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Analysis of Nest Sites of the Resplendent Quetzal (*Pharomachrus mocinno*): Relationship between Nest and Snag Heights

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ABSTRACT.—The Resplendent Quetzal (*Pharomachrus mocinno*) is of particular conservation concern because of its iconic status in Central American culture. This species is a secondary cavity nester and modifies abandoned woodpecker nest sites in dead tree trunks (i.e., snags). We used 11 historical nest sites, reported in 1969, from Atitlan, Guatemala and 10 recent nest sites from San Gerardo de Dota, Costa Rica to examine if a relationship exists between nest and snag height. There were significant differences between Costa Rica and Guatemala in both nest height (6.3 vs. 10 m, respectively; $t\text{-test}_{14} = -2.49$, $P = 0.042$) and snag height (8.1 vs. 14.0 m, respectively; $t\text{-test}_{13} = -2.39$, $P = 0.033$). There was no difference in nest heights relative to snag heights for Costa Rica (0.76) and Guatemala (0.77; $t\text{-test}_{17} = -0.20$, $P = 0.84$). One aspect of conservation efforts for this species has been placement of nest boxes to provide nesting sites for additional pairs. Our results provide a better understanding of placement requirements for nest boxes to encourage their use anywhere within the range of the species. *Received 3 December 2009. Accepted 5 April 2010.*

Cavity nesting-species have challenges from finding the limited resource of a nest cavity (Cornelius et al. 2008) to predation events on eggs, chicks, or adults (Martin and Li 1992, Brightsmith 2005). Many cavity-nesting species in both temperate and tropical latitudes display preferences for cavity height in relation to height of the tree or snag (i.e., relative nest height). Primary cavity-nesting species, including Red-headed Woodpecker (*Melanerpes erythrocephalus*), Northern Flicker (*Colaptes auratus*), and Acorn Woodpecker (*M. formicivorus*), place nests at relative nest heights of 0.49–0.58 (Sedgwick and Knopf 1990, Hooge et al. 1999). Some secondary-cavity nesters in the temperate zone select relative nest heights with more variation: Black-capped Chickadees (*Poecile atricapillus*) and House Wren (*Troglodytes aedon*) at 0.37–0.38, European Starlings (*Sturnus vulgaris*) and American Kestrels (*Falco sparverius*) at 0.5 (Sedgwick and Knopf 1990), and Eastern Screech-Owls (*Megascops asio*) at 0.31 (Belthoff and Ritchison 1990).

Less information is available in tropical areas about selection of relative nest heights by secondary-cavity nesters. The Resplendent Quetzal (*Pharomachrus mocinno*) is an exclusive secondary-cavity nester (Johnsgard 2000) that, as an iconic species, has become the focus of conservation efforts at many locations throughout Central America. More efficient planning and implementation has occurred with concomitant conservation benefits for many other species in focusing on one vulnerable and highly mobile species (Wheelwright 1983, Powell and Bjork 1995). The Resplendent Quetzal throughout its range uses natural cavities created from stubs of fallen branches or abandoned nest cavities of other species, primarily woodpeckers, which

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Resplendent Quetzals occupy and enlarge (Wheelwright 1983). The Acorn Woodpecker is the primary excavator in the Talamanca Mountain Range of southern Costa Rica. This species excavates several locations for nesting and then abandons these sites as the level of decay increases (Koenig et al. 1995). We examined nest heights of currently active (in Costa Rica) and historical (in Guatemala; Bowes and Allen 1969) Resplendent Quetzal nests and compared them to heights of snags where they occur. We sought to ascertain if there were: (1) any differences in nest placement between countries, (2) consistent relative nest heights for Resplendent Quetzals, and (3) any implications for future conservation efforts.

METHODS

Study Site.—The San Gerardo de Dota Valley is on the Pacific Slope of the Talamanca Mountain Range, 85 km southeast of San Jose below the Cerro del Muerte on the Pan-American highway. The Quetzal Education Research Center (QERC; 9° 33′ 08.67″ N, 83° 48′ 23.18″ W; 2,200 m asl) is part of a 400-ha preserve consisting of homesteads pioneered in 1952 for dairy farming. Much of the pasture land was converted to fruit-tree orchards starting in 1984 and the last pasture areas were allowed to begin the process of succession to forest in 1996 (Neuenschwander 2001). The primary forest is dominated by oaks (*Quercus* spp.) with an understory dominated by Lauracea, Moracea, and Fabacea. Secondary forest areas have similar composition. The Savegre River bisects the valley and most human activity occurs in the associated riparian area. This area has been planted with eucalyptus (*Eucalyptus* spp.) trees for erosion control to supplement the remaining native species.

Data Collection.—Our initial search for both active and past nests from January through April 2008 involved interviewing local guides and individuals in San Gerardo de Dota, Costa Rica who were familiar with nest locations. We searched along established trails to locate these and other nests. Eight of the 10 sites that we located were active and two were not being used although observations in previous years indicated these were active nest sites. We observed pair activity including exchange of occupancy or delivery of food items at a site to document it was active. We measured nest and snag height using a standard metric tape measure and clinometer (Suunto PM-5). We calculated relative nest height as the height of the nest divided by the height of the snag. This calculation was also done for the 11 reported sites from Guatemala (Bowes and Allen 1969). We used 21 nest sites for analysis, 10 from Costa Rica and 11 sites in Guatemala reported by Bowes and Allen (1969). All 21 sites were in trunks of dead trees (i.e., snags).

Statistical Analysis.—We had unequal number of sites in each country and a recognized difference in subspecies. Thus, we used two-sample *t*-tests assuming unequal variance to compare nest and snag heights, and the ratios between countries (Van Emden 2008). We used Pearson product-moment correlation to examine if the nest-to-snag relationship was linear across sites. We used Systat 11 (Systat 2004) for all of our calculations.

RESULTS

There was only one Resplendent Quetzal nest cavity per tree at each Costa Rica site. There were many woodpecker holes in a snag, but the majority, based on shape and depth, were relic foraging holes. There were two additional large holes in the case of tree # 4; one was 1 m above the active nest while the other was 650 cm below it facing a different direction. Tree # 2 had one hole 500 cm above the nest that was used by Spot-crowned Woodcreepers (*Lepidocolaptes affinis*). Nesting success was difficult to ascertain and it remains unclear how many nest sites were successful. However, we observed a nestling that left nest # 1 prematurely and died, and that nest # 5 was abandoned by the adults prior to fledging.

Snag heights in Costa Rica averaged 8.1 m (s = 2.78, range = 1.9–10.8 m, n = 10) and were lower than those used in Guatemala, where the average was 14.0 m (s = 7.57, range = 5.8–29.0 m, n = 11; $t\text{-test}_{13} = -2.39$, $P = 0.033$). The average nest height of snags used in Costa Rica (6.3 m, s = 2.53, range = 1.4–10.1 m, n = 10) was also lower than in Guatemala (10.8 m, s = 6.15, range = 4.0–24.4 m, n = 11; $t\text{-test}_{14} = -2.49$, $P = 0.042$). The product-moment correlation between snag height and nest height was high ($r = 0.976$, $P < 0.0001$; Fig. 1). No difference was found in nest heights relative to snag heights for Guatemala (0.77) and Costa Rica (0.76; $t\text{-test}_{17} = -0.20$, $P = 0.84$).

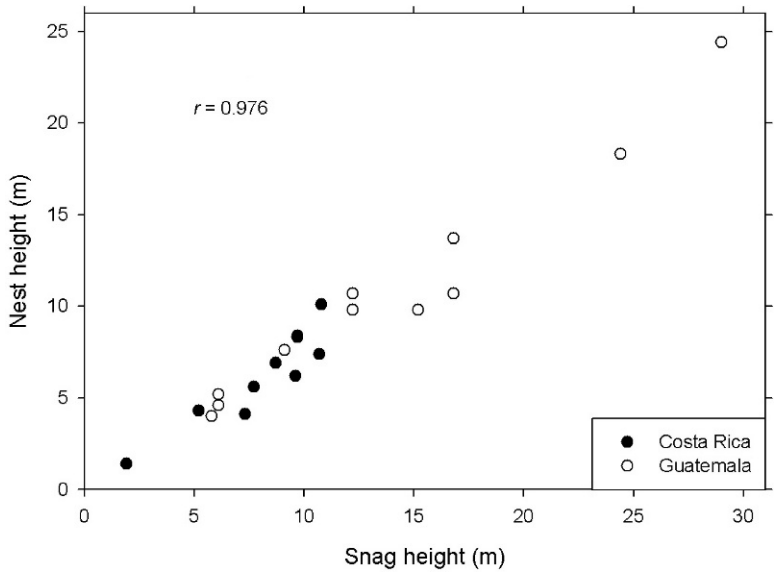

FIG. 1. Relationship of snag versus nest height of Resplendent Quetzals in two populations in Costa Rica and Guatemala ($r = 0.976$, $P < 0.0001$).

DISCUSSION

Successful nesting by Resplendent Quetzals is dependent on numerous factors; from males having sufficient covert lengths and display flights (Unger 1988) to defending and provisioning chicks. One aspect that is crucial to successful nesting is finding suitable cavities. Resplendent Quetzals in the northern portion of their range excavate entire nests as there are no woodpeckers or their allies that produce a cavity of suitable size (Renner 2005). We observed Resplendent Quetzals at San Gerardo de Dota making small holes in dead trees prior to mating, but nest cavities were developed from cavities initially excavated by Acorn Woodpeckers. The difference may be related to most nest sites at San Gerardo de Dota being in trunks of oaks, which have relatively hard wood.

Finding abandoned Acorn Woodpecker nests appears to be important, but relative nest height may be of primary importance in selecting a nest site. Average relative nest height was 0.65 (Renner 2005) when no previously excavated cavities were available, primarily due to a lack of sufficiently large woodpecker species. Average relative nest heights were 0.76 and 0.77, respectively in our study and the earlier study in Guatemala (Bowes and Allen 1969). Both our Costa Rica site and the Guatemala (Bowes and Allen 1969) site are within the range of a woodpecker species that is sufficiently large to excavate a cavity that may then be enlarged by the Resplendent Quetzal (Skutch 1944, Bowes and Allen 1969, Johnsgard 2000).

The primary-cavity nester at San Gerardo de Dota is the Acorn Woodpecker. This species nests roughly half way up in a snag (Hooge et al. 1999). As the snag ages, material is lost from the top reducing the overall relative nest height. It is only after sufficient decay that the site is abandoned by woodpeckers and becomes available for Resplendent Quetzals. Nests are often used by Resplendent Quetzals for several years until the snag finally collapses.

The continued presence of Resplendent Quetzals is of primary interest to the inhabitants of San Gerardo de Dota as there are more than 12,000 visitors annually to the Quetzal Education Research Center. Conservation efforts at numerous locations throughout the range of the Resplendent Quetzal have included addition of artificial nest boxes (Bowes and Allen 1969, LaBastille 1974). Approximately four nest boxes per year, including replacements, have been in place since 1993 at San Gerardo de Dota. These boxes potentially could provide nesting sites for additional pairs, but none has been used. Thus, there may be sufficient numbers of natural sites for the number of nesting pairs. However, it is possible the

existing boxes are inappropriately positioned. These boxes are mounted at the top of 2.5 m posts, which do not extend above the boxes like the snags above the natural nesting cavities. Further, the absolute height of the nest boxes is considerably below the average heights of natural nesting cavities recorded in our study.

Conservation efforts for the Resplendent Quetzal have implications for many other species in the tropical cloud forests of Central America following succession, which provides new areas for nesting. Completion of the proposed Meso-American biological corridor in this area could be beneficial for Resplendent Quetzals and other species (Kaiser 2001).

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