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Nest-box use by Prothonotary Warblers (*Protonotaria citrea*) in riverine habitat.—Nest boxes are often used in studies of cavity-nesting species (e.g., Dahlsten and Copper 1979), and they have been particularly important in conservation studies of Eastern Bluebirds (*Sialia sialis*) (Zeleny 1976). Many cavity-nesting birds have been shown to prefer nest boxes to natural cavities (McComb and Noble 1981, Brawn 1984).

The Prothonotary Warbler (*Protonotaria citrea*) is one of only two cavity-nesting wood warblers in North America. They nest in swampy or flooded forest areas (Bent 1953), and their populations may be declining due to loss of habitat (Graber et al. 1983). Although nest box use has been well documented for many secondary cavity nesters, little work of this kind has been conducted on the Prothonotary Warbler.

In 1984, we conducted an evaluation of the effects of industrial fluoride contamination on the egg viability and clutch size of Prothonotary Warblers. We erected nest boxes to facilitate finding nests in our study areas. Here, we report on the use of three different types of nest boxes by Prothonotary Warblers, along with factors that may influence their selection.

Study area and methods.—In March 1984 we placed 301 nest boxes in flooded riparian habitat along the Tennessee River in Benton and Humphrey counties, Tennessee. Woody vegetation in the river floodplain is dominated by willows (*Salix* spp.), buttonbush (*Cephalanthus occidentalis*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), elms (*Ulmus* spp.), and hackberry (*Celtis occidentalis*).

We erected 145 cardboard milk cartons (Fleming and Petit 1986), 84 standard wooden bluebird boxes (Zeleny 1977), and 72 tubes of black PVC pipe (30-cm long × 10.2-cm diameter) with plastic caps attached on top and bottom. The volume of each box was measured from the bottom of the box to the lower lip of the entrance hole. Tubes had the greatest volume (1226 cm^3), followed by wooden boxes (1218 cm^3) and milk cartons (903 cm^3), respectively.

All boxes had entrance holes approximately 3.75 cm in diameter, centered 5 cm from the top of the box. Milk cartons and tubes were spray-painted gray in order to make them less conspicuous. Wooden boxes were not painted because their natural wood color made them sufficiently inconspicuous. All boxes were placed on trees, 1.5–2.0 m above the water surface

TABLE 1

PROTHONOTARY WARBLER USE OF THREE TYPES OF NEST BOXES IN RIPARIAN HABITAT ALONG THE TENNESSEE RIVER IN WEST CENTRAL TENNESSEE, 1984

	Sites available[a]		Sites used[b]	
Nest site	No.	%	No.	%
Milk carton	143	48.2	79	67.5
PVC tube	71	23.9	32	27.4
Wooden box	83	27.9	6	5.1
Total	297	100.0	117	100.0

[a] Nest boxes containing species other than Prothonotary Warblers are not included.

[b] *G*-test of next box use vs availability: $G = 60.78$, df $= 2$, $P < 0.001$.

(most nests in natural cavities were within this range), and were erected before Prothonotary Warblers arrived in the spring.

We placed boxes at about 40-m intervals along the main shoreline and on the periphery of islands in the river. All three box types were distributed haphazardly in each stretch of suitable habitat.

Boxes were checked for active nests at least bi-weekly from 15 May–1 August 1984. Log-likelihood ratio (*G*) tests for contingency analysis were used to test for nonrandom patterns of box occupancy.

Prothonotary Warbler clutches initiated (first egg laid) before 25 June were considered to be first clutches (early), and those initiated after that date were considered to be second clutches (late). Clutch sizes were compared among nest box types in early and late nests using two-way analysis of variance (ANOVA).

We also noted frequencies of parasitism by Brown-headed Cowbirds (*Molothrus ater*) and predation in the different box types. Nests were assumed to have been depredated if young or eggs disappeared before the predicted fledging date, or if the nest was destroyed. The rate of predation we report here may be slightly low because not all nests were monitored from egg-laying through fledging. Most, however, were followed at least through incubation.

Results.—Prothonotary Warblers nested in 117 (38.9%) of 301 nest boxes, Tree Swallows (*Tachycineta bicolor*) used three boxes, and a pair of Tufted Titmice (*Parus bicolor*) used one. Boxes with the titmice and swallows were omitted from the analysis because they were unavailable to the warblers.

Prothonotary Warblers showed a significant preference for milk cartons and an avoidance of wooden boxes (Table 1). Tubes were used in approximate proportion to their availability.

Percentages of boxes used did not differ between early and late clutches among the three nest-box types. Thirteen (11.0%) of the 117 nest boxes used by Prothonotary Warblers were used twice during the breeding season. Renesting attempts occurred in similar proportions in cartons (9.9%) and tubes (15.2%); the warblers apparently did not renest in wooden boxes.

Clutch size did not differ significantly among nests in different nest box types ($F = 0.31$, df $= 2$, $P > 0.05$). Although early clutches were significantly smaller than late clutches ($F = 9.10$, df $= 1$, $P < 0.01$), this trend was independent of the type of box ($F = 0.09$, df $= 1$, $P > 0.05$).

Cowbird parasitism occurred in 23.0% of warbler nests. Cartons, tubes, and wooden boxes had parasitism in 20 of 79 (25.3%), 6 of 32 (18.8%), and 1 of 6 (16.7%) boxes, respectively (no significant differences in parasitism rates; $G = 0.72$, df $= 2$, $P > 0.05$). Only 3 (2.6%) of the 117 nests were depredated.

Discussion.—We suggest several reasons why Prothonotary Warblers more readily nested in milk cartons and tubes than in wooden boxes. One obvious difference between the box designs was volume. Peterson and Gauthier (1985) showed that cavity volume was the single most important factor influencing nest-site selection by five species of cavity-nesting birds in Canada. Greater volume of a nest box may discourage use by Prothonotary Warblers because of increased effort involved in filling the box (nearly to the entrance hole) with nesting material (pers. obs.).

Although we attempted to place the three box types randomly throughout the habitat, the design of the wooden boxes limited their placement to larger trees (diameter at nest box height >15 cm). Cartons were affixed with strapping tape to trees, allowing them to be placed on trees of smaller diameter. Tubes were also fastened to smaller trees. For nests in natural cavities on our site, mean diameter at cavity height was 13.6 cm (N = 11). Thus, our data may be biased by substrate size.

As wooden boxes were left unpainted while cartons and tubes were painted gray, wooden boxes may have been less conspicuous to the birds. However, wooden boxes were the bulkiest of the three box types, and enough were present in the study area that it seems unlikely that the birds overlooked them.

Incidence of predation was very low, and rates of brood parasitism were similar in the different box designs, suggesting that the suitability of a nest box was not based on its susceptibility to either of these factors. Although we do not have data to show reproductive success (e.g., number of young fledged), Prothonotary Warbler clutch sizes were not statistically different in cartons and tubes.

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Sage Grouse use of snow burrows in northeastern Nevada.—Apparently all species of *Tetraoninae* roost in snow for thermal conservation, provided that the snow is sufficiently deep and no ice crust occurs at the surface (Kuzmina 1961). However, the type of roost may vary with snow conditions or weather. We distinguish between 2 roost types: "snow forms" and "snow burrows." Snow forms are shallow depressions or open bowls in the snow in which the dorsal surface of the bird is exposed. Snow burrows are deep holes or tunnels in which the bird actively burrows completely under the snow surface. The difference in the thermal protection afforded by each roost type may be quite large. Gullion (1970) found that temperatures under 20 cm of soft snow in hardwood stands were between −3° and −12°C when ambient air temperature was as low as −35°C. Snow burrows provide a warmer microenvironment than do snow forms, and the covering of snow reduces radiant heat loss. Because of differences in thermal protection provided by snow forms and snow burrows, we recommend that ambiguous terms such as dug outs, snow roosts, or roost depressions be avoided when describing roost sites or behavior.

The use of snow burrows has been reported for Ruffed Grouse (*Bonasa umbellus*) (Bump et al. 1947), Sharp-tailed Grouse (*Tympanuchus phasianellus*), Greater Prairie Chicken (*T. cupido*) (Ammann 1957), Willow Ptarmigan (*Lagopus lagopus*) (Irving 1960), White-tailed Ptarmigan (*L. leucurus*) (Braun and Schmidt 1971), Capercaillie (*Tetrao urogallus*), Black Grouse (*Lyrurus tetrix*), and Hazel Grouse (*Testrastes bonasia*) (Formozov 1946). Although Sage Grouse (*Centrocercus urophasianus*) are exposed to subfreezing temperatures and snow conditions that are often suitable for snow burrowing, we could find no published reports of snow burrowing by this species. Griner (1939:42), Ihli et al. (1973:75), and Beck (1977: 23) reported Sage Grouse roosting in "holes," "snow caves," and "roost depressions," respectively. Their descriptions suggest that snow forms, rather than snow burrows, were observed. Patterson (1952:179) reported Sage Grouse used snow forms but found no evidence that they burrowed.

We observed 83 snow burrows at 13 different locations while conducting a Sage Grouse winter movement study in northeastern Nevada from 1982 to 1985. On all but one occasion, burrowing occurred within one week of snowfall. Minimum temperatures during the periods of snow-burrow use were <-10°C in all but one instance.

Snow burrows occurred in unpacked, soft drifts on the lee side of shrubs (N = 21) and in open, level areas with no shrub cover visible above the snow (N = 62). "Drift burrows" were made by birds tunneling into the drift on one side and exiting from the other. Entrance holes were plugged by the snow roof collapsing behind the birds. Mean length of drift burrows was 56 cm (range = 48–63 cm, N = 21). Mean depth (from snow surface to bottom of the burrow) was 30 cm (range = 26–35 cm, N = 21). The mean "roof" thickness above the roost site (i.e., above the dropping accumulation) was 9 cm (range = 8–11, N = 14). "Open-snow burrows" were made in soft, dry snow >25 cm deep and had a mean length of 110 cm (range = 74–152 cm, N = 30) and mean depth of 35 cm (range = 25–39 cm, N = 30). The mean roof thickness was 13 cm (range = 10–16 cm, N = 13). Open-snow burrows were longer (*t*-test, df = 49, $P < 0.001$), deeper (df = 49, $P < 0.001$), and had more snow over