UTILIZATION OF NATURAL NEST SITES BY EASTERN BLUEBIRDS IN SOUTHWESTERN VIRGINIA

by

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INTRODUCTION

The Eastern Bluebird (*Sialia sialis*) is a species which has, according to the literature, been subject to marked fluctuations in numbers. One reaction of those concerned with the reductions in bluebird numbers was the provision of artificial nest sites through the erection of nest boxes. Indeed, the continuing interest in nest box projects, the so-called "bluebird trails", is perhaps one indication of the popularity of this species.

The ease with which bluebirds are attracted to nest boxes has provided many scientific investigators with a relatively large number of birds which are close at hand and thus easily studied. As a result, the overwhelming majority of scientific investigations of the Eastern Bluebird has centered around nest boxes and bluebird trails.

This tendency for investigators to erect nest boxes instead of locating natural nests is perhaps responsible for the current lack of knowledge concerning the nesting habits of the Eastern Bluebird under natural, i.e. non-nest box, conditions. Such knowledge would, for managerial purposes, be unnecessary if bluebird numbers could be maintained in perpetuity through the use of nest boxes.

However, it is not known whether bluebird numbers can be maintained through the use of nest boxes. Pinkowski (1974) has suggested that it is not likely, and if that is the case, information concerning the natural nesting habits of the Eastern Bluebird could be critical to the management and ultimate survival of this species.

Therefore, the first objective of this study was to determine if there were Eastern Bluebirds utilizing natural nesting sites in the vicinity of Blacksburg, Virginia. Once these nesting sites were located, further objectives were to quantitatively describe the nest cavity, habitat surrounding the nest, and the utilization of habitat by the bluebirds.

LITERATURE REVIEW

The Bluebird "Decline"

Since before the turn of the century, articles in the ornithological literature have alluded to the decline in the population numbers of the Eastern Bluebird. During this time periods of local and regional scarcity have been noted, and many arguments advanced to account for the low population levels. These are summarized in the following paragraphs. Throughout this report, avian nomenclature follows the guidelines of the American Ornithologist's Union (1957, 1973, 1976).

The Eastern Bluebird must certainly be included in the list of those species that were greatly benefited by the colonization and settlement of North America by white man. Pinkowski (1974:4) stated, "It was not until human settlement, with large-scale lumbering, the establishment of orchards and clearing for agriculture that optimum conditions for the bluebird developed in the northern United States."

Therefore, it is possible that the Eastern Bluebird was relatively scarce in North America before colonization and settlement, and it wasn't until after white man's activities that enough suitable habitat was made available for the bluebird to become a common and abundant species. However, Butler (1898) noted that bluebirds were becoming noticeably less numerous and had been so for the previous 20 or 25 years.

Effects of Weather

Butler (1898) also discussed a decrease in bluebird numbers which occurred in 1895 and attributed the low numbers to severe winter weather. During January and February 1895 unusually harsh weather conditions prevailed throughout the Eastern Bluebird's winter range. Few birds survived to return to the breeding grounds in the spring of 1895. Other authors referred to the severity of the decline in bluebird numbers using such phrases as, "...the Bluebirds [sic] were almost exterminated." (Jacobs 1912:163), and "The bluebird perished in immense numbers...it was noticeably rare, ..." (Griscom 1941:193). However, Griscom (1941) also noted that the recovery of the bluebird was quite rapid and by 1900 they were as numerous as ever.

Wayne (1899) described the effects of a cold wave which struck the coast of South Carolina in February 1899. The extreme severity of the weather resulted in the deaths of millions of birds, including Pine Warblers (*Dendroica pinus*), Fox Sparrows (*Passerella iliaca*) , and Dark-eyed Juncos (*Junco hyemalis*). Bluebird numbers were "decimated". Apparenty a decline in numbers on the breeding grounds was not noted, for reports of this nature were not found in the literature.

A local decrease in bluebirds was noted in Missouri in the summer of 1906. This decrease was attributed to the worst March weather in Missouri's history (Widmann 1906). Twenty-three dead bluebirds, mostly females, were found in two holes in trees and a hole in a hollow telephone post. The local nature of this decrease is evident from Hegner (1906) who stated that in the vicinity of Decorah, Iowa, bluebirds were so numerous that almost every available nest cavity contained an active nest.

A long, continued cold winter in the region extending from the Potomac and Ohio Rivers to the northern boundaries of the Gulf States resulted in a scarcity of bluebirds in some portions of the breeding range in 1912 (Cooke 1913b). Bluebirds were reported to be scarce in the vicinity of Williamstown, Massachusetts (Cartwright 1912). Jones (1912) stated that bluebirds were fewer in number in northern Ohio, yet from Oberlin to Toledo they were as numerous as ever. According to Logan (1912), bluebirds were not scarce near Royalton, Minnesota. Thus, bluebird numbers appear to have been affected only locally by winter weather in 1912.

A snow and ice storm in late February and early March 1940 after bluebirds had begun migrating northward resulted in noticeable daily decreases in numbers (Musselman 1941). In normal years ninety-three percent of Musselman's nest boxes near Quincy, Illinois, were occupied by April. In

1940 only forty-six percent of the nest boxes contained nests. Fifty-three percent of the boxes were normally occupied during the second nesting, whereas in 1940 only twenty-three percent were occupied. He concludes that about fifty percent of the bluebirds in his region were killed by the snow and ice storm.

The winter of 1958 resulted in a drastic reduction in bluebird numbers throughout the breeding range, "...the unprecedented winter of 1958 will go down in history as a disaster of major proportions for bluebirds and other insectivorous species that winter in the southern states." (Wallace 1959:193). Wallace (1959) also reported that bluebirds were scarce in Michigan throughout the spring, summer, and fall of 1958.

Using data from Christmas Bird Counts for twenty years prior to 1958 to obtain an estimate of "average" bluebird population levels, James (1961:304) made the following statement, "[the bluebird] has now reached an all-time population low of only one-third its normal abundance." Further reductions resulted in bluebirds attaining only 18 percent of their normal abundance in the southeast in the winter of 1961 (James 1962).

James (1959) demonstrated a statistically significant inverse relationship between winter weather and bluebird population levels. Population levels were lower when a winter had a larger number of cold days. A graphical analysis of bluebird numbers and winter weather (James 1962) revealed that the trend of severe winters and low population levels began prior to the winter of 1957-1958, beginning as early as 1954 in the mid-South latitudes. Furthermore, since 1959 a succession of milder winters has not resulted in corresponding increases in bluebird numbers. Therefore, "...some other major factor now is affecting bluebird populations." (James 1962:311).

In addition to the direct mortality of bluebirds caused by winter weather, several indirect influences have been noted. Musselman (1939) noted that freezing weather early in the spring resulted in a delay of about two weeks in the nesting season. This delay served to increase competition with and destruction of eggs by the House Wren (Troglodytes aedon). Zeleny (1975) who, like Musselman, reported on bluebirds nesting in nest boxes, also noted a delay in the nesting season and increased competition with House Wrens caused by cold and windy weather in early April. This cold weather also appeared to reduce the number of third broods produced by the bluebirds. Cold weather may indirectly reduce population numbers by affecting insect abundance (James 1959). Frazier and Nolan (1959) stated that the affect of snow and ice on the availability of food is the most important cause of winter weather mortality of Eastern

Bluebirds.

Competition for Nest Sites

Since competition for nest sites is often given as a reason for the decline in bluebird numbers, it is appropriate to discuss the interactions that have been noted between bluebirds and other cavity nesting species. The list of known competitors for nest sites with bluebirds includes other birds, mammals, and insects.

Avian species reported to compete with bluebirds include two introduced species, the Starling (Sturnus vulgaris) and the House Sparrow (Passer domesticus). Starlings were allegedly introduced into this country in order to acquaint Americans with all the birds mentioned by Shakespeare. Eighty Starlings were released at New York's Central Park in 1890 and were nesting there the following spring. Since that time they have become the most numerous bird species in the country (Miller 1975). Competition for nest sites between Starlings and bluebirds is a factor, according to Bull (1974:437), in keeping the bluebird population at low levels, for Starlings are well established in nest sites before the bluebirds return from the south to their northern breeding grounds.

The Starling is considered by many to be the worst enemy of the bluebird, both as a competitor for nesting cavities and as a predator on bluebird nests (Zeleny 1970).

However, surprisingly few cases of actual observed interaction have been noted. Kohler (1912) noted that Starlings were "engaged in conflicts" (p. 45) with both bluebirds and Common Flickers (Colaptes auratus); three bluebird nests were taken over by the Starlings. Gardner (1925) stated that Starlings used many of the nest cavities previously used by bluebirds, but does not record observed interaction. Pinkowski (1974) noted that a male nesting in a natural cavity deserted the nest after "continual fighting with Starlings [sic]" (p. 121).

People who maintained nest boxes soon recognized that Starlings could be prevented from entering the nest box if the cavity opening was 3.8 cm in diameter (Allen 1930). Adherence to this recommendation apparently has served to minimize the interaction between Starlings and bluebirds nesting in nest boxes. Musselman (1942) reported the discovery of a two-thirds grown Starling sitting on top of four bluebird nestlings in a nest box. Starlings had not previosly interfered with any of the 500 nest boxes he maintained.

Eight pairs of House Sparrows were originally introduced at Brooklyn, New York, in the spring of 1851. During the next two decades House Sparrows were liberated in over a hundred cities in thirty-three states and Canada (Barrows 1889). According to Forbush (1929:419) House

Sparrows began to drive bluebirds away from nesting places in the 1870's. This caused bluebirds to move from nesting near human habitation to the country, away from human settlements (Barrows 1912:727, Peterson 1936). House Sparrows are non-migratory and are thus well established in nest cavities when bluebirds arrive on the northern breeding grounds (Peterson 1936).

Several instances of interaction between bluebirds and House Sparrows have been noted. Bennett (1905) noted that House Sparrows drove a pair of bluebirds from a nest box. Miller (1912) and Jackson (1913) both record House Sparrows destroying the eggs of bluebirds nesting in a nest box. The only reported interaction between House Sparrows and bluebirds nesting in a natural cavity is that by Love (1902); House Sparrows drove a pair of bluebirds away from a nest hole in an apple (*Malus* spp.) tree.

Sherman (1928) attributed the decline in bluebird numbers to the interference of the House Wren. It has also been noted that both wrens and Tree Swallows (*Iridoprocne bicolor*) are successful in driving bluebirds away from nest sites. However, competition for nest sites with House Wrens and Tree Swallows has only been documented for nest boxes; it has never been reported to occur with natural nests. Waring (1912), Reed (1924), and Pinkowski (1974) noted bluebirds defending nest boxes against House Wrens.

However, Byrens (1925) noted that bluebirds and House Wrens both nested in the same nest box project without interaction occurring, "...there were always plenty of houses, and there existed no necessity for driving away other species." (p. 159). Bluebirds and House Wrens nested in and both fledged young from the same multi-celled Purple Martin (*Progne subis*) house (Lewis 1927). Cooke (1913a) reported another instance of interaction at a martin house. House Wrens, bluebirds, and Great-crested Flycatchers (*Myiarchus crinitus*) were involved; the flycatchers drove the other species away.

The following have recorded interactions between bluebirds and Tree Swallows at nest boxes: Jacobs (1923), Reed (1924), Byrens (1925), Hersey (1933), Krieg (1971), and Pinkowski (1974). In one case, (Byrens 1925), the bluebirds drove the Tree Swallows away, while in another instance (Hersey 1933), the Tree Swallows were successful in driving the bluebirds away from the nest box. In summarizing the interaction between bluebirds and Tree Swallows, Pinkowski (1974:393) stated, "...the longest resident bird in an area or the rightful owner of the nest usually prevailed."

Thomas (1946) studied bluebirds nesting in nest boxes for nine years and reported that bluebirds did not interfere with other cavity nesters such as Carolina Chickadees (*Parus carolinensis*), Tufted Titmice (*Parus bicolor*), Bewick's

Wrens (*Thryomanes bewickii*), Carolina Wrens (*Thryothorous ludovicianus*), Great-crested Flycatchers, and Common Flickers. Thomas (1946) also recognized that competition for nest sites among species using nest boxes could be reduced by placing boxes as follows: bluebird and flycatcher boxes in the open, titmouse boxes on trees, chickadees with smaller boxes placed on low posts under oak (*Quercus* spp.) trees, wren boxes built shallow and placed under eaves or inside a shed or barn, and flicker boxes made too deep to be used by the other species, particularly bluebirds.

Interaction between bluebirds and several species of woodpeckers at natural cavities has been noted. Christman (1924) noted that a pair of bluebirds drove a female Downy Woodpecker (*Picoides pubescens*) away from the hole the woodpecker had used as a winter roosting site and subsequently nested there. A pair of bluebirds was observed driving a Hairy Woodpecker (*Picoides villosus*) from a half completed nesting hole and then nesting in the cavity (Mousley 1916). Red-cockaded Woodpeckers (*Picoides borealis*) were seen to defend their cavities against bluebirds (Ligon 1970).

Several mammalian species have been reported as being competitors for nest sites with the Eastern Bluebird. These include red squirrels (*Tamiasciurus hudsonicus*), the Northern flying squirrel (*Glaucomys sabrinus*), white-footed mice (*Peromyscus leucopus*) (Pinkowski 1974), and deer mice (*Peromyscus maniculatus*) (Allen 1930).

Nest site competition may occur between bluebirds and "bees" (Allen 1930:155) or "bumble bees" (Bent 1949:253). Pinkowski (1974) stated that paper wasps (*Polistes* sp.) may compete for nest sites with bluebirds.

Interaction with Other Species

Several instances of aggressive encounters between nesting Eastern Bluebirds and other species have been noted. Bluebirds chased a pair of Black-capped Chickadees (*Parus atricapillus*) from the bluebird's nesting hole (Fitch 1958). However, the observer felt the chickadees were merely inspecting the cavity rather than trying to secure possession of it.

A pair of bluebirds nested in a cavity 23 cm above a second cavity used by two pairs of Brown-headed Nuthatches (*Sitta pusilla*) (Houck and Oliver 1954). The nuthatches were constantly attcked by the bluebirds even though they displayed no aggression toward them. Bluebirds, flickers, and American Kestrels (*Falco sparverius*) all nested at the same time in the central trunk of a sycamore (*Platanus occidentalis*) (Morgan 1913). In this instance the lack of interaction is noteworthy.

Interaction not involving the possession of a nest site between bluebirds and Downy Woodpeckers has been noted. A male Eastern Bluebird chased a Downy Woodpecker from a limb on which the woodpecker was feeding and attempted to feed upon the grubs the woodpecker had exposed. A pair of bluebirds pulled feathers from the backs of Downy Woodpeckers and used them for a nest lining (Forbush 1929:420).

Carr and Goin (1965) observed a pair of bluebirds feeding Mockingbird (Mimus polyglottos) nestlings. The bluebirds were always chased away from the nest by the adult Mockingbirds, but continued to feed the young even after they had fledged. A pair of American Robins (Turdus migratorius) built a nest on top of a nest box used by bluebirds. Both the robins and the bluebirds were successful in fledging young (Handley 1927).

Scarcity of Nest Sites

Another reason given for the decline in bluebird numbers is the scarcity of nest sites that exists for all cavity nesting species (Krug 1941, Bent 1949). Zeleny (1968) stated that a critical shortage of natural nesting sites is believed to be one of the major reasons for the decline in bluebird numbers. A shortage of nest sites has resulted from wooden fence posts and rails being replaced by steel posts and wire, and from modern orchard practices in which trees and stumps are chopped down, hollow limbs trimmed, and rot and excavations discouraged by applying chemicals (Musselman 1934). The rapid occupancy of nest boxes suggests that intense competition for nest sites does, in fact, exist (Ligon 1969). This phenomenon was noted by McKinnon (1909) and Lippincott (1916).

Pesticides

In the late 1950's it was considered that pesticides may be responsible for the lowered bluebird population levels. Wallace (1959) cited the disappearance of bluebirds from modern orchards, croplands, and roadsides in settled areas as evidence for the effects of pesticides. It has been noted (James 1962) that bluebird declines in the southeast coincided with the treatment of rural areas in the Gulf States with heptachlor to control the fire ant (*Solenopsis invicta*). Insecticides may kill bluebirds directly if enough can accumulate from contaminated insects (James 1962). All three *Sialia* species are probably harmed more by pesticides indirectly through loss of food, for pesticides affect spring, summer, and autumn food supplies (James 1962, Pinkowski 1974).

Scott et al. (1959) found that next to Common Flickers, bluebirds were the least affected by a field application of dieldrin. Ferguson (1964) noted that although fluctuations in bird populations occurred on a 19.4 ha (48 ac) plot treated with a 2.2 kg/ha (2.0 lb/ac) application of heptachlor, only one dead bird, an Eastern

Bluebird, was found. Rosene (1965) stated that no bluebirds were found on an area treated with heptachlor, while three were seen on the untreated area. Thus the hypothesized effect of pesticides on bluebird numbers has neither been supported nor refuted by field studies.

Human Activities

The affects of human activities on population levels of the Eastern Bluebird have been discussed by Pinkowski (1974). He listed the following as human activities detrimental to bluebirds: dead tree removal, forest fire suppression, clearcutting, the fire ant control program and pesticides in general, and monoculture. Furthermore, he concluded that, "...the Eastern Bluebird is presently limited in its range and distribution by the absence of areas which satisfy both its feeding and nesting requirements." (p. 433). Wallace (1959:193) likewise concludes, "Perhaps the key to the whole problem lies in the widespread loss of favorable habitat from all causes."

Status of Mountain Bluebird

Power (1966) suggested that there has been a similar decline in the population levels of the Mountain Bluebird (*Sialia currucoides*). He concluded that the highly specialized nesting requirements of the Mountain Bluebird have made it a relatively unadaptable species, and environmental changes have led to low population numbers.

However, he also stated, "The various possible causes of the alleged Mountain Bluebird population decline discussed herein are largely unsupported by direct evidence" (p. 369).

The Blue List

In 1971 *American Birds* initiated the Blue List. Species named to the Blue List "...have recently or are currently giving indications of non-cyclical declines or range contractions, ..." (Anon. 1971:948). Species, "...which for reasons of effects of chemicals on breeding biology, reduction of breeding or wintering habitat, predator problems (including man) or other causes, are now-or seem to be-substantially reduced in numbers, either regionally or throughout their range" (Anon. 1971:948), are included on the Blue List.

All three species of *Sialia* were included on the Blue List for 1971, the Eastern Bluebird, the Mountain Bluebird, and the Western Bluebird (*Sialia mexicana*) (Anon. 1971). The Blue List for 1973 again included all three species of *Sialia* (Arbib 1972). As pointed out by Pinkowski (1974), *Sialia* was the only genus, except for those with only one species, to be entirely represented on the Blue List for 1971.

No *Sialia* species were included on the Blue List for 1974 (Arbib 1973). The Mountain Bluebird was included on the Blue List for 1975 (Arbib 1974). The Western Bluebird was listed as a "possible future candidate" (p. 974); no mention was made of the Eastern Bluebird. The Blue List for 1976 once again included the Mountain Bluebird. The Eastern and Western Bluebirds were listed as "future candidates" (Arbib 1975:1071).

Nesting Ecology

Cavity nesting birds are generally classified as primary cavity nesters or secondary cavity nesters. Primary cavity nesters have the ability to excavate their own cavities. Secondary cavity nesters possess limited or no excavating capabilities and must rely on cavities made by primary cavity nesters such as woodpeckers or naturally occurring cavities formed by fire, lighting, or natural decay (Balda 1975). The Eastern Bluebird is thus classified as a secondary cavity nesting species, and as such has been known to nest in a wide variety of nest sites as summarized below.

Nest Sites

The following trees have contained cavities in which bluebirds nested: oak, pine (*Pinus* spp.), elm (*Ulmus* spp.), willow (*Salix* spp.), cherry (*Prunus* spp.), pear (*Pyrus* spp.), birch (*Betula* spp.) (Pinkowski 1974), apple (Keesler 1921), sycamore (Morgan 1913), plum (*Prunus domestica*) (Hegner 1906), pecan (*Carya illinoensis*) (Houck and Oliver 1954), cypress (*Cupressus* spp.), and chinaberry (*Melia* azedarach) (McIlhenny 1943).

Pinkowski (1974) records the following concerning nest cavities in trees: approximately half (45 percent) were found in oaks; seventy-five percent were in woodpecker holes (See below); nineteen percent were in knotholes and cavities resulting from natural decay; seven percent of the nest cavities resulted from fire-caused decay; ten of 74 nests were located in trees which were alive; in all but two of these, the limb containing the nest was dead.

Another natural structure which has been known to contain bluebird nests is old, rotted stumps (Claude 1912, Sawyer 1919, Harper 1926, Karr 1968). Other "natural" structures which may contain bluebird nests are telephone poles (Ferguson 1936) and fenceposts (Hegner 1899, Howell 1932:362).

Bluebirds often nest in cavities made by woodpeckers (Pinkowski 1974). Those woodpecker species whose cavities have been used by bluebirds include the Common Flicker (Conner and Adkisson 1974), Red-bellied Woodpecker (Centurus carolinus), Red-headed Woodpecker (Melanerpes erythrocephalus) (McIlhenny 1943), Hairy Woodpecker (Mousley 1916), Downy Woodpecker (Pettingill 1936), and Red-cockaded Woodpecker (Dennis 1971).

Two instances have been recorded of bluebirds nesting in an active Cliff Swallow (Petrochelidon pyrrhonota) colony

(Herman 1935, Preston 1938). In each case the bluebirds were successful at least to the point of having nestlings in the nest. In one case (Herman 1935) the bluebirds had apparently ousted the pair of swallows and then taken over the nest. In the second instance (Preston 1938) the bluebirds nested in an old nest which was not being used by the Cliff Swallows.

A variety of man-made "cavities" have been used by nesting bluebirds. Reed (1915) and Cole (1921) both record bluebirds nesting in mail boxes. Reed (1915) also reported bluebirds nesting in an old oil can on the top of a street lamp. A nest in an earthern jar lying on its side on the ground contained four eggs (Townsend 1916). In Corsicana, Texas, bluebirds nested in a hole in an iron post in the city cemetery; five young were fledged (Hagar 1930). Stevenson (1932) reported that bluebirds nested in an old coffee pot which was hanging on the side of a barn. Laskey (1971) noted that a pair of bluebirds nested in one compartment of a concrete block in a house under construction. The nest was about twenty feet from ground level, and three young were fledged.

An unusual bluebird nest was reported by Sprunt (1946). The nest was not in a cavity, but was "...saddled on the horizontal limb of an oak tree" (p. 95) on the campus of Clemson College, South Carolina. The nest was 4 m to 5 m above the ground and 5 m out from the trunk on a branch which overhung a "much frequented street."

An interesting account of bluebird nests in Bermuda was given by Reid (1884:175), "I have found them commonly in holes in old quarries or roadside cuttings; also in crevices of walls; in rocks, even when some little distance from the shore; in holes in trees; on the branches of trees; in stove and water pipes;...in the folds of a canvas awning...; and in several other curious situations...It occasionally drives the Red Bird, Cardinalis virginianus from its nest even after eggs have been laid and uses it for a foundation for its own." Bourne (1958:128) interpreted this account as follows, "My eventual interpretation of this record was that when the Bluebird [sic] was unusually abundant in Bermuda it appears to have been forced to adopt an unusual variety of nest sites, including unusually open ones."

Only recently have measurements of natural nesting cavities been reported. Conner and Adkisson (1974) reported the following concerning seven nests located in standing dead trees: The dead trees were 23.6±8.4 cm in diameter at breast height (DBH) and 133.9±79.7 m from mature woodlands; nest cavities were 17.1±3.9 cm in diameter and 3.3±1.0 m above the ground; entrances to nest cavities ranged from 4-12 cm in diameter. Measurements of natural cavities were also reported by Pinkowski (1974, 1976).

Pinkowski (1974) also reported the following concerning nest site selection. Bluebirds select nest cavities which are visible from a distance and can be observed from a conspicuous perch; nest sites surrounded by tall trees are rejected. Nest cavities used for summer nests averaged higher than spring nests (4.0±3.5 m vs. 3.0±2.2 m).

The behavioral patterns involved in the actual selection of a nest site by a pair of bluebirds has been described by Krieg (1971) and is summarized below. The basic nest site selection process involves the advertisement of several potential nest sites by the male and the eventual acceptance of one of these sites by the female for the actual nest site.

Krieg (1971) used the term nest demonstration display to describe this advertisement of the nest site by the male. The display consists of the male flying to and perching by the nest box (cavity) entrance with his tail and wings spread, revealing the blue color of the back. The male may also put his head in and out of the entrance hole in rapid succession and eventually enter the box (cavity). Other behavioral patterns associated with this display are wing-lifting and wing-waving in which the wings are moved up and down away from the body. The display is also accompanied by song.

Nesting Habitat

Descriptions of bluebird nesting habitat are for the most part descriptive rather than quantitative. The "...nesting site is near some open field or in a grass-grown orchard where it finds a hollow branch or an old woodpecker's hole..." (Forbush and May 1925:385). Kendeigh (1945) described the Eastern Bluebird as chiefly a forest-edge species.

"The Bluebird [sic] requires a nest environment with open grassy places, spacious lawns, meadcws, abandoned fields, pasture or fallow lands, or the margin of thin woods. Bluebirds can live neither in dense woods, nor in closely built residential sections of towns," (Thomas 1946:146). Wallace (1959) noted that the bluebird in Michigan was largely restricted to jack pine (Pinus banksiana) areas of the northern counties and remote, abandoned, or uncultivated farmlands.

Pinkowski (1974) stated that in the temperate deciduous forest region the best natural habitat for the Eastern Bluebird is that found in a wooded area following a fire. Lloyd (1938:1057) also noted that fire may create suitable nesting habitat for bluebirds and House Wrens which "...appear as if from nowhere, building their nests soon after embers have cooled." In addition, open woodlands of pine and oak in which the ground cover is sparse and dead lower branches provide feeding perches were also satisfactory (Pinkowski 1974).

Clearcuts have been found to create suitable bluebird nesting habitat (Conner and Adkisson 1974). Standing dead snags in clearcuts can create suitable nesting habitat for at least 12 years following clearcutting operations. Other human activities beneficial to bluebirds are the erection of fences, the creation of orchards and pastures, the planting of fruit-bearing shrubs, and lawn mowing (Pinkowski 1974).

The critical nesting habitat requirements of the Eastern Bluebird are the least known aspects of its ecology. The availability of a suitable nesting cavity, be it nest box, or natural cavity, is the most important element in the selection of the nesting territory (Krieg 1971). This is also true for other cavity nesting species such as the Pied Flycatcher (Muscicapa hypoleuca) and the Great Tit (Parus major) (von Haartman 1957).

In addition to the nest site, potential bluebird nesting habitat must contain adequate feeding perches and sparse ground cover in order to meet foraging requirements (Krieg 1971, Pinkowski 1974). No one has yet determined exactly what is a "suitable" nest cavity, an "adequate" number of feeding perches, or "sparse" ground cover.

Since potential bluebird nesting habitat must meet foraging requirements, it is appropriate to discuss bluebird foraging behavior. The following summary of the foraging behavior of Eastern Bluebirds is taken from Pinkowski (1977), except where otherwise indicated.

Bluebirds forage in relatively open areas and use a lookout perch to locate prey on the ground. Dropping, or flydown (Goldman 1975), is the most common foraging tactic used by bluebirds. After prey is located on the ground the bird "drops" to the ground and seizes its prey with the bill. Other foraging tactics include flycatching, which involves capturing aerial insects by short flights into the air from a perch, and gleaning, which occurs when the bird lands on and removes prey from the foliage and branches of trees and shrubs, or the main trunks of trees. Flight-gleaning is a modification of the dropping tactic in which, after locating prey, the bird descends toward the ground but remains in flight while plucking prey from vegetation.

PROCEDURES AND TECHNIQUES

Data were collected over two breeding seasons, 1976 and 1977. The study area encompassed portions of the following counties in southwestern Virginia: Montgomery, Giles, Craig, Roanoke, and Pulaski. All nest sites were within a 32-km radius of Blacksburg, Virginia.

Nest Location

Early in the investigation it was realized that several areas, such as rural areas and portions of the Jefferson National Forest recently clearcut, might support nesting bluebirds. However, it also became apparent that much time would be spent in travel, and a compromise had to be made between searching areas differing in habitat and possibly sacrificing sample size. Since other investigators had previously reported on bluebirds nesting in wooded areas (Conner and Adkisson 1974, Pinkowski 1974, 1976), it was decided to concentrate the majority of effort in rural farm areas, including abandoned farmland.

The 1976 breeding season was spent indentifying and locating roads through rural areas. This was done primarily through the use of topographic maps and in conversation with those familiar with local land uses. Once these roads were located they were driven and the presence or absence of bluebirds noted. The majority of these roads were county secondary roads with a low traffic volume, thus facilitating the search for bluebirds. Individual bluebirds were most often discovered perched on utility lines or along fencerows. Males were often located because of their vocalizations. Once individual birds were spotted they were observed in order to determine the location of the nest.

An effort was also made to search for nests away from roads. This was done by scanning fencerows and utility wires with binoculars and by searching along fencerows on foot. Scanning fencerows and utility wires with binoculars was done more or less incidentally to driving along roads. This method was used at certain places along secondary roads where there was sufficient room to park the research vehicle and potential or likely-looking bluebird nesting habitat nearby.

Scanning with binoculars, in effect, extended the search from a distance limited by the naked eye and ear to the limit of the ability of the binocular to resolve the image of a bluebird. The foraging behavior of the Eastern Bluebird, sitting on a conspicuous perch in the open and characteristically dropping to obtain prey and returning to the perch, aided in identifying bluebirds at a distance.

Access, i. e. landowner permission, was obtained at four locations away from roads where there was a large expanse of pasture surrounded by fencerows. These fencerows were searched on foot and each fencepost was observed for the presence of nest cavities and/or nesting birds.

Indian Run, a subdivision adjacent to Blacksburg town limits, was also searched for bluebirds in both years by driving roads through the area and on foot. This area was once a large farm but had been sold and subdivided into 2 ha (5 ac) lots. The area searched for bluebirds was generally abandoned pasture undergoing secondary succession. A few remnant fenceposts still stood and there were scattered woodlots primarily composed of black locust (*Robinia pseudoacacia*). Thus, the area was similar in habitat and plant species composition to Radford Army Ammunition Plant (hereafter RAAP).

Individual nest sites were located as follows. If a pair of bluebirds was located, they were observed closely during foraging. Once the bird had obtained a food item, the bird's use of the item usually revealed whether the bird was involved in nesting activities. If the bird failed to swallow the food item after preparation, it was assumed that a nest containing nestlings was nearby. The bird was observed until it went to the nest with the food item. If the bird swallowed the food item, it was then possible that either the bird was not involved in nesting activties, or that a nest nearby contained eggs. Thereafter observations were concentrated on the female in the hope that she would return to the nest to continue incubation of the eggs. In some cases the presence or location of the nest could not be determined during the period of observation and the sighting of the birds was noted for future surveys. Likewise, the sighting of individual birds, particularly vocalizing males, was noted.

During the 1977 breeding season, only those areas in which bluebirds were most efficiently located, a subjective estimate of the most birds seen per miles traveled and time spent, were revisited to be included in the data collection for that year. In addition, an effort was made to locate nests within RAAP, an area which might provide bluebird nests in a different habitat type than rural areas with a minimal expenditure of travel time.

The New River Plant of the RAAP located in Pulaski County near Dublin, Virginia, was searched for bluebirds throughout the breeding season of 1977. Preliminary observations of a bluebird nest were made in July 1976, thus it seemed possible that other bluebird nests might be located within the area. The New River Plant of the RAAP is an 826 ha area enclosed by a 2.3 m cyclone fence. The area consists of large open tracts of rolling abandoned pastureland with scattered Eastern redcedars (*Juniperus virginiana*) and considerable broomsedge (*Andropogon virginicus*), hardwood woodlots, and an 81 ha pine plantation. An extensive system of roads permeates the area. All woodlots within RAAP were searched on foot for bluebirds in the early spring (late April-early May). In addition, bluebirds were also searched for by driving through the area at a slow speed, looking for bluebirds on conspicuous perches and listening for vocalizations.

During the 1976 season the location of bluebird nests and observations on nesting success and interspecific interaction were recorded. In 1977 daily records were kept of all observations of bluebirds in the field.

Nest Cavity Parameters

Data were collected from all nest cavities used in both the 1976 and 1977 breeding seasons. Table 1 lists those parameters obtained from nest cavities. Structure refers to that which contained the nest cavity. In this investigation this was a tree or fencepost. Height of cavity entrance was taken as the perpendicular distance from the ground to the bottom of the cavity entrance. Outside diameter of the structure at cavity entrance and cavity bottom was measured to the nearest 0.2 cm with a steel diameter tape. All other linear measurements were made to the nearest millimeter with a steel tape.

Diameter of cavity entrance was the vertical and horizontal dimensions of the cavity entrance. A stiff, but flexible, wire was used to measure internal cavity diameter, which consisted of four measurements, two taken at both the

Table 1. Parameters obtained from natural nest cavities of Eastern Bluebirds in southwestern Virginia, 1976-1977.

Type of structure containing nest cavity (fencepost or tree)
If structure was tree, live or dead, species, DBH, height
Cavity origin (woodpecker or natural decay)
Total height of structure
Height of cavity entrance
Diameter of structure at cavity entrance
Diameter of structure at cavity bottom
Diameter of cavity entrance
Internal cavity diameter at cavity entrance
Internal cavity diameter at cavity bottom
Cavity depth
Distance from bottom of cavity entrance to cavity bottom
Orientation of entrance

cavity entrance and cavity bottom. Cavity depth was the distance from the highest point in the cavity to the cavity bottom and was measured with a weighted line. The distance from the bottom of the cavity entrance to the bottom of the cavity was measured in a similar fashion. Orientation of the entrance was determined with a compass. Any debris, particularly nesting material, was removed from the cavity before internal cavity measurements were taken. Inspection of the cavity interior was facilitated by a modified flashlight device as described by Seidensticker and Kilham (1969).

Cavity volume was determined from the internal cavity parameters, internal diameter and cavity depth. The cavity interior was assumed to be cylindrical in shape and the formula for the volume of a cylinder was used to calculate cavity volume. The average of the four measurements of internal diameter, divided by two, was used as the radius, r. Cavity depth and distance from entrance to cavity bottom were used as height, h, in the formula to calculate cavity volume and cavity volume below entrance, respectively.

Individual nest cavities are referred to by a numeral and a letter. The numeral was assigned to the cavity in consecutive order of discovery beginning with 1 for the first cavity discovered, 2 for the second, and so on. The letter assigned to the cavity indicates the year of the investigation in which it was used, A for 1976 and B for 1977. Since most data were collected in 1977, that year was used as the basis for referring to a cavity used during both years of the study.

Nest Habitat

The habitat surrounding nest sites utilized during 1977 was analyzed by sampling vegetation within a 0.05 ha circle around the nest. The sampling technique was a combination of techniques previously used for forest birds (James and Shugart 1970) and grassland birds (Wiens 1969). A nylon cord 12.6 m long, the radius of a 0.05 ha circle, was used to delineate the boundary of the circle and two transects, perpendicular to each other, with the center of the circle and transects at the nest. The orientation of the first transect was established by converting a three-digit number from a random numbers table to an azimuth; the second transect was then established perpendicular to the first. The cord was marked off into five equal lengths, and these five points were used to establish ten sample points along each transect, a total of 20 sample points per circle.

At each sample point the following was recorded: the presence or absence of canopy cover determined by sighting overhead through a sighting tube, and the presence or absence of ground cover determined by contact of the sample point with herbaceous vegetation. In addition, a metal rod

6.4 mm in diameter was lowered vertically into the vegetation and the number of contacts with herbaceous vegetation per 10 cm interval along the rod was recorded. Two points 0.3 m on either side of a sample point were sampled with the metal rod, a total of 40 points per circle.

The following data were recorded for all trees within the circle: diameter at breast height (DBH), measured to the nearest 0.2 cm with a steel diameter tape; height, measured to the nearest 0.3 m with an Abney level; and species. The number and species of all shrubs, woody stems less than 5 cm DBH, encountered in two armslength transects along the sampling lines were also recorded. Sampling nest habitat was generally done as soon as possible after the completion of a nesting attempt. Sampling followed the fledging of young after successful nesting attempts, or the interruption of a nesting attempt at unsuccessful nest sites.

Utilized Activity Space

During the 1977 breeding season an attempt was made to delineate the utilized activity space of adult birds during the nestling stage. The term "utilized activity space" is explained below. The term territory is classically defined as "any defended area" (Noble 1939:267). Thus, as discussed by Weeden (1965), this term should be applied only to observations of defense. Weeden (1965) measured the space used by a male bird in a clearly defined time interval and used the terms "daily activity space" and "total activity space" to describe the phenomena she observed. The observations in this investigation should most precisely be termed "daily utilized activity space-nestling stage," hereafter "utilized activity space".

In order to map the utilized activity space in the least amount of time yet yield valid and standardized observations, it was necessary to determine when the adult birds were most actively feeding young, so as to obtain the greatest amount of data in a specified time period. Pinkowski (1974) determined that the feeding rate of the young by the adults was greatest between day 10 and day 17 of the nestling stage. Also, the cessation of diurnal brooding by the female occurred between day 10 and day 13 of the nestling stage. Therefore, an attempt was made to observe nests within this time period, as determined by observations of the nest throughout the earlier stages of the nesting cycle. Pinkowski (1974) also reported that the diurnal feeding rate was greatest between 0800-1300 hours (EST). Therefore, realizing the geographical differences in the study areas, a four-hour observation period between 0800-1200 hours (DST) was used to standardize observations.

The field methods were as follows. Prior to the start of the four-hour observation period a rough sketch map of the general area in the vicinity of the nest was made noting such features as trees, roads, and fencerows. This sketch map was later enlarged as needed. Once the period of observation began, all major changes in the location of the adult birds were noted. These observations were numbered consecutively and separate observations of adult male and adult female were noted. Particular attention was paid to how the birds utilized the habitat, especially areas used for foraging. Other observations such as inter- or intraspecific interaction, removal of fecal sacs, presence of fledglings from previous nesting attempts, and other species seen in the activity space were also noted during the four hour period.

At the end of the observation period, the outermost points on the sketch map were connected, subject to observations of the actual area utilized by the birds. The points were not joined to form a regular polygon, instead the points were joined to include areas utilized and exclude areas not utilized by the birds. Once the boundaries of the utilized area were determined, the bearings of the boundary lines were determined using a hand-held forester's compass, and the distances between points were measured with a steel tape. Slope degree was measured with an Abney level and ground distances were corrected to horizontal distances. It was then possible to produce an accurate map of the boundaries of the utilized activity space. The area of the activity space was then determined using a compensating polar planimeter.

Statistical Procedures

Simple descriptitve statistics such as means and standard errors of the mean were calculated by computer, using the Statistical Analysis System (SAS) of Barr et al. (1976). A discriminant function analysis was used to discover differences in cavity dimensions. Discriminant function analysis is a multivariate statistical procedure which distinguishes between two or more groups using a collection of variables that measure characteristics on which the groups are expected to differ (Nie et al. 1975). The analysis was performed using the PROC DISCRIM option of SAS (Barr et al. 1976).

Pearson correlation coefficients among nest cavity dimensions were calculated by the Statistical Package for the Social Sciences (SPSS) of Nie et al. (1975). Data on cavity entrance orientation were analyzed using a chi-square goodness of fit test, the mean angular direction, and a parametric two-sample test as described by Batschelet (1965) and Zar (1974). Differences in means were tested for significance using a two-tailed Student's t-test.

RESULTS

Nest Cavities

Nest Location

A total of 47 natural nest sites of Eastern Bluebirds was discovered in this investigation. Table 2 presents the number of nests discovered by each method of search in rural areas and at RAAP. Approximately one-half (57 %) of the nests were discovered by driving along rural roads. In most cases these nests were in fenceposts in fencerows that ran parallel to the road. In addition, bluebirds were highly visible as they perched on utility wires which also ran parallel and adjacent to the highway. However, it should be pointed out that most of the time spent searching for bluebird nests was spent driving along roads. Thus, it is not known whether the large proportion of nests discovered using this technique was indicative of bluebirds being concentrated along roadsides or a result of more time being spent using this method.

Searching fencerows on foot produced relatively few nests for the amount of time spent. Areas searched on foot included two areas along Bishop Road, another along Rt. 624 near the intersection of Rt. 624 and Rt. 697, and the fourth on Rt. 785 near the confluence of Mill Creek and the North

Table 2. Number of natural nest sites of Eastern Bluebirds discovered by method of search in rural areas and at RAAP in southwestern Virginia, 1976-1977.

	Driving road	Scanning with binocular	On foot	Reported by others
Rural areas	27	6	2	5
RAAP	6	0	1	0
Total	33	6	3	5

Fork of the Roanoke River. The fencerows were searched on foot and only one bluebird nest and two Starling nests were discovered, both at the site on Rt. 624.

Searching woodlots on foot within RAAP was likewise relatively unproductive. One additional nest was discovered using this method. Six nests (86 %) within RAAP were discovered by driving the roads through the area. However, most nest sites at RAAP were not adjacent to roads.

The final bluebird nest discovered by searching on foot was at Indian Run. A pair of bluebirds had been seen in the area and it was suspected that they were nesting there. Several fencerows, some with fencepost cavities, were searched on foot, but the nest site was discovered by accident as the female was flushed from the nest in the trunk of a black locust as the observer walked along a fencerow nearby.

Of the nests whose location was reported by others, three were in fenceposts adjacent to roads and were discovered as the individuals drove past them, one was adjacent to a schoolyard and was discovered by persons attending a picnic there, and the final nest was behind the house of the person who reported it.

Several nests of other cavity nesting species were discovered in fencerows incidental to searching for bluebird nest cavities. These included six Starling nests, and one each of chickadee, House Wren, and Common Flicker. The flicker nest cavity was occupied by the flickers during the 1976 breeding season, and by Starlings during 1977.

A summary of the roads which were surveyed for the presence of bluebirds is given in Table 3. Nests discovered by driving roads were located adjacent to these roads. Nests discovered by the other methods were, in most cases, not far from these highways. A more complete description of the actual portions of the highways surveyed and the general location of bluebid nests appears in Appendix Table I.

Cavity Structure and Origin

Only two types of structures were found to contain bluebird nest cavities, fenceposts and trees. Thirty-seven (78%) of the natural nest cavities used by Eastern Bluebirds were in fenceposts. Fenceposts that contained nest cavities were in all cases part of a fencerow bordering a cropfield, pasture, hayfield, or woodlot. Although the species of wood of fenceposts was not determined, most were probably made from black locust, which is commonly used for fenceposts in the area. Fenceposts containing bluebird nest cavities stood generally upright, i. e. perpendicular to the ground. Two fenceposts that leaned considerably were used by nesting bluebirds.

Several landowners were informally intervived in order to determine the general age of fenceposts that contained

Table 3. Summary of surveys for the presence and/or nesting activity of Eastern Bluebirds along roads in southwestern Virginia, 1976-1977.

Road	Bluebirds present-nest discovered		Bluebirds present-but no nest discovered	
	1976	1977	1976	1977
Bishop Road[1]	O[2]	X[3]	X	X
Indian Run	X	O	X	O
Glade Road	X	O	O	X
Shadow Lake Road	X	X	O	O
Meadowbrook Drive	O	X	X	X
Tom's Creek Road	O	X	O	X
603-622-629[4]	X	--[5]	X	--
723	X	O	X	X
785	X	X	X	X
624	--	X	--	X
700	O	--	X	--
602	X	--	X	--
685	X	X	X	X
601	X	X	X	X
Va. Route 42	--	X	--	X
642-643	O	--	O	--
657-808	O	--	X	--
603-604	O	--	X	--

Table 3. Summary of surveys for the presence and/or nesting activity of Eastern Bluebirds along roads in southwestern Virginia, 1976-1977 (continued).

Road	Bluebirds present-nest discovered		Bluebirds present-but no nest discovered	
	1976	1977	1976	1977
663	--	X	--	O
621	--	O	--	X
(Poverty Creek)	O	--	X	--

[1] Roads within Blacksburg city limits are designated by name.
[2] "O" indicates the road was surveyed and no bluebird activity found.
[3] "X" indicates the road was surveyed and bluebird activity as described was encountered.
[4] County secondary roads are designated by a three-digit numeral greater than 600; primary roads by a two-digit numeral.
[5] "--" indicates the road was not surveyed.

nest cavities. Most landowners either did not know the age of the fenceposts or said the fenceposts were already in place when they had purchased the property. One landowner indicated the general age of a fencepost containing a nest cavity to be approximately forty years.

Tree limbs and trunks contained 22 percent of the natural nest cavities. Included in this broad category of trees is one nest cavity in a stump that had recently been sawed off and another in a dead tree which was broken off above the cavity entrance. Of the ten nest cavities in trees, eight were within RAAP and two were in rural areas.

Species, DBH, height, and condition of trees containing nest cavities are presented in Table 4. Three nests were in black locust and black cherry (Prunus serotina), one in a honey locust (Gleditsia triacanthos), and one in an ash (Fraxinus spp.). Tree species could not be determined in two cases. Nest cavities were found in about equal numbers in living and dead trees. Nest cavities were located in the main trunk of trees (N=5) and in limbs (N=5). All limb cavities were in dead limbs, regardless of whether the tree was live or dead.

Table 5 presents the origin of nest cavities for each type of structure and for all cavities combined. A distinction should be made here between the word "natural" as applied to nest cavities and "natural" as applied to

Table 4. Characteristics of trees containing nest cavities of Eastern Bluebirds in southwestern Virginia, 1976-1977.

Nest No.		DBH (cm)	Height (m)	Live or dead tree
20B	Honey locust, (*Gleditsia triacanthos*)	30.0	4.3	dead
2B[1]	Black cherry, (*Prunus serotina*)	56.4	13.1	live
16B	Black locust, (*Robinia pseudoacacia*)	39.9	13.7	live
17B	Ash, (*Fraxinus* spp.)	50.3	14.5	dead
29A	Black locust	41.9	18.3	live
1B[2]	Black locust	--	1.7	--
30B	Black cherry	--	12.5	live
2A	Black cherry	--	--	live
13B[3]	--	21.8	4.1	dead
23B[4]	--	--	1.9	dead

[1] Nest used twice during 1977.
[2] Nest cavity in sawed off stump.
[3] Nest used once in 1976, once in 1977.
[4] Nest cavity in dead tree broken off above cavity entrance.

Table 5. Origin of nest cavities of Eastern Bluebirds in fenceposts and trees in southwestern Virginia, 1976-1977.

	Origin		
	Woodpecker	Natural	Unknown
Fencepost	34	0	3
Tree	9	1	0
Total	43	1	3

cavity origin. Throughout this report the phrase "natural nest cavity" refers to any cavity that is not a nest box or otherwise man-made, artificial cavity. "Natural" as applied to origin refers to any natural process such as rot or decay which might produce a cavity.

Forty-three nest cavities (91 %) were made by woodpeckers. Two criteria which were used to classify a cavity as having been made by woodpeckers were: 1) a very well defined and roughly circular cavity entrance, and 2) a uniformly round to gourd-shaped interior. Bluebirds have been known to nest in the cavities of most of the eastern woodpeckers, and the cavities observed in this investigation were most likely made by Downy and Hairy Woodpeckers. Three nest cavities, two in trees and one in a fencepost, were quite large and probably made by Common Flickers.

Natural decay produced one cavity observed in this study. The cavity was in the trunk of a black locust, and contained debris from the rot. The entire bark layer around the tree was decaying and loose. It is interesting to note that other black locusts examined during the course of this study contained similar cavities, all apparently originating from natural decay.

The origin of three nest cavities in fenceposts could not be determined. In two of these cavities, the orientation of the entrance was upward, i. e. the cavities opened from the top, and this was the only entrance available to the nesting birds. The third cavity had an opening to the top, but a side entrance was used by the nesting birds to enter and leave the cavity.

Cavity Usage

The number of nesting attempts by Eastern Bluebirds in natural nest cavities in each year of the investigation is presented in Table 6. It is evident from the data presented that most nest sites were used only once and that few cavities were used for a second or third nesting attempt.

The total number of consecutive nesting attempts in those natural cavities observed during both years of the study is presented in Table 7, with the same pattern of one nesting attempt per cavity. Cavities in areas not surveyed both years are not included in these data. Of the 32 nest sites observed during both years of the study only 5 (16%) were used both years. A complete list of all cavities and their usage may be found in Appendix Table II.

The major factor which precluded the usage of a cavity during both years was the loss of or removal of the cavity structure. Four cavities were lost between the 1976 and 1977 breeding seasons, three fencepost cavities and one tree limb cavity. Two of the fencepost cavities were lost due to the replacement of the fencepost containing the cavity. In one case the fencepost had rotted away and broken off at

Table 6. Number of nesting attempts in natural nest cavities of Eastern Bluebirds in southwestern Virginia, 1976-1977.

No. of nesting attempts	No. of nest cavities	
	1976	1977
1	19	22
2	1	6
3	2	1

Table 7. Total number of consecutive nesting attempts by Eastern Bluebirds in natural nest cavities observed both years in southwestern Virginia, 1976-1977.

No. of nesting attempts	No. of nest cavities
1	22
2	7
3	1
4	1
5	1

ground level. The second case involved a fencepost that was rapidly deteriorating. The cavity was open to the top and there were two other cavity openings facing different directions in the side of the post. These fenceposts were replaced between the 1976 and 1977 breeding seasons. A third fencepost cavity was lost due to the rotting of the post. In 1977, it appeared to be no longer suitable for nesting by bluebirds, for the interior of the post had rotted away and filled the cavity interior. The tree limb cavity was lost after the dead limb containing it broke off at the cavity.

Cavity Dimensions

The dimensions of all natural nest cavities used by Eastern Bluebirds are presented in Table 8. An attempt was made to obtain all 12 of the measurements taken in the field from all cavities used as nest sites. However, several tree cavities were inaccessible because of their height or position. The twelve measurements obtained in the field from each accessible natural nest cavity of Eastern Bluebirds are presented in Appendix Table III, and are the basis of the mean cavity dimensions. In computing the mean dimensions, the observations from each cavity were weighted by the number of nesting attempts in that cavity. Since the mean dimensions of fencepost cavities and tree cavities were in some cases quite different, the dimensions for these

Table 8. Dimensions of all natural nest cavities (Mean±SE) used by Eastern Bluebirds in southwestern Virginia, 1976-1977.

Dimension	N	Mean±SE	Range
1. Height of structure (*cm*)	62	294.6±48.3	113.8-1828.8
2. Height of cavity entrance (*cm*)	62	172.1±15.2	78.9- 883.9
3. Diameter of structure at cavity entrance (*cm*)	60	17.3± 0.9	9.9- 53.3
4. Diameter of structure at cavity bottom (*cm*)	58	17.3± 0.9	10.7- 53.6
5. Cavity entrance height (*cm*)	60	4.9± 0.2	3.0- 9.5
6. Cavity entrance width (*cm*)	60	4.4± 0.1	3.2- 7.8
7. Diameter of cavity entrance (*cm*)[1]	60	4.6± 0.2	3.4- 7.9
8. Length of cavity interior at entrance (*cm*)[2]	50	7.6± 0.2	5.7- 12.2
9. Width of cavity interior at entrance (*cm*)[3]	50	7.1± 0.3	3.9- 15.4
10. Length of cavity interior at bottom (*cm*)[2]	56	7.5± 0.2	5.3- 12.5
11. Width of cavity interior at bottom (*cm*)[3]	56	7.8± 0.2	5.2- 15.4
12. Interior diameter (*cm*)[4]	56	7.5± 0.2	5.8- 11.9
13. Cavity depth (*cm*)	58	21.7± 0.9	12.0- 41.0
14. Distance from entrance to cavity bottom (*cm*)	58	14.7± 0.6	5.2- 27.1
15. Cavity volume (*cc*)	56	968.2±75.6	399.7-3696.6
16. Cavity volume below entrance (*cc*)	56	671.7±50.6	252.4-2622.4

[1] Average of the two measurements, 5 and 6.
[2] Front to back measurement.
[3] Left to right measurement at 90° from side of cavity.
[4] Average of the four measurements, 8-11.

cavities are presented in Table 9 and Table 10, respectively.

During the course of observing bluebirds in the field, male bluebirds were frequently observed giving nest demonstration display (see page 22) at fencepost cavities. Sites where the display took place were in some cases later used as a nest site and in other cases they were never used as a nest site. Hereafter, nest demonstration display sites will refer to those cavities where the display was observed, but which were not subsequently used as nest sites. The mean dimensions of these cavities are presented in Table 11.

As reported previously, eight nest cavities used by other avian species were discovered incidental to the search for bluebird nests. In order to compare the dimensions of these nest cavities with blueibrd nest cavities, the mean dimensions of the Starling nest cavities are presented in Table 12, and Table 13 presents the dimensions of the single nest cavities of the Common Flicker, House Wren, and chickadee.

A question one might ask upon examination of the various tables presenting cavity dimensions is, are there significant differences among any of the groups in cavity dimensions? In univariate statistics, this question would be answered by performing a series of t-tests, one for each dimension and each pair of groups. However, to perform this

Table 9. Dimensions of fencepost cavities (Mean±SE) used by Eastern Bluebirds in southwestern Virginia, 1976-1977.

Dimension	N	Mean±SE	Range
1. Height of structure (cm)	51	159.5± 2.5	113.8- 200.2
2. Height of cavity entrance (cm)	51	133.1± 2.7	78.9- 181.3
3. Diameter of structure at cavity entrance (cm)	51	15.8± 0.5	9.9- 25.1
4. Diameter of structure at cavity bottom (cm)	49	15.7± 0.4	10.7- 25.1
5. Cavity entrance height (cm)	51	4.7± 0.2	3.0- 9.5
6. Cavity entrance width (cm)	51	4.4± 0.2	3.2- 7.8
7. Diameter of cavity entrance (cm)[1]	51	4.5± 0.2	3.4- 7.8
8. Length of cavity interior at entrance (cm)[2]	50	7.6± 0.2	5.7- 12.2
9. Width of cavity interior at entrance (cm)[3]	50	7.1± 0.3	3.9- 15.4
10. Length of cavity interior at bottom (cm)[2]	49	7.5± 0.2	5.6- 12.5
11. Width of cavity interior at bottom (cm)[3]	49	7.8± 0.3	5.2- 15.4
12. Interior diameter (cm)[4]	49	7.5± 0.2	5.8- 11.9
13. Cavity depth (cm)	49	21.9± 1.1	12.0- 41.0
14. Distance from entrance to cavity bottom (cm)	49	14.9± 0.6	6.8- 27.1
15. Cavity volume (cc)	49	987.5±84.7	399.7-3696.6
16. Cavity volume below entrance (cc)	49	689.8±56.0	252.4-2622.4

[1] Average of the two measurements, 5 and 6.
[2] Front to back measurement.
[3] Left to right measurement at 90° from side of cavity.
[4] Average of the four measurements, 8-11.

Table 10. Dimensions of tree cavities (Mean±SE) used by Eastern Bluebirds in southwestern Virginia, 1976-1977.

Dimension	N	Mean±SE	Range
1. Height of structure (<u>cm</u>)	11	921.0±180.3	171.7-1828.8
2. Height of cavity entrance (<u>cm</u>)	11	352.8± 62.3	82.7- 883.9
3. Diameter of structure at cavity entrance (<u>cm</u>)	9	25.4± 4.7	11.7- 53.3
4. Diameter of structure at cavity bottom (<u>cm</u>)	9	25.6± 4.6	13.0- 53.6
5. Cavity entrance height (<u>cm</u>)	9	5.8± 0.8	3.9- 9.3
6. Cavity entrance width (<u>cm</u>)	9	4.7± 0.3	3.7- 6.5
7. Diameter of cavity entrance (<u>cm</u>)[1]	9	5.3± 0.6	4.0- 7.9
8. Length of cavity interior at entrance (<u>cm</u>)[2]	9	9.2± 0.7	5.8- 12.1
9. Width of cavity interior at entrance (<u>cm</u>)[3]	9	7.7± 1.2	3.9- 11.9
10. Length of cavity interior at bottom (<u>cm</u>)[2]	7	7.4± 0.4	5.3- 8.7
11. Width of cavity interior at bottom (<u>cm</u>)[3]	7	7.1± 0.5	6.2- 10.1
12. Interior diameter (<u>cm</u>)[4]	7	7.4± 0.5	6.2- 9.8
13. Cavity depth (<u>cm</u>)	9	20.5± 1.5	14.3- 26.0
14. Distance from entrance to cavity bottom (<u>cm</u>)	9	13.4± 1.4	5.2- 20.6
15. Cavity volume (<u>cc</u>)	7	832.9±119.4	424.8-1331.5
16. Cavity volume below entrance (<u>cc</u>)	7	544.7± 94.5	291.1-1055.0

[1] Average of the two measurements, 5 and 6.
[2] Front to back measurement.
[3] Left to right measurement at 90° from side of cavity.
[4] Average of the four measurements, 8-11.

Table 11. Dimensions of fencepost cavities used as nest demonstration display sites[1] (Mean±SE) by Eastern Bluebirds in southwestern Virginia, 1976-1977.

Dimension	N	Mean±SE	Range
1. Height of structure (cm)	6	151.1± 8.1	134.1- 182.5
2. Height of cavity entrance (cm)	6	128.9± 5.0	112.2- 145.8
3. Diameter of structure at cavity entrance (cm)	6	16.0± 1.4	13.2- 21.3
4. Diameter of structure at cavity bottom (cm)	5	16.0± 1.4	13.5- 20.6
5. Cavity entrance height (cm)	6	5.1± 0.9	3.5- 8.2
6. Cavity entrance width (cm)	6	4.4± 0.5	3.2- 6.3
7. Diameter of cavity entrance (cm)[2]	6	4.7± 0.7	3.4- 7.0
8. Length of cavity interior at entrance (cm)[3]	6	8.0± 0.6	5.7- 9.3
9. Width of cavity interior at entrance (cm)[4]	6	8.6± 1.7	4.6- 15.0
10. Length of cavity interior at bottom (cm)[3]	5	6.5± 0.3	5.9- 7.5
11. Width of cavity interior at bottom (cm)[4]	5	7.9± 1,4	4.7- 11.9
12. Interior diameter (cm)[5]	5	7.9± 0.9	5.2- 9.9
13. Cavity depth (cm)	5	16.7± 3.7	8.4- 30.1
14. Distance from entrance to cavity bottom (cm)	5	10.9± 3.1	4.0- 22.7
15. Cavity volume (cc)	5	978.3±367.3	180.1-2212.9
16. Cavity volume below entrance (cc)	5	653.4±278.4	85.8-1668.8

[1] Sites referred to as nest demonstration display sites were not subsequently used as nest sites.
[2] Average of the two measurements, 5 and 6.
[3] Front to back measurement.
[4] Left to right measurement at 90° from side of cavity.
[5] Average of the four measurements, 8-11.

Table 12. Dimensions of fencepost nest cavities (Mean±SE) used by Starlings in southwestern Virginia, 1976-1977.

Dimension	N	Mean±SE	Range
1. Height of structure (cm)	6	151.6± 5.1	138.2- 169.2
2. Height of cavity entrance (cm)	6	96.8± 11.1	64.0- 122.4
3. Diameter of structure at cavity entrance (cm)	6	18.4± 1.4	14.2- 22.9
4. Diameter of structure at cavity bottom (cm)	5	19.2± 1.5	16.0- 23.1
5. Cavity entrance height (cm)	6	5.8± 0.4	4.5- 7.2
6. Cavity entrance width (cm)	6	5.5± 0.5	4.0- 7.5
7. Diameter of cavity entrance (cm)[1]	6	5.6± 0.4	4.4- 6.8
8. Length of cavity interior at entrance (cm)[2]	6	11.4± 1.2	7.2- 15.9
9. Width of cavity interior at entrance (cm)[3]	6	9.5± 1.0	5.9- 11.8
10. Length of cavity interior at bottom (cm)[2]	4	9.4± 1.0	7.5- 11.3
11. Width of cavity interior at bottom (cm)[3]	4	9.5± 1.4	6.6- 13.5
12. Interior diameter (cm)[4]	4	10.0± 1.2	7.4- 13.0
13. Cavity depth (cm)	6	45.7± 5.4	33.1- 69.5
14. Distance from entrance to cavity bottom (cm)	6	31.6± 3.3	24.5- 46.7
15. Cavity volume (cc)	4	3999.8±857.0	1994.9-5819.1
16. Cavity volume below entrance (cc)	4	2572.5±496.5	1680.0-3919.0

[1] Average of the two measurements, 5 and 6.
[2] Front to back measurement.
[3] Left to right measurement at 90° from side of cavity.
[4] Average of the four measurements, 8-11.

Table 13. Dimensions of nest cavities (N=1) of three cavity nesting species encountered during study in southwestern Virginia, 1976-1977.

Dimension	Common Flicker	Chickadee	House Wren
1. Height of structure (cm)	158.3	152.9	148.5
2. Height of cavity entrance (cm)	65.8	112.9	134.0
3. Diameter of structure at cavity entrance (cm)	16.0	16.8	10.7
4. Diameter of structure at cavity bottom (cm)	--	17.0	14.2
5. Cavity entrance height (cm)	6.0	2.9	4.0
6. Cavity entrance width (cm)	7.5	3.9	3.4
7. Diameter of cavity entrance (cm)[1]	6.8	3.4	3.7
8. Length of cavity interior at entrance (cm)[2]	12.3	4.6	6.3
9. Width of cavity interior at entrance (cm)[3]	11.8	5.9	7.2
10. Length of cavity interior at bottom (cm)[2]	--	6.0	7.8
11. Width of cavity interior at bottom (cm)[3]	--	6.0	6.0
12. Interior diameter (cm)[4]	12.0	5.6	6.8
13. Cavity depth (cm)	33.1	22.0	14.4
14. Distance from entrance to cavity bottom (cm)	24.5	17.1	10.6
15. Cavity volume (cc)	3774.8	546.7	526.8
16. Cavity volume below entrance (cc)	2794.0	424.9	387.8

[1] Average of the two measurements, 5 and 6.
[2] Front to back measurement.
[3] Left to right measurement at 90° from side of cavity.
[4] Average of the four measurements, 8-11.

series of t-tests, one would be assuming that each test is independent of the other. However, the dimensions of all bluebird cavities are correlated with each other, some significantly so (Table 14). All other cavity groups show similar correlations among the dimensions. Therefore, univariate statistics are inappropriate for analyzing the data, and discriminant function analyses were used.

Discriminant Function Analysis of Cavity Dimensions

Discriminant function analysis was applied to the 16 variables obtained from all of the nest cavities encounterd during the study and to fencepost cavities used as nest demonstration display sites by bluebirds. The great disparity in the number of nest cavities for each group placed certain limitations on the analysis and the conclusions to be drawn from it. However, certain interesting relaticnships were discovered among the data.

This statistical procedure was first applied to the data obtained from fencepost cavities used as nest sites by bluebirds and Starlings and nest demonstration display sites by bluebirds. Only those cavities from which all of the variables had been obtained could be used in the analysis. Thus, the group sample sizes were 49, 5, and 4 for bluebird fencepost cavities, nest demonstration display sites, and Starling fencepost cavities, respectively. The first step was the choosing of a set of variables which it was thought

Table 14. Pearson correlation coefficients for 14 dimensions of Eastern Bluebird nest cavities (N=56) in southwestern Virginia, 1976-1977.

	1[1]	2	3	4	5	6	8	9	10	11	13	14	15
2	0.86[4]												
3	0.43[4]	0.17											
4	0.46[4]	0.20	0.99[4]										
5	0.16	-0.07	0.25[2]	0.23[2]									
6	-0.02	-0.03	0.01	0.01	0.39[3]								
8	0.10	0.05	-0.03	-0.01	0.13	0.07							
9	0.00	-0.06	0.02	0.05	0.20	0.34[3]	0.24[2]						
10	0.31[2]	0.14	-0.03	0.01	0.26[2]	0.04	0.44[4]	0.25[2]					
11	-0.04	-0.26[2]	0.29[2]	0.32[3]	0.41[4]	0.46[4]	0.15	0.65[4]	0.32[3]				
13	-0.08	-0.18	-0.19	-0.20	0.46[4]	0.37[4]	0.19	0.01	0.25[2]	0.35[3]			
14	-0.12	-0.15	-0.14	-0.15	0.49[4]	0.57[4]	0.17	-0.06	0.09	0.27[2]	0.77[4]		
15	0.00	-0.16	-0.02	-0.00	0.57[4]	0.46[4]	0.52[4]	0.44[4]	0.64[4]	0.69[4]	0.71[4]	0.60[4]	
16	-0.07	-0.18	-0.04	-0.02	0.55[4]	0.54[4]	0.55[4]	0.43[4]	0.52[4]	0.65[4]	0.64[4]	0.72[4]	0.95[4]

[1] Numbers correspond to dimensions as labeled in Table 8, page 52.
[2] Significant at 0.05 level.
[3] Significant at 0.01 level.
[4] Significant at 0.001 level.

would best discriminate among the groups. The small number of observations of demonstration sites and Starling nests limited the number of variables to three, one less than the smallest group sample size of four. Field observations suggested that these three groups seemed to differ most in the height of the cavity entrance, the diameter of the cavity entrance, and in the interior dimensions of the cavity.

The four variable sets used in the analysis were: 1) height of cavity entrance, entrance diameter, cavity volume; 2) height of cavity entrance, entrance diameter, distance from entrance to cavity bottom; 3) height of cavity entrance, entrance diameter, width of cavity interior at entrance; and 4) height of cavity entrance, entrance diameter, cavity depth. Each of these variables was used as it was entered in the analysis and corresponded to the variables of the same description as given in the tables presenting cavity dimensions, except entrance diameter, which was the product of the two dimensions, cavity entrance height and cavity entrance width. Two variables, height of cavity entrance and entrance diameter were common to all four variable sets; they differed only by the third variable.

The actual statistical analysis was based on the following: A vector of means of the three variables for each group; the covariance matrix for each group; and the proportion of observations in the population, or prior probability of membership, for each group. From these a posterior probability of membership was calculated for each observation and the observation was then classified as belonging to that group for which the probability of membership was greatest. Misclassified observations are those that belong to one particular group in the original data set, but are reclassified into another group by the discriminant function analysis. The ability of the three variables to discriminate among the groups can then be based on the number of misclassified observations. That variable set with the smallest number of misclassified observations best discriminates among the groups.

In the statistical analysis the vector of means and the covariance matrix are based on the actual data set. The proportion of observations in the population for each group may or may not be based on the data, depending on the method of sampling. If all groups are randomly sampled, then the proportion of observations in each group in the sample will be the same as the proportion of observations in each group in the population. For example, in this set of data the group sample sizes are 49, 5, and 4. Thus the proportion of observations in each group in the sample is 0.84, 0.09, and 0.07. However, the groups were not randomly sampled since the majority of searching was for bluebird nests and the other groups were observed incidental to that.

In the discriminant function analysis this proportion of observations in each group affects the analysis as follows. The larger the proportion of observations in a group the greater is the probability of an observation being classified into that group. Thus, if one particular group has a greater proportion of observations or probability of membership in the original data set, it is less likely that observations will be misclassified from this group into another group.

Three different estimates of prior probabilities were arbitrarily chosen and used in the analysis. One assumed that random sampling had been used and thus the proportions in the sample were representative of the population. The second estimate assumed that there were more bluebird and Starling nest cavities than demonstration sites, and that bluebird nests and Starling nests were present in equal numbers. Thus, the proportion of bluebird nest cavities, nest demonstration sites, and Starling nest cavities were 0.45, 0.10, and 0.45, respectively. The third estimate assumed that the three groups were equally represented in the population, thus the proportion of bluebird nest cavities, nest demonstration sites, and Starling nest cavities were 0.33, 0.33, and 0.33, respectively.

A total of twelve discriminant function analyses was performed, three different prior probabilities for each of the four variable groups. The number of misclassifications for each of these analyses is presented in Table 15. Note that for each variable set as the prior probability for a nest cavity belonging to the first group, i. e. a bluebird nest cavity, decreased, the number of misclassifications increased. Of the four variable groups, Variable Set2, height of cavity entrance, entrance diameter, and distance from entrance to cavity bottom produced the fewest misclassifications and thus discriminated among the groups better than the other variable combinations. The next best three-variable set for discriminating among the groups was height of cavity entrance, entrance diameter, and cavity depth, Variable Set3.

To better illustrate the statistical procedure, a summary of a discriminant function analysis using the best three-variable model and prior probabilities of 0.45, 0.10, and 0.45, is presented in Table 16, taken directly from the computer printout. Note that each cavity is classified into that group for which its posterior probability of membership is greatest. The three misclassifications include one bluebird nest cavity classified as a demonstration site, and one demonstration site classified as a bluebird nest cavity.

Once a discriminant function analysis has been used to

Table 15. Results of discriminant function analysis of nest cavity dimensions for three prior probabilities for each of four three-variable sets.

	Variable Set1[1]			Variable Set2[2]			Variable Set3[3]			Variable Set4[4]		
	PP1[5]	PP2[6]	PP3[7]	PP1	PP2	PP3	PP1	PP2	PP3	PP1	PP2	PP3
Accurate Classifications	51	50	38	57	55	52	54	48	41	56	54	44
Misclassifications	7	8	20	1	3	6	4	10	17	2	4	14

[1] Height of cavity entrance, entrance diameter, cavity volume.
[2] Height of cavity entrance, entrance diameter, distance from entrance to cavity bottom.
[3] Height of cavity entrance, entrance diameter, width of cavity interior at entrance.
[4] Height of cavity entrance, entrance diameter, cavity depth.
[5] Prior probabilities of 0.85, 0.09, and 0.07 for bluebird nest cavities, nest demonstration display sites, and starling nest cavities, respectively.
[6] Prior probabilities of 0.45, 0.10, and 0.45 for bluebird nest cavities, nest demonstration display sites, and starling nest cavities, respectively.
[7] Prior probabilities of 0.33, 0.33, and 0.33 for bluebird nest cavities, nest demonstration display sites, and starling nest cavities, respectively.

Table 16. Classification of Eastern Bluebird nest cavities, nest demonstration display sites, and starling nest cavities by discriminant function analysis using three variables and prior probabilities of 0.45, 0.10, and 0.45, respectively.

Cavity	From N[1]	Classified into N	Posterior probability of membership in N		
			1	2	3
3B	1	1	1.000	0.000	0.000
7B	1	1	0.505	0.000	0.495
10B	1	1	1.000	0.000	0.000
12B	1	1	0.818	0.182	0.000
18B	1	1	1.000	0.000	0.000
22B	1	1	0.968	0.000	0.032
24B	1	1	1.000	0.000	0.000
25B	1	1	1.000	0.000	0.000
26B	1	1	1.000	0.000	0.000
27B	1	1	1.000	0.000	0.000
28B	1	1	1.000	0.000	0.000
15A	1	3[2]	0.400	0.115	0.484
5A	1	2[2]	0.459	0.541	0.000
7A	1	1	0.972	0.028	0.000
9A	1	1	0.877	0.000	0.123
26A	1	1	0.752	0.248	0.000
19A	1	1	0.806	0.013	0.180
18A	1	1	0.980	0.020	0.000
17A	1	1	0.545	0.101	0.354
23A	1	1	0.725	0.135	0.140
25A	1	1	1.000	0.000	0.000
4B(2)[3]	1	1	0.876	0.124	0.000
5B(2)	1	1	0.731	0.122	0.147
6B(2)	1	1	0.928	0.072	0.000
8B(5)	1	1	0.996	0.003	0.001
11B(2)	1	1	1.000	0.000	0.000
14B(2)	1	1	0.997	0.003	0.000
15B(3)	1	1	0.653	0.347	0.000
19B(2)	1	1	0.819	0.009	0.172
21B(4)	1	1	0.984	0.016	0.000
8A(2)	1	1	1.000	0.000	0.000
3A(2)	1	1	0.939	0.000	0.061

Table 16. Classification of Eastern Bluebird nest cavities, nest demonstration display sites, and starling nest cavities by discriminant function analysis using three variables and prior probabilities of 0.45, 0.10, and 0.45, respectively (continued).

Cavity	From N[1]	Classified into N	Posterior probability of membership in N		
			1	2	3
2D	2	2	0.237	0.763	0.000
1D	2	2	0.000	1.000	0.000
3D	2	1[2]	0.782	0.210	0.008
4D	2	2	0.032	0.968	0.000
5D	2	2	0.184	0.816	0.000
5S	3	3	0.000	0.000	1.000
1S	3	3	0.000	0.000	1.000
2S	3	3	0.003	0.000	0.997
4S	3	3	0.000	0.000	1.000

[1] N=1 for bluebird nest cavities; N=2 for nest demonstration display sites; N=3 for starling nest cavities.
[2] Misclassified observation.
[3] Numbers in parentheses are weights applied to observations based on the number of nesting attempts in the cavity.

distinguish among several known groups, additional observations of unknown origin may be subjected to the analysis and assigned to these groups. However, since there were no data on unused nest cavities, ten observations were randomly chosen from the bluebird nest cavities and subjected to this analysis. Removing ten observations left 39 observations for bluebird nest cavities, with the five demonstration sites and four Starling nests as before. In addition to the ten randomly chosen bluebird nest cavities, the data from the chickadee and House Wren nest cavities were included in the analysis. The best three-variable model for discriminating among the groups was used along with prior probabilities of 0.33, 0.33, and 0.33. The results are presented in Table 17. Only two observations were misclassified, both from a bluebird nest cavity to a nest demonstration display site. Furthermore, both the chickadee and wren nest cavities were classified as bluebird nest cavities.

A discriminant function analysis was also used to find those variables which would best distinguish between bluebird nest cavities in fenceposts and bluebird nest cavities in trees. A cursory examination of Table 9 and Table 10, where the dimensions for these groups are presented, reveals the following. First, it is obvious that trees containing nest cavities are generally, if not always,

Table 17. Classification of ten randomly chosen Eastern Bluebird nest cavities and nest cavity used by Chickadee and House Wren by discriminant function analysis.

Cavity	From N[1]	Classified into N	Posterior probability of membership in N		
			1	2	3
19B	1	1	0.782	0.042	0.175
11B	1	1	0.999	0.001	0.000
8B	1	1	0.988	0.012	0.000
25A	1	1	0.996	0.004	0.000
18A	1	1	0.925	0.075	0.000
17A	1	2[2]	0.348	0.366	0.285
19A	1	1	0.780	0.055	0.165
7A	1	1	0.763	0.237	0.000
5A	1	2[2]	0.010	0.990	0.000
12B	1	1	0.534	0.466	0.000
CH	5	1[2]	1.000	0.000	0.000
HW	6	1[2]	0.656	0.344	0.000

[1] N=1 for bluebird nest cavities; N=2 for nest demonstration display sites; N=3 for starling nest cavities; N=5 for chickadee nest cavity; N=6 for house wren nest cavity.

[2] Misclassified observation.

taller than fenceposts, thus, it would be trivial to include the variable height of structure in the analysis. Secondly, the entrance diameter and the interior dimensions are roughly similar in the two groups.

Therefore, there appear to be only two variables which might distinguish between the two groups, height of cavity entrance, and either one of the variables of diameter of structure. A discriminant function analysis was performed using height of cavity entrance and diameter of structure at cavity entrance, with prior probabilities of 0.5 and 0.5, assuming that fencepost nest cavities and tree nest cavities are present in equal numbers. The results of this analysis were as follows: no fencepost nest cavities were misclassified as a tree nest cavity and only one tree nest cavity was misclassified as a fencepost nest cavity. The structure containing the misclassified tree nest cavity was a small diameter standing dead snag which had broken off just above the cavity entrance, thus it resembled a fencepost.

General Condition of Nest Cavities

During the measurement of various cavity dimensions in the field, observations on the general condition of the cavity were made and recorded. As mentioned previously, an attempt was made to establish the approximate age of fenceposts containing nest cavities by interviewing landowners, and one landowner indicated the approximate age of a fencepost containing a nest cavity to be forty years. Another indicator of age might be the general condition of the fencepost or cavity. Most fencepost and tree cavities were generally intact, perhaps indicating the relative younger age of these cavities. However, several cavities had additional holes or various other abnormalities, which probably indicate the advanced age of both the fencepost and cavity.

Most fencepost cavities had a single entrance in the side of the cavity which was used by the adult birds to enter and leave the cavity. Several other cavities had a single entrance which opened to the top of the fencepost. Six fencepost cavities had a side entrance used by the adults, but were also open to the top. These openings were roughly circular in shape and ranged in size from 1.8 cm x 5.2 cm to 6.0 cm x 6.5 cm. At only one nest were the adult bluebirds observed to use both entrances to the cavity. Eight fencepost cavities had vertical slits in the wood, some running from the top of the post to the bottom of the cavity, others only several centimeters long. Eight fencepost cavities also had other holes in the side of the cavity in addition to the cavity entrance. Three cavities each had two such holes. These holes were generally circular in shape, ranging in size from 0.4 cm x 1.9 cm to

3.0 cm x 5.5 cm. One cavity had a loose, rotten base and the fencepost was hollow below the cavity base.

Only one tree nest cavity showed such signs of age; the cavity in a dead limb in a dead tree had a vertical slit running along the back side of the cavity opposite the cavity entrance. Two Starling fencepost cavities showed similar signs of age, one post was open at the top, had a slit 7.5 cm long along the length of the cavity and had three holes in the side of the cavity in addition to the cavity entrance. A second Starling fencepost cavity was open at the top, in addition to the side entrance.

Another interesting observation concerned the presence of projections of wood extending upward from the base of the cavity. One Starling nest cavity and one nest demonstration display site, both made by woodpeckers, had such projections, which apparently resulted from the incomplete excavation of the cavity. No nest cavity used by bluebirds had such projections.

Cavity Entrance Orientation

The orientation of entrances to bluebird nest cavities in trees and in fenceposts is presented in Fig. 1. In addition, the orientation of entrances to bluebird nest demonstration display sites, Starling nest cavities, the chickadee nest, and the House Wren nest is illustrated in Fig. 2. Two bluebird fencepost cavities and one Starling

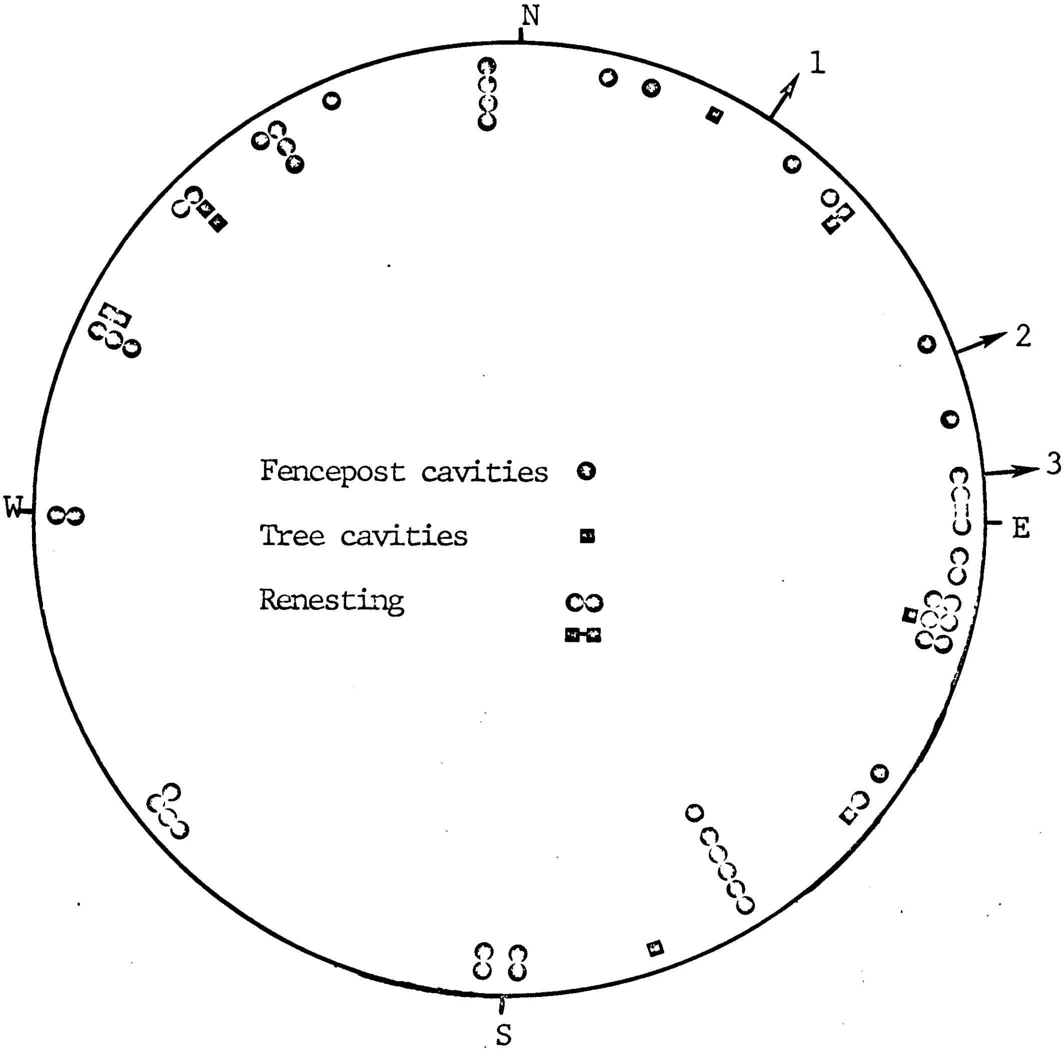

Fig. 1. Circular distribution of entrances of natural nest cavities of Eastern Bluebirds in southwestern Virginia, 1976-1977. Mean directions are indicated as follows: #1 = mean for tree nest cavities; #2 = mean for all nest cavities; #3 = mean for fencepost nest cavities.

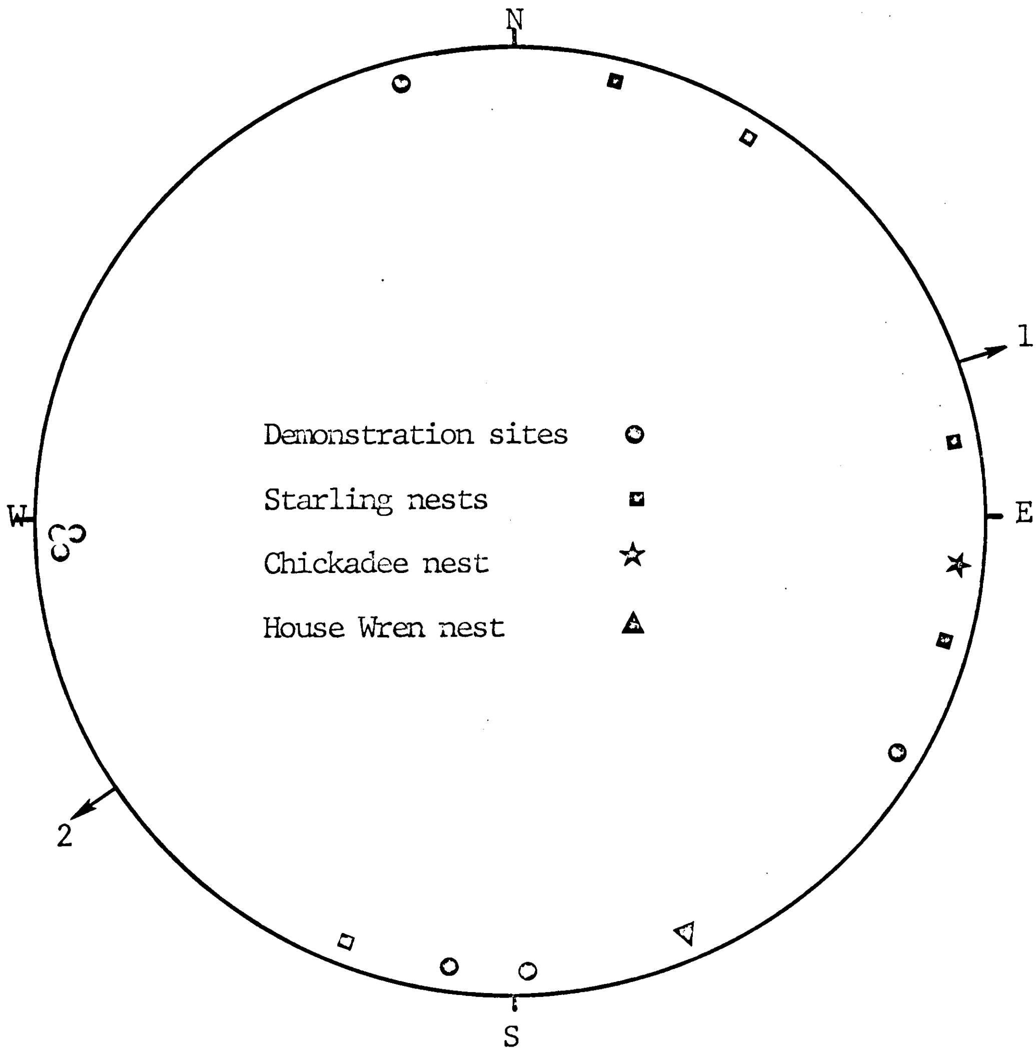

Fig. 2. Circular distribution of entrances of nest demonstration display sites of Eastern Bluebirds, and nest cavities of other species in fenceposts in southwestern Virginia, 1976-1977. Mean directions are indicated as follows: #1 = mean for Starling nest cavities; #2 = mean for nest demonstration display sites.

fencepost cavity had an upward exposure, i. e. the cavity entrance was the open top of the fencepost.

Several approaches were used to analyze these data statistically. First a chi-square goodness of fit test was performed, but it was discovered that the results of the test depended upon the number of groups into which the observations were divided. The test involved arbitrarily choosing an interval length in degrees, determining the number of observations in each interval, and testing to see if the observed number was significantly different from the expected number at the 0.05 level. The expected frequency assumed the observations to be uniformly distributed, thus, there was an equal number of expected observations in each interval. The results of these tests were as follows. When the interval length was 30, 60, or 90 degrees the test failed to reject the hypothesis that the observations were uniformly distributed. However, when the interval length was 40 degrees the hypothesis that the observations were uniformly distributed was rejected.

Further statistical analysis involved the computation of a mean angle or mean direction of cavity entrances for each group of data. The mean angle was computed from the angle of the entrance orientations, with due north as the starting point (0/360 degrees). The mean angle was based on the sine and cosine of these angles and thus was independent of the choice of the starting point. Using this method it was also possible to compute a parameter S, a measure of dispersion similar to the standard deviation, and R, a measure of the concentration about the mean direction. The results of these computations are presented in Table 18. In addition, the mean directions are illustrated in Fig. 1 and Fig. 2. In general the mean angles had considerable dispersion as illustrated by the rather large values of S and little or no concentration about the mean direction as illustrated by the small values of R. Most statitical tests are not valid for such large values of S; however, a parametric two-sample test revealed that there were no significant differences in the mean direction of cavity entrances between the following pairs of groups: bluebird fencepost cavities and bluebird tree cavities; bluebird fencepost cavities and bluebird nest demonstration display sites; bluebird fencepost nest cavities and Starling fencepost nest cavities.

Nest Habitat

Twenty-five 0.05 ha circles around 21 different nest sites were sampled during the 1977 breeding season. At four nest sites used for more than one nesting attempt, the surrounding habitat was sampled twice during the breeding season, to detect any changes in nest habitat.

Table 18. Mean direction of entrances to nests of cavity nesting birds and demonstration display sites used by Eastern Bluebirds in southwestern Virginia, 1976-1977.

	N	Mean direction	S[1]	R[2]
Bluebird nests (fenceposts)	49	84°	112°	0.1496
Bluebird nests (tree)	11	32°	89°	0.2981
All bluebird nests	60	69°	109°	0.1616
Demonstration sites	7	236°	74°	0.4304
Starling nests	5	71°	68°	0.4916

[1] "S" is a measure of dispersion, the mean angular deviation. It has properties similar to the standard deviation (Batschelet 1965).

[2] "R" is a measure of dispersion, the concentration about the mean direction. Its value ranges from 0 to 1; the higher the concentration the closer "R" is to the value 1 (Batschelet 1965).

General Description of Habitat

Of the 21 nest sites sampled, 15 (71%) of the nest cavities were in fenceposts. Nine sites were directly adjacent to roads, i. e. the fencerow containing the fencepost cavity ran parallel to the road. Fencerows tended to divide the habitat surrounding the nest into two or more different types, with dissimilar vegetation on one side of the fence as opposed to the other side. Roadside habitat adjacent to nest cavities generally consisted of a swath of herbaceous vegetation either mowed or unmowed, and the surfaced highway proper. At eight of the nine nest sites adjacent to roads the habitat on the side of the fence away from the road consisted of actively grazed pasture. In the one remaining case, the field was mowed regularly.

The remaining six nest cavities in fenceposts included two sites with a planted alfalfa (Medicago sativa) field on one side and mowed field on the other; one with actively grazed pasture on one side and a mowed field on the other side; one completely surrounded by actively grazed pasture; one with three-fourths old field and one-fourth cultivated corn (Zea mays); and one with one-half old field, one-fourth corn field, and one-fourth mowed field.

Of six nest sites in tree cavities sampled at RAAP, two were adjacent to roads. One nest was in a tree stump at the end of a row of trees adjacent to a road; one was in a standing dead snag beside a road. Two of the remaining nests were in living trees at the edge of small woodlots; one was in a dead tree at the edge of a pond; and one was in a small dead tree surrounded by free growing herbaceous vegetation.

Trees and Shrubs

A total of 14 trees was within the 0.05 ha circle at the 21 nest sites sampled, or 0.67±0.29 (mean±SE) trees per nest site. Only six of 21 nest sites (28%) had trees within the circle, four of six sites (67%) at RAAP, and only two of 15 sites (13%) surrounding fencepost cavities. The number of trees within the 0.05 ha circle surrounding nest sites is presented in Table 19. Black cherry, ash, and black locust were the most common of seven species of trees within the 0.05 ha circle surrounding nest sites.

Trees within the 0.05 ha circle were 28.3±0.5 cm (mean±SE) in DBH and 10.5±1.2 m (mean ±SE) in height. The basal area, the cross-sectional area of a tree bole at breast height of trees surrounding nest sites is presented in Table 20. The mean basal area of trees surrounding nest sites at RAAP is significantly different ($P<0.001$) from that of other nest sites.

However, the basal area of trees around nest sites at RAAP includes the trees which contained the nest cavities. Excluding live trees containing nest cavities from the

Table 19. Number of trees within 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds in southwestern Virginia, 1977.

No. of trees	No. of nest sites
0	15
1	2
2	2
3	1
4	0
5	1

Table 20. Basal area (Mean±SE) of trees within 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds in southwestern Virginia, 1977.

	N	Basal area ($\underline{m}^2$) per 0.05 ha	Basal area ($\underline{m}^2$) per ha
RAAP nests	6	0.14±0.04	2.76±0.92[1]
Other nests	15	0.02±0.02	0.38±0.31[1]
All nests	21	0.05±0.02	1.06±0.41

[1] Means significantly different at 0.001 level.

calculation of basal area, nest sites at RAAP contained 1.52 ± 0.83 m² (mean±SE) of basal area. This mean basal area is not significantly different from the mean basal area surrounding other nest sites.

Four nest sites at RAAP contained a total of seven dead standing trees. At three of these sites, a dead tree contained the nest cavity. These trees were 26.8 ± 5.7 cm (mean±SE) in DBH, 9.9 ± 1.9 m (mean ±SE) in height, and 10.07 ± 0.55 m² (mean±SE) in basal area.

Fourteen woody stems were encountered in all nest sites sampled, or 0.67 ± 0.27 (mean±SE) per nest site. Seven of 21 nest sites (33%) contained shrubs, one of six sites (17%) at RAAP and six of 15 sites (40%) at fencepost cavities. The number of woody stems in two armslength transects of the 0.05 ha circle surrounding nest sites is presented in Table 21. Sassafras (*Sassafras albidum*) and *Malus* spp. were the most common of eight species of woody stems encountered. The mean number of woody stems in two armslength transects of the 0.05 ha circle for RAAP nests and nests in other areas is presented in Table 22. The difference in mean number of woody stems between RAAP and other nests was not significant.

The results of resampling four nest sites during subsequent nesting attempts were as follows. At three nest sites the number of shrubs or woody stems present was

Table 21. Number of woody stems in two armslength transects of 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds in southwestern Virginia, 1977.

No. of woody stems	No. of nest sites
0	14
1	3
2	3
3	0
4	0
5	1

Table 22. Number of woody stems (Mean±SE) within two armslength transects (0.008 ha) of 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds in southwestern Virginia, 1977.

		No. of woody stems	
	N	per 0.008 ha	per ha
RAAP nests	6	0.17±0.17	19.67±19.67
Other nests	15	0.87±0.36	102.27±42.88
All nests	21	0.67±0.27	78.67±31.88

unchanged. At the fourth site, one of the woody stems, a clump of multiflora rose (*Rosa multiflora*), encountered during the first sampling had been removed by the landowner from an actively grazed pasture. Thus, the number of shrubs encountered in the two armslength transects decreased from two to one from the first to the second sampling.

Ground and Canopy Cover

Ground and canopy cover surrounding RAAP nests, other nests, and all nests combined are presented in Table 23. The difference in the mean ground cover of RAAP nests and other nests was not significant, while the difference in the mean canopy cover was ($P<0.001$). The ground and canopy cover for nests sampled twice during 1977 is presented in Table 24. Ground cover tended to increase slightly, while canopy cover also increased at the one site where it occurred.

Herbaceous Vegetation

A vertical density profile of herbaceous vegetation surrounding nests at RAAP and at other sites is presented in Fig. 3. In a goodness of fit test, the distribution of contacts, or height and density of the herbaceous vegetation, was significantly different ($P<0.005$) between RAAP and other nest sites. However, a goodness of fit test of the total number of contacts at each sample point, or the density of the herbaceous vegetation, was not significantly

Table 23. Ground and canopy cover (Mean±SE) within 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds in southwestern Virginia, 1977.

	N	Ground cover (%)	Canopy cover (%)
RAAP nests	6	85.00±16.56	14.17±3.57[1]
Other nests	15	82.50±10.33	1.49±1.00[1]
All nests	21	83.21± 3.39	5.54±2.01

[1] Means significantly different at 0.001 level.

Table 24. Ground and canopy cover at natural nest sites of Eastern Bluebirds in southwestern Virginia sampled twice, 1977.

	Ground cover (%)		Canopy cover (%)	
Nest site	Sample1[1]	Sample2	Sample1	Sample2
2B	100	100	25	35
4B	85	100	0	0
5B	70	75	0	0
8B	70	75	0	0

[1] Nest sites were sampled and resampled on the following dates: 2B-5 May, 18 August; 4B-27 May, 17 August; 5B-1 June, 21 June; 8B-20 June, 8 August.

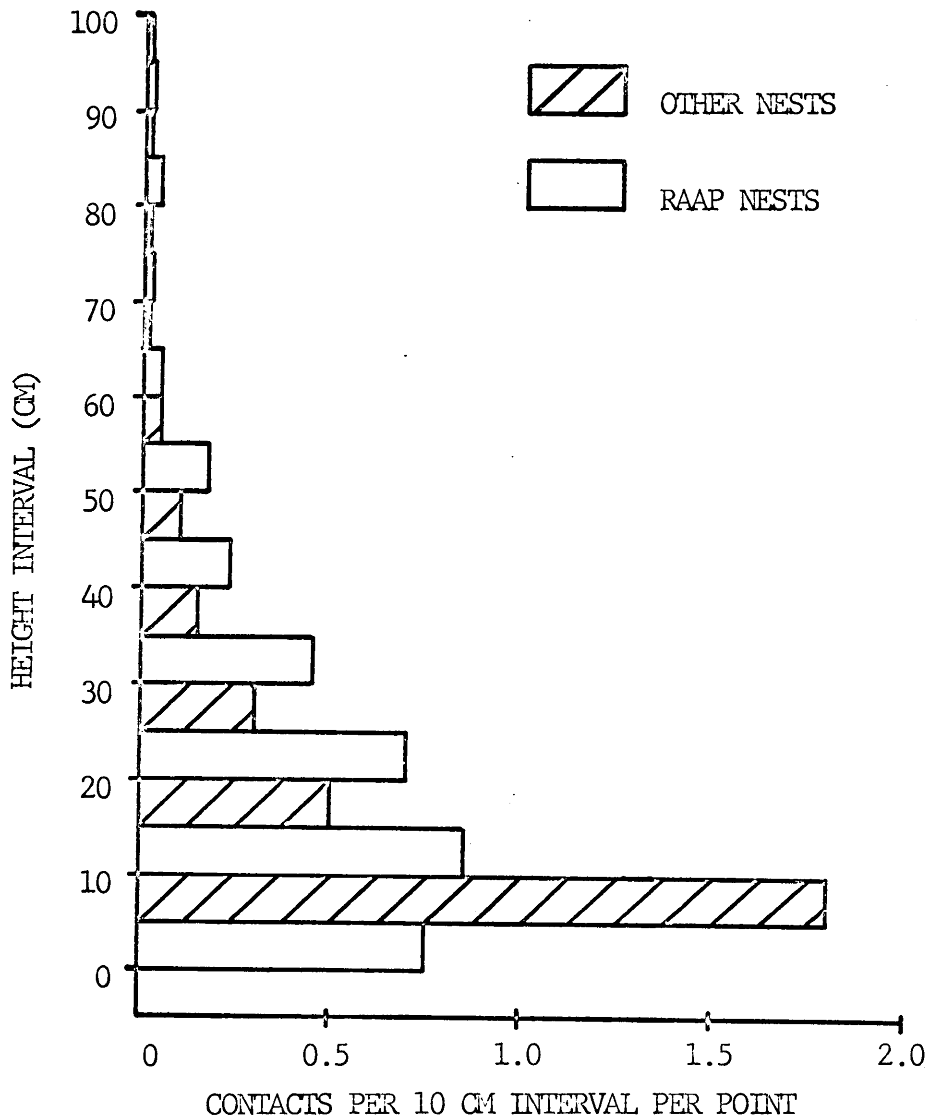

Fig. 3. Vertical density profile of herbaceous vegetation within 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds at RAAP (N=6) and other nests (N=15) in southwestern Virginia, 1977.

different between RAAP and other nest sites.

Resampling nest sites revealed the following changes in herbaceous vegetation during the breeding season. Nest site 2B, at RAAP, was completely surrounded by free growing herbaceous vegetation. No mowing or grazing had taken place between the first sampling on 5 May and the resampling on 18 August. The vegetation density profile for the initial sampling and resampling is presented in Fig. 4, revealing about the same pattern of contacts, with a shift to the right, with more contacts per interval, especially at the higher height intervals.

The fencerow at 4B divided the herbaceous vegetation within the 0.05 ha circle into two types. One side was grazed throughout the breeding season, and one side was a free growing hayfield when the habitat was sampled on 27 May. However, this hayfield had been mowed just prior to resampling on 17 August. The vegetation density profile for the two samplings is presented in Fig. 5.

Both nest sites 8B and 5B were adjacent to roads and their habitats were divided by the fencerow into road and roadside on one half, and actively grazed pasture on the other half. Resampling at these sites revealed very little change in the herbaceous vegetation, except for a tendency towards fewer contacts in each 10 cm interval in the resampled data.

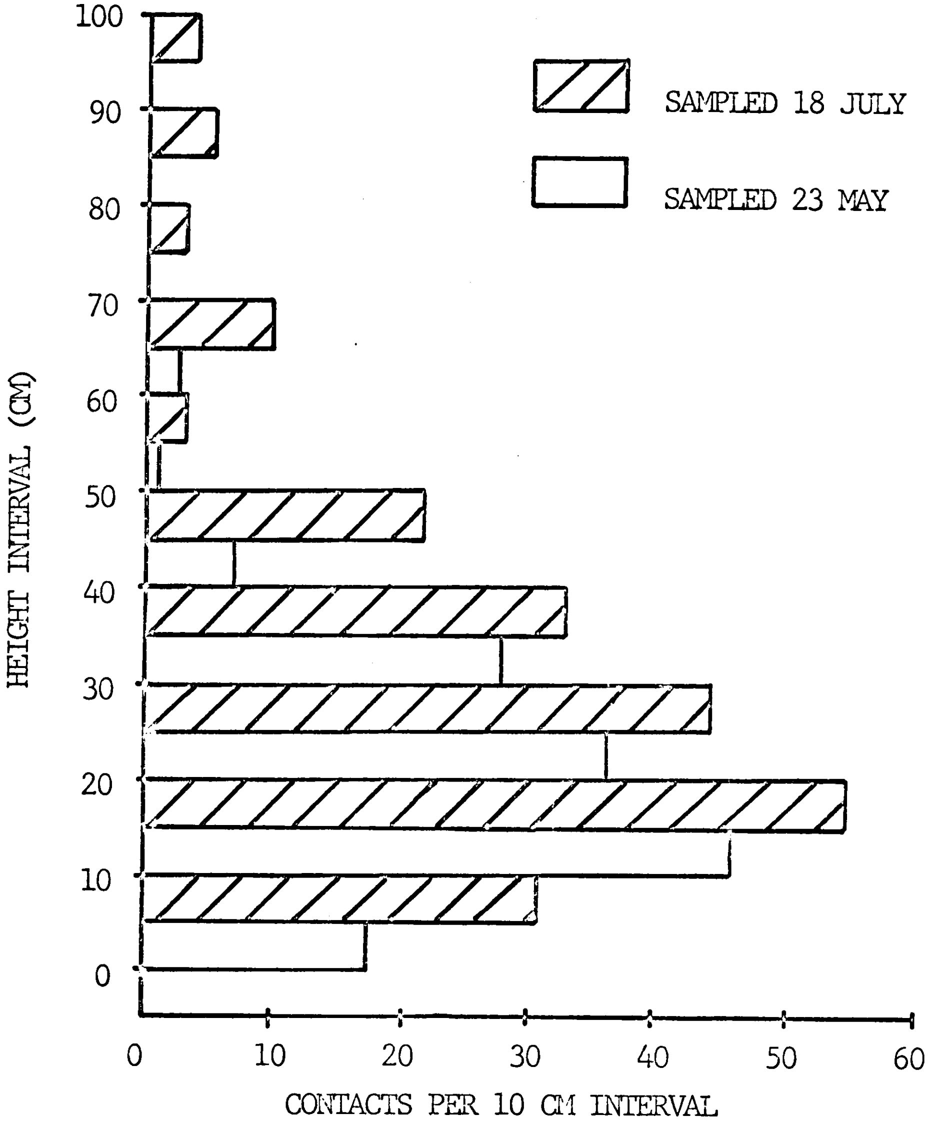

Fig. 4. Vertical density profile of herbaceous vegetation within 0.05 ha circle surrounding natural nest site (2B) of Eastern Bluebirds in southwestern Virginia sampled twice, 1977.

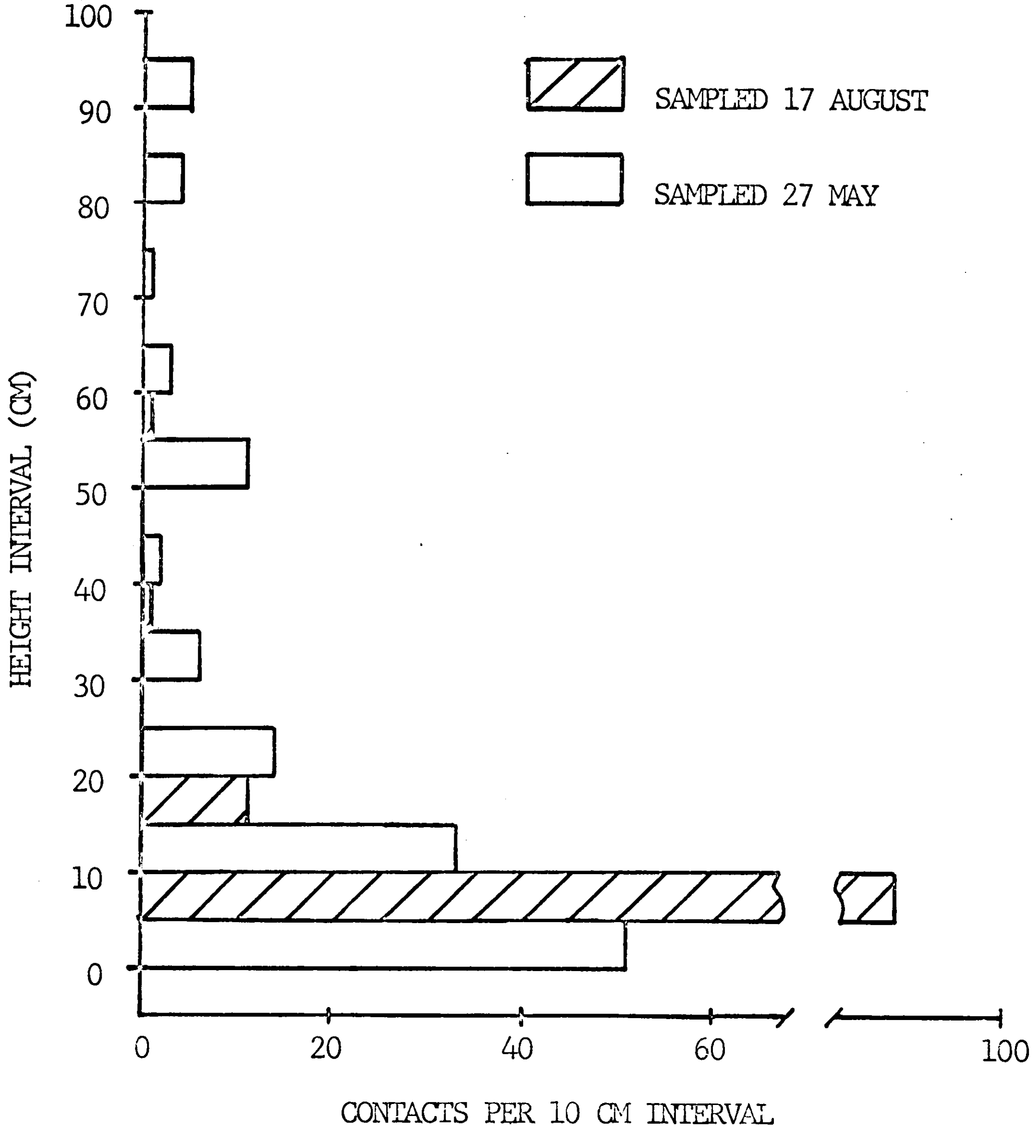

Fig. 5. Vertical density profile of herbaceous vegetation within 0.05 ha circle surrounding natural nest site (4B) of Eastern Bluebirds in southwestern Virginia sampled twice, 1977.

Utilized Activity Space

As prevoiusly described, an attempt was made to map the utilized activity space of adult birds between day 10 and day 17 of the nestling stage. This requirement placed restrictions on the number of nests which could be obserevd in order to map the activity space. First, the nesting attempt had to reach the nestling stage; nests unsuccessful prior to that stage could not be used. Second, the exact ages of nestlings were not known, therefore, feeding behavior of the adults, whether the adult entered the cavity to deliver food items to the young or perched by the cavity entrance, observations of nestlings within the cavity, and fecal sac removal had to be used to determine approximate nestling age. These criteria of nestling age generally proved satisfactory, however, in several instances prepararions were made to map an activity space only to discover that the young had already fledged from the nest.

A four hour observation period at each nest site was used in mapping activity spaces. In general, this time period seemed adequate for the purposes of this investigation. At several nest sites the adult birds made no major changes in location after two hours' observation. In other cases there was no doubt that the birds were utilizing a larger area than it was possible to map. In these instances, terrain, and the use of only one observer in the field prevented a more thorough mapping of the activity space. In one instance the adult birds were observed for the prescribed time period, but too few observations had been made to map the space completely. Therefore, this site could not be included in the results.

<u>General Description of Utilized Activity Spaces</u>

It is difficult to characterize the general shape of activity spaces. All were irregular polygons, most more or less rectangular in shape. This tendency for activity spaces to be more linear than circular in shape was the result of the boundaries following fencerows, roadsides, or utility wires which were used as perches or for foraging by bluebirds.

At three of the seven nest sites where activity spaces were mapped, the structure containing the nest cavity was directly adjacent to a road. However, all seven spaces included roads, and roads and roadsides were used as foraging strata by bluebirds. Activity spaces at RAAP included, in addition to roads, old field habitat and either lone standing trees or woodlot edges. Activity spaces in areas other than RAAP included actively grazed pastures, hayfields in various stages of growth, scattered trees, and planted alfalfa fields. Four activity spaces included streams or standing water within their boundaries. Sites 4B and 8B, which overlapped slightly, both included a portion of Tom's Creek; site 11B included a portion of the North Fork of the Roanoke River; and the nest cavity at 17B was in a dead tree beside a small pond.

As mentioned earlier, the activity spaces at sites 4B and 8B overlapped, with two separate pairs of bluebirds utilizing separate nest cavities. At RAAP, sites 1B and 16B also overlapped. In this instance it appeared from observations in the field that it was the same pair of bluebirds utilizing two separate nest cavities in succession.

Size of Utilized Activity Spaces

A summary of the mapping of, location, and size of utilized activity spaces is presented in Table 25. The seven activity spaces were 1.8±0.2 ha (mean±SE) in area, with spaces at RAAP 2.4±0.1 ha (mean±SE) and at other sites 1.4±0.3 ha (mean±SE) in area. The difference in the mean area of activity spaces at RAAP and at other sites is significant at the 0.05 level.

As mentioned previously, observations of bluebirds in the field were of adult bluebirds foraging and feeding nestlings. Thus, the term "utilized activity space" does not mean "territory", which connotes defense of an area. However, at nest site 15B observations of defense activities were made during the mapping of the utilized activity space, as described below.

Table 25. Summary of mapping and size of utilized activity spaces of Eastern Bluebirds in southwestern Virginia, 1977.

Nest site	Date Mapped	Location	Area (*ha*)
1B[1]	10 May	RAAP	2.3
4B	27 May	Shadow Lake Road	0.7
11B	28 June	Rt. 785	1.5
15B	6 July	Rt. 601	1.3
16B[1]	7 July	RAAP	2.3
17B	19 July	RAAP	2.5
8B	28 July	Shadow Lake Road	2.2

[1] These activity spaces involved the same pair of bluebirds using two different nest sites in succession.

During the course of observing the adult bluebirds at this site, a second, apparently unmated, male bluebird appeared, vocalizing, and approaching the female near the nest cavity. The resident male on several occasions chased the intruding male from the vicinity of the nest cavity, the chases taking place over a planted alfalfa field. However, neither the resident male nor the resident female ever utilized the alfalfa field for foraging. The resident male did deposit fecal sacs over the field on four occasions, flying over the field and dropping the sac while in flight, and landing in a black locust sapling, on a branch 1.8 m high. The portion of this alfalfa field defended by the male comprised a total area of 0.9 ha.

Utilization of Activity Spaces

The principal activity of bluebirds observed was foraging, with particular attention given the type of perch used and the general areas where foraging took place. The types of perches used for foraging perches and their heights are presented in Table 26. Foraging perches (N=63) were 5.0±0.4 m (mean±SE) in height.

The type of perch used most often by bluebirds were dead, leafless branches. These branches were generally found beneath the canopy of the tree or were leafless branches extending beyond leaved branches within the canopy of the tree. Leafless branches were the most commonly used

Table 26. Height (Mean±SE) of foraging perches used by Eastern Bluebirds in southwestern Virginia, 1977.

Type of perch	N	Height (m)
Leafless branch, live tree	24	4.9±0.7
Utility wire	15	7.1±0.5
Top of shrub or tree	9	5.2±1.2
Highway sign	4	2.5±0.1
Leafless branch, dead tree	2	3.6±0.9
Leaved branch, live tree	2	10.1±1.8
Split rail fence	2	1.2±0.0
Dead common mullein stalk (*Verbascum thapsus*)	1	1.8
Reflector post	1	0.9
Concrete ledge	1	2.7
Metal rod	1	1.8
Stone monument	1	3.4
Fencewire	1	1.1

perches at RAAP and at other sites. Other perches used at RAAP for foraging perches were the tops of shrubs or small trees, highway signs, metal rods atop bunkers, concrete ledges along the facade of bunkers, and dead common mullein (Verbascum thapsus) stalks. Foraging perches (N=25) at RAAP were 3.4±0.5 m (mean±SE) in height. Foraging perches in areas other than RAAP included utility wires, fencepost tops, and strands of fencewire. Foraging perches (N=39) in these areas were 6.1±0.5 m (mean±SE) in height. The difference in mean foraging perch height between RAAP and other areas is significant ($P<0.001$).

Areas used at RAAP for foraging by bluebirds included mowed vegetation bordering roads, road sufaces, mowed areas around bunkers, bare rock surfaces, and vegetation directly beneath trees whose branches were used as foraging perches. All of these, with the exception of bare rocks and the latter, were the result of man's activities in the area. In addition, all of these areas were unevenly spaced throughout the utilized activity space. Open, old field habitat, as characterized by the vertical density profile of herbaceous vegetation surrounding nest sites (See Fig. 3) was not used for foraging by bluebirds. Although measurements of vegetation density beneath trees used for foraging were not taken, the vegetation in these areas seemed to be less dense than in open fields, perhaps due to the decreased light reaching the herbaceous vegetation layer because of the overhead canopy.

At nest sites in other areas, roads and roadsides were also used as foraging strata by bluebirds. In addition, actively grazed pastures and mowed hayfields or lawns were used for foraging. In contrast to RAAP, these areas used for foraging comprised the major portion of the activity space. In addition, the vegetation density profile of these strata could be characterized by the vegetation density profile surrounding nest sites (See Fig. 3), since they were included within the 0.05 ha circle used for sampling nest habitat.

At nest site 4B, the fencerow divided the habitat surrounding the nest into an actively grazed pasture on one side and a hayfield on the other. During the mapping of the utilized activity space, it was observed that the bluebirds were foraging in the grazed pasture, but not in the hayfield. The vegetation density profile of these two strata is presented in Fig. 6.

Observations of bluebirds foraging at nest site 11B also revealed some interesting relationships between foraging tactics and vegetation density. At this site, the fencerow divided the habitat into mowed field on one side and a planted alfalfa field on the other. The vegetation density profile of these two strata is presented in Fig. 7.

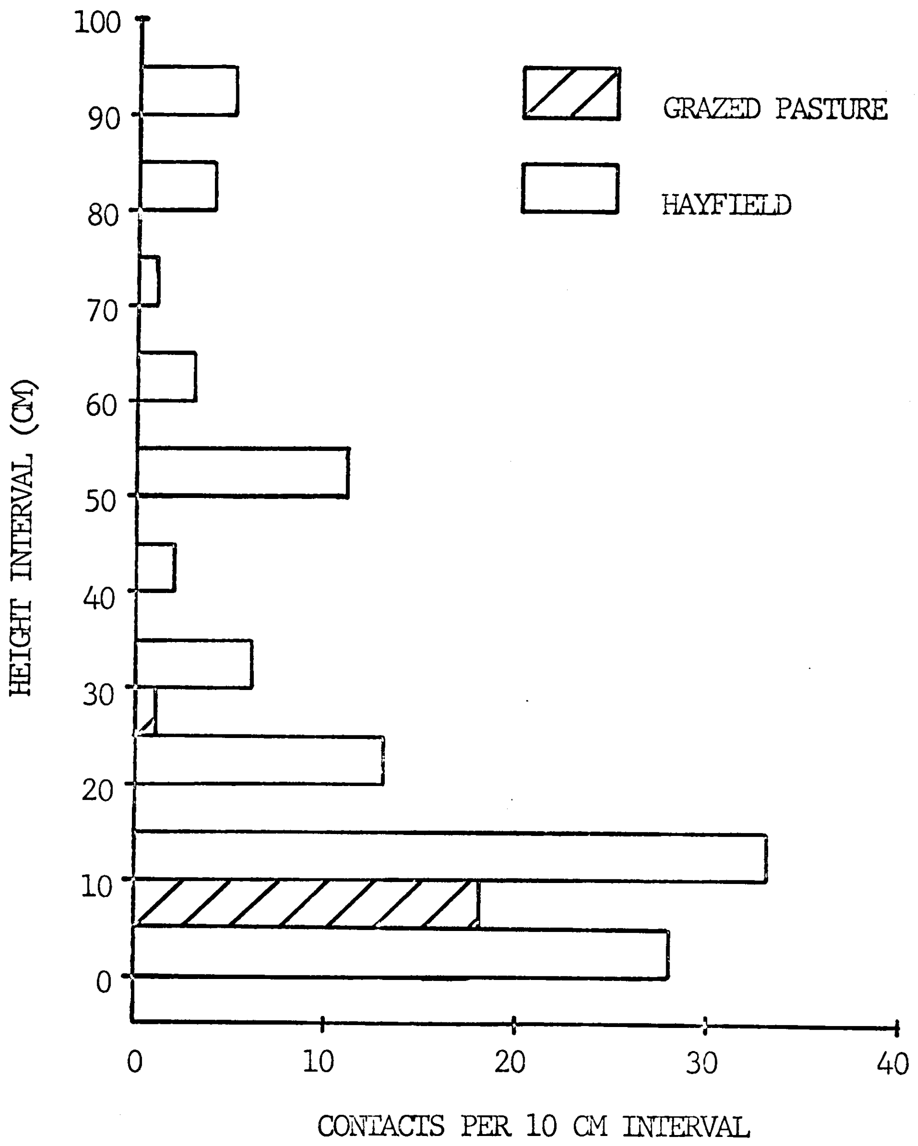

Fig. 6. Vertical density profile of two herbaceous vegetation types within 0.05 ha circle surrounding natural nest site (4B) of Eastern Bluebirds in southwestern Virginia, 1977.

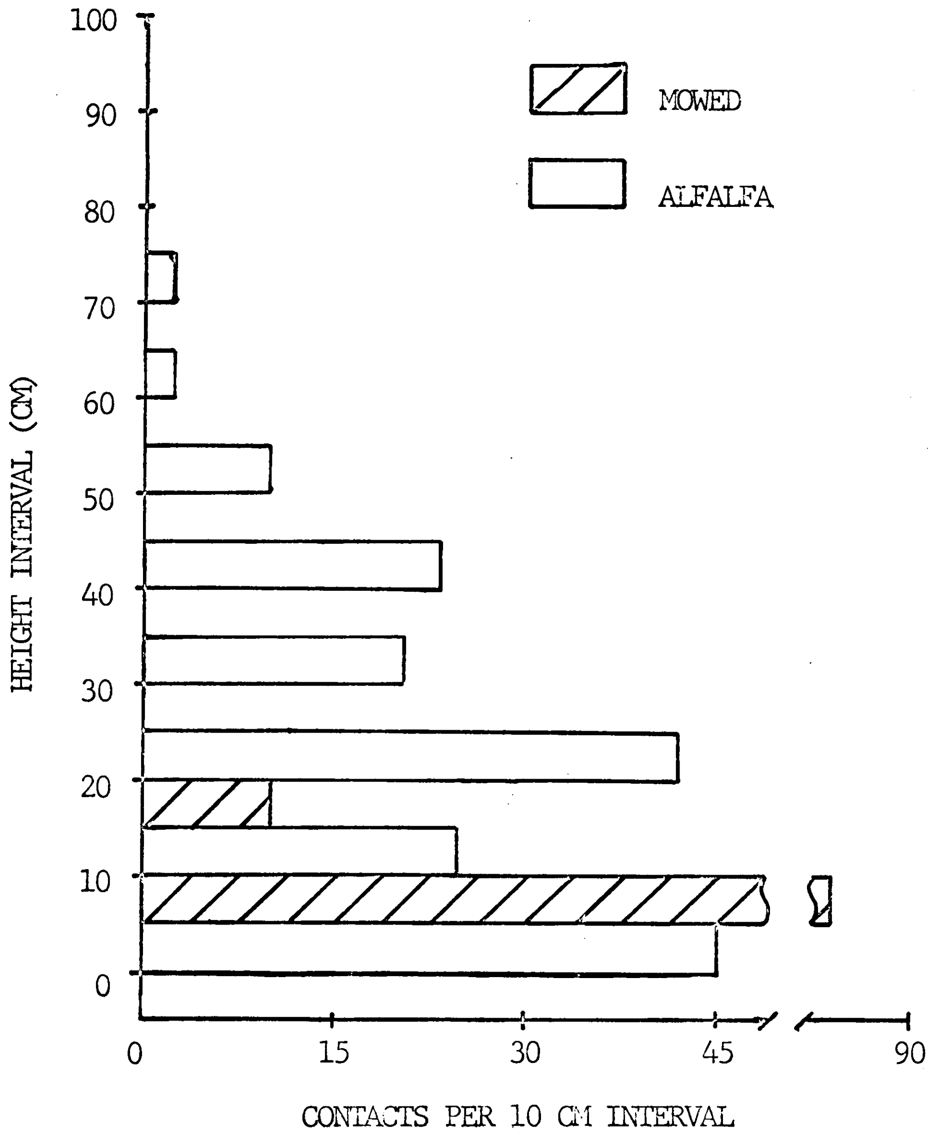

Fig. 7. Vertical density profile of two herbaceous vegetation types within 0.05 ha circle surrounding natural nest site (11B) of Eastern Bluebirds in southwestern Virginia, 1977.

Bluebirds foraged in their usual manner, employing the drop or flydown method, on the mowed field. However, the male bluebird was observed using the flight-gleaning foraging tactic, hovering over the alfalfa and plucking larvae from the vegetation. This tactic was observed repeatedly, and the male would glean 3-4 larvae in succession before returning to the nest to feed the nestlings.

Another activity of bluebirds observed in the field was the removal of fecal sacs from the nest cavity. This activity was observed fourteen times with the following results: Seven times the fecal sac was deposited on leafless branches 5.7±0.8 m high (mean±SE) in living trees, once on a leafless branch 7.6 m high in a dead tree, and once on a utility wire 8.2 m high. Five times the fecal sac was dropped in flight. All fecal sacs were deposited at a considerable distance from the nest, and the points where fecal sacs were deposited were often the points farthest from the nest site in the utilized activity space.

Other Relevant Observations From Field Notes

During the course of observing bluebirds in the field, many relevant observations were made on several aspects of bluebird nesting behavior and ecology. These observations are summarized below. All dates are for 1977 unless otherwise indicated.

Nest Site Competition

Not one single instance of aggressive interaction between bluebirds and other cavity nesting species at a nest cavity was observed in the field. In fact, several cavity nesting species were often observed nesting in the vicinity of each other without aggressive or defensive interaction, as was the case at nest site 4B.

At this site there was one fencerow running perpendicular to the road and a second fencerow running more or less perpendicular to the first, and parallel to, though at some distance from, the road. On 1 April, a pair of chickadees was observed flying from a fencepost cavity in the first fencerow, apparently excavating small wooden chips from the nest cavity. On 4 May a pair of bluebirds was seen at a second nest cavity in a fencepost in the second fencerow, the female apparently incubating eggs at this time. On 27 May the utilized activity space of the bluebirds was mapped, and during those observations a Starling was seen carrying nest material into a cavity in a fencepost in the same fencerow as the bluebird nest cavity, 12 m away. No interaction was observed between the Starling and bluebirds.

The bluebird young fledged on 7 June, and at this time the Starling young could be heard vocalizing in their fencepost cavity, and a pair of House Wrens was building a nest in the third fencepost cavity at which the chickadees had been seen earlier. By 15 June the Starling nest was empty and a large quantity of droppings around the cavity entrance and on the ground below the cavity entrance suggested that the Starling young had fledged. The wren nest contained five eggs on this date. In addition, location calls of bluebirds were heard and four bluebirds were seen flying across an open field above their former nest site. The wrens were observed feeding young in their nest cavity on 4 July, and the nest was empty on 15 July. All three species apparently were successful in fledging young.

Meanwhile, a female bluebird was observed carrying nest material to nest site 4B on 15 July, and entering the nest cavity on 26 July. On 2 August one recently hatched young and two eggs were observed in the nest cavity. However, no adult bluebirds were seen in subsequent observations at the nest site, and on 10 August the nest cavity was empty. Neither the Starling nor the the wren renested at this site.

Importance of Trees to Recently Fledged Young

Recently fledged young were always found perched on tree limbs, usually on the larger limbs and near the tree trunk. During this time the young were still fed by the adults, and their spotted plumage aided in camoflaging the young against the background of tree bark patterns. The trees or groups of trees where the young were found were always close to the original nest site. In fact, at nest sites where utilized activity spaces were mapped, fledglings were subsequently discovered in trees that were within the activity space boundaries.

Obstruction of Fencepost Cavities by Virginia Creeper

Two fencepost nest cavities, 6A and 3B were obscured by Virginia creeper (*Parthenocissus quinquefolia*) during the nesting season and were not reused for a second nesting attempt even though both of the nesting attempts had been successful. Both nests were used early in the nesting season, as summarized below.

Nest 6A was discovered on 2 May 1976, and the adults were then feeding well developed young. By 12 May 1976, the young had fledged and the adults and fledglings were seen in the vicinity of the nest on 19 May 1976. Later in the breeding season it was discovered that Virginia creeper had obscured the nest cavity entrance. No subsequent nesting attempts were observed at this nest cavity.

The female bluebird was seen carrying nest material into cavity 3B on 14 April. On 16 May the female was apparently incubating eggs in the nest cavity, the entrance of which had already been obscured by Virginia creeper. By 26 May the young had fledged and were observed about 0.3 km (0.2 mi) away from the nest site. The bluebirds did not renest in cavity 3B.

DISCUSSION

Nest Cavities

Nest Location

Bluebirds were discovered along roads in rural areas because they were nesting in fenceposts adjacent to roads, or they were conspicuously perched on utility wires that ran next to roads. Undoubtedly there were bluebirds nesting in areas beyond the limits of the search methods used in this investigation. However, searching fencerows on foot proved to be relatively unproductive. All searches on foot in rural areas were conducted in areas where bluebirds had been previously sighted, and the failure to find additional nest cavities perhaps indicates that had most of the time been spent searching for nest cavities on foot, few would have been found.

At RAAP, bluebirds were discovered along roads for a different reason, namely that mowed strips of vegetation along roads provided foraging strata for bluebirds that could not be found elsewhere in the area. Thus, searching along roads was the ideal method for finding bluebirds within RAAP.

Cavity Structure and Origin

Most nest cavities found were in fenceposts, therefore man's activities in this area have a profound influence on the number of nest cavities available to bluebirds. Approximately one-fourth of the fenceposts with nest cavities were quite old, and likely to be replaced in a few years. Replacement of fenceposts by landowners most certainly depends on a complex set of sociological factors as well, including perhaps the financial status of the landowner, and the particular level of maintenance followed by the landowner.

Two fenceposts containing nest cavities were replaced by landowners between the 1976 and 1977 breeding seasons, and a third fencepost cavity had rotted away and was no longer usable. However, no new cavities were observed being excavated by woodpeckers in fenceposts during the entire study. Furthermore, few woodpeckers were discovered utilizing existing fencepost nest cavities. In fact, only one active woodpecker nest cavity was discovered. This represents a net loss in the number of fencepost nest cavities available for bluebirds, and although only a small number might be lost each year, would eventually mean the loss of all such cavities if no replacements become available.

Many questions regarding fencepost cavities remain unanswered. At what age do fenceposts first become suitable for woodpeckers to excavate cavities? Does *Fomes rimosus*, a heart rot that infects black locust (Fowells 1965), play a similar role in woodpecker nest cavity excavation in fenceposts as *Fomes pini* does in pine tree nest cavities (See Conner et al. 1976, for a review of this subject)? How long do fenceposts last, and therefore, how long do fencepost cavities last? Do fencepost cavities last longer than tree limb nest cavities that are susceptible to rotting and breaking off?

On a larger scale, land use patterns may also affect the number of fencepost cavities available for nesting. Suburbanization and the conversion of former pasture land to residential subdivisions was evident even during the short time span of this study. Fenceposts and fencerows once used for enclosing cattle were being replaced by decorative fencerows made from chemically treated fenceposts. This chemical treatment of fenceposts is intended to delay or eliminate rot, and should limit the excavation of fencepost cavities by woodpeckers.

Of the four species of trees which contained nest cavities, three species had not previously been reported to contain bluebird nest cavities. These were black locust, honey locust, and ash. Many other naturally decayed cavities were found in black locust, and these may eventually become large enough for use by bluebirds.

Cavity Usage

One advantage in studying bluebirds in nest boxes as opposed to bluebirds in natural cavities is that nest box trails provide a known number of nest sites in known locations. This would facilitate the monitoring of nest boxes to determine usage and nesting success. Furthermore, bluebirds in nest boxes can easily be banded, particularly young and females. The first year of this study was spent locating general areas where bluebirds were nesting, and the second year was the year when most data were collected. New bluebird nests were discovered throughout the breeding season in both years and the usage, prior to their discovery, of nest cavities discovered late in the breeding season was not known. This may account for some of the nest cavities being used for only one nesting attempt.

An unsuccessful nesting attempt may cause bluebirds to choose a different nest site for subsequent nests, although an exception to this generalization was observed. One factor which may determine the reuse of a nest cavity after an unsuccessful nesting attempt is the cause of the nest failure and the presence or absence of broken eggs or dead young in the nest cavity. At one nest site the eggs disappeared from the nest cavity while the nest material inside the cavity remained intact. This predation was probably the action of a snake, based on criteria provided by Pinkowski (1975). In this instance the male remained near the nest cavity and eventually renested with either the female from the previous nesting attempt or a new female. In another unsuccessful nesting attempt, three dead nestlings were found inside the nest cavity. The male and female then renested in another nest cavity nearby.

Bluebirds seemed more likely to renest in a nest cavity following a successful nesting attempt, although exceptions to this generalization were also observed. Bluebirds on two occasions failed to renest after a successful nesting attempt, nesting successfully in another nest cavity.

<u>Cavity Dimensions</u>

Several dimensions are of particualr interest in discussing cavity dimensions: cavity entrance diameter, interior cavity diameter, and cavity depth. Entrance diameter has been assumed to be critical in nest box construction, with an entrance diameter of 3.8 cm recommended for excluding larger cavity nesting species, particularly Starlings, from nest boxes (Kibler 1969). Few natural nest cavities had entrance diameters less than 3.8 cm: eight of 34 fencepost nest cavities, and 0 of 7 tree nest cavities (See Appendix Table III).

Nest cavity 10B is worthy of particular note. This cavity had an entrance diameter height of 3.3 cm and a cavity entrance width of 3.4 cm. Upon observing this nest in the field it was noticed that the female bluebird seemed to struggle somewhat while entering the cavity. Therefore, this entrance diameter seems to represent a minimum that bluebirds are capable of utilizing. This value is also far below a minimum entrance diameter of 3.7 for bluebird tree nest cavities reported by Pinkowski (1976).

Interior diameter is also a dimension which probably has some minimum below which the cavity would not be acceptable for nesting by bluebirds. Pinkowski (1976) reported a minimum of 5.7 cm which he considered to be critical. This minimum was exceeded by all of the nest cavities examined in this study.

Interior diameter at the cavity bottom for all bluebird nest cavities was 7.3±0.3 cm (mean±SE). Assuming the cavity interior to be circular, the area of the cavity bottom was 45.7±2.6 cm^2 (mean±SE). Various authors have recommended the area of the bottom of nest boxes to be 70-160 cm^2 (See summary by Kibler 1969). It was observed during the present study that nests in natural cavities were quite smaller than nests previously observed in nest boxes. Pitts (1976) also observed that nest box size influenced nest size, with larger nests being built in larger nest boxes. The building of larger nests in nest boxes would place greater energy demands on female bluebirds, particularly early in the nesting season, and the increased activity might attract predators to the nest box. It is therefore recommended that the area of the floor in nest boxes be no greater than 50 cm^2, an area equivalent to a square 7 cm on a side.

Cavity depth may have some influence on nesting success, with very shallow nest cavities being more susceptible to predation than deeper nest cavities. Two nest cavities in this study had cavity depths below the minimum of 7.6 reported by Pinkowski (1976) (See Appendix Table III, Distance from entrance to cavity bottom, Dimension 14, is equivalent to cavity depth as measured by Pinkowski 1976). Nest cavity 10B had a cavity depth of 6.8 cm and cavity 29A had a cavity depth of 5.7 cm. The single nesting attempt in cavity 10B was unsuccessful, due to predation, however, the single nesting attempt at 29A was successful.

Discriminant Function Analysis

In the discriminant function analysis, the prior probabilities of membership in each group, or proportion of observations in each group, had to be arbitrarily chosen. However, involved in the choice of these probabilties were some very basic questions concerning cavity nesting species and the availability of nest cavities.

Of primary importance is the availability of nest cavities. It has long been assumed that there is a shortage of nest cavities, and thus, intense competition for available nest sites. A shortage of nest sites has often been cited as a reason for the decline in bluebird numbers (Krug 1941, Bent 1949, Zeleny 1968). However, few attempts have been made to determine the actual number of nest cavities available in a given area and the percentage of available cavities actually used. Gysel (1961) inventoried natural cavities in several different forest types and found that of those tree cavities that were judged to be suitable for use, only a small proportion was actually used.

The statistical analysis allowed for the choosing of several different prior probabilities, each with a different effect on the outcome of the analysis. However, a research project which would determine these probabilities by employing random sampling in the field would greatly add to the understanding of the interactions between cavity nesitng species. The objective of such a project would be to determine the total number of available nest cavities in a given area; the use of these nest cavities by avian and other species; and the number of unused cavities.

In the statistical analysis, the three variables height of cavity entrance, entrance diameter, and distance from entrance to cavity bottom were found to best discriminate among the groups of fencepost cavities. Height of cavity entrance was chosen for use in the analysis because it had been observed in the field that entrances to bluebird fencepost nest cavities were generally near the top of the fencepost and that entrances to Starling nest cavities were much closer to the ground (Compare Dimension 2 in Tables 9 and 12). The other two variables were used because they related to general cavity size and it had been observed that Starling nest cavities were much larger than bluebird nest cavities (Compare Dimensions 5-14 in Tables 9 and 12).

Height of cavity entrance was not a good dimension for distinguishing between bluebird nest cavities and nest demonstration display sites (Compare Dimension 2 in Tables 9 and 11). In cavity entrance diameter, nest demonstration display sites averaged larger than bluebird nest cavities and smaller than Starling nest cavities. In distance from entrance to cavity bottom, nest demonstration display sites averaged shallower than either bluebird or Starling nest cavities.

Were bluebird nest demonstration display sites acceptable as nest cavities and therefore represented unused, but avaialble, nest sites? From observations in the field, it appeared that two of the sites (4D, 5D) were far too shallow to be used as nest sites. In the discriminant function analysis (See Table 16), one nest demonstration display site, 3D, was misclassified as a bluebird nest cavity. In other analyses, nest demonstration display sites were not misclassified as bluebird nest cavities, except for those analyses that were least able to discriminate among the groups, e. g. Variable Set1 in Table 16. Therefore, it appears that nest demonstration display sites, with the exception of 3D, were not suitable for use as bluebird nest cavities.

Therefore, the observation of a male bluebird giving nest demonstration display at a cavity does not necessarily mean the cavity is suitable as a nest cavity. Males were often observed to give the display at totally inappropriate "cavities," e. g. the end of an open pipe, and incomplete drill holes of woodpeckers. The male bluebird will display at a number of potential nest cavities, with the female accepting one of the nest cavities as the nest site (Krieg 1971).

Of the ten randomly chosen bluebird nest cavities subjected to the discriminant function analysis, eight were classified accurately and two were misclassified. This would seem to represent a reasonable level of accuracy for the analysis. Furthermore, discriminant function analysis would be ideal for assigning unused cavities observed in the field to one of several groups of cavity nesting species. This would, in part, help to answer the question of whether there is a shortage of available nest cavities. If unused cavities were classified into a particular species group, then we could conclude that, based on the analysis, there are unused nest sites available for nesting. Such an analysis would also have to consider the habitat surrounding the nest site in deciding potential cavity use by individual species, particularly in the case of bluebirds.

<u>Cavity Entrance Orientation</u>

Although few conclusions could be drawn from the statistical tests, the data in this study seem to indicate that bluebirds have little or no preference as to nest cavity entrance orientation. Indeed, it would be difficult to imagine a pair of bluebirds failing to nest in a cavity, assuming all other dimensions were acceptable, because of the entrance orientation. It is therefore felt that entrance orientation has little or no influence on the acceptability of a nest cavity by Eastern Bluebirds in this latitude.

In chi-square goodness of fit tests of uniform versus non-uniform distribution, one must assume that the primary cavity nesters, woodpeckers, excavate cavities with entrance orientations displaying a uniform distribution. The ideal test to perform on bluebird nest cavity entrance orientations, then, would be one testing if that distribution differed from the distribution of entrance orientations of all cavities available for nesting. Conner (1975) reported on the orientation of 78 nest cavities of six woodpecker species located within a 64 km (40 mi) radius of Blacksburg, Virginia. Although his data are for tree cavity entrance orientations, upon comparing entrances of all bluebird nest cavities, both tree and fencepost, found in this study, the distribution of entrance orientations is quite similar between the two studies.

Nest Habitat

Previous descriptions of bluebird nesting habitat have been descriptive rather than quantitative evaluations (Forbush and May 1925, Thomas 1946). Land use practices which have been reported as providing bluebird nesting habitat are remote, abandoned, or uncultivated farmlands (Wallace 1959); wooded areas following a fire (Pinkowski 1974); and clearcuts (Conner and Adkisson 1974).

In this study, abandoned farmlands at Indian Run and RAAP were found to support nesting bluebirds. In addition, bluebirds were found nesting in areas grazed by livestock and areas adjacent to mowed fields. Therefore, these areas, if surrounded by fencerows or other structures containing nest cavities, can provide bluebird nesting habitat.

Since most nest sites were located from roads, a possible bias in the distribution of nest sites may have been introduced into these data. The proximity of nest sites to roads resulted in a portion of the road being included within the 0.05 ha circle at nine of fifteen sites (60%) in rural areas and two of six sites (33%) at RAAP.

One might expect nest habitat sampling in burned-over areas or clearcuts to have different results, nevertheless, these data are representative of bluebird nest sites in rural areas. Furthermore, from a managerial standpoint, data from natural nest sites near roads would be of value in the placement of nest boxes since most bluebird trails are likewise located along roads.

Few nest sites in rural areas were surrounded by trees, but trees that were within the 0.05 ha circle were large, mature trees. In addition, few nest sites at RAAP had trees within the 0.05 ha circle, excluding the trees which themselves contained the nest cavities. Likewise, few nest sites at RAAP or other areas contained shrubs within the 0.05 ha circle.

Admittedly, the sampling technique used to sample around nest sites was intended to be used for comparisons between species groups or forest stands and not for extensive descriptive purposes. An arbitrary decision was made on the area to be intensively sampled, and perhaps it could have been larger. Observations on foraging, deposition of fecal sacs, and other activities during the mapping of the utilized activity space complemented the nest habitat sampling and gave a broader picture of the use of habitat by bluebirds. Thus, although few trees or shrubs were within 12.6 m of nest sites of Eastern Bluebirds, trees and shrubs at greater distances from the nest were an important component of bluebird utilized activity spaces. This will be discussed further in a later section.

Although few trees were within the 0.05 ha circle around nest sites, these trees were large, with substantial crowns, and thus contributed to canopy cover. Canopy cover by itself has little meaning without comparisons with other avian species. Nevertheless, we could conclude from the very low values of this parameter that bluebirds nest in "open" areas. At RAAP, nest sites in live trees had the highest values of canopy cover since the nest and therefore the nest tree was the center point of the transects used in sampling. This may account for the significant difference between mean canopy cover at RAAP nest sites and mean canopy cover at other nest sites.

Ground cover was perhaps the one variable most affected by the proximity of nest sites to roads, as transects across road surfaces resulted in low values of this variable. The significance of this variable as it relates to bluebird foraging behavior will be discussed in a later section.

The vertical density profile of herbaceous vegetation within the 0.05 ha circle surrounding natural nest sites of Eastern Bluebirds presented in Fig. 3, reveals a quite different profile of herbaceous vegetation between nests at RAAP and nests at other sites. Nests in rural areas were surrounded by pasture, hayfields, cultivated crops, and roads and roadsides. Activities such as the grazing of pastures and mowing of hayfields and roadsides kept the herbaceous vegetation cropped close to the ground. This resulted in the pattern of contacts illustrated in Fig. 3, with most contacts below the 30 cm interval. However, at RAAP, no activities such as mowing took place near nest sites, except for the mowing of roadside vegetation at two nest sites adjacent to roads. This resulted in a significantly different vegetation profile from that of other nest sites.

Neither density nor height of herbaceous vegetation seemed to affect the choice of a nest site. Pinkowski (1974) stated that Eastern Bluebirds choose nest sites that are visible from a distance. Grazing and mowing around nest sites in rural areas resulted in a low herbaceous vegetation layer, making all nest sites visible from a distance. Although the herbaceous vegetation layer was higher and more dense at the upper height intervals at RAAP, the height of nest cavity entrances, 386.5±49.5 m (mean±SE), meant that they too were not obscured by herbaceous vegetation. The most significant influence of the herbaceous vegetation layer upon the nesting of Eastern Bluebirds observed in this study was on foraging. This will be discussed in a later section.

The herbaceous vegetation layer was also the most subject to change during the breeding season of all the habitat variables measured. Although the herbaceous vegetation layer around two nest sites showed little change throughout the breeding season, others did show considerable change as the result of natural growth of the herbaceous vegetation (See Fig. 4) and of man's activities, particularly mowing. Mowing near nest site 4B resulted in a drastic change in the vertical density profile (See Fig. 5). This change could affect bluebird foraging behavior, as a hayfield previously unusable for foraging was made suitable by mowing. It would have been interesting to have observed the bluebirds at this nest site to see if they then used the mowed area for foraging. Unfortunately, the second nesting attempt at this nest site failed coincidental to the mowing and subsequent observations of bluebirds could not be made.

Utilized Activity Space

The purpose of mapping the utilized activity spaces of bluebirds was to see how large an area the bluebirds were utilizing during the nestling stage. Particular attention was paid to foraging activity of bluebirds, since other authors had previously stressed the importance of potential bluebird nesting habitat meeting foraging requirements (Krieg 1971, Pinkowski 1974). Activity spaces at RAAP were significantly larger than activity spaces at nest sites in rural areas, and it was felt that this was due to bluebirds foraging at greater distances from nest sites, as discussed below.

Pinkowski (1977:412) reported that he measured ten "foraging areas" of bluebirds during the nestling period, but gives no description of the methods he used in determining the size of these areas. Nevertheless, he reported that the foraging areas ranged in size from 4.4-38.9 ha, while the size of the area containing perches was 3.9-8.4 ha. Not knowing Pinkowski's method of determining area makes it difficult to compare the two studies. However, two factors may account for the difference in the size of the utilized activity spaces of this study and the foraging areas of Pinkowski (1977).

The first factor is habitat. Pinkowski (1977) stated that bluebirds were observed foraging in old fields. In this type of habitat bluebirds would encounter an irregular distribution of the acceptable perch-vegetation areas needed for foraging and would thus need to use a larger area. Areas where foraging was observed in the present study were large expanses of suitable vegetation profile, pasture, mowed field, and roadsides close to nest sites, with utility wires and leafless tree branches supplying perches.

Secondly, Pinkowski (1977) does not make it clear whether the bluebirds he studied were utilizing natural nest cavities or nest boxes. If they were utilizing nest boxes, this could account for the larger foraging areas. Nest boxes are artificial nest cavities and may be placed without regard to surrounding habitat. Nest boxes placed at some distance from acceptable foraging areas, if used, would result in the bluebirds having to traverse farther from the nest to utilize these areas. Indeed, one would expect bluebirds themselves to be better judges of acceptable habitat than someone indiscriminantly placing nest boxes in the field.

The question remains as to which is the more important factor in bluebird nesting ecology, an acceptable nest cavity or acceptable foraging areas? To what extent will the presence of a suitable nest cavity cause bluebirds to compromise in terms of nearby foraging areas? Bluebirds, although displaying some adaptability in foraging tactics, have very definite foraging requirements, e. g. a low vegetation profile, as quantified in this report. Bluebirds nesting at RAAP were limited to nest sites which were surrounded by herbaceous vegetation which was not suitable for foraging. The bluebirds responded by foraging at greater distances from the nest than at nest sites in other areas surrounded by pastures and mowed fields.

Trial observations of a utilized activity space were made at nest site 29A in 1976. The nest was at the edge of a small woodlot surrounded by old field habitat. A road separated the woodlot and old field from a more extensive woodlot, and beyond that was an actively grazed pasture. After several hours' observation it became apparent that the bluebirds were not foraging in the old field habitat or woodlot edges, but were foraging in the grazed pasture at a distance from the nest site exceeding any subsequent observations, even those at RAAP. It seemed from these observations that the presence of a suitable nest cavity superseded the lack of suitable foraging habitat nearby.

Therefore, the presence of a suitable nest cavity appears to be the more important element in the selection of a nest site, with bluebirds compensating for a lack of suitable foraging areas nearby by foraging at greater distances from the nest. Undoubtedly there is a limit to the distance from the nest site that bluebirds can forage and still meet the nutrient requirements of themselves and their young.

Foraging

Hunting perches in this study averaged 5.0 m in height and ranged from 0.9-16.5 m. These values are much higher than foraging perch heights previously reported. Goldman (1975) did not specify the types of perches used by bluebirds he observed, but they ranged in height from 0.6-8.2 m, with a mean perch height of 2.3 m for males and a mean perch height of 1.8 m for femlaes. Pinkowski (1977) reported that bluebirds commonly used dead or defoliated tree limbs and branches, fencepost tops, boulders, and coarse weed stalks, similar to the types of perches observed in this study except for the utility wires observed here. He also reported a mean height of 2.02 m for spring foraging perches and 3.76 m for summer foraging perches. These means were significantly different. The significant difference in the mean perch height observed in this study is probably accounted for by the use of utility wires, which were higher than most other types of perches used, at other nest sites, but not at RAAP.

Several of the subjects previously discussed are relevant to a discussion of foraging by bluebirds and will now be discussed in this context. These include trees and shrubs near the nest site, ground cover, the vertical density profile of herbaceous vegetation surrounding nest sites, and utilized activity spaces.

Few trees and shrubs were within the 0.05 ha circle surrounding nest sites. Nevertheless, trees and shrubs were an important component of utilized activity spaces, with leafless branches in trees and the tops of shrubs and small trees being two of the three most commonly used types of foraging perches.

Pinkowski (1977:413) referred to the term "sparse ground cover" in describing what he felt created ideal bluebird foraging habitat. In this study this qualitative term was quantified by two of the nest habitat variables measured, ground cover and the vertical density profile of herbaceous vegetation. Observations of foraging bluebirds revealed that grazed pastures near nest sites were used for foraging in rural areas, while the free growing vegetation around nest sites at RAAP was not used for foraging. Therefore, data from the 0.05 ha circle at nest sites in rural areas represent acceptable bluebird foraging habitat, while those data from the 0.05 ha circle at nest sites at RAAP represent unacceptable bluebird foraging habitat.

Comparing ground cover between the two areas (Table 23) it is apparent that it did not differ between nest sites in rural areas and nest sites at RAAP. Therefore, this variable does not seem to distinguish between the herbaceous vegetation in these areas.

However, upon comparing the vertical density profile between RAAP and other nest sites (Fig. 3), there is quite a difference in these data between the two areas. The profile of herbaceous vegetation around other nest sites represents an acceptable bluebird foraging stratum, while the profile around RAAP nest sites represents an unacceptable foraging stratum. A similar density profile is presented in Fig. 6, with bluebirds observed foraging in the grazed pasture while no foraging was observed in the hayfield at this nest site.

Adaptability in foraging tactics is illustrated by the foraging of a male bluebird at nest site 11B. As shown in Fig. 7, the vertical density profile of the alfalfa field is even more dense at the height intervals below 60 cm than the hayfield at nest site 4B where foraging was not observed. By modifying foraging tactics, employing flight-gleaning, the male was able to utilize this vegetation which was not suitable for the drop, or flydown, foraging tactic.

The fact that the herbaceous vegetation around nest sites at RAAP was not acceptable for foraging accounts for the significantly larger utilized activity spaces around the nest sites at RAAP. Observations of foraging bluebirds revealed that bluebirds nesting at RAAP foraged at greater distances from nest sites, utilizing mowed areas along roads and around bunkers in most of the foraging drops observed. At other nest sites, grazed pastures adjacent to nest sites provided acceptable foraging conditions closer to nest sites, thus, the activity spaces around these nest sites were significantly smaller than activity spaces at RAAP.

Nest Site Competition

It is significant that few instances of defensive interaction between bluebirds and other cavity nesting species were observed in the field. In fact, several cavity nesting species were observed utilizing nest cavities in close proximity to each other, without interaction. One could explain this lack of observed interaction by postulating that nest cavities in the study area were abundant, and therefore cavity nesting species had no difficulty in obtaining nest sites. Although this may be the case, it must be kept in mind that the vast majority of interaction between bluebirds and other species reported in the literature has taken place around nest boxes. Only two instances of aggressive interaction between Starlings and bluebirds at natural cavities (Kohler 1912, Pinkowski 1974), and only one instance of interaction between House Sparrows and bluebirds at a natural cavity (Love 1902) have ever been reported in the literature.

Three factors may account for the majority of the reported instances of nest site competition between bluebirds and other species at nest boxes rather than natural cavities. First, most studies of nesting bluebirds have concerned bluebirds in nest boxes. Second, nest box trails provide a number of available nest cavities in a given area, and thus may concentrate cavity nesting species in a smaller area than would exist under natural conditions. Third, nest boxes placed near human dwellings are particularly attractive to Starlings and House Sparrows and bluebirds may thus encounter competition from these species if they attempt to use nest boxes near human dwellings.

SUMMARY AND CONCLUSIONS

Eastern Bluebirds were found to be utilizing natural nest sites in the vicinity of Blacksburg, Virginia. Forty-seven natural nest sites of Eastern Bluebirds were discovered, 37 in fencepost cavities and 10 in tree cavities. Approximately one-half of the nests were discovered by driving roads in areas where active farming and grazing was taking place and by driving roads at RAAP.

Bluebirds were discovered along roads in rural areas because they nested in fenceposts adjacent to roads and perched on utility wires along roadsides. At RAAP bluebirds were foraging along roads, utilizing mowed strips of vegetation along roads and road surfaces.

Tree nest cavities used by bluebirds included cavities in the main trunk and in tree limbs in both live and dead trees. All nest cavities in limbs were in dead limbs, regardless of whether the tree was live or dead. Three tree species not previously reported as containing nest cavities of bluebirds were black locust, honey locust, and ash. Over 90 percent of all nest cavities in trees and fenceposts were made by woodpeckers.

Most nest cavities were used for only one nesting attempt, with less than one-third of the nest cavities observed in both years of the study being used for more than one nesting attempt. Although exceptions were observed, bluebirds seemed more likely to renest in the same nest cavity following a successful nesting attempt and less likely to renest in the same cavity after an unsuccessful attempt.

One tree limb and three fencepost nest cavities were lost between the 1976 and 1977 breeding seasons. Two fencepost cavities were lost when the fenceposts were replaced by landowners. However, no new nest cavities were observed being excavated in fenceposts. Therefore, there was a net loss in the number of fencepost cavities observed during this study. Perhaps an even greater threat to the availability of fencepost cavities is the loss of entire fencerows as former pasture lands are converted to residential subdivisions.

Several bluebird nest cavities had dimensions that were below minima previously reported. One nest cavity had an entrance diameter of 3.35 cm, and from observations in the field it seemed that this is the smallest entrance diameter that bluebirds are capable of utilizing. Two nest cavities had cavity depths below the minimum previously reported for this dimension. Observations on nest size and the interior diameter of nest cavities led to the recommendation that the area of the bottom of nest boxes be no more than 50 cm^2.

A discriminant function analysis of the dimensions of bluebird fencepost nest cavities, nest demonstration display sites, and starling fencepost nest cavities revealed that the three dimensions height of cavity entrance, entrance diameter, and distance from entrance to cavity bottom were best able to distinguish among the three groups.

Approximately one-fourth of all fencepost nest cavities showed some sign of advanced age, such as being open to the top; vertical slits in the post, some running the length of the nest cavity; other holes in the nest cavity in addition to the cavity entrance; and the fencepost hollow below the nest cavity. One landowner indicated the approximate age of a fencepost containing a nest cavity to be forty years.

Fenceposts containing nest cavities were quite old, and the replacement of fenceposts containing nest cavities resulted in a reduction in the number of nest sites available for bluebirds. However, each fencepost was replaced with another wooden fencepost; therefore, it may provide a nest cavity in the future. If the wooden fenceposts had been replaced with metal fenceposts, the potential for future nest cavities would no longer exist. Therefore, the replacement of wooden fenceposts with metal fenceposts should be discouraged.

The continued existence of nest cavities for bluebirds in fenceposts depends on the excavation of additional nest cavities to replace those lost. Therefore, the failure to observe new nest cavity excavation by woodpeckers in fenceposts is disturbing. If fencepost nest cavities continue to be lost at the rate observed in this study and no new nest cavities become available, nest boxes should be provided to replace the natural nest cavities lost.

Bluebirds were found nesting on abandoned farmlands. In addition, active farming areas where grazing and mowing were taking place were found to support nesting bluebirds. This is the first study of bluebirds nesting in these areas.

Few nest sites had trees or shrubs within the 0.05 ha circle used for sampling nest habitat. However, trees and shrubs at greater distances from the nest cavity were utilized by bluebirds. Tree limbs were used as foraging perches, for the deposition of fecal sacs, and provided shelter for recently fledged young. The tops of shrubs and small trees also provided foraging perches for bluebirds. Thus, trees and shrubs were an important component of utilized activity spaces and would seem to play an important role in nest site selection by bluebirds.

Utilized activity spaces were more or less rectangular in shape due to boundaries following fencerows, utility wires, and roads. All seven utilized activity spaces included roads, and four activity spaces included streams or standing water. Activity spaces at RAAP were significantly larger than activity spaces around nest sites in other areas.

Dead, leafless branches were most often used as foraging perches by bluebirds. Other foraging perches included the tops of shrubs or small trees and highway signs at RAAP, and utility wires and fencepost tops in other areas.

Observations of foraging bluebirds revealed that grazed pastures and mowed fields near nest sites in areas of active farming were used for foraging, while the free growing vegetation around nest sites at RAAP was not used for foraging. The vertical density profile of herbaceous vegetation around nest sites in other areas therefore represented an acceptable bluebird foraging stratum. The unacceptable foraging stratum around nest sites at RAAP accounted for the significantly larger utilized activity spaces there, as bluebirds foraged at greater distances from the nest, utilizing mowed vegetation along roads.

Therefore, man's activities provided foraging areas for bluebirds in this area. These activities, the grazing of cattle and the mowing of hayfields and roadsides are likely to continue and should provide suitable bluebird foraging habitat in the future. In addition to removing potential fencepost nest cavities, the development of pastures and hayfields into residential subdivisions also eliminates the areas used for foraging by bluebirds. The fate of the Eastern Bluebird in this region may therefore depend more on the economy of the area and suburban expansion than on environmental factors.

The following recommendations are made concerning the placement of nest boxes. Nest boxes should be located adjacent to pastures or mowed fields with utility wires nearby, if possible, to provide foraging perches. Nest boxes should not be located within 15 m of trees or shrubs, but large scattered trees near the nest will provide foraging perches for adult bluebirds and escape cover for recently fledged young. Nest boxes should be placed at least 200 m from human dwellings or buildings such as barns that are likely to attract House Sparrows. Based on observations of utilized activity spaces, 0.7-2.3 ha of suitable foraging habitat should surround each nest box. Optimum distances between nest boxes would best be determined from observations of bluebirds at nest boxes in the field.

The majority of previous studies of nesting bluebirds have involved bluebirds utilizing nest boxes. This study was the first attempt to study bluebirds solely utilizing natural nest cavities. The results of this study would seem to indicate that other rural areas similar to the environs of Blacksburg, Virginia, could support nesting bluebirds. It is therefore hoped that the success of this study in locating natural nest cavities would encourage other investigators to study bluebirds utilizing natural nest sites.

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APPENDIX

Appendix Table I. Portions of highways surveyed and general location of natural nests of Eastern Bluebirds in southwestern Virginia, 1976-1977.

Highway	Portion surveyed-nest location
Bishop Road	From intersection with U.S. 460 Bypass to Mt. Tabor Road and from Mt. Tabor Road to terminus. One nest (27B) located across field in fencerow running perpendicular to highway 1.4 km (0.9 mi) from U.S. 460 Bypass.
Indian Run	From intersection of 1101 and 1103 to intersection of 1103 and 1105. One nest (29A) located in black locust on left side of 1103 0.8 km (0.5 mi) from intersection of 1101 and 1103.
Glade Road	From Glade Road Baptist Church to intersection with Meadowbrook Drive. One nest (2A) located in row of trees bordering Tuyrkey Research Center 1.1 km (0.7 mi) from church.
Shadow Lake Road	Entire length from intersection with Glade Road to intersection with Meadowbrook Drive. Two nests (4B, 5B) located near crossing of Tom's Creek 1.3 km (0.8 mi) from intersection with Glade Road.
Meadowbrook Drive	Entire length from intersection with Glade Road to Tom's Creek Road. One nest (19B) located 0.3 km (0.2 mi) from left turn from Shadow Lake Road, one nest (18B) 0.8 km (0.5 mi) from right turn from Shadow Lake Road intersection.

Appendix Table I. Portions of highways surveyed and general location of natural nests of Eastern Bluebirds in southwestern Virginia, 1976-1977 (continued).

Highway	Portion surveyed-nest location
Tom's Creek Road	From intersection with Meadowbrook Drive to intersection with U.S. 460 Bypass. No nests located.
785	From city limits to Catawba Substation. Nests located at following distances from Luster's Gate intersection of 785 and 723: 3.0 km (1.9 mi) 6B, 11B — 17.2 km (10.7 mi) 24B 6.3 km (3.9 mi) 26B — 17.6 km (10.9 mi) 25B 11.3 km (7.0 mi) 26A — 18.2 km (11.3 mi) 22B 16.7 km (10.4 mi) 19A — 18.2 km (11.3 mi) 23A 17.1 km (10.6 mi) 29B — 18.5 km (11.5 mi) 18A
723	From intersection of 723 and 785 to intersection of 723 and 603. Nests located following distances from intersection of 723 and 785: 0.5 km (0.3 mi) 8A — 0.8 km (0.5 mi) 9A
601	From intersection with 602 to intersection with Va. Rt. 42. Nests located following distances north of intersection of 601 and 685: 0.2 km (0.1 mi) 10B — 3.2 km (2.0 mi) 15A 1.3 km (0.8 mi) 28B — 3.2 km (2.0 mi) 15B

Appendix Table I. Portions of highways surveyed and general location of natural nests of Eastern Bluebirds in southwestern Virginia, 1976-1977 (continued).

Highway	Portion surveyed-nest location
685	From intersection with 602 to intersection with 601. Nests located following distances from intersection of 685 and 602: 0.6 km (0.4 mi) 21B 1.0 km (0.6 mi) 7B 0.8 km (0.5 mi) 14A intersection 685-601 6A
602	From intersection with 700 to intersection with 601. Nests located following distances from intersection of 602 and 700: 0.3 km (0.2 mi) 4A 0.5 km (0.3 mi) 5A
700	From intersection with U.S. 460 to 0.6 km (0.4 mi) beyond intersection with 602. No nests located.
624	From city limits to intersection with 697. Two nests (5B, 12B) located 0.6 km (0.4 mi) west of intersection of 624 and 697.
603-622-629	Observations confined to this approximately oval-shaped system of roads near Ironto. Two nests on 603, 25A 1.3 km (0.8 mi) and 17A 1.4 km (0.9 mi) west of intersection of 603 and 629. One nast (16A) located at intersection of 622 and 629.

Appendix Table I. Portions of highways surveyed and general location of natural nests of Eastern Bluebirds in southwestern Virginia, 1976-1977 (continued).

Highway	Portion surveyed-nest location
Va. Rt. 42	From intersection with U. S. 460 to Simmonsville. One nest (14B) located 0.5 km (0.3 mi) south of intersection of 42 and 628.
663	From intersection with Va. Rt. 114 to intersection of 828. One nest (3B) located 1.0 km (0.6 mi) from intersection of 663 and Va. Rt. 114.
642-643	642 from intersection of 642 to intersection of 642 and 643, and 643 from intersection of 643 and 642 to intersection of 643 and U.S. 460. No nests located.
808-657	808 from intersection with U.S. 460 Bypass to intersection of 808 and 657, and 657 from intersection of 657 and 808 to intersection of 657 and Price's Fork Road. No nests located.
603-604	603 from intersection of 603 and 604 to intersection of 603 and 602, and 604 from intersection of 604 and 601 to intersection of 604 and 700. No nests located.
621	From intersection of 621 and U.S. 460 to intersection of 621 and Forest Service Road 630. No nests located.
(Poverty Creek)	Forest Service Road 209 to 708 to 625 to U.S. 460. No nests located.

Appendix Table II. Number of nesting attempts in natural nest cavities of Eastern Bluebirds in southwestern Virginia, 1976-1977.

Nest	Year 1976	Year 1977	Nest	Year 1976	Year 1977
1B	X[1]	1	26B	0	1
2B	X	2	27B	0	1
3B	X	1	28B	0	1
4B	0	2	29B	0	1
5B	X	2	30B	0	1
6B	1	1	2A	1	R[2]
7B	0	1	3A	1	1
8B	3	2	4A	1	R
10B	0	1	5A	1	0
11B	1	1	6A	1	R
12B	X	1	7A	1	0
13B	1	1	8A	2	0
14B	X	2	9A	1	0
15B	0	3	14A	1	0
16B	X	1	15A	1	0
17B	X	1	16A	1	R
18B	0	1	17A	1	X
19B	0	2	18A	1	0
20B	X	1	19A	1	0
21B	3	1	23A	1	0
22B	0	1	25A	1	X
23B	X	1	26A	1	0
24B	0	1	29A	1	0
25B	0	1			

[1] "X" indicates the area or road was not surveyed that year, thus cavity usage not known.
[2] "R" indicates the cavity structure was removed or lost and cavity not available for use.

Appendix Table III. Twelve dimensions of nest cavities of Eastern Bluebirds as obtained in the field in southwestern Virginia, 1976-1977.

Nest	Ht Struct (1)[1]	Ht Cav Ent (2)	Diam Struct Ent (3)	Diam Struct Bot (4)	Ent Diam Ht (5)	Ent Diam Width (6)	Length Int Ent (8)	W idth Int Ent (9)	Length Int Bot (10)	Width Int Bot (11)	Cav Depth (13)	Dist Ent Bot (14)
1B	171.7	82.7	53.3	53.6	4.2	4.2	5.8	11.9	6.4	6.2	18.4	14.1
2B	1310.6	365.1	19.0	20.3	3.9	4.3	7.8	4.7	7.6	6.8	19.1	14.4
3B	168.9	160.2	14.7	14.7	3.6	4.1	6.2	6.6	6.4	11.0	17.0	11.1
4B	151.8	129.2	16.0	16.5	4.5	3.8	7.5	7.4	6.1	7.2	17.5	13.5
5B	150.4	135.6	11.7	12.4	3.0	4.1	8.9	7.9	8.6	7.8	29.1	15.2
6B	167.1	135.8	18.3	17.3	7.8	4.3	6.1	6.5	6.4	7.8	28.5	19.0
7B	113.8	105.0	18.5	18.3	4.5	3.7	6.2	3.9	10.0	5.2	17.8	13.7
8B	139.3	121.5	15.5	16.0	3.8	4.1	7.4	7.1	8.3	9.8	15.4	12.0
10B	194.8	172.7	20.8	20.1	3.3	3.4	7.7	5.7	7.2	6.9	12.0	6.8
11B	151.8	137.2	20.1	18.5	6.2	7.8	6.2	7.8	6.2	7.6	26.1	26.1
12B	138.4	131.2	10.4	12.2	4.5	4.5	6.6	5.3	6.4	5.3	19.0	13.8
13B	411.5	381.0	17.5	17.3	9.3	6.5	12.1	11.6	--	--	25.9	15.2
14B	150.6	139.7	25.1	25.1	4.5	3.6	6.2	7.8	7.0	8.9	14.9	10.9
15B	156.7	128.0	13.7	14.0	3.5	5.8	8.5	6.7	7.4	8.7	18.1	11.2
16B	1371.6	266.5	26.2	24.9	4.7	4.2	10.0	6.8	8.7	6.8	26.0	20.6
17B	1447.8	883.9	--	--	--	--	--	--	--	--	--	--
18B	158.9	78.9	18.5	18.3	9.5	4.8	9.1	8.3	8.3	7.6	36.9	23.7
19B	147.4	128.1	14.2	13.5	4.2	4.0	5.7	6.6	8.1	8.1	36.4	16.6
20B	426.7	251.1	11.7	13.0	4.0	4.0	8.5	3.9	8.0	6.2	20.4	12.1
21B	155.0	138.5	19.7	17.8	4.0	4.0	5.9	4.5	7.5	5.4	15.0	11.9
22B	163.4	148.6	14.2	14.5	3.6	3.7	7.5	4.9	6.7	5.5	20.4	15.5
23B	190.8	161.0	19.3	19.0	4.5	3.7	7.7	4.5	5.3	7.1	14.3	9.8
24B	200.2	181.3	14.5	15.7	4.5	5.5	8.0	6.9	9.4	7.3	25.6	20.6

Appendix Table III. Twelve dimensions of nest cavities of Eastern Bluebirds as obtained in the field in southwestern Virginia, 1976-1977 (continued).

Nest	Ht Struct (1)[1]	Ht Cav Ent (2)	Diam Struct Ent (3)	Diam Struct Bot (4)	Ent Diam Ht (5)	Ent Diam Width (6)	Length Int Ent (8)	Width Int Ent (9)	Length Int Bot (10)	Width Int Bot (11)	Cav Depth (13)	Dist Ent Bot (14)
25B	179.7	165.8	12.7	12.4	4.9	3.8	7.7	5.0	6.7	6.0	21.8	17.3
26B	123.8	100.4	18.3	19.0	9.5	6.0	12.2	10.6	12.5	9.1	38.2	27.1
27B	151.1	100.8	14.2	13.2	5.8	4.1	9.1	9.2	7.5	8.7	21.8	13.4
28B	176.1	155.1	18.5	19.0	3.9	4.2	8.4	6.5	7.6	6.2	17.6	13.7
29B	174.5	141.8	19.8	--	4.1	3.3	6.3	12.1	--	--	--	--
30B	1249.7	457.2	--	--	--	--	--	--	--	--	--	--
3A	167.7	116.9	13.2	13.2	4.7	3.4	8.2	6.2	5.6	6.5	20.8	13.3
5A	179.1	131.7	19.3	19.6	6.3	6.7	8.8	15.4	7.9	15.4	21.2	14.8
6A	151.9	134.0	14.6	--	3.7	3.5	--	--	--	--	--	--
7A	160.0	143.2	13.5	13.0	6.2	4.6	6.6	6.4	7.2	8.9	17.9	12.6
8A	187.5	166.4	11.7	12.4	5.0	4.2	8.1	8.7	8.0	8.7	17.8	13.1
9A	163.6	81.4	12.4	11.7	5.5	3.7	10.1	8.3	6.1	5.4	38.2	17.8
15A	195.6	142.8	9.9	10.7	3.4	5.4	5.7	8.7	6.1	7.8	30.3	20.6
17A	167.3	132.7	15.5	16.0	3.5	4.1	11.2	8.6	8.1	8.7	30.7	16.5
18A	170.6	139.8	14.0	14.2	4.5	3.6	11.4	5.8	8.9	8.9	19.2	14.4
19A	189.3	123.9	18.3	19.0	4.0	3.2	7.9	4.4	6.5	7.3	16.9	12.9
23A	166.6	133.9	13.0	12.4	3.7	3.3	8.8	7.3	8.2	7.3	18.4	13.9
25A	153.4	131.9	13.7	14.2	7.2	7.3	8.1	10.2	6.9	8.4	41.0	21.1
26A	157.6	127.9	12.2	11.9	4.1	3.6	6.1	5.9	6.5	5.3	16.1	11.4
29A	1828.8	286.0	45.0	45.0	8.8	4.6	11.2	9.8	7.9	10.1	15.8	5.2

[1] Numbers in parentheses refer to nest cavity dimensions as numbered in Table 8, page 52.

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UTILIZATION OF NATURAL NEST SITES BY EASTERN BLUEBIRDS IN SOUTHWESTERN VIRGINIA

by

Thomas A. Pierson

(ABSTRACT)

Eastern Bluebirds (Sialia sialis) were found to be utilizing natural nest sites in the vicinity of Blacksburg, Virginia, during 1976 and 1977. Forty-seven natural nest sites, 37 in fencepost cavities and ten in tree cavities were discovered by driving roads in rural areas, scanning fencerows and utility wires with binoculars, and by searching fencerows on foot. Ninety-one percent of nest cavities used by bluebirds were made by woodpeckers. Height of cavity entrance, entrance diameter, and distance from entrance to cavity bottom were best able to distinguish among bluebird fencepost nest cavities, nest demonstration display sites, and Starling (Sturnus vulgaris) fencepost nest cavities, using discriminant function analysis. Four nest cavities used by bluebirds in 1976 were no longer available in 1977 due to the replacement of fenceposts and tree limb breakage. No new cavities in fenceposts were

observed being excavated by woodpeckers. One-fourth of all nest cavities examined showed some sign of advanced age. Few trees or woody stems were within a 0.05 ha circle surrounding bluebird nest sites. Pastures, mowed fields, and roadsides were used for foraging by bluebirds. The herbaceous vegetation surrounding nest sites at RAAP was allowed to grow freely, but was grazed by cattle or mowed at other nest sites. The herbaceous vegetation around nest sites at RAAP was not used for foraging by bluebirds, they foraged at greater distances from nest sites utilizing mowed vegetation along roads. No instances of nest site competition between bluebirds and other cavity nesting species were observed.