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ABSTRACT— A study of nest box use from November through August by birds in Minnesota farmstead shelterbelts was initiated subsequent to a two-year study showing that cavity-dependent species were absent from shelterbelts during winter and spring. The purpose of the study was to determine use of nest boxes by birds in shelterbelts otherwise devoid of cavities for roosting and nesting purposes. Fifteen of 22 boxes (68%) were used as nest sites in spring and summer by house wrens (*Troglodytes aedon*) and black-capped chickadees (*Parus atricapillus*). Neither nested in the shelterbelts before the nest boxes were available. Red-breasted nuthatches (*Sitta canadensis*) roosted in nest boxes during winter but had not been found in shelterbelts during the previous 2 years. A lack of snags or artificial cavities apparently limits densities and distributions of several cavity-dependent species in farmstead shelterbelts. Thus, provision of nest boxes and retention of snags in shelterbelts should be an important management consideration for landowners in intensively-farmed regions of the Midwest.

Abundance and distribution of cavity-nesting birds are contingent on the availability of food and nesting or roosting sites (Brewer, 1963; Mueller, 1973; Galli *et al.*, 1976). Farmstead shelterbelts in the Midwest are man-made habitats consisting of rows of trees and shrubs that are designed to protect farmsteads from inclement weather in winter (Smith and Scholten, 1980). Shelterbelts also serve as important avian habitats throughout the year (Martin, 1980; Yahner 1981, 1982a). However, snags are virtually absent from many farmstead shelterbelts (Yahner, 1983), and cavity-dependent birds may be restricted in their use of these habitats. During a two-year study (1978-80) of avifauna in shelterbelts, wintering or breeding species that require cavities were absent (Yahner, 1982b, 1983). The purpose of this study was to test the effects of nest boxes on use of farmstead shelterbelts by cavity-dependent species during winter and spring of the following year.

MATERIALS AND METHODS

The study was conducted from November 1980 to August 1981 at the Rosemount Agricultural Experiment Station, Dakota County, Minnesota. Four farmstead shelterbelts were selected for study, ranging in date of establishment from 1946 to 1961 and in size from 0.37 to 0.79 ha. Number of rows of trees and shrubs per shelterbelt ranged from four to nine, with widths of 14 to 27 m, and lengths of 162 to 498 m (see details in Yahner, 1982a, 1982b).

Nest boxes were constructed of 2.5 cm pine and were painted with oak stain. Inside dimensions of boxes were 12.7 × 12.7 × 20.6 cm. An entrance hole, 2.9 cm in diameter, was positioned 15.2 cm above the base; 5 cm of wood chips and sawdust were placed in each box. This box design was intended to attract three "target" species, including black-capped chickadees (*Parus atricapillus*), red-breasted nuthatches (*Sitta canadensis*), and house wrens (*Troglodytes aedon*), but to exclude larger species (e.g., house sparrows, *Passer domesticus*). The 22 nest boxes were spaced 50 m apart along a medial row of trees in each of the four shelterbelts in early November 1980. Each was placed 2 m above the ground, and entrance holes were oriented southeast.

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From November 1980 to late August 1981, boxes were inspected every 5 to 10 days for avian use (based on presence of feathers, feces, nesting material, eggs, or young).

Seven habitat variables measured in the vicinity of each nest box were: (1) basal area, (2) frequency of trees (>7 cm diameter breast height, DBH) within a 15 m radius of the box, (3) density (no./m^2) of shoulder-high contacts of shrubs (woody plants < 7 cm DBH) in 2 perpendicular transects, each 1 m in width and 15 m in length, (4) maximum canopy height (m) in a 15 m radius of the box, (5) distance (m) to the nearest clearing, defined as an area > 3 m in radius and devoid of trees and canopy cover, (6) distance (m) to the nearest boundary of a shelterbelt, and (7) DBH (cm) of the tree to which a box was attached (modified from Conner and Adkisson, 1977).

RESULTS

Nest box use

In the two breeding seasons (1978-79) prior to erection of nest boxes, black-capped chickadees and house wrens did not nest in the shelterbelts at the Rosemount Station. From mid-May to mid-July 1980, one black-capped chickadee and 20 house wren clutches were produced in 15 (68 percent) of the 22 boxes. One of the 15 boxes was used successfully by both species at different times: a pair of black-capped chickadees occupied the box from mid-May to late June, and a pair of house wrens used the same box from mid-July to late August. No clutches of either species were found in the remaining seven boxes, but three of these contained partial nests of house wrens (see Bent, 1948). Abundant avian feces and a dead red-breasted nuthatch were found in two adjacent boxes in the shelterbelt during winter 1980-81. In addition, five (22.7 percent) of the boxes were used as nest sites by *Peromyscus leucopus* in July and August 1981.

Production of young in nest boxes

One brood of house wrens was fledged in 13 (59 percent) of the 22 boxes, whereas two broods were fledged in two (9 percent) boxes. Eleven (55 percent) of the 20 clutches produced by house wrens were initiated in mid-to-late May, three (15 percent) in mid-to-late June, and six (30 percent) in mid-July (hereafter May, June, and July clutches, respectively). July clutches were produced only in boxes that previously contained May clutches, suggesting that perhaps the same pair renested in that box. June clutches were never followed by a subsequent clutch.

The single clutch produced by black-capped chickadees consisted of nine eggs, eight of which resulted in young that fledged in late June. A total of 114 eggs was produced in the 20 clutches of house wrens during the study; 70 (61 percent) occurred in May clutches, 19 (17 percent) in June clutches, and 25 (22 percent) in July clutches. Mean number of eggs per clutch was 6.4 (SD=±1.4) in May, 6.3 (±0.6) in June, and 4.2 (±1.7) in July for both successful and unsuccessful clutches ($F = 5.0$; d.f. = 2, 17; $p < 0.05$; single-classification analysis of variance; Sokal and Rohlf,1981). Second clutches (July, $N = 6$) of house wrens tended to have fewer eggs compared to first clutches (May or June, $N = 14$).

Ninety-two (81 percent) of the total eggs produced by house wrens resulted in fledged young. Fifty-eight (63 percent) of the 92 successful young came from May clutches, 14 (15 percent) from June clutches, and 20 (22 percent) from July clutches. Mean number of young house wrens fledged per clutch was 4.8 (SD= ± 2.7) in May, 4.7 (± 0.6) in June, and 3.3 (± 2.6) in July; these means were not significantly different ($F = 0.7$; d.f. = 2,17; $P > 0.05$). Moreover, an average of 4.2 young house wrens was fledged in each of the 22 boxes during the year, giving a production of 35.9 young per ha (total area = 2.56 ha).

Relationship between habitat and breeding success

Three of seven habitat variables measured in the vicinity of nest boxes varied ($P < 0.05$; df = 7,15; Wilcoxon two-sample test; Sokal and Rohlf, 1981) between successful boxes (boxes in which at least one brood of either house wrens or black-capped chickadees was fledged, $N = 15$) and unsuccessful boxes (box in which no broods were fledged, $N = 7$). Frequency of shoulder-high contacts of shrubs was less near successful boxes (mean± SD =0.57±0.51 contacts/m^2) than near unsuccessful boxes (1.31 ± 1.04 contacts/m^2) (Mann-Whitney $U = 85$). Successful boxes were attached to trees of larger DBH (31.9 ± 16.8 cm) compared to unsuccessful boxes (19.9 ± 3.3 cm) ($U = 81$). Further, successful boxes were positioned at greater distances from nearest boundaries of shelterbelts (10.3 ± 2.8 m) than were unsuccessful boxes (7.1± 2.7m) ($U = 89$).

DISCUSSION

A lack of cavities is apparently a major factor determining use of farmstead shelterbelts by small, cavity-dependent avian species, although food availability, shelterbelt dimensions, and other factors also may be important. Family groups of black-capped chickadees were common in shelterbelts during summer and autumn prior to the present study (Yahner, 1983), suggesting that food resources were not limiting use of these habitats (see Mueller, 1973).

House wrens and black-capped chickadees occur in forest edges (Kendeigh, 1942; Johnson, 1947; Brewer, 1963), but breeding densities may be reduced by restricting nesting habitats to very narrow strips (Stauffer and Best, 1980). However, both species nested in boxes despite the narrow width (< 27 m) of shelterbelts in this study. House wrens readily occupy a large percentage of available nest boxes in other habitats. For example, Willner *et al.* (1983) noted that 23 (45 percent) of 51 boxes were used for nesting by house wrens in a Maryland habitat characterized by abandoned farmland and woodland. Red-breasted nuthatches occurred in extensive woodlots within 1 km of the Rosemount Station in winters 1978-79 and 1979-80 (personal observation) but were never observed in shelterbelts (Yahner, 1983). After placement of nest boxes in the shelterbelts, a pair of red-breasted nuthatches was sighted regularly in one shelterbelt containing boxes (Yahner, 1982c).

The current study provides no evidence that house wrens prevented black-capped chickadees from using nest boxes or shelterbelts (see Bent, 1948; Scott *et al.*, 1977). Perhaps, at least in black-capped chickadees, few birds nested in shelterbelts when boxes were available because young birds may select suitable nesting areas in late summer or early autumn; this searching period preceded the November placement of nest boxes (see Adams and Brewer, 1981).

Kendeigh (1942) recognized two nesting periods in house wrens, May-June and July-August, in Ohio. Further, he found that a greater percentage of total nests was constructed during the first period ($N = 737$, 70 percent) relative to the second period ($N = 319$, 30 percent) over a 19-year study. No nests of house wrens were initiated in August in the present study, but percentages of nests constructed per period in Kendeigh's (1942) study were identical to those obtained during the May-June period ($N = 14$, 70 percent) and the July period ($N = 6$, 30 percent) in this study. An average clutch size of six to seven eggs in house wren nests (presumably constructed in both natural and artificial cavities) in Pennsylvania and New Jersey (Harlow, 1918) was comparable to the average clutch size in may-June nests but not in my July nests.

Long-term nesting studies of house wren productivity have been based on nest box use in a variety of habitats. For instance, McAtee (1940) found that 84 percent of the total eggs ($N = 469$) resulted in fledged young in Maryland orchards. Kendeigh (1942) observed that 79 percent of the total eggs ($N = 6{,}773$) resulted in fledged young in Ohio deciduous forest edges. Thus, an 81 percent success rate of total eggs in my shelterbelts is similar to productivity of house wrens in other types of habitats. In contrast, Walkinshaw (1941) noted that only 48 percent of the total eggs ($N = 333$) produced resulted in fledged young in Michigan bottomland forests.

Snags are often removed from shelterbelts by landowners (Yahner, 1983). Therefore, provision of nest boxes in shelterbelts conceivably could minimize intra- and inter-specific competition for cavities (Erskine and McLaren, 1976; McComb and Noble, 1978), thereby affecting distribution and abundance of these small cavity-dependent species in the intensively-farmed regions of the Midwest where cavities are scarce (Gallei *et al.*, 1976). Further, the value of this management practice to birds, such as house wrens, may be enhanced if nest boxes are placed in areas relatively devoid of dense woody stems, are positioned away from the periphery of shelterbelts, and are attached to large diameter trees. Based on my data, nests constructed in boxes at these locations were less susceptible to failure. Perhaps nest boxes located in areas of shelterbelts with reduced woody stem density allow house wrens to better detect and deter potential nest predators (e.g., snake, *P.leucopus*; see Kendeigh, 1942). Because predator use of linear habitats is highest at edges (Gates and Gysel, 1978), possibly nests in boxes positioned within the interior of shelterbelts were less likely to be encountered by a potential predator than boxes in trees near boundaries of shelterbelts. Greater nesting success in house wrens that used boxes attached to large diameter trees may be related to box: tree dimensions. Total width of nest boxes in my study was about 25.6 cm. Conceivably, boxes of this dimension were less conspicuous to predators when against backgrounds of larger diameter trees ($\overline{x}$ = 31.9 cm for successful nests) compared to boxes attached to smaller diameter trees ($\overline{x}$ = 19.9 cm for unsuccessful nests). Finally, an additional management recommendation may be to vary heights of nest boxes in shelterbelts. For instance, heights of natural cavities used by nesting black-capped chickadees and house wrens averaged 2.2 and 5.4 m above ground, respectively, in Iowa riparian habitats (Stauffer and Best, 1982).

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