AN ABSTRACT OF THE THESIS OF

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Title: NEST BOX SELECTION OF WOOD DUCKS AS INFLUENCED BY COLOR AND SITE FACTORS

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Howard M. Wight

Selection of colored nest boxes by wood ducks (Aix sponsa) was evaluated during the breeding seasons of 1967-68 in Benton County, Oregon. No color or site factor influence was observed in 1967 when nest boxes were erected in sets of eight boxes served in 1967 when nest boxes were erected in sets of eight boxes adjacent to water. Color and site factor influence was observed in 1968 when the nest boxes of a set were erected on a diagonal plane extending from water's edge into the woods. Nest box selection by adult hens in 1968 was influenced by a strong fidelity to color of the box in which they had successfully nested in 1967. Nest box selection by yearling hens in 1968 was not influenced by color of the box in which it hatched but was related to an interaction of color and vegetational obstruction in the foreground of the box. Bright colors (white, yellow, orange and red) appeared to offset the adverse
effects of vegetational obstruction on nest box selection. Nest box selection and inspection was found to be influenced by visibility of the entrance hole. No relationship was determined between the location of the first nest selected within a set and selection of subsequent nest boxes within the same set.

It appears that erecting boxes painted conspicuous colors will enhance utilization of boxes in woody areas and will increase the available nesting habitat away from the margins of a pond or a stream.
Nest Box Selection of Wood Ducks as Influenced by Color and Site Factors

by

Thomas Earl Morse

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NEST BOX SELECTION OF WOOD DUCKS AS
INFLUENCED BY COLOR AND SITE FACTORS

INTRODUCTION

For the past 30 years, conservation agencies have been erecting nest boxes to benefit wood duck populations. Emphasis given to wood duck box investigations in the past have been development of predator-proof boxes (Bellrose, Johnson and Meyers, 1964), studies of population dynamics and general ecology (Grice and Rogers, 1965), and studies to evaluate the effectiveness of nest box erection programs as a management tool (McLaughlin and Grice, 1952; Naylor, 1960). The basic factors influencing nest box selection by wood ducks have not received intensive investigation. This is a report on investigations of some factors influencing nest box selection by wood ducks.

Hilden (1965) in a review of habitat selection in birds reported that nest site selection is an instinctive activity. As with instinctive activities in general, the nest-site-selection behavior is an innate reaction released by certain environmental stimuli, according to the principle of stimulus summation. However, the releasing mechanism of nest site selection seems to be triggered by a few key perceptual cues. For example, in the northern eider, (Somateria mollissima borealis), a key stimulus for nest site selection is the presence of stone shelters (Cooch, 1965). In cavity nesting species,
the key stimulus for nest site selection is the presence of a suitable
nest hole (von Harrtman, 1957).

Variance in selection of nest boxes by wood ducks according to
types of boxes and placement of boxes has been suggested in data
reported by Bellrose et al. (1964), McLaughlin and Grice (1952) and
Naylor (1960). Bellrose et al. (1964), reporting on attempts to devel-
op a more effective predator-proof nest box, stated that metal houses
need improvements to make them more acceptable to wood ducks
initially. McLaughlin and Grice (1952) and Naylor (1960) report that
wood ducks are not particularly adept at locating nest boxes and the
more conspicuous the box, the greater the chance of occupancy by
wood ducks. These conclusions were based upon observations of new
wooden boxes being selected over older, more weathered boxes. Also
these investigators noted that boxes in open stands near water were
selected in preference to boxes away from water and in dense woods.
Data gathered by the author in Benton County, Oregon, during the
1965 breeding season revealed that new nest boxes were initially
selected at a greater rate than older nest boxes. These data were the
basis of a preliminary investigation during the 1966 breeding season
on the response of wood ducks to a small sample of colored nest boxes.
I investigated the nest box selection response of wood ducks to sets of
red, green and old natural nest boxes (unpainted, weathered, wooden
boxes) on the William L. Finley National Wildlife Refuge and to sets
of yellow, white, green, new natural (unpainted, unweathered, wooden boxes) and old, natural nest boxes in an "off refuge" study area. The results of this investigation indicated a strong selection by wood ducks of red boxes in the refuge sample and of yellow and white boxes in the "off refuge" sample regardless of other site factors such as height of nest box, nearness to water and vegetational obstruction of the box.

Although a color selection response was indicated by the 1966 study, it was believed that the results should be considered inconclusive because:

1) The colors used did not adequately represent the major bands of the visible spectrum.

2) The sample size for each color was too small for the data to be conclusive.

3) The colors used on one study area did not always have a counterpart on the other area; therefore, selection responses on the two areas could not be compared.

4) Other site preference factors were not uniformly controlled.

The 1966 study suggested that presence of physical factors such as color and/or conspicuousness of the entrance hole might be related to nest site selection; thus providing the basis for undertaking the research reported here. Specific objectives of this research were:

1) To determine the relationship of entrance hole sign stimuli to nest box selection.
2) To determine the existence of a color preference by the female wood duck as indicated by nest box selection.

3) To determine the relationship of visibility of the area of the nest box to nest box selection.

4) To determine if the color of a box in which the female nested in one year, or in the case of yearling females the color of box in which it hatched, influenced the selection of a color the following year.
STUDY AREA

The study area was situated on the alluvial flats of Benton County, Oregon. The geomorphology of the area was typical of most of the Willamette Valley of Oregon (Baldwin, 1964). Oxbow lakes, sloughs and meandering streams bordered by trees were the breeding habitats of the wood duck in this area. The common tree species in the study area were red alder (Alnus rubra), Oregon white oak (Quercus garryana), hawthorn (Crataegus sp.), big leaf maple (Acer macrophyllum), Oregon Ash (Fraxinus latifolia) and Douglas fir (Pseudotsuga menziesii). (Nomenclature follows the U. S. Forest Service Check List of Native and Naturalized Trees of the United States, 1953.)
METHODS

This research was founded on the hypothesis that there are perceptual cues associated with a nest box which influence wood ducks to inspect and possibly select a particular box as a nest site. The 1966 study suggested that color was one of the most promising of these perceptual cues to be investigated. Through the use of paints for which the dominant wave lengths and degrees of purity are known, a range of perceptual cues including color and conspicuousness of the nest box becomes measurable and may be analyzed as factors influencing nest box selection.

Seven colors were selected to be tested. These colors were selected from the Kern Bulletin line of paints of the Sherwin-Williams Company. The colors selected were Bright Red, Medium Orange, Lemon Yellow, Light Blue, Medium Green, Black and White. Natural wood finish was used as the control color. The dominant wave length and degree of purity for each of the paints used are presented in Table 1. The degree of purity is a rough estimate of the saturation (the vividness of a hue, as differing in degree from grey) of a color. The fully desaturated white represents a zero purity (Wight, 1946). These colors were applied to the exterior surface of the nest boxes. The interiors of all nest boxes were painted flat black to enhance the contrast of the dark entrance hole to the exterior color of the box and
to standardize this contrast among boxes of the same color.

The nest boxes were erected prior to the breeding season in sets of eight with each color represented. To insure randomization of colors and equal color juxtaposition among sets, the balanced Latin square design was employed in erecting the boxes within the sets. Sixteen sets of eight nest boxes were erected. Because the nest boxes were attached to trees, a number of environmental factors were introduced. The following standardized methods were used when erecting the sets. All nest boxes in a set were erected at the same height. The space between nest boxes ranged between 25 and 50 feet, and all nest boxes within a set were of the same design and size. All nest boxes were constructed from 1 x 12" cedar boards. About 1/3 of the boxes were of the design described by Bellrose (1953). The rest of the boxes differed only by having a 1:12 incline to the face of the box. Depth and kind of nesting material was uniform.

The number of sets per area was determined by the number of females expected to nest on a given area. The number of nest boxes erected on each area was roughly twice the number of females that were estimated to return to that area. The number of returning females was calculated by applying the mortality rate estimates for wood ducks in the Mississippi Flyway (Bellrose et al., 1964) to the number of birds nesting and produced on the study area in 1966. These mortality rates were used because no reliable mortality rates were available for the Pacific coast wood duck population.
Nest boxes were inspected at least twice weekly during the nesting season. Data collected at each inspection were: presence of a bowl formed by a female in the nesting material, amount of down, number of eggs, number of young and the species nesting. One other species of cavity nesting waterfowl, the hooded merganser, \textit{(Lophodytes cucullatus)}, nested on the study area. Because of the paucity of information on the breeding biology of the hooded merganser and because of the low numbers of breeding birds, they were allowed to nest within the boxes on the study area. The decision to allow the hooded merganser to nest within the experimental nest boxes necessitated adding an additional nest box of the same color in the same location as the box which the merganser selected. In this manner the wood duck could select from the entire range of colored boxes.

A nest box was considered selected when a nest was formed within the box. A nest is defined as one in which one or more eggs were incubated or in which down was deposited.

In order to determine what influence a particular colored nest box had on the subsequent nest site selections of individual birds, an attempt was made to band all incubating hens and their young. Incubating hens were banded with standard U. S. Fish and Wildlife Service bands. The young were banded with fingerling fish tags (Style 1005, Size No. 1), as described by Grice and Rogers (1965). The incubating hen was captured on the nest by attaching a small board
over the entrance hole. The hens were trapped and banded during their second or third week of incubation. The young were trapped in the nest box on the day of hatch. The technique of handling the young during banding was the same as described by Grice and Rogers (1965). Application of the fingerling tags differed slightly from the method described by Grice and Rogers (1965). By sharpening both ends of the tag, I was able to apply the tag by pushing both ends through the web. The tag was then closed with the aid of a pair of needle-nosed pliers. This application technique reduced handling time by approximately one-half of that required to tag the birds using the application methods of Grice and Rogers (1965) and gave satisfactory tagging results.

Three basic set designs were utilized in this research. In 1967 each set was erected adjacent to the water's edge in such a manner that nothing obstructed the visibility of the box from the water. Sixteen sets were erected in 1967. In 1968 two set designs were used. The primary design was the erection of 16 sets on a diagonal plane from the water's edge and proceeding back into the woods. The objective of this design was to determine the influence of color on nest box selection within an increasing gradient of vegetational obstruction. Henceforth these sets will be referred to as diagonal sets. Two additional sets were erected in 1968. These were erected adjacent to water. Every other box in the set was attached to the side of the
tree facing away from the water. The main objective of this design was to measure the significance of the entrance hole as a perceptual cue. These sets will hereafter be referred to as alternate sets. All sets in 1968 were relocated so that site fidelity by returning hens and their progeny to a specific area would not be a major factor in the analysis of the 1968 data.

Because the basic objective of the diagonal set design was to evaluate the influence of color as a nest selection factor in a situation of increasing amounts of vegetational obstruction it became necessary to make estimates of the amount of vegetational obstruction of each nest box within a set. This was done in the following manner: a piece of white canvas measuring three feet by two feet was partitioned into six inch squares with one-half inch black electricians tape. This "cover density sheet" was then wrapped around the nest box. Each of the three sides had eight squares of 36 square inches each. The individual who attached the sheet to the box then directed the observer to four observation points in front of the box (Figure 1). At each point the observer counted the number of squares seen (a maximum of 16 was possible) from an elevation approximately equal to the height of the box. This estimate was taken at the time of complete foliage. After each estimate of complete foliage was made, the individual at the nest box looked toward the observer and estimated how many more squares could have been seen if there had been no leaves,
giving an estimate of the visibility prior to leafing-out. The sum of the squares seen and estimated at all four points was divided by the total number of squares possible from all four points (64). This technique resulted in an index of the vegetational obstruction between the box and the water. This index will hereafter be referred to as visibility index and/or visibility of the box. While it can be justly criticized that the estimate of vegetational obstruction prior to foliation is crude, it was not discovered that these measurements were needed until the completion of the 1968 breeding season.

One additional measurement was obtained so that color and visibility could be evaluated as factors of nest box selection. This measurement was an estimate of the role that color played in the conspicuousness of the box. Samples eight inches square of all eight colors were erected in two situations. In one situation the colors were placed in the shade and in the other they were placed in the sunlight. Trees were the background in both situations. In each case observers were transported in a car from a starting point 0.5 mile from the colored samples. Nine stops were made at 0.05 mile intervals. The observers recorded which colors were seen from all points. This method resulted in a frequency distribution of colors seen at all points. I then determined a relative conspicuousness ranking of each color in an ascending order. It was assumed that the scale of color conspicuousness for a group of men approximated that for wood ducks.
The ranking of the colors in sunlight in an ascending order from least to most conspicuous was black, green, blue, natural, red, orange, white and yellow. The conspicuousness ranking of the colors in a shaded situation was black, natural, green, blue, yellow, red, orange and white. The latter ranking of conspicuousness was utilized because the shaded situation most closely approximated the conditions of the erected boxes.

Females were aged during the 1968 breeding season only. Age of the nesting females was determined by two methods: presence of a marking from the previous year (standard leg bands, web-tags or scars of web-tag tear-outs), and by wing plumage characteristics. Presence of a leg band indicated the bird to have nested on the study area in previous years or to have been banded and aged in fall banding operations. Presence of a web-tag or scar of a web-tag tear-out indicated a yearling duck because web-tags were applied for the first time in 1967. The wing and body plumage characteristics of the web-tagged hens nesting on the study area in 1968 were checked for retention of juvenile plumage characteristics. All nine of the web-tagged females that nested on the study area in 1968 possessed the wing characteristics reported by Carney (1964) for the immature female during the early part of the fall. Other plumage characteristics of the yearlings were brown flaking in the crown feathers and a dull brown coloration of the neck, back and rump feathers. These
characteristics, however, were variable and not as consistent as the wing characteristics. The adult hens possessed the adult wing of the fall and iridescent coloration of the rump, back and crown feathers. The plumage characteristics of the unmarked females nesting on the study area were checked and these birds were classified as yearling or adult on the basis of wing characteristics.

Table 1. Dominant wave lengths and percent purity of paints used in this investigation.

<table>
<thead>
<tr>
<th>Color of Paint</th>
<th>Black</th>
<th>Blue</th>
<th>Green</th>
<th>White</th>
<th>Yellow</th>
<th>Orange</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant Wave Length</td>
<td>479</td>
<td>477.8</td>
<td>521</td>
<td>579</td>
<td>580</td>
<td>594</td>
<td>618</td>
</tr>
<tr>
<td>Percent Purity</td>
<td>2.0</td>
<td>60.8</td>
<td>22.0</td>
<td>2.0</td>
<td>89.5</td>
<td>83.8</td>
<td>75.0</td>
</tr>
</tbody>
</table>
Figure 1. Location of the four observation points from which the vegetational obstruction was estimated. Observation points of the first and last box in a diagonal set are illustrated to indicate relative distance and position of the observer.
RESULTS

Nesting Chronology

The pattern of nest initiation for the 1967 and 1968 breeding seasons was roughly bimodal with one peak occurring in early April and another in late April or early May (Figure 2). The first peak of nest initiation represented the nesting activities of adult hens. The second peak was primarily the result of yearling nest initiations, with some nests by adults represented (Figure 2). The adult nests during this second period may be renesting attempts (Grice and Rogers, 1965). The nest initiation dates for wood ducks in the study area were quite similar to those reported for wood ducks in the Eastern United States (Bellrose et al., 1964; Grice and Rogers, 1965).

Site Factors and Nest Box Selection

The factors relating to nest box selection considered in this study were divided into two general categories: factors associated with the site of the wood ducks nest box, and those associated with color of the nest box. Because visibility of the box is influenced by both the site and the color of the box, visibility will be discussed twice: once, when only visibility as affected by obstruction of foliage is considered, and again when the color of the box and the obstruction by foliage are considered together.
Figure 2. The nest initiation chronology of wood ducks for the years 1967 and 1968 with nest initiation dates of adult yearling hens being noted.
**Tree Diameter**

In 1967 nest boxes were erected in such a manner as to eliminate most of the site variables; however, the diameter at breast height (d. b. h.) of the trees (to which nest boxes were erected) varied. An analysis of the influence of d. b. h. on nest site selection during 1967 revealed no differences in the rates of selection of boxes attached to trees of varying d. b. h. (Table 2). The selection rate of boxes attached to trees in all three d. b. h. categories was approximately equal. It is the opinion of the author that no differences in the selection rates of boxes as related to d. b. h. of the tree should be expected. In nature the only apparent significance of d. b. h. is that it limits the maximum inside dimensions of the cavity. Wood ducks are selecting nest boxes, in part, on the basis on the "d. b. h." of the box which in this case was the same for all boxes of a set.

**Position of the Box Within the Set**

Although it has been reported that the wood duck does not exhibit territorialism and as a result can be induced to nest in colonies (Grice and Rogers, 1965), it was possible that a preferential selection could exist for boxes in certain positions within the set due to boxes being concentrated in sets. Analysis of box selection by wood ducks with regard to position of the box within the set revealed no
differential selection during 1967 (Table 3).

Table 2. The relationship of nest box selection by wood ducks and diameter of the supporting tree (1967).

<table>
<thead>
<tr>
<th>Tree diameter at breast height (inches)</th>
<th>4-8 inches</th>
<th>8-12 inches</th>
<th>12+ inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. available</td>
<td>21</td>
<td>62</td>
<td>45</td>
</tr>
<tr>
<td>No. boxes selected</td>
<td>10</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>Selection rate</td>
<td>48%</td>
<td>52%</td>
<td>49%</td>
</tr>
</tbody>
</table>

Table 3. The number of wood duck nests initiated in each box position within the set in 1967.

<table>
<thead>
<tr>
<th>Box Position*</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nests</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

* Because these sets were erected in a row adjacent to water, positions 1 and 8, 2 and 7, 3 and 6 and 4 and 5 are essentially identical as to position.

Influence of Position of First Nests on Subsequent Nest Site Sections

During 1967 it appeared to the author that the selections of nest boxes within sets tended to be clustered about the nest box first chosen. Should this be true then two possible factors other than color could be influencing the selection of boxes. One of the most obvious factors would be environmental variation within the set. Differences in environmental variation would be smallest between adjacent boxes.
and therefore the clustering of nests in adjacent boxes may be a reflection of response to a preferred habitat. The second possible factor would be the social stimulus of the bird in the first nest. Bellrose et al. (1964), reported that yearlings "attach" themselves to a pair of older ducks and accompany them on their trips from water areas to the area of the nest. As a result the yearling hens might be influenced to nest near adults. Under the conditions of the 1967 set design (eight boxes in a row) it would be possible for ducks to be influenced in selecting a box adjacent to a nest already initiated. The frequency of selection of boxes adjacent to an active nest was compared to the frequency of selection of non-adjacent boxes. This was done only for selections by the second and third birds nesting within a set. This analysis was made by computing the ratio of the number of adjacent boxes selected to the number of adjacent boxes available and comparing to the ratio of the number of non-adjacent boxes available, for all sets in which at least two nests were initiated (Table 4). A Chi-square test was performed to determine if a significant difference existed between the two ratios. The resultant Chi-square value of 0.7356 (one d. f.) indicated that nest site selection for the second and third nests within the sets was essentially random (P>0.5 but <0.3). It was concluded that there was no attraction of ducks in a set due to preferred habitat. It was also concluded that the presence of an established nest within a set did not influence subsequent selection
Table 4. The selection of boxes by wood ducks adjacent and non-adjacent to the first and second nests initiated within a set (1967).

<table>
<thead>
<tr>
<th>Box Selections</th>
<th>No. adjacent boxes available</th>
<th>No. adjacent boxes selected</th>
<th>No. non-adjacent boxes available</th>
<th>No. non-adjacent boxes selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second nest¹</td>
<td>24</td>
<td>4</td>
<td>69</td>
<td>10</td>
</tr>
<tr>
<td>Third nest²</td>
<td>31</td>
<td>7</td>
<td>46</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>11</td>
<td>115</td>
<td>16</td>
</tr>
</tbody>
</table>

¹ The second nest within a set was analyzed as to selection of boxes adjacent and non-adjacent to the first nest.

² The third nest within a set was analyzed as to selection of boxes adjacent and non-adjacent to the first and second nest within a set.
other than to make this box unavailable. Only the first three nest selections were analyzed because it would be here that clustering of nests due to one of the two factors would occur. After the third nest box was chosen in a set the number of adjacent boxes available was equal to or greater than the number of non-adjacent boxes. A biased answer would therefore result if more than three nests in a set had been used in the analysis. Only those situations in which the second or third nest was initiated before the young hatched and left the first nest were used in the analysis. No attempt was made to analyze the adjacent and non-adjacent nest box selection in 1968 because of the obvious environmental dissimilarity between boxes within a set.

Visibility of the Nest Box as a Factor of Nest Site Selection

Visibility of the nest box has been recognized by most investigators to be an important factor influencing box usage by wood ducks. McLaughlin and Grice (1952) state that "evidently the wood duck is not particularly skillful in locating the boxes if at all hidden. The female begins her search for a nesting cavity in the trees bordering or nearest to a waterway. If the boxes are placed so that the entrance is visible from the travel lanes or waterways used by the returning ducks, they will be easily seen and more readily utilized." In general the greatest usage of nest boxes occurs when they are placed in open situations (Bellrose, 1953; Bellrose et al. 1964; Naylor, 1960;
Because the basic objective of the 1968 experimental set design was to evaluate the role of color as a factor of nest box selection in a situation of decreasing nest box visibility (increasing vegetational obstruction), it was necessary to obtain estimates of the vegetational obstruction for each nest box. Two estimates were needed: one prior to bud burst and leafing out, and one afterward. April 20, 1968 was the median date for leafing out of different species of trees on the study area. The visibility index estimated for each box for each time period was plotted with the position of the box within the set (Figures 3 and 4). In general there was an increasing amount of vegetational obstruction in front of the box when it was placed further back into the woods.

To determine the influence of vegetational obstruction on nest site selection, the number of boxes available within four visibility index categories was compared to the number of boxes selected within each category prior to and after April 20, 1968 (Table 5). The pattern of nest box selection within the four visibility categories was the same prior to and after April 20, and demonstrated decreasing utilization as vegetational obstruction increased. A standardized index of utilization was determined by dividing the selection rate of boxes within a visibility index by the sum of the selection rates of boxes in all visibility index categories of a time period (Table 5).
Figure 3. Estimates of the visibility of the boxes prior to April 20, 1968 in each position within the diagonal set. Position 1 is adjacent to water; position 8 is the last box in the set and is placed back into the woods.
Figure 4. Estimates of the visibility of the boxes after April 20, 1968 in each position within the diagonal set. Position 1 is adjacent to water; position 8 is the last box in the set and is placed back in the woods.
Table 5. The selection rates of nest boxes by wood ducks in four categories of vegetational obstruction in 1968 (color of the boxes is ignored)*.

| Visibility Index | Prior to April 20 | | | After April 20 | | |
|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | No. boxes selected | Rate of selection % | Standardized index of selection | No. boxes selected | Rate of selection % | Standardized index of selection |
| 75-100           | 38               | 11               | 29               | .57              | 14               | 6               | 43               | .50              |
| 50-74            | 30               | 5                | 17               | .33              | 28               | 7                | 25               | .29              |
| 25-49            | 19               | 1                | 5                | .10              | 38               | 7                | 18               | .21              |
| 0-24             | 8                | 0                | 0                | .00              | 22               | 0                | 0                | .00              |

* Only those data from those diagonal sets in which boxes were selected were used in this table.
This calculation allowed us to compare the probable selection rates within each category should the number of available boxes within each category be equal. In general nearly half of the boxes selected were situated so that 75 - 100 percent of the nest box could be seen from four positions in front of the box. One-third of the boxes selected were 50-74 percent visible and only 10 - 20 percent of the nest boxes which were selected were from 25 - 49 percent visible. No box with a visibility index of 0 - 24 was selected.

**Nest Site Selection in Alternate Sets**

In 1968 two additional sets of boxes were erected on the study area. These sets were erected in a row adjacent to water with every other box in the set attached to the side of the tree facing away from water. These sets are referred to as alternate sets. The purpose of this design was to investigate the importance of the entrance hole as a perceptual cue in nest box selection.

Inspection and selection of nest boxes within the two sets of boxes facing alternate directions were strongly oriented to those boxes facing the water. Sixty-six percent of the boxes selected as nest sites in these two sets were boxes facing the water. Seventy-one percent of the bowls formed in the litter in the bottom of the box (a positive indication of a nest box inspection) were formed in boxes facing the water (Table 6). These data indicate that nest box
Table 6. Nest box selection and bowl formation in the two sets of alternately facing boxes (1968).*

<table>
<thead>
<tr>
<th>Orientation of nest box</th>
<th>Water No.</th>
<th>%</th>
<th>Woods No.</th>
<th>%</th>
<th>Total No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nests</td>
<td>6</td>
<td>66.6</td>
<td>3</td>
<td>33.3</td>
<td>9</td>
<td>100.0</td>
</tr>
<tr>
<td>Bowls</td>
<td>54</td>
<td>71.0</td>
<td>22</td>
<td>29.0</td>
<td>76</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* 16 boxes were erected in a row adjacent to water with every other box attached to the side of the tree facing the woods.

Inspection and selection are strongly influenced by the presence of an entrance hole visible from water. The inspection and selection of boxes facing away from water were likely the result of random searching behavior of the wood duck such as described by F. Leopold (1951). The possibility of form recognition cannot, however, be totally excluded as a stimulus for inspection of a nest box. The following account lends support to this suggestion. One of the alternate sets was observed for a four-day period beginning March 30, 1968 to determine the investigative behavior by wood ducks to this experimental situation. A pair of wood ducks landed on the slough approximately 75 yards from a black box facing away from the water (the end box of the set). The feeding movements of these ducks brought them to within 20 feet of the tree supporting the black nest box. The female then flew from the water to a limb directly above this box. Next the hen flew to the top of the box, walked to the front
edge and peered down into the entrance hole. After this brief examination the hen returned to the drake resting on the water in front of the tree.

It is possible for form recognition to develop as the result of repeated exposure to several nesting boxes. It may occur during the five to six days of nest box inspection, reported by Leopold (1951), prior to selection; or it may develop as the result of the successful use of a particular type of nesting structure. In short, form recognition could develop as a result of the animal perceiving additional cues while initially responding to rather specific cues, in this case, the presence of an entrance hole of an acceptable nesting cavity. After repeated experiences with similar types of nesting structure, it would be possible for a duck to respond to the form of the structure without having perceived the entrance hole.

Color Factors and Nest Box Selection

Color Selection in 1967

The results of the pilot study of 1966 suggested that color influenced the selection of nest boxes by wood ducks. As a result, in 1967 this investigation was initiated to determine the degree of influence of color as a factor in selection of a box. Eight boxes, of which seven were painted various colors (white, black, blue, green, yellow,
orange and red) and one natural box, were erected in sets in such a manner that all boxes were equally visible from the water area. It was hypothesized that such a design would allow wood ducks to demonstrate a predilection for a certain color or colors. In order for this hypothesis to be tested adequately, the site factors that could influence selection (height, distance from water, spacing between boxes) were controlled within the limitations of the environmental situation at the set site. It has been demonstrated that nest box selection by wood ducks in 1967 was not influenced by physical and social factors such as d.b.h. of the tree, position of box within the set and the stimulus of nesting hens. It was therefore concluded that any difference in the selection rates of colored boxes would be due to stimulus of the color(s) of the boxes chosen. The analysis of the nest boxes selected by 64 wood ducks in 1967 indicates no predilection by wood ducks for a particular color (or group of colors) when colored nest boxes are erected so that all boxes within each set are equally exposed (Table 7).

Table 7. The selection of colored nest boxes by wood ducks during the 1967 nesting season.

<table>
<thead>
<tr>
<th>Color of box</th>
<th>black</th>
<th>natural</th>
<th>green</th>
<th>blue</th>
<th>yellow</th>
<th>orange</th>
<th>red</th>
<th>white</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nests</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>9</td>
<td>64</td>
</tr>
</tbody>
</table>
The color selection responses of wood ducks in 1967 repudiated the suggestion formed from the 1966 pilot study (that color influences nest box selection). Because of the contradictory data of 1966 and 1967 the methods of both studies were re-evaluated to determine what, if any, differences existed. The main difference between the methods employed in both years was the controls imposed upon the erection of boxes. In 1966 considerable environmental variation existed between the nest box sites within each set. The results of the 1966 study suggested that light colors (white, yellow and red) were selected regardless of degree of vegetational obstruction. In general dark colored boxes (natural and green) were selected after the light colored boxes; also these were selected only in situations of low vegetational obstruction. This re-evaluation of the 1966 data led to the implementation of the experimental set design of 1968. The primary objective of this design was to evaluate the relationship of vegetational obstruction and color to nest box selection. An analysis of the selection response by 38 wood ducks to colored boxes in the diagonal sets suggests no differential selection of colored nest boxes (Table 8). These data agree with the results of the 1967 investigation. However, a comparison of colors selected by adults and yearlings showed some important differences which will be discussed in the next section.
Table 8. The selection of colored nest boxes by wood ducks within diagonal sets during the nesting season of 1968.

<table>
<thead>
<tr>
<th>Color of nest boxes</th>
<th>black</th>
<th>natural</th>
<th>green</th>
<th>blue</th>
<th>yellow</th>
<th>orange</th>
<th>red</th>
<th>white</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Nests</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>38</td>
</tr>
</tbody>
</table>

Color Selection by Adult and Yearling Females

The color selections by adult and yearling wood ducks were compared to determine if any differences existed between these two age groups for the years 1967 and 1968. As noted previously a rather well-defined separation of nest initiation dates existed for adult and yearling wood ducks during the 1968 breeding season. This separation has also been reported for other wood duck populations (Bellrose et al., 1964; Grice and Rogers, 1965). Separation of the 1967 breeding season at the approximate mid-point (April 22) roughly partitioned the nest initiation dates of adult and yearling hens for that year (Figure 2). The selection of colored nest boxes during these two time periods were then compared for differences in selection rates. No difference in the selection rates of individual or groups of colors, during these two time periods, were found (Table 9). No differences in the selection rates of colored nest boxes were found for the breeding season of 1968 when considered as a whole (Table 8); however, differences were found in the selection responses...
Table 9. Colored nest box selections of adult and yearling wood ducks for the breeding seasons of 1967 and 1968*.

<table>
<thead>
<tr>
<th>Year</th>
<th>Category</th>
<th>black</th>
<th>natural</th>
<th>green</th>
<th>blue</th>
<th>yellow</th>
<th>orange</th>
<th>red</th>
<th>white</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>Seasonal selection</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>9</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Adult selection</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Yearling selection</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>1968</td>
<td>Seasonal selection</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Adult selection</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Yearling selection</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

* Only the selection data within the diagonal sets in 1968 were used in this table.
of adult hens when compared with those of yearling hens (Table 9). The colors of nest boxes that adult hens selected indicated a general orientation to dark-colored boxes, eg. black, blue, green and natural. Seventy-two percent of the boxes selected by 18 adults were dark colors. In contrast, the colors selected by 20 yearling hens indicated that 65 percent were light-colored boxes, eg. yellow, orange, red and white. The greater selection of the dark-colored boxes by adult hens and light-colored boxes by yearling hens, when summed, produced a balanced seasonal distribution of colors selected by wood ducks (Table 9).

Results of selections of colored nest boxes by adult and yearling hens during 1968 appear contradictory to results of selections by adult and yearling hens during 1967. These contradictory results can be partially explained when color fidelity as a factor in selection response by adults in 1968 is examined.

Color Fidelity of Adult and Yearling Females

An objective of this research was to investigate whether color of the box in which a female successfully nested (or hatched, in the case of yearling hens) influenced nest box selection in the following year. I term this phenomenon color fidelity of the "experienced" nesting duck. An experienced duck is one which nested or hatched in a colored box. The color of the box in which the bird had nested (or
hatched) the previous year was compared to the selection of boxes of the same color, to boxes of adjacent hues (within the spectrum), and to selection of boxes of other colors. In addition, standardized indices of selection were calculated. These indices reflect the relative probability of selection from one of the three categories of colored boxes mentioned above if the sample size of available boxes within each category were equal. The relative probability of an experienced adult hen selecting either a box of the same color as the previous year, or of an adjacent color within the spectrum greatly exceeded the probability of her selecting a box of another color (Table 10). The relative probability of a yearling hen selecting a box of the same color (or of an adjacent color) as the box in which she hatched was almost equal to the probability of her selecting a box of any other color (Table 10). In brief, color fidelity was a dominant influence in color selection by "experienced" adult hens, but was not a factor in color selection by "experienced" yearling hens. As with the possible development of form recognition, color fidelity in a hen could result from repeated stimulation from the color of the box in which she nests. A wood duck hen during the laying of a clutch and while incubating would be repeatedly stimulated by the color of the box as she entered and exited. The yearling hen has only one opportunity to be stimulated by the color of the box, during exodus from the nest box after hatching.
Table 10. Influence of the color of nest box in which the female wood duck successfully nested or hatched to color of nest box selected in the following year, 1966-1968.

<table>
<thead>
<tr>
<th>Color of box</th>
<th>Selection of colored boxes</th>
<th>Yearling hens</th>
<th>Selection of colored boxes</th>
<th>Yearling hens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult hens</td>
<td></td>
<td>Standardized 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. boxes available</td>
<td>No. boxes selected</td>
<td>Selection rate %</td>
<td>index of selection</td>
</tr>
<tr>
<td>Same 1</td>
<td>14</td>
<td>5</td>
<td>36.0</td>
<td>.58</td>
</tr>
<tr>
<td>Adjacent hue 2</td>
<td>20</td>
<td>5</td>
<td>20.0</td>
<td>.32</td>
</tr>
<tr>
<td>Other colors</td>
<td>67</td>
<td>4</td>
<td>6.0</td>
<td>.10</td>
</tr>
</tbody>
</table>

1 Color of the box in which the female had nested or hatched, in the previous year.

2 Colors adjacent (within the spectrum and not in position within the set) to the color of box in which the female nested or hatched, in the previous year.

3 The relative probability of selection if number of available boxes were equal in each category. Calculated by dividing the selection rate in each category by the sum of the selection rates in all three categories for each group of females.
Data on color fidelity makes possible a better evaluation of the apparent contradiction of the color selections by adult hens in 1968 to color selections by adult hens in 1967. Eight of the 18 boxes selected prior to April 20, 1968 (the period in which most adults nested) were selected by hens which had nested on the study area in 1967. Data on these eight birds were removed from the sample of nest attempts during this period because of the influence of color fidelity in these birds. Removal of these data from the sample allows an evaluation of color selections by adult hens which had theoretically never been exposed to colored nest boxes. The frequency of distribution of colored nest boxes selected by hens which had never been exposed to colored nest boxes indicates that these birds chose colored nest boxes essentially at random (Table 11). These data are similar to the color selection by adult and yearling hens in 1967 (Table 9).

Table 11. The selection of colored nest boxes by adult hens nesting in the study area for the first time in 1968.

<table>
<thead>
<tr>
<th>Color of box</th>
<th>black</th>
<th>natural</th>
<th>green</th>
<th>blue</th>
<th>yellow</th>
<th>red</th>
<th>orange</th>
<th>white</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of nests</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Color and Visibility of the Area of the Nest Box as Factors Influencing Selection

Color, whether chromatic or achromatic, has at least three physical characteristics which, theoretically, an animal with color
vision can use to discriminate between objects within its environment. These characteristics are hue, brilliance and saturation. It is my opinion that even though each color used in this investigation can be quantitatively identified as to wave length, saturation and brilliance, it cannot be assumed that the wood duck has this capacity. As Wight (1946) stated, the physical attributes and psychological attributes of color are not identical. It was therefore concluded that the evaluation of the selection responses of wood ducks to color must be based upon the summation of a color's basic characteristics of hue, saturation and brilliance. Thus, the wood ducks response to colored nest boxes must be evaluated in terms of the color as a whole. This characteristic can be called conspicuousness, i.e., the characteristics which either enhance or depress the distinctiveness of an object within its environment. The capacity of most birds to discriminate colors is similar to that of man (Walls, 1941). The colors used in the experiment were ranked in order of conspicuousness according to which colors could first be seen by observers approaching from a distance of 0.5 mile. It was assumed that this ranking of conspicuousness would be similar for wood ducks. The conspicuousness ranking of the colors on an ascending scale when placed in a shaded situation was black, natural, green, blue, yellow, red, orange and white.

The ease with which an object can be distinguished in nature is
influenced not only by its coloration but also by the amount of vegeta-
tional obstruction between the object and the observer. With the visi-
bility index values of the area of the box and a ranking of conspicu-
ousness for the colors of the nest boxes, an evaluation of visibility
and color as factors of nest box selection can be made. The available
boxes and the boxes selected by wood ducks in diagonal sets were
plotted to their respective visibility index values and color for the
time periods prior to and after April 20, 1968 (Figures 5 and 6). The
location of a color on the horizontal axis was determined by its con-
spicuousness rank within the colors used. The evaluation of the
selection response by predominantly adult wood ducks (Figure 5) is
affected by color fidelity of returning hens. No differences existed in
the selection rates of different colors by adults nesting on the study
area for the first time in 1968. Amount of visibility in the area of the
nest box appears to be the common factor in the selection of these
boxes.

In contrast the selection response of predominantly yearling
hens nesting after April 20, 1968 is influenced by visibility of the box
area and conspicuousness of the color of the box (Figure 6). It
appears that the more conspicuous colors enhance the selection in
situations of heavy vegetational obstruction while the dark colors
depress these selections. Because no boxes with visibility index
values of 0-24 were selected, it was assumed that boxes within this
Figure 5. The relationship of visibility of the box (visibility index) and conspicuousness of the color of the box (prior to April 20, 1968) to nest box selection by wood ducks. Color conspicuousness ranking is on an ascending scale from the least conspicuous color (black) to the most conspicuous color (white), in a shaded situation.
range could be considered as unavailable. Therefore only those boxes with visibility indexes of 25 to 100 were used in a Chi-square analysis. The analysis compared the selection rates of dark colors (black, natural, green and blue) and light colors (yellow, red, orange and white) in two categories of visibility indices, those above and those below a visibility index of 60 (Table 12). The visibility index 60 was selected because it was the approximate mid point of the visibility index range in which boxes were selected (Figure 6). The results of these tests are as follows: (1) When data were analyzed with high and low visibility indices combined into one category, light colors were selected at a significantly greater rate ($P<0.05$) than were dark colors ($X^2 = 11.221$, 3 d.f.); (2) There was no significant difference in the selection rate of dark colors in the high visibility index category when compared to the selection rate of light colors in the same category ($X^2 = 0.995$, 1 d.f.); (3) Light colors were selected at a significantly greater rate ($P<0.01$) than were dark colors in the low visibility index category ($X^2 = 10.173$, 1 d.f.); (4) Dark colors in the high visibility index category were selected at a greater rate ($P<0.05$) than were dark colors in the low visibility index category ($X^2 = 9.902$, 1 d.f.); (5) There was no significant difference in the selection rates of light colors in the high visibility index when compared to selection rates of light colors in low visibility index category ($X^2 = 0.110$, 1 d.f.).
The results of the Chi-square tests support the conclusion that color can enhance or depress the conspicuousness of an object in the environment, and as a result influence the selection rates of colored nest boxes. It should not be overlooked, however, that regardless of the conspicuousness of a color a certain degree of visibility is also required before a box will be selected (above a visibility index of 25).

Table 12. The selection of dark and light colored boxes by yearling hens in two categories of visibility index values.

<table>
<thead>
<tr>
<th>Visibility index range</th>
<th>Color of box</th>
<th>Dark colors</th>
<th>Light colors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(black, natural, green, blue)</td>
<td>No. boxes available</td>
<td>No. boxes selected</td>
</tr>
<tr>
<td></td>
<td>(yellow, red, orange, white)</td>
<td>No. boxes available</td>
<td>No. boxes selected</td>
</tr>
<tr>
<td>60-100</td>
<td>11</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>25-59</td>
<td>36</td>
<td>2</td>
<td>40</td>
</tr>
</tbody>
</table>

*The visibility index 60 was chosen as the separation point because it was the approximate mid point of the visibility range in which nest boxes were selected.*
Figure 6. The relationship of visibility of the box (visibility index) and conspicuousness of the color of the box (after April 20, 1968) to nest box selection by wood ducks. Color conspicuousness ranking is on an ascending scale from the least conspicuous color (black) to the most conspicuous color (white) in a shaded situation.
MANAGEMENT IMPLICATIONS

This study suggests that nest box selection by the wood duck is determined to a large extent by the visibility of the box. It is therefore important to know the approximate levels of vegetational density which will influence the utilization rate of nest boxes and/or nesting cavities within a given area. There is little value in measuring the number of nesting cavities within a woods if vegetational density is such that these cavities are not utilized. Also needed is information with which to make decisions regarding habitat manipulations for the benefit of cavity nesting waterfowl. These data and those of Prince (1968) suggest two methods with which the wildlife manager can use to enhance utilization of boxes or natural cavities in wooded areas. These methods are selective removal of vegetation and erection of nest boxes painted a conspicuous color. The advantages of erecting conspicuous boxes over the removal of vegetation are: (1) Ecology of the area is not changed in regard to other species. (2) Young forests with few cavities can be transformed into areas of productive habitat. By erecting conspicuously painted boxes the vegetational density, which is characteristically high in young forests, is offset by the conspicuousness of the painted box. (3) Distribution of nest boxes no longer need be restricted to areas of optimum visibility in order to secure initial use by wood ducks. As a result, it is possible that
raccoon (*Procyon lotor*) predation may be reduced because boxes would not be concentrated in or adjacent to water areas where raccoons hunt most frequently. (4) It is conceivable that erection of conspicuously painted boxes in dense woods would reduce competition for nest boxes between the wood duck and the starling (*Sturnus vulgaris*). The starling prefers the more open situations such as open woods and fields and does not venture into dense woods to nest (Bellrose *et al.* 1964), thus an additional reason for not removing vegetation. (5) Painting will undoubtedly add to the life of the box. Furthermore, I surmise that the added conspicuousness will result in greater use.

It is more expensive to remove vegetation and erect natural boxes than it is to erect painted boxes in the existing habitat. Removal of vegetation to enhance visibility of a box has only temporary value, because the problem of vegetational obstruction may recur in the future due to regrowth. Nest box utilization in dense woods should increase due to nest site and color fidelity and to decreasing vegetational obstruction as the canopy increases in height.
CONCLUSIONS

The primary purpose of this investigation was to identify and evaluate some of the basic factors of nest box selection by wood ducks. Some information on color perception and discrimination was gathered. In addition, factors associated with the site of the nest box were evaluated in terms of nest box selection.

The data collected in this research provides some information on the capacity of wood ducks to perceive and discriminate color. It appears that the color perception of the wood duck is similar to that of man. This speculation is derived, in part, from the "ranking" of conspicuousness of colors of boxes used by yearling hens during 1968 in situations of decreasing visibility index values (Figure 6). These rankings are similar to rankings made by a group of men observing samples of the same colors. Additional and perhaps stronger evidence for color discrimination was the degree of color fidelity demonstrated by "experienced" adult females.

Discrete differences were observed in the selection of colored nest boxes by the adult and yearling segments of the breeding population. The adult wood duck demonstrates a strong nest site fidelity in its selection of a nesting cavity (Bellrose et al., 1964; Grice and Rogers, 1965). The adult hen was also influenced in its selection of a nest box in this study by the color of the nest box in which it last
successfully nested. It is conceivable that the adult hen would also be influenced in its selection by the type of nesting structure in which it last successfully nested. Should this be true then the low initial acceptance by wood ducks of metal houses as nest sites reported by Bellrose et al. (1964) would be partially explained.

Nest box selection by the yearling hen is influenced primarily by the perceptual cues associated with the nest box and its entrance hole. In this study these perceptual cues were affected by visibility and conspicuousness of the nest box. Nest site fidelity of the yearling hen is not as strongly developed as it is in the adult hen. In general, however, the yearling hen will return to the natal area (Bellrose et al., 1964; Grice and Rogers, 1965). No evidence of color fidelity was observed for yearling hens. Because the yearling hen is least influenced by past experience, it is this age group which will do most of the pioneering of either new habitat or types of nesting structures. It is the stimulus of the entrance hole that is the primary stimulus of cavity inspection in any cavity nesting species. This study suggests that in some situations this stimulus can be enhanced by painting the nest box a conspicuous color.
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