

Nest Site Selection by a Secondary Cavity-Nesting Species, the Mountain Bluebird

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Abstract:

As secondary cavity-nesters, mountain bluebirds are limited in their selection of nest sites by the choices of primary (excavating) cavity nesters. In the aspen forests of Colorado, red-naped sapsuckers are the primary excavators and several species depend on sapsucker nest cavities for their own nests. Our goal was to determine whether secondary cavity-nesters selected particular nest cavity characteristics from the array of available nests, or if their choice was random. We focused on mountain bluebirds because most previous studies used populations nesting in artificial nest boxes. In order to determine the characteristics of mountain bluebird nests we measured diameter at breast height (DBH), nest height, percent tree cover, nest opening orientation and distances to edge of aspens, nearest willow and nearest water. We compared these characteristics of mountain bluebird cavities to the same characteristics of cavities occupied by other secondary cavity nesters and we found very few differences. Bluebirds nest in trees with a slightly larger DBH and appear to nest farther from willows and water than other secondary cavity nesters. Bluebird cavity openings are also non-randomly oriented to the east-southeast; however, this was not significantly different from orientation of other cavities. All other analysis revealed no significant differences. We conclude that mountain bluebirds select larger-diameter trees than do other secondary cavity nesters. We also suggest that the strongest determining factor of mountain bluebirds could be a characteristic that we did not measure, namely distance to other mountain bluebird nesting pairs. We suggest further study on territory requirements of mountain bluebirds to test this hypothesis.

Introduction:

Keystone species, by definition, have a disproportionate impact on their environment given their biomass and/or abundance. Environmental engineers are examples of keystone species (Jones et al. 1994). Jones et al.(1994) described ecosystem engineers as species that indirectly influence the life histories of other species by modifying habitat without necessarily increasing their own fitness in the

process. An example is the beaver (*Castor canadensis*). By damming rivers and creating wetlands the beaver creates new habitat for itself and other species and also modifies nutrient cycling and water movement. The actions of ecosystem engineers influence other species beyond mere direct interactions.

In aspen (*Populus tremuloides*) woodlands of the Colorado Rocky Mountains, red-naped sapsuckers (*Sphyrapicus nuchalis*) are keystone species, as several cavity-nesting birds depend on sapsuckers for nests (Daily et al. 1993). Each year sapsuckers excavate new nest cavities in aspen trees infected with heartwood rot fungus (*Phellinus tremulae*). The fungus softens the heartwood of aspens allowing sapsuckers to create cavity nests more easily than in healthy wood (Jackson and Jackson 2004). As a result, sapsuckers nest almost exclusively in aspens infected with the fungus (Jackson and Jackson 2004). Together, heartwood rot fungus and red-naped sapsuckers strongly influence the avian communities in aspen forests. The abundance of cavities created by sapsuckers becomes essential habitat for at least seven species of secondary cavity-nesters in subsequent years (Daily et al. 1993).

Cavity use analysis by Owens and Bennett (1995) suggested that adoption of cavity-nesting in the ancient history of birds led to decreased reproductive effort and ultimately had a significant impact on evolution of diverse life history traits. Not only do the cavities provide direct protection from predators, but they also reduce the cost of anti-predation strategies. A common anti-predation strategy for non-cavity nesting birds is to leave the nest for long periods of time and then sit on the eggs for long periods of time. This strategy reduces activity at the nest and detection by predators. However, cavity nesting birds are able to make shorter trips away from the nest because the cavities are safer from predators (Conway and Martin 2000). A cost of the strategy of leaving the nest for long periods is that the eggs get colder and may require longer incubation times as a result. Cavity nests have been found to be warmer than outside temperatures by 2.5°C to 4.9°C due to decreased wind (Cooper 1999). As a result of these nest habitat benefits, cavity nesting birds had lower rates of adult and offspring mortality and, therefore, required lower reproductive effort (Owens and Bennett 1995). The success of cavity nesters is thought to have allowed for rapid diversification of bird species resulting in several species of cavity nesters (Owens and Bennett 1995).

Of four ecological traits examined by Owens and Bennett (1995) only nest habitat had a significant impact on evolution of life history traits and reproductive effort. Our study further examined the niches of secondary cavity-nesters. Cavity-nesting provides safer nesting for many birds (Owens and Bennett 1995), but birds secondarily nesting in cavities are then limited to location and characteristics determined by the excavator. In our study, we sought to determine if certain nest cavity characteristics are associated with particular species. Given that the supply and characteristics of cavities is initially determined by the excavators that create them, the secondary cavity nesters may choose particular traits of available cavities when selecting nests, such as location in relation to food sources and water or nest location/orientation on the tree. Though several species rely on nest cavities created by sapsuckers, we focus on the mountain bluebird (*Sialia currucoides*).

Nearly all of what is known about mountain bluebird nesting is based on studies of populations nesting in nest boxes (Power and Lombardo 1996). Our study, in contrast, aims to gain information on the natural nest choice of mountain bluebirds. Our objective was to determine the characteristics of mountain bluebird nest sites, relative to the available cavity nests. Daily et al. (1993) found that sapsuckers preferred nest sites close to willows, where the sapsuckers harvest sap from wells that they excavate. In addition, nests closer to the edge of the aspens that are larger are used more often by secondary nesters (Aitken, et al. 2002). Thus, we hypothesized that the mountain bluebird will be found nesting in trees near the edge of the forest and near willows where they would be close to foraging habitat. Losin, et al (2006) found that the heartwood rot fungus thinned the healthy sapwood on the south side of trees more extensively than other sides and found that sapsucker cavity entrance orientations were correspondingly biased to the south-southeast side of the tree. We therefore hypothesize that mountain bluebird nests follow the same pattern with nest openings oriented to the south-southeast.

Methods:

In order to determine nest site attributes, we measured nest height, nest opening compass orientation, the distance from the nest to the edge of the aspens, distance to

the nearest willows, distance to nearest water, diameter at breast height and percent tree cover around the nest. Nest site characteristics of mountain bluebirds were compared to characteristics of available nest cavities to determine whether bluebirds preferentially select nest sites with certain characteristics, or if their choice is random.

Between 18 June and 10 July 2009, we sampled nest sites by walking approximately 30 m wide transects in aspen forests between 2800 – 3050 m elevation in Gunnison National Forest lands near the Rocky Mountain Biological Laboratory, Gothic, Colorado. Many cavity-nesting bird species fly in and out of the nest more frequently during this time period, and it is easier to determine which species are in the cavity. All second-cavity nests found were marked with flagging and a small aluminum tag nailed to the tree. Latitude, longitude and elevation were recorded at each site using a hand-held GPS unit; we also recorded the number of occupied and unoccupied cavities.

We found 237 cavities, of which eight had mountain bluebirds nesting in them. However, due to time constraints, we were unable to collect data for all of the non-bluebird cavities. Subsamples were selected by using a random number generator and selecting numbers 1 through 15 of each species to measure. If we did not have 15 cavities of a particular species, all cavities of that species were measured.

For each selected tree, we counted the number of holes, recorded the compass orientation of the opening, estimated the nest height and measured distances to willows water and edge of aspens. We found the directional orientation by lining one person up directly under the cavity, and taking a reading on a compass. To measure nest height, one person held a dead branch or tree against the tree with the cavity while the other person spotted where the nest was along the dead tree. The dead tree or branch was then lowered and we measured the distance from the bottom to the spotted point with a tape measure.

We used a tape measure to record the distances to edge, willows and water within 100 meters. The edge was determined by walking to the edge of the trees, specifically, the edge of the canopy. We defined the edge as the edge of a meadow $\geq 100 \text{ m}^2$ (10 x 10 m, 8 x 12.5 m, or 5 x 20 m) not containing any aspen trees $> 5 \text{ cm}$ DBH. We similarly defined willows as a willow patch covering approximately 100 m^2 . If

the distance to the variable was greater than 100 m, we measured the distance using GPS points.

Once all measurements that could be made at the nest sites were complete, we measured the remaining distances and calculated percent tree cover around each tree using aerial images from Google Earth. While in the field, several GPS points were taken at willows, water and edges in order to easily calculate distances using a computer. We used the existing nest site GPS points to map their locations. We used the ruler tool in Google Earth to measure distances between GPS points. We overlaid a one hectare grid onto Google Earth images, centering each point within the grid. Then, we counted the number of intersections within the grid that contained woodland cover, and calculated the percent of the hectare that was forest.

We analyzed all data with the exceptions of orientation and nest height using Van der Waerden tests. This test compared mountain bluebird cavity means to means of all other cavities and adjusted for non-normality. Nest height data were analyzed using a t-test because the data met the assumptions of normality. Data on cavity opening compass orientation were analyzed using Rayleigh's test to determine if the sample was non-random and a Watson U^2 test was used to compare mountain bluebird cavity orientation to other cavity orientations (Zar 1999).

Results:

Van der Waerden tests comparing mountain bluebirds to all other cavities did not reveal significant differences; however, a few characteristics showed noticeable tendencies. Analysis of diameter at breast height (Figure 1) showed that mountain bluebirds have a tendency to select larger trees than do other secondary cavity nesters (Table 1). The distance to nearest willows was slightly farther for mountain bluebird cavities when compared to other cavities as shown in Figure 2.

Diameter at Breast Height of Tree

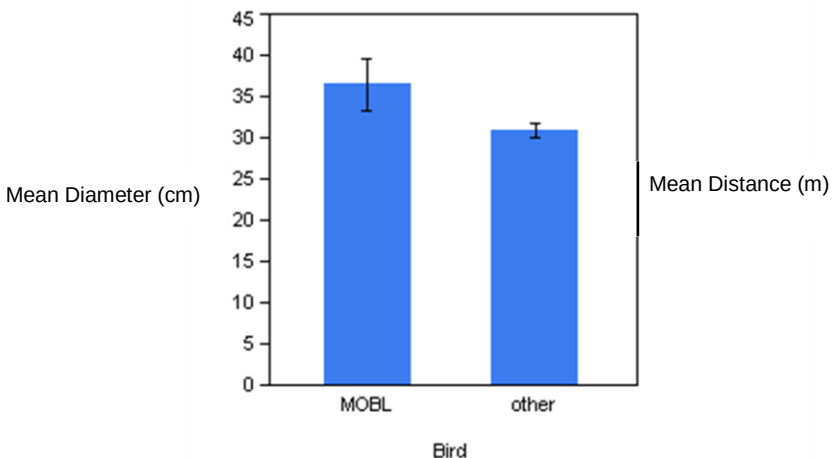


FIGURE 1. Comparison of DBH between mountain bluebird (MOBL) cavities and other secondary-cavity nest. There is a tendency for bluebirds to nest in larger trees than other second-cavity nesters ($p=0.06$).

Distance to Nearest Willows

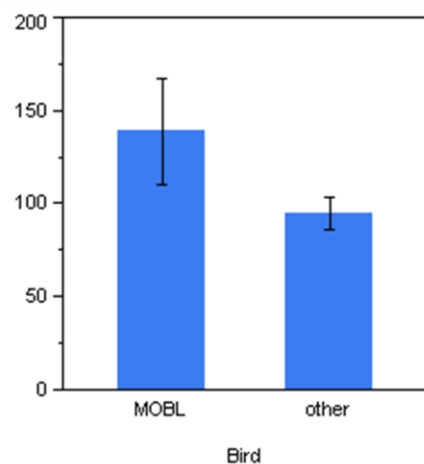


FIGURE 2. Comparison of mean distance to nearest willows between mountain bluebird (MOBL) cavities and all other cavities. The mean distance of mountain bluebird nests to willows is slightly farther from the willows than other secondary-cavity nests ($p=0.10$).

The mean distance to nearest water was slightly greater for mountain bluebirds (Figure 3).

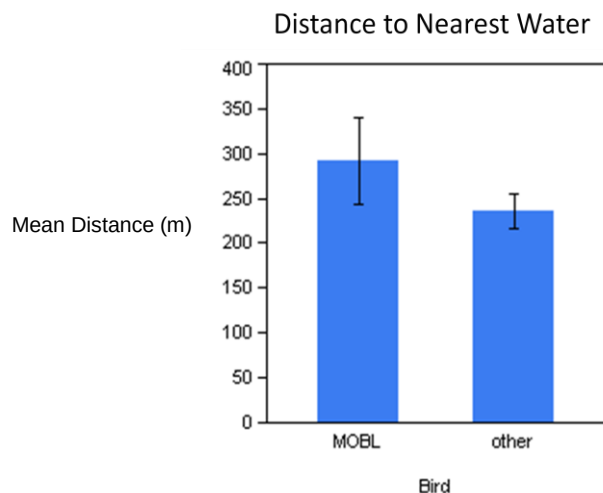


FIGURE 3. Comparison of mean distance to nearest water between mountain bluebird (MOBL) cavities and all other cavities. There is a slight tendency for MOBL cavities to be farther from water than other cavities ($p=0.19$).

There was no significant difference between mountain bluebird cavities and other cavities for all other characteristics. The mean distances of all cavities to edge were generally equal as were mean proportions of tree cover. Nest height was evaluated using a t-test because the data were normal. The difference between mean bluebird nest height and mean height of other cavities was also insignificant.

A Rayleigh's test of the mean nest opening orientation revealed that mean mountain bluebird nest opening orientation is significantly non-random as is opening orientation of all other cavities. Mean mountain bluebird cavity orientation is east-southeast and mean other cavity orientation is southeast. However, further analysis using Watson's U^2 method showed that opening orientation of mountain bluebird cavities did not significantly differ from orientation of other cavities (Zar 1999).

Measured Variable	Mean MOBL	Mean Other	SD MOBL	SD Other	P
DBH (cm)	36.4438	30.8662	9.01053	7.47361	0.06
Distance to Willows (m)	139.006	94.603	80.5493	72.2943	0.10
Distance to Water (m)	291.264	235.320	135.558	154.312	0.19
Distance to Edge (m)	26.1788	23.7231	36.6834	24.1572	0.62
% Tree Cover	61.4663	65.2863	25.1302	23.2863	0.63
Orientation of MOBL cavities	114.363° (E-SE)	N/A	50.635°	N/A	0.02
Orientation of other cavities	N/A	139.049°(SE)	N/A	76.857°	<0.001
Difference between orientation of MOBL cavities and others	114.363° (E-SE)	139.049°(SE)	50.635°	76.857°	$U^2=0.09$

Height of Nest	3.59000m	3.76982m	1.09555m	1.20836	0.72
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TABLE 1. The last column lists p -values for all tests comparing mountain bluebird cavities to all secondary cavity-nesters. Circular statistics were used to analyze cavity orientation, which gives a U^2 value instead of a p -value. The p -value for % Tree Cover was found by using an arcsin transformation. Orientation results are from Rayleigh's test of non-random orientation and the Watson U^2 test. The critical value for our data for the Watson U^2 is 0.1855.

Discussion:

The strongest difference we found for mountain bluebird nest sites is a preference for trees with a larger DBH. These trees are likely selected for thermoregulation purposes and may protect birds from predators. For example, Wiebe (2001) found that cavities in smaller or dead trees had more extreme temperatures during the day and were colder on average during the night than cavities in larger trees. In contrast, cavities in larger trees had a more stable, warmer temperature. Wiebe (2001) suggests that warmer cavities are advantageous in climates with extreme temperatures, such as the Rocky Mountains, and to prevent eggs from becoming too cold when both parents are absent. Thermoregulation is also the likely cause for the non-random orientation of nest cavity openings. Wiebe (2001) found that cavities oriented to the sunny side of the tree were warmer than cavities oriented in other directions. The east-southeast orientation of mountain bluebird cavities would allow the cavities to receive the morning sun. Although, there appears to be considerable benefit to warmer cavities, analysis of cavity temperature in terms of general reproductive success across multiple species has been inconclusive. Further study of reproductive success of mountain bluebirds in relation to cavity temperature would greatly aid in understanding their choice of cavities and nest site requirements.

Another possibility is that the larger trees offer protection from predators and overcrowding. Wiebe (2001) positively correlated tree size to cavity size and Wiebe and Swift (2001) found that birds nesting in larger cavities experienced lower rates of predation and nestling mortality. This possibility assumes that the cavities in larger trees are indeed larger than those in smaller trees. A comparative study of cavity size in trees

of varying size or mountain bluebird cavity size to other cavities would be valuable in determining the advantages of larger trees as nest sites.

The difference between bluebird cavity distance to willows and other cavity distance to willows suggests that proximity to willows is either less important to bluebirds than other factors or that bluebirds are unable to compete successfully for nest sites near willows. Bluebird nest sites are, on average, farther from willows than other nest sites. During this study, we observed one incident of a tree swallow evicting a bluebird leading us to believe that other secondary cavity nesters out-compete bluebirds for nest sites. A study by Aitken and Martin (2008) found that mountain bluebirds are a less dominant cavity nester. This study also found that mountain bluebirds appear to be generalists in cavity selection. Bluebird population does not decrease even when excellent nest sites are limited. Aitken and Martin suggest that the bluebirds became generalists as a result of competition. The bluebirds broadened their niche because they could not out-compete other species for nest sites.

Based on our results, bluebirds select nest sites based on tree size, to some extent on distance to willows but not the other characteristics we evaluated. We believe bluebirds choose sites based on other factors, in particular, we hypothesize that mountain bluebirds select nest sites based on the proximity of other bluebirds and generally inhabit a broad niche. Our casual observations and difficulty finding bluebird nests suggest a wide dispersion of nesting pairs. In addition, a study of secondary cavity nester patch selection found a dispersed rather than random distribution of mountain bluebird nesting pairs. The same study found that mountain bluebirds choose to defer breeding rather than nest close to another pair of mountain bluebirds even when nest sites were “good” (Holt and Martin 1997). These data and our own data resulting in no significant difference cause us to hypothesize that mountain bluebirds select nests to be no less than a certain distance to other bluebird nesting pairs. We encourage further study to test this hypothesis.

We conclude that mountain bluebirds can nest in a wide range of nest sites but require large areas in order to disperse. The species will continue to thrive with forests managed to provide an abundance of cavities. Bluebirds will suffer if forests shrink or excessive tree removal takes place.

These results have implications for the management of biodiversity in forested landscapes. For example, Lohmus and Remm (2005) found that availability of high quality nest cavities determined the population and breeding success of passerines. Jacot, et al (2009) found that secondary nesters spent more time foraging and feeding their young when they nested in poorer quality cavities than did those nesting in high quality cavities. The birds invested more in one brood and worked harder to raise them when the territory was not ideal (Jacot, et al. 2009). It is therefore essential to know what makes a high quality nest to help understand population fluctuations and protect these species.

Furthermore, studies have found that populations of cavity nesting birds, especially mountain bluebirds, are nest site limited (Holt and Martin 1997 and Lawler and Edwards 2002). This means that the strongest determining factor of an area's cavity nesting population is the availability of suitable nest sites. Holt and Martin (1997) suggest that nest site limitation is of particular concern in managed forests where dead or old trees are frequently removed. These are the same trees that often provide nest habitat for cavity nesting birds. Understanding nest site requirements will aid in forest management decisions and protection of secondary cavity nesting species.

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