Nest site selection criteria of House Wrens (*Troglodytes aedon*) at the Beaverhill Bird Observatory.

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Introduction

The House Wren is a small, brown, sexually monomorphic, cavity nesting bird commonly found in backyards and forests of North America. The House Wren is among the many species present at the Beaverhill Bird Observatory near Tofield, Alberta. Four grids of nest boxes found in the Observatory's Aspen-Poplar woodland are highly attractive to the Wrens and provide an opportunity to study their habits. Observations were gathered during the summer of 2015, including, throughout the season, the number of eggs, number of nestlings, and parent encounters. Observations regarding general surrounding vegetation, nest box orientation, nest entrance height, and tree diameter were gathered at the close of the study period. Wren literature was reviewed in order to illuminate the behaviors of House Wrens. Our research aimed to answer the question of whether nest entrance height or orientation or tree diameter, location or species, affect House Wren nest site selection.

Literature Review

House Wrens are found throughout North, Central, and South America; they occupy a diverse range of habitats (Cornell University, 2015). In nature, these cavity nesters seek out hollows and crevices, which provide structural support and protection from the elements, to build their twig nests. Nest boxes offer a convenient option for birds and researchers alike and are a commonly used tool for studying cavity nesters. House Wrens may even occupy a used nest site again in the spring so long as it's in good condition, providing researchers with long-term data collection opportunities (Johnson, 1996). The following literature review summarizes the findings of previous studies concerning House Wren habitat and mate selection, and breeding and parenting behaviors.

A great deal of research has gone into determining key nest characteristics, such as tree diameter, vegetation density, and entrance size, which contribute to House Wren habitat selection and reproductive success. A study in the Midwestern United States found no correlation between nest site selection and box height, distance from water, canopy shading, or recreational activity (Dailey, 2003). This study found did show a peculiar preference for trees with a smaller diameter, even though small trees were found to be somewhat significantly less safe for wren nests than larger trees. Further study of the relationship between nest site selection and tree diameter was suggested, as the benefits of smaller trees were unknown (Dailey, 2003). Finch found nests with sparse surrounding foliage had a greater number of positive reproductive outcomes (1989). The researcher proposed less vegetation surrounding the nest site enabled parent wrens to better detect and deflect predators. A small entrance to the nest was found to be an important feature in deterring predators and parasitic birds (Stanbeck et al., 2013). If the nest entrance is not small enough, wrens build up the structure of the twig nest, creating a berm, to act as barrier (Stanbeck et al., 2013). Entrance shape and size affects the final nest architecture; males will choose narrower twigs from a lighter less dense species of tree when the entrance is smaller, and twigs from thicker heavier species of tree for a larger entrance (Kennedy & White, 1992). Once House Wren males have selected a territory, courtship can begin.

House Wren nest selection and breeding behavior are closely intertwined. The primary architecture of the nest is determined by the male House Wren who initializes building by creating a twig structure within a hollow space, bringing materials into the nest site one at a time (Kennedy & White, 1992). Each male will stake out and protect a territory; the fitter the male, the larger its territory and the more opportunities it will have to mate (Finch, 1989). Males create multiple nests within this territory to increase their chances with a female, though they appear to have no specific site selection criteria (Finch, 1989). His song is then wards off competing males and predators from his territory as well as attracts females to form a primary pairing for the breeding season (Johnson & Searcy, 1996; Brylawski & Whittingham, 2004). The female then selects the most suitable site amongst the male's nests and adds lining material such as grasses, feathers, and other soft found materials (Kennedy & White, 1992). The remaining male nests, known as dummy nests, may also serve to distract/deflect predators from the actual nest (Finch, 1989). Once the nest has been selected and completed the female will insulate the nest with softer materials, lay her clutch, and incubate the eggs.

The female House Wren lays a clutch of approximately two to eight eggs, and incubates the nest alone. Females may choose to delay incubation until their entire clutch is laid causing the nestlings to hatch synchronously. Bowers, Sakaluk, and Thompson (2011) found this behavior resulted in more consistent nestling size and weight upon hatching compared to immediate incubation; synchronous hatching was more likely if resources were plentiful during the nesting period. Throughout incubation, the male returns to the nest frequently. Once he encounters hatched nestlings, he begins aiding in their provisioning (Johnson, Brubaker, & Johnson, 2008). Nestling begging behaviors guide the rate parents provide for their young. Parasitism, such as that of blow fly larvae, can cause nestlings to weaken and lowers their ability to beg for more food (Morrison & Johnson, 2002). When the parents were not aware of the nestlings' need for more resources, there was no difference in the rate parents fed healthy nestlings and nestlings afflicted with blow fly larvae (Morrison & Johnson, 2002). A more recent study revealed the presence of cooperation amongst nestlings, where even though older more developed nestlings may be ready to fledge sooner, they may choose to delay fledging until their younger siblings are also ready (Bowers, Sakaluk, & Thompson, 2013). Delayed fledging prolongs parental care for all nestlings and increases survival chance of all nestlings whether older or younger (Bowers, Sakaluk, & Thompson, 2013). Many efforts are made by both parents towards reproductive success and survival of their offspring.

A great deal of effort is made by the House Wrens to ensure reproductive success. To successfully raise a clutch of nestlings, nesting conditions must meet the female's expectations. Based on information gathered in the literature review, the male House Wren designates his territory, finds suitable nest sites, and builds several nests. The female then selects the nest site that best suits their needs; tree diameter, foliage cover, and entrance size may all play a factor in this decision. With our own research, we were able to study the effects of tree diameter and species, as well as nest box height, orientation, and location on the female's nest site selection

Methods

In order to understand which factors contribute to nest site selection in House Wrens, primary research was conducted on four separate grids (labeled A, B, C, and D) on the Beaverhill Bird Observatory ground east of Tofield, Alberta, Canada. Each grid contained 24 or 25 nest boxes for a total of 99 boxes of identical shape and structure approximately thirty paces apart and marked by pink flag tape. Box lids were secured with wire, which was replaced as necessary throughout the study period. Five boxes were occupied by Tree Swallows (*Tachycineta bicolor*) prior to the House Wren breeding season. While observations were still taken on these nests, this data was not used in the final data analysis as these boxes were not available to the House Wrens for habitat selection. Thus, a sample size of 94 boxes remained.

Observations were conducted twice a week during the House Wren breeding season throughout June and July, ranging from three to five days apart for a total of 16 observations per box. To monitor habitat selection, behavior, and development of House Wrens (*Troglodytes* *aedon*), our observations included nest activity and development, egg count and temperature, presence of adult birds, and, later, nestling number and age. Pictures of nestlings were taken on smart phones to assist with aging. Data regarding tree identification and diameter, box height and direction, and nest characteristics (berm height and cup depth) were taken in August 2015 following the fledging of all nestlings. Dimensional measurements were taken using a measuring tape, while direction facing was recorded using a compass application on a smart phone. Because of questionable accuracy of the compass application, only the cardinal directions were used in analysis.

Raw data from the initial observations were used to determine reproductive success, incubation periods, and time until fledge for each nest. However, researchers agreed that these observations were not frequent enough to provide reliable data for the evaluation of developmental or behavioral attributes.

In an attempt to answer the research question of whether nest characteristics, such as box height, orientation, and location and tree species and diameter, affect female House Wren nest site selection, multiple single-factor ANOVA, Spearman's rank correlation, and Chi^2 (test for association using a contingency table and test for homologous frequencies) tests were performed using Microsoft Excel.

Results

Fifty boxes showed nest building activity; of these, 34 were successfully used to foster young ("active"). Of these active boxes, 28 were occupied by House Wrens and six by Tree Swallows. Boxes that showed initial nesting activity -- but never developed a cup or housed a clutch -- were assumed to be dummy nests built by the male House Wren at the beginning of the breeding season.

Our own observations of nests matched the general descriptions found in other literature; a deep twig nest with lined cup. Lining materials observed were usually dried grasses and gathered herbs, though occasionally, shed snake skins and even flag tape were found incorporated into nest lining.

A total of 164 nestlings were recorded to have fledged throughout the study period, 27 of which were Tree Swallows; the remaining were House Wrens. This data excludes two boxes used for a House Wren nestling aging study in which, in order to reduce stress placed on the nestlings, regular observations avoided. Nest state, box orientation, tree diameter, and nest entrance height, were still recorded for data analysis in these boxes. Average reproductive success of House Wrens (number of eggs laid versus nestlings successfully fledged) was 0.796, meaning approximately 80% of eggs laid survived to fledge the nest

The remaining data gathered has been organized into categories for further analysis: continuous data and categorical data.

Continuous data

Tree Diameter.

Spearman's Rank Order was used to test for correlation between tree diameter and nesting state. Analysis of the tree diameters of active, dummy, and inactive nests (assigning active a high numerical value, and inactive a low value) revealed an R_s value of -0.207, which is less than the left-tailed critical value of -0.175. The null hypothesis was rejected; a significant correlation between tree diameter and nesting state was found. These results were supported by a Single-Factor ANOVA test comparing the mean diameters of trees with active, dummy, and inactive nests. This analysis produced an F value of 3.69, which is greater than the F_{crit} of 3.10, with a probability of 0.035. Based on these results, we can reject the null hypothesis for the

ANOVA. There is a difference amongst the mean diameters of trees with active, dummy, and inactive nests.

Table 1. Single-Factor ANOVA results comparing nesting state and tree diameter.

Source of Variation	SS	df	MS	F	P-value	F-crit
Between Groups	930.28	2	465.14	3.69	0.029	3.10
Within Groups	11093.72	88	126.07			
Total	12024	90*				

*It should be noted that tree diameter for one box was missed in the data collection. Data for that nest box was not used in this analysis.

Nest Box Height.

Spearman's Rank-Order correlation analysis and single factor ANOVA were also used to compare nest box heights of active, dummy, and inactive nests. The Spearman Rank-Order, when assigning an active state a high numerical value and inactive a low value, revealed an R_s value of-0.198, which was less than the left-tailed critical value of -0.176. Results of a Single-Factor ANOVA yielded an F value of 4.37, which was greater than the F_{crit} of 3.10 with a probability of 0.015. The null hypotheses of both tests were rejected. A significant difference was found between the mean nest box heights of active, dummy, and inactive nests and a significant correlation was found between nest box height and nesting state.

Table 2. Single-Factor ANOVA results comparing nesting state and entrance height.

Source of Variation	SS	df	MS	F	P-value	F-crit
Between Groups	825.82	2	412.9127	4.37	0.015	3.10
Within Groups	8400.02	89	94.38			

Total	9225.85	91

Categorical data

Categorical data including tree species the box was mounted on, direction the box faced, and grid in which the box was located were analyzed to determine if they impacted habitat selection. A Chi-Square test for association was performed on all active, dummy, and inactive boxes for each aforementioned parameter to determine if there was a difference in the distribution of these parameters between activity levels. Three Chi-Square tests for homologous frequencies were also conducted on the active boxes to determine if there was a difference in frequencies among these parameters compared to the entire data set.

Tree Species.

The Chi-Squared test for homologous frequencies, using the Yate's correction for continuity, was performed to determine if there was a divergence from the expected frequencies of tree species (either *Populus tremuloides* or *Populus nigra)* within the active box compared to the entire data set. The null hypothesis was rejected, and a difference from the expected ratios was observed (X^2=0.25, df=1, $p(H_o)$=0.38). The test showed the ratio of active boxes situated on *Populus tremuloides* trees was greater than that of all available nest boxes (active, dummy, and inactive) on *Populus tremuloides* available. However, the Chi-Square test for association indicated there was no significant difference in the distribution of tree species between the active, dummy, and inactive box sets (X^2=2.03, df=2, $p(H_o)$=0.36). The alternative hypothesis that tree species distribution would differ between the different levels of activity was rejected.

Box Orientation.

Both Chi-Squared tests were performed in a similar fashion to compare the frequencies of boxes oriented in one of six cardinal directions (north, northeast, east, southeast, south, and southwest) in the various activity levels. It is important to note that none of the boxes in the study were facing west or northwest, so these levels were omitted from the analysis. The Chi-Squared test for homologous frequencies was used to determine if there was one direction the female birds preferred in order to carry the nest out to a fully active state. The test for homologous frequencies showed no such significant difference; the null hypothesis failed to be rejected (X^2=3.16, *df*=5, $p(H_o)$=0.68). The distribution of active boxes as to which direction the boxes were facing did not deviate from that of the full data set. The Chi-Square test for association also did not find a significant difference (X^2=10.50, *df*=10, $p(H_o)$=0.40) and there was a failure to reject the null hypothesis that stated there was no association between box orientation and activity levels.

Box Location.

Finally, the same Chi-Squared tests were used to determine if there was a difference in activity levels by grid. The Chi-Squared test for homologous frequencies compared the distribution of active boxes between grids to that of all boxes being used for data collection. This test resulted in a failure to reject the null hypothesis; there was no significant difference found between the frequencies of active boxes compared to all boxes in each grid (X^2=5.17, *df*=3, $p(H_o)$=0.16). The Chi-Squared test for association also found no difference between the frequency distribution of active, dummy, and inactive nests in each grid; there was a failure to reject the null hypothesis that there is no association between nest activity and grid location (X^2=10.55, *df*=6, $p(H_o)$=0.10).

Discussion

Spearman's rank correlation revealed an inverse association between tree diameter and nesting state; activity decreased as tree diameter. The ANOVA revealed a significant difference amongst the mean tree diameters of active nests, dummy nests, and inactive nests. Further testing would be required to reveal the precise nature of the difference. This analysis supports Dailey's study of nest site characteristics and nest use, which found tree diameter affected nesting state (2003). This study indicated that House Wrens might prefer smaller diameter trees, though the reason for this was not known (2003). It is possible the diameter of the tree indicates some level of suitability to the House Wren. Perhaps a smaller tree would seem younger, healthier, and, therefore, safer for nesting. It is also possible that the female might associate a smaller diameter tree with a smaller nesting cavity may be more easily secured against predators and parasitic Cowbirds.

Spearman's rank correlation also revealed a negative association between nest box height and nesting state: box height increased as activity decreased. The ANOVA revealed a significant difference amongst the mean nest box heights of active nests, dummy nests, and inactive nests. Further testing might reveal the precise nature of this difference. Where this study found the possibility of an association between nest box height and nesting state, Dailey's study found none (2003). Dobkin, Rich, Pretare, & Pyle (2015) also found that House Wrens exhibited the widest range in nest height entrance amongst several other cavity dwellers. It is possible House Wrens in different populations and environments have developed some divergent behaviors to account for differences amongst vegetation or predator variety. Box height may be relative to surrounding vegetation; if certain nest box heights were more likely to have cover via the surrounding undergrowth that might explain the correlation. It has been shown that House Wrens, unlike some other altricial birds, actually prefer less cover surrounding their nest entrance, as that allows male a better vantage from which to warn females of the presence of predators (Finch, 1989).

A Tukey test may serve to indicate which means have a significant interaction post-ANOVA; however, in analyzing both tree diameter and box height, there is an unequal number of observations for each sample. A Tukey test cannot be run unless there are an equal number of observations per sample. More definitive conclusions with regards to tree diameter or nest box height compared to nesting state could perhaps be made with more data. Future interns could gather similar observations and use data from multiple years to pinpoint more precise relationships.

The majority of categorical data showed no significant difference in terms of tree species, direction in which the box was facing, or grid location when analyzed using the Chi-Squared test for homologous frequencies and the Chi-Squared test for association. These tests were chosen to determine if there were any distinguishable criterion sought out by female (indicated by active boxes) House Wrens when choosing nest site compared to male House Wrens (indicated by active and inactive boxes). Based on the results, the birds have no preference in any of these categories with the exception of the results in the test for homologous frequencies for tree species. This test showed a larger proportion of active nests located on *Populus tremuloides* than the proportion of available boxes on these trees. While the test statistic was larger than the critical value found during the analysis, the p-value was quite high, leading to the assumption that this difference was not significant. The ratios were only off by 1.8 trees, which may have been by chance or due to a small sample size, resulting in a Type 1 error. This inference is supported by the results of the equivalent test for association. It found no difference in the ratio of *Populus nigra* and *Populus tremuloides* trees between the active, inactive and dummy boxes. Further testing is recommended using a larger sample and wider variety of trees (as *Populus* *tremuloides* and *Populus nigra* are closely related) to determine whether tree species influences nest site selection.

Information regarding the purposeful eastward orientation of the nest boxes was relayed to the researchers at a later time. This action is congruent with the research conducted by Dobkin, et al. (2015) that showed that most non-excavating cavity dwelling species, including House Wrens, prefer east facing entrances. This same research however, found an aversion to boxes oriented towards southwest, which was not consistent with our findings. Our study showed no difference in the levels of activity between the boxes of the remaining six cardinal directions.

It is recommended that the categorical data be analyzed using the G-Test for more accurate depictions of associations and frequency distributions. While this test is very similar to the Chi-Squared test and offers similar results, it offers more accurate distribution as its values are additive. Using a more powerful test on the grid analysis is especially recommended, as both Chi-Squared tests displayed low p-values (<0.17). Unfortunately, this test was beyond the scope of the researchers and thus was not included in the study.

While these results reflect the nesting activity of the House Wrens present at the Beaverhill Bird Observatory this year, the sample sizes were quite small. A total of only 28 active nests does not allow for sweeping generalizations. Further study using larger sample sizes or comparing data over multiple breeding seasons is recommended to confirm the conclusions of this study.

Conclusion

Research revealed the presence of a negative correlation between tree diameter, nest box height, and nesting state. There was also a significant difference amongst the mean tree diameters and mean nest box heights of active, dummy, and inactive nests. It appears that tree diameter and nest box height have an effect on the nest site selection of female House Wrens. Female House Wrens prefer smaller, younger trees, and nest boxes somewhat lower to the ground; the reasons for this are not known. Categorical data analysis revealed no significant difference inactivity level frequencies in tree species, box orientation (excluding north and northwest orientations), or grid location. These nest characteristics seem to have no effect on nest site selection in House Wrens. Further study, perhaps comparing multiple years of observations at the Beaverhill Bird Observatory, could supply more data for analysis, larger sample sizes, and thus, more authoritative results and conclusions. Discovering which combination of tree diameter and nest box height House Wrens prefer, future House Wren grids could be set up accordingly in order to promote nesting activity.

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