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NEST-SITE SELECTION OF THE BLACK-CHINNED HUMMINGBIRD IN SOUTHEAST ARIZONA

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The selection of safe breeding sites is an important behavioral component of avian population ecology (Newton 1998), and nest predation is a major ecological force limiting reproductive success and shaping the spatial distributions of breeding birds (Ricklefs 1969, Martin 1995). Avian nesting sites can be examined at multiple spatial scales, from broad landscape levels, to nest and patch characteristics, to microsite features such as overhead concealment and nest orientation (Martin 1993, Paton 1994). Microhabitat features of the vegetation used as nest substrates are especially important for camouflage and protection from inclement weather (Martin 1995, Deeming 2002, Kolbe and Janzen 2002). Numerous studies have linked specific aspects of nest microsites and nesting success in a variety of birds (e.g., Martin and Roper 1988, Liebezeit and George 2002, Aguilar et al. 2008, Powell et al. 2010, Miller 2014). While many studies of avian nesting success focus on predation or brood parasitism (e.g., Li and Martin 1991, Larison et al. 1998, Lima 2009), in some species, particularly species with narrow physiological tolerances like hummingbirds (Calder and Booser 1973, Calder 1994, 2002), nest placement may also be important for maintaining the microclimate around the nest (Deeming 2002).

The Black-chinned Hummingbird (*Archilochus alexandri*) is a migratory species that nests from southern British Columbia to extreme northern Mexico and southern Texas, wintering from southern Texas to south-central Mexico (Baltosser and Russell 2000). As pointed out by Baltosser (1978), its choice of nesting substrate tends to vary geographically, so detailed studies are needed from multiple areas before we can assess the relative importance of geographic variation in its nest placement. Additionally, though there are many anecdotal accounts of the nesting of the Black-chinned Hummingbird, most studies addressing nest-site selection have focused on habitat structure or species of tree used as nest substrate rather than actual nest placement or microsite characteristics (e.g., Stamp 1978, Brown 1992, Smith et al. 2009). If not, their sample sizes are very small (e.g., Christy 1932).

The success of Black-chinned Hummingbird nests in southeastern Arizona has been linked to their placement in relation to nests of the Cooper's Hawk (*Accipiter cooperii*) and Northern Goshawk (*A. gentilis*) and to the spatial patterns of foraging by the Mexican Jay (*Aphelocoma wollweberi*), an important predator of eggs (Greeney and Wethington 2009, Greeney et al. 2015). To provide baseline information on nest-microsite selection to explore this trophic cascade further, we describe the microsite and placement of Black-chinned Hummingbird nests on the basis of 412 nests in the Chiricahua Mountains of southeastern Arizona. We made all observations in the vicinity of the Southwestern Research Station (31° 53' N, 109° 12' W; elevation 1600 m), located west of Portal, Arizona. We located the nests by searching riparian areas at elevations of 1400–1750 m from April to July during 2007 and 2008. We

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located 95% of nests by observing the female's behavior and following her to the nest, circumventing the concealing effect of nest height and foliage density.

We measured 11 variables at each nest. We estimated the height of substrate trees to the nearest 0.5 m with a 7-m pole and used a tape to measure the trunk's diameter at breast height (DBH). Using a 7-m pole, we also measured nest height to the nearest 10 cm, estimating the height of nests over 7 m by using the pole as a gauge. We visually estimated the distance of the nest from the central portion of the tree and from the outer edge of the foliage at nest height, and estimated the diameter of the supporting branch by visually estimating the relative sizes of each feature in relation to the width of the nest in question, using mean measurements taken from 26 nests collected in the same study area (Greeney unpubl. data). We noted many nests placed near forked limbs, which appeared as a horizontally oriented "Y," with one arm of the fork overhanging the nest and one supporting it, so we estimated the distance between the nest and the fork, as well as the distance from the nest rim to the overhanging arm of the fork, and then estimated the diameter of this overhead cover. For each nest we also noted if the supporting branch was angled, and whether it was living or dead, and we made note of all nests that were constructed on the visible remains of an old nest. We recorded the orientation of nests in relation to the substrate tree with a hand-held compass.

We used circular statistics to test for non-uniform directionality of nest orientation (Bergin 1991), running Rao's uniformity test (*U*: Rao 1976, Batschelet 1981) in Oriana 2.0 (Kovach, Pentraeth, Wales). In addition to the probability, we present mean vector length (*r*), which is a unitless measure (0–1) of the dispersion of the data, with a value of 0 being widely dispersed (uniform) and 1 being tightly concentrated.

Of 412 nests, 266 (64.6%) were in alligator juniper (*Juniperus deppeana*). The remainder were built in Arizona sycamore (*Platanus wrightii*; 17.5%), oaks (*Quercus* spp.; 10.9%), one-seeded juniper (*J. monosperma*; 2.2%), spiny hackberry (*Celtis ehrenbergiana*; 2.2%), pines (1.2%), and Wright's siltkassel (*Garrya wrightii*; 0.7%), as well as one nest (0.2%) in each of Fremont cottonwood (*Populus fremontii*), pecan (*Carya illinoensis*), and Arizona cypress (*Cupressus arizonica*). Substrate trees had an estimated mean height of 11.3 ± 3.7 m ($n = 399$) and a mean DBH of 37 ± 25 cm ($n = 362$).

Mean estimated nest height was 5.7 ± 2.6 m ($n = 411$), with 56% of nests in the upper half of the substrate (tree) and 28% in the upper third ($n = 400$). Mean estimated distance from the nest to the center of the tree was 2.6 ± 1.4 m ($n = 408$), and mean estimated distance to the end of the supporting branch was 1.1 ± 0.6 m ($n = 408$); thus 63% of nests were in the outer third of the foliage (as measured at the height of the nest). Nests showed a significant bias toward orientation south-southeast with respect to the substrate tree ($n = 98$, $U = 156.408$, $r = 0.627$, $p < 0.01$; Figure 1). Black-chinned Hummingbirds were more likely to nest on slightly angled branches (56%, $n = 403$) as well as on living branches (57%, $n = 409$), and branches used had a mean estimated diameter of 1.6 ± 0.9 cm. Most nests were also placed close to the fork of a branch oriented so that they were covered by one arm of the "Y" (65%, $n = 412$). Where a covering branch was present, nests were built an average of 6.9 ± 3.5 cm below this branch and 7.4 ± 5.2 cm from the forking of the supporting arm, and overhead branches were on average 2.7 ± 1.8 cm in diameter ($n = 266$).

At a mean height of almost 6 m above the ground, the Black-chinned Hummingbird nests we studied were at the higher end of the range reported in the literature or from collected nests. While Baltosser (1986), also working in southeastern Arizona, found most nests 5–6 m above the ground, studies in California and northern Arizona suggest a mean height of 2 m (Brown 1992, Baltosser and Russell 2000). Pitelka (1951) described most nests as 2–3 m up in southern California, while studies in New Mexico and Texas reported nests generally below 4 m (Baltosser 1978, Ortego and Sargent in Baltosser and Russell 2000). It should be noted, however, that mean substrate height varies considerably by site (e.g., 2.4 m, Brown 1992, vs. 11.3 m, this study)

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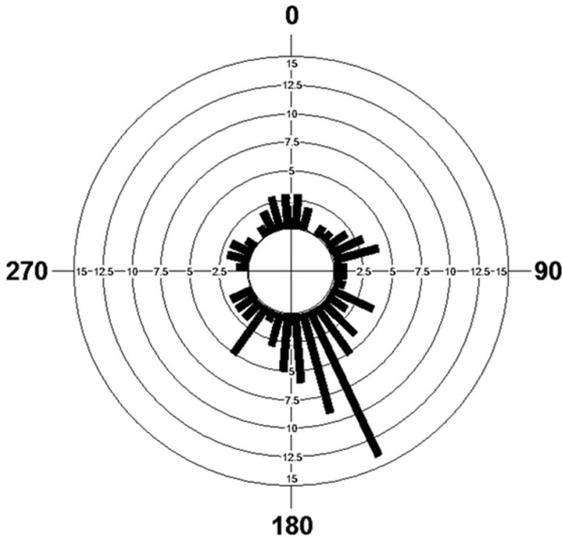


Figure 1. Compass orientation, with respect to the substrate's trunk, of Black-chinned Hummingbird nests in southeast Arizona (0° = north). The length of a given bar expresses the number of nests oriented in that direction.

The Black-chinned Hummingbird's preference for nesting in riparian areas is well established (Grinnell and Miller 1944, Baltosser 1989, Strong and Bock 1990), but other habitats are also commonly used, including orchards (Grinnell and Miller 1944, Woods 1936, Small 1994) and well-irrigated urban areas (Rosenberg et al. 1987), perhaps suggesting that humidity is an important factor in nest-site selection. While we did not thoroughly search areas outside of riparian zones, no females we followed were attending nests away from riparian zones, and we did not find any nests outside of riparian zones during casual searches or travel between focal areas. Even within southeast Arizona the preferred species of substrate tree varies considerably from study to study: Baltosser (1978, 1989) found sycamores, cypresses, and maples to be preferred nesting substrates, with the population closest to our site (Rucker Canyon) showing a secondary preference for junipers (Baltosser 1978). Elsewhere, Brown (1992) reported the introduced tamarisk (*Tamarix ramosissima*) as the preferred substrate in northern Arizona, as did Smith et al. (2009) working in southwestern New Mexico, where they also noted use of Russian olive (*Elaeagnus angustifolia*) and eastern cottonwood (*Populus deltoides*). California studies have shown a preference for sycamore, with oak and willow also used (Wueste 1902, Pitelka 1951, Baltosser and Russell 2000). Prior authors have remarked on the Black-chinned Hummingbird's use of the outer portions of substrate trees (Merriam 1896, Unglish 1932, Woods 1936), while others have found a preference for the lower strata of substrate trees (e.g., Ortego and Sargent in Baltosser and Russell 2000).

The population of Black-chinned Hummingbirds we studied showed a clear preference for the upper, outer portions of junipers, choosing slightly angled, living branches, smaller in diameter than the nest and with a branch sheltering it from above. We believe that such details of site selection may be important for successful reproduction, with any geographic variation in substrate species more likely to be explained by which tree species is locally abundant and having a growth form with architectural qualities to provide such sites.

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We suggest the preference for nesting at branch tips, along with the use of thin supports, may be in response to pressures by non-aerial predators such as snakes and squirrels, and that overhead cover is an important microsite characteristic that has been overlooked in prior studies (but see Holland 1916). Simply because of the density of the trees in which we found nests, we suspect that many of our nests that were *not* categorized as having overhead cover were actually shaded by thin foliage to some degree. Additionally, we speculate that a thick branch directly above the nest may encourage arboreal predators such as squirrels to travel along these upper branches, reducing the chance that they will physically or visually encounter a hummingbird nest hidden below the branch.

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