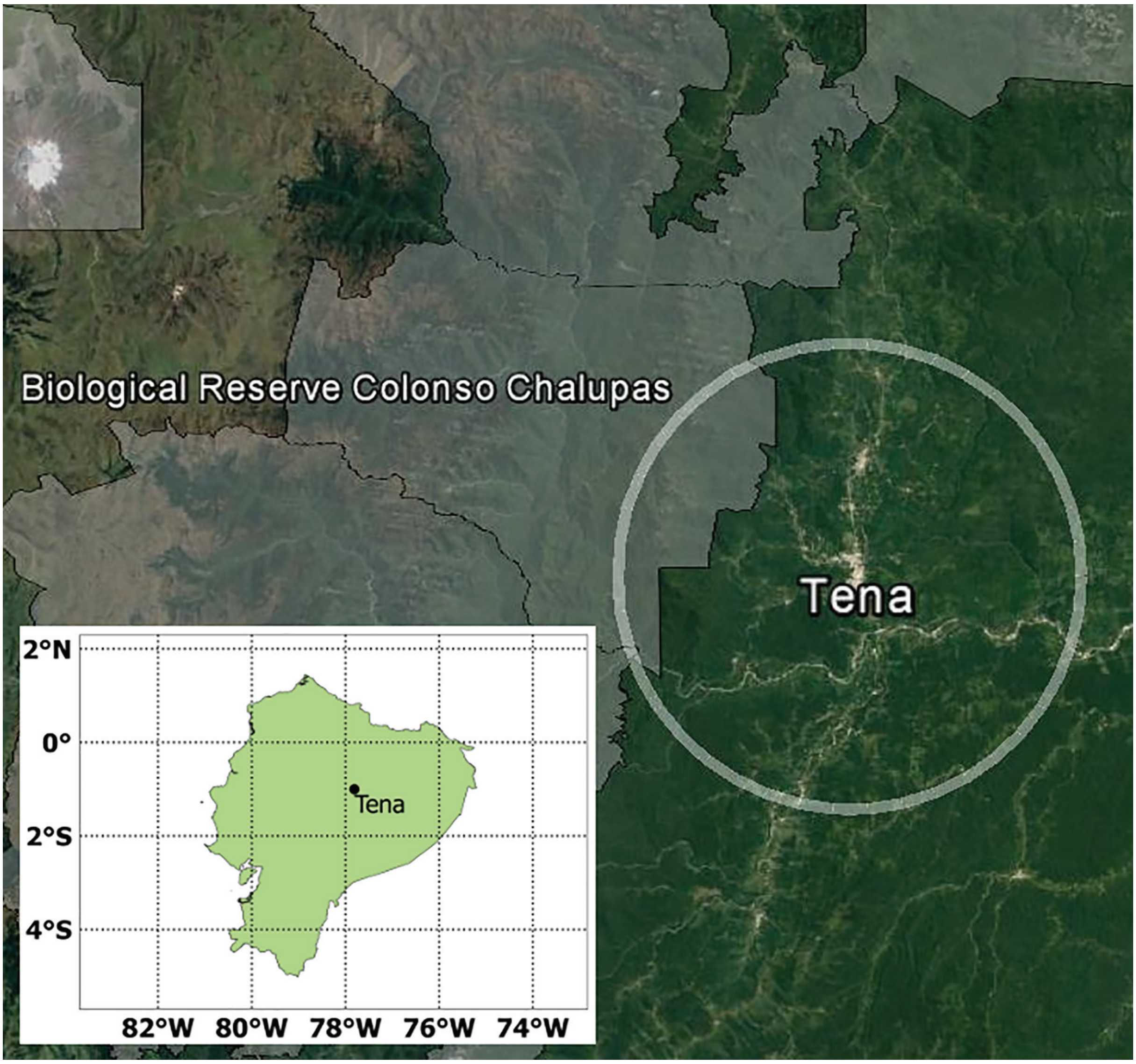

FIGURE 1. Study area (circle) near the city of Tena, Napo, Ecuador (0°59'S, 77°48'W).

one cavity in disturbed and undisturbed landscapes separately, as well as the mean DBH and height of dead (tree conditions 3 and 4) or living (tree conditions 1 and 2) cavity-bearing trees. Finally, we created a multiple logistic regression model to estimate the probability that a tree contained a cavity (cavity = 1, no cavity = 0). We tested models with all possible combinations of predictor variables: tree health condition, DBH, height, and landscape category, and subsequently selected the best model based on the lowest Bayesian information criterion (BIC). For the best model, we used a Wald statistic to determine the significance of coefficients.

RESULTS AND DISCUSSION

Using a list of observed birds in our study area for the presence of known tree-cavity nesters (van der Hoek et al. 2017 in press) we estimate that our study area potentially supports up to 78 tree cavity nesting species, 12 species of obligate excavators, 5 facultative excavators and 61 non-excavating tree-cavity-nesting species (Table S1, Supplementary Material online). Undisturbed landscapes support the richer assemblages of both excavators and non-excavators compared to disturbed landscapes (14 and 8 species of excavators, including both obligate and facultative excavators) and 50 versus 41 species of non-excavators, respectively).

We found excavated cavities in 55 individual trees, of which 10 were located along our transects and the remaining 45 found through opportunistic searches. These trees contained 145 cavities, of which 86 cavities in 23 trees were identified as most likely excavated by Yellow-tufted Woodpecker (*Melanerpes cruentatus*). We assigned these cavities to Yellow-tufted Woodpeckers due to direct observation of excavation activities (at 18 trees, which together contained 77 cavities) or a combination of characteristics indicative of Yellow-tufted Woodpecker activities

Table 1. Results from a multiple regression of the relationship between the probability of trees containing excavated cavities and the size (diameter breast height) and condition (live vs. dead) of trees as well as their forest habitat type (disturbed vs. undisturbed landscapes). *Significance levels *P* < 0.001.

Variable	Model coefficients	Odds ratios
Diameter breast height (cm)	0.049*	1.05
Tree condition (live vs. dead tree)	3.44*	31.29
Landscape type (disturbed vs. undisturbed)	-2.59*	0.08

Table 2. Diameter at breast height (DBH) and height of trees bearing excavated cavities near Tena, Ecuador.

Trees bearing = 1 cavity	Mean DBH (cm) (SE)	Mean height (m) (SE)
Woodpecker (Picidae)-formed cavities	45.3 (3.7)	14.2 (0.8)
Yellow-tufted Woodpecker (*Melanerpes cruentatus)*-formed cavities	51.6 (7.9)	18.5 (1.1)
Dead trees	43.7 (4.0)	13.2 (0.9)
Live trees	53.3 (9.9)	18.9 (1.6)
Disturbed landscape	42.8 (4.5)	14.8 (1.1)
Undisturbed landscape	50.3 (6.9)	12.9 (1.3)

(e.g., when the tree was at least partially dead, found in a highly disturbed landscape, and contained multiple oval cavities of ~ 4–5 cm in diameter; van der Hoek 2016). We did not observe any other woodpecker species excavating cavities with those dimensions in disturbed landscapes, although seven other woodpecker species are known to reside in the study area. Six excavated cavities were found in large branches, and all other cavities occurred in the main trunk of trees.

Over eighty percent of cavity-bearing trees were dead (46 of 55 trees). We identified 26 cavity-bearing trees as *Cecropia* spp. (Urticaceae; 11 trees with excavated cavities), *Ficus* spp. (Moraceae; four trees with excavated cavities), *Piptocoma discolor* (Asteraceae; one tree with an excavated cavity), *Ocotea javitensis* (Lauraceae; one tree with excavated cavities), *Parkia velutina* (Fabaceae; one tree with excavated cavities), other Lauraceae (three trees with excavated cavities), Arecaceae (two palms with excavated cavities), and three unidentified bamboo species (Bambusoideae; all with excavated cavities). We were unable to identify 29 cavity-bearing trees to species (53% of all cavity-bearing trees) due to advanced amounts of decay.

Presence of cavities was best predicted by a multiple regression model that included DBH, landscape type, and tree condition (lowest BIC; *P* < 0.001 for all three predictor variables; overall model *P* < 0.001), with the odds of a tree containing at least one cavity increasing by 1.05 for each cm increase in tree size (DBH), increasing by 31.29 when a tree was dead rather than alive, and decreasing by 0.08 when a tree was found in undisturbed rather than disturbed landscape (Table 1). Our results highlight the importance of dead trees as substrates for cavities in the Ecuadorean Amazon region. Moreover, we show that woodpeckers tend to excavate in dead trees with a relatively large diameter in both disturbed and undisturbed landscapes (Table 2).

We acknowledge that there are potential biases in our capacity to accurately record tree-cavities in our plots. These biases may have caused slight errors in our estimation of trees without cavities (i.e., the 'absences' in the multiple logistic regression model used for the prediction of cavity presence) as well as the calculation of mean DBH and height of cavity-bearing trees. Cavities might have especially gone undetected when above 10 m, in branches, or behind epiphytes and other structural elements. In addition, we may have misclassified some decay-formed cavities as excavated if the entrance hole was oval or round (Boyle et al. 2008, Cockle et al. 2012). Finally, we usually assigned excavated cavities to woodpeckers, but it is possible that some cavities were created by the barbet species (Capitonidae, obligate excavators) present in our study area.

It has been widely recognized that solitary or small patches of trees in otherwise sparsely forested landscapes ('scattered trees') (Manning et al. 2006, Gibbons et al. 2008, Fischer et al. 2010) and dead trees (Gibbs et al. 1993, Cockle et al. 2011a) are important keystone elements for ecosystem functioning and conservation of cavity-nesting. However, we are the first to determine the importance of dead trees near the equator in the Neotropics, especially dead trees that occur in agricultural landscapes that contain forest stands with a limited number of trees large enough to support cavities. Retention of dead trees, and living trees with large diameters, is likely key for the conservation for many cavity-users in our region, especially for woodpeckers. Future research may determine the importance of excavators in disturbed landscapes, as well as the key habitat and other requisites required to maintain diverse excavator assemblages in tropical piedmont landscapes altered by anthropogenic activities.

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