

Development and Implementation of a GIS Model for Determining Optimal Nest Box Placement for Eastern Bluebirds (*Sialia sialis*)

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Abstract

The eastern bluebird (*Sialia sialis*) was nearly eliminated during the mid 1900's by habitat destruction, competition, and other human-related disturbances. However, the past few decades have seen an unprecedented resurgence in bluebird numbers thanks in a large part to the placement of bluebird nest boxes by concerned citizens. A study was conducted using geographic information system (GIS) technology to determine the optimal nest box locations for bluebirds in Minnesota by analyzing nest site selection in relation to the distance between nest boxes and elements of the landscape such as roads, buildings, water, trees, and other boxes. Thirty-five years worth of data of roughly 80 nest boxes from an existing study near Pierz, MN were provided by bluebird researchers Dave and Carol Fiedler of Buffalo, MN. Field work included marking the locations of the boxes with a global positioning system (GPS) as well as describing the landscape characteristics surrounding the box. Distances were measured using ortho-rectified aerial photographs with much of the display and analysis done using Arcview 3.2 and ArcGIS. Each of the bluebird competitors was analyzed separately and then combined to develop buffer distances for ideal bluebird box placement.

Introduction

Once "as common as robins" in the late 1800's, the Eastern Bluebird (*Sialia sialis*) did not fare as well for much of the 20th century. From the 1920's to the 1970's, bluebird populations declined by as much as 90 % (Grooms and Peterson, 1991). Habitat eradication, toxic chemicals, inclement weather, and competition from non-native bird species have all been cited as contributors to this tragic story (Grooms and Peterson, 1991).

An inherent source of the bluebirds' struggles is that they are secondary cavity nesters. They are not capable of creating a nest cavity on their own and must rely on pre-existing nest cavities (Zeleny, 1976). Over the years, dead snags, full of old woodpecker's cavities useful for nesting

sites, were removed as old woodlots were cleared for agriculture. The bluebird's preference for scattered hardwoods and grasslands in a rural setting (Northern Prairie Wildlife Research Center, 2002) has also been an inherent problem for sustaining their numbers in the last century. "When small farms were replaced by large ones, patchwork fields with grassy corners gave way to vast acreages of monoculture row crops. Urban development and highway construction caused enormous amounts of bluebird habitat to disappear forever under acres of concrete and asphalt" (Grooms and Peterson, 1991). Another major factor directly affecting bluebird success is competitors and predators, many of them introduced by humans. Zeleny (1976) states

that, “the case of the bluebirds is somewhat special because man has upset the balance of nature for them, not just by destroying their natural nesting sites, but [also] by introducing alien species of birds whose spread and multiplication have left the bluebird at a great disadvantage.” These non-native species, such as house sparrows and starlings, are more aggressive than bluebirds and can claim priority to desirable nesting sites.

Since the 1970’s, however, the bluebird has had one of the most storied comebacks in birding history. Awareness of the bluebird’s plight resulted largely from the work of Lawrence Zeleny, Dr. Thomas Musselman, William Duncan, Dick Peterson, and others (Stokes and Stokes, 1991). In 1976, Zeleny’s landmark book, *The Bluebird, how you can help its fight for survival*, really brought light to the decline of the bluebird population. It led to the establishment of the North American Bluebird Society (NABS) in 1978, which helped promote the use of bluebird nest boxes to provide a safe place for bluebirds to raise their young (Grooms and Peterson, 1991).

It is widely regarded that the increase in awareness of the bluebird’s plight coupled with the resulting push to erect nesting boxes has led to an increase in bluebird numbers seen throughout the Midwest. Breeding Bird Survey (BBS) data indicate a general decline in bluebird numbers from 1966 to 1978. Minnesota showed a 2.5 % decline. Populations then rebounded from 1978 to 1987 with a 16.6 % increase in Minnesota (Sauer and Droege, 1990). This recovery trend is consistent with most other observations of bluebird numbers (Van Horn and Bacon, 1989). In his 1987 book, *Birds in Minnesota*, Minnesota bird expert, Robert Janssen indicated that “with the advent of bluebird trails and the putting up of thousands of nest boxes for this species, the

breeding population appears to be healthy and increasing in many areas in the state.” He also indicates that bluebirds seem to be found in abundance in the central and north-central part of the state while less frequently in the northern boreal forests and southwestern prairies (Janssen, 1987).

However, with thousands of bluebird boxes dotting the landscape, it brings up a serious issue of whether or not it is enough to simply put up a nest box. One critical element in helping the bluebird recovery effort is the importance of regular monitoring of each bluebird box. Monitoring is essential for not only cleaning out the used bluebird nest in preparation for a second (or rarely third) brood, but it is also necessary to keep an eye out for threats to the bluebird’s nesting success. Zeleny stated that, “for successful rehabilitation of the bluebirds to take place now, it is essential not only to provide them with nesting sites but to do whatever else is needed to protect the birds from their enemies, both native and imported, during the nesting season” (Zeleny, 1976). Without consistent monitoring throughout the nesting season, “boxes can become death traps, resulting in the loss of one or both adults” (Grooms and Peterson, 1991). Squirrels, cats, raccoons, snakes, and sparrows can all prey on bluebirds. Although, control measures can be taken (especially against mammalian/reptilian predators), the easiest way to avoid potential threats and competition is by correct nest box placement. By understanding the dynamics between nest boxes and elements of the surrounding landscape, a successful bluebird trail (i.e. a series of boxes) can be developed. After all, what good is it to put up a bluebird box, only to be frustrated with constant visits by unwanted competitors and predators?

Methods

This study is an attempt to create a Geographic Information System (GIS) to help determine the optimal location/habitat for placing bluebird boxes. Bluebird nesting data are gathered every year by many birding enthusiasts who make weekly visits to each of their nest boxes to determine the stage of the bluebirds in the nesting process and to identify and eliminate any problems from predators. By adding this data to a GIS containing spatial statistics (including location, distances, and direction) for each box, a thorough study can be conducted to determine why some box locations attract more bluebirds than others and why some box locations promote a higher success rate of bluebird broods. This study uses the existing work of Dave and Carol Fiedler of Buffalo, MN. They have been researching bluebirds since the mid-1960's (Fiedler, 1974). Their study area lies in central

Morrison County, MN, with the primary focus being the land adjacent to the Skunk River, near the small, farming community of Pierz (Figure 1). Since 1965, they have monitored over 80 boxes, making weekly visits to check on the status of each box. In their field notebooks, they have noted the occupants (bluebirds and otherwise) as well as the stage of the nesting process (number of eggs, number of nestlings, age of nestlings, etc.). From their field books, a number of relevant data categories were gathered, compiled, and summarized into a computer spreadsheet. These included the total number of bluebird nesting attempts, successful nesting attempts, predators, and competitors. An attempt was defined as the presence of a completed nest in the box. A successful attempt was an attempt in which at least one young bluebird fledged. Thus, if a bluebird pair raised two broods during a summer the population was, at minimum, maintained (in theory).

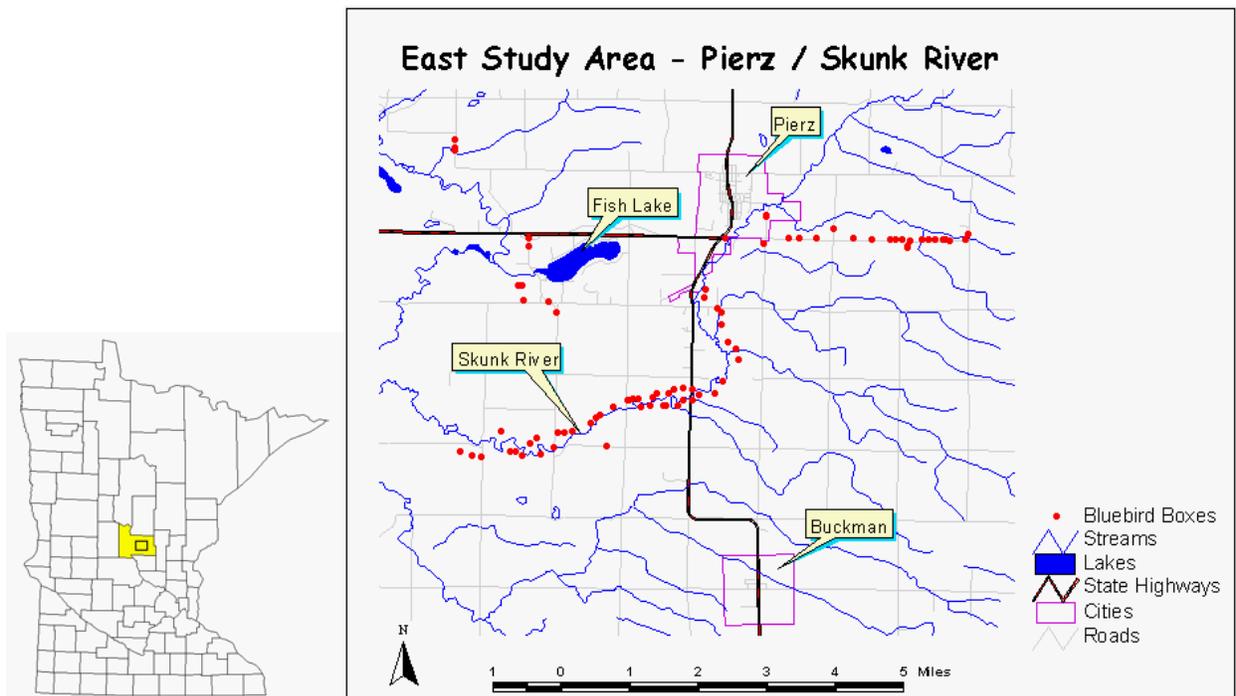


Figure 1: Fiedlers' study area – Morrison County, Minnesota

During the spring and summer of 2002, the positions of 80 boxes in the study area were marked using the Garmin 12 Global Positioning System (GPS). A description and photograph (optional) of the box were gathered with notes about its surroundings. The direction the box faced was also noted. The locations were downloaded to ArcView GIS software (v. 3.2) for further analysis. Aerial photographs (in the form of Digital Orthophoto Quadrangles-DOQs) were used to gather further spatial data. These data included the distances to the nearest roads, nearest buildings or other man-made structures, nearest group of trees/brush, nearest neighboring nest box, and closest source of water. In addition, aerial photographs from 1955, 1970, and the 1980's were scanned into the computer and geo-referenced using ArcGIS (v. 8.1) software in order to note any changes to the landscape over time. Since much of the measuring came from 1991 aerial photographs, field verification was conducted throughout the summer to insure accuracy.

Discussion/Analysis

The Fiedlers' study area was initially set up with the intent of being used as a research tool. They eliminated as much bias as possible by using the same type of box (square, wooden) with the same size cavity diameter (1.5 inches) and mounting them all at the same height (roughly five feet) on wooden fence posts. Periodically, over the years they have had to fix, replace, and move boxes as livestock, vandalism, and the Minnesota climate have taken their toll on both the boxes and the fence posts supporting them. Relocations of nest boxes over significant distances were recorded in the data.

The first analysis procedure was to isolate the specific habitats and biological niches of each of the bluebird's competitors and determine the individual effects they had on bluebird nest box selection and success. By looking at each competitor separately, a statistically consistent analysis could be conducted without fear of introducing any unnecessary bias. However, it had to be first determined if there was any direct correlation between the frequency of use by bluebirds and the presence of their competitors. If no correlation could be detected, any further analysis of this bluebird/competitor interaction would be futile. The SPSS statistics program was used to plot the total number of competitors at each box versus the total number of bluebird attempts. (As mentioned earlier, a bluebird attempt was defined as the presence of a completed nest in the box). The Pearson Correlation Analysis yielded a correlation coefficient (r) of $-.667$, which proved to be statistically significant to the $.01$ level ($p < 0.01$) with a 1-tailed t-test for significance (Figure 2). Thus, it was safe to begin the analysis of the avian competitors that visited the Fiedlers' bluebird trail: house wrens, house sparrows, and tree swallows.

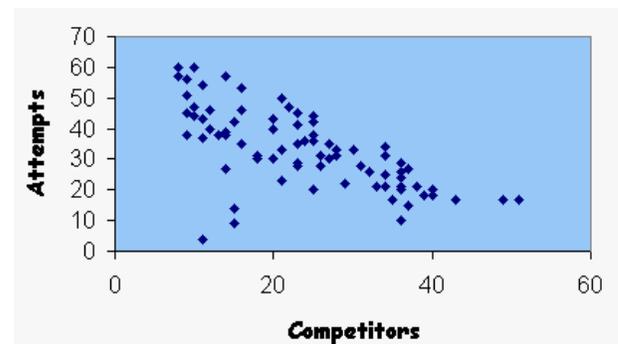


Figure 2: Correlation between the number of bluebird attempts and the number of competitors

Wrens

House wrens (*Troglodytes aedon*) are a bluebird nemesis. Not only do they compete for the same nesting cavities, but the males are also notorious for filling up as many as eight boxes with twigs in hopes of attracting a female to nest in any one of them. Even if a bluebird has already claimed a box, that does not seem to prevent wrens from filling it with twigs and/or pecking at the bluebird eggs or nestlings (Scriven, 1993).

Fortunately, since wrens prefer to dwell in brushy, forested habitats, their interaction with bluebirds can be minimized by simply placing the nest box away from these areas. However, it was necessary to know the safe distance to keep them away.

The first step was plotting the distance of each box from trees (as measured from the DOQs) versus the number of wren occurrences (Figure 3).

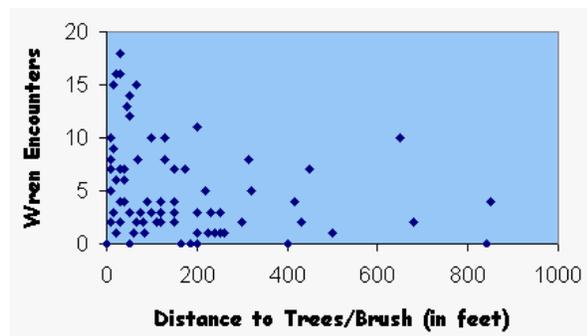


Figure 3: Wrens vs. distance to trees/brush

SPSS Pearson Correlation Analysis was again used to determine if a correlation existed. Indeed, a significant correlation was present ($p < 0.01$). Linear regression analysis in SPSS was used to fit a line to the data in order to find the x-intercept (i.e. the distance at which no wren interaction exists). The statistical analysis in Figure 3 showed a safe distance of nearly 900 ft. However, this was 800 feet further than

many bluebird experts recommended (Stokes, 1991, Grooms and Peterson, 1991). Another look at the data plotted in Figure 3, indicated that there are several wren records occurring past 500 feet that seem to be unusually high. Upon consulting Carol Fiedler, it was learned that a number of these anomalies were boxes had been moved from their original locations, many of them in forested areas. Running the linear regression analysis again showed an x-intercept of about 530 ft (Figure 4).

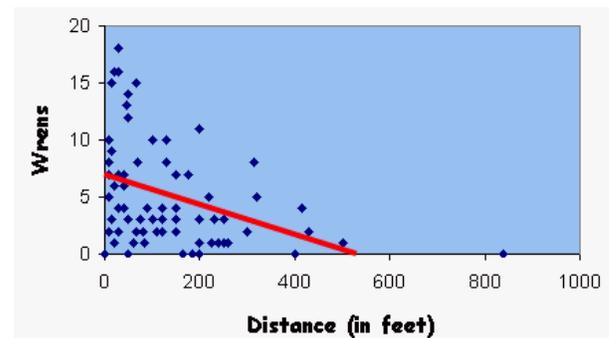


Figure 4: Linear regression of wren encounters vs. distance to trees/brush

After arriving at an optimal distance, a dilemma arises when it is not physically possible to place boxes at least 530 feet from trees. Since it is often necessary to accommodate nest box placement within the confines of the available space, an alternate model was developed. Figure 4 shows that much of the data appear to be inside the 250-300 ft range. To see the exact concentration of these records, data limits were set at 90% and 80%. By eliminating 10% of the records on the outer edge of the optimal distance, the maximum distance that wrens were found extended only to 300 feet. By eliminating 15% and 20%, the distance fell to 250 feet and 220 feet respectively. These adjusted distances are shown on the following page (Figure 5).

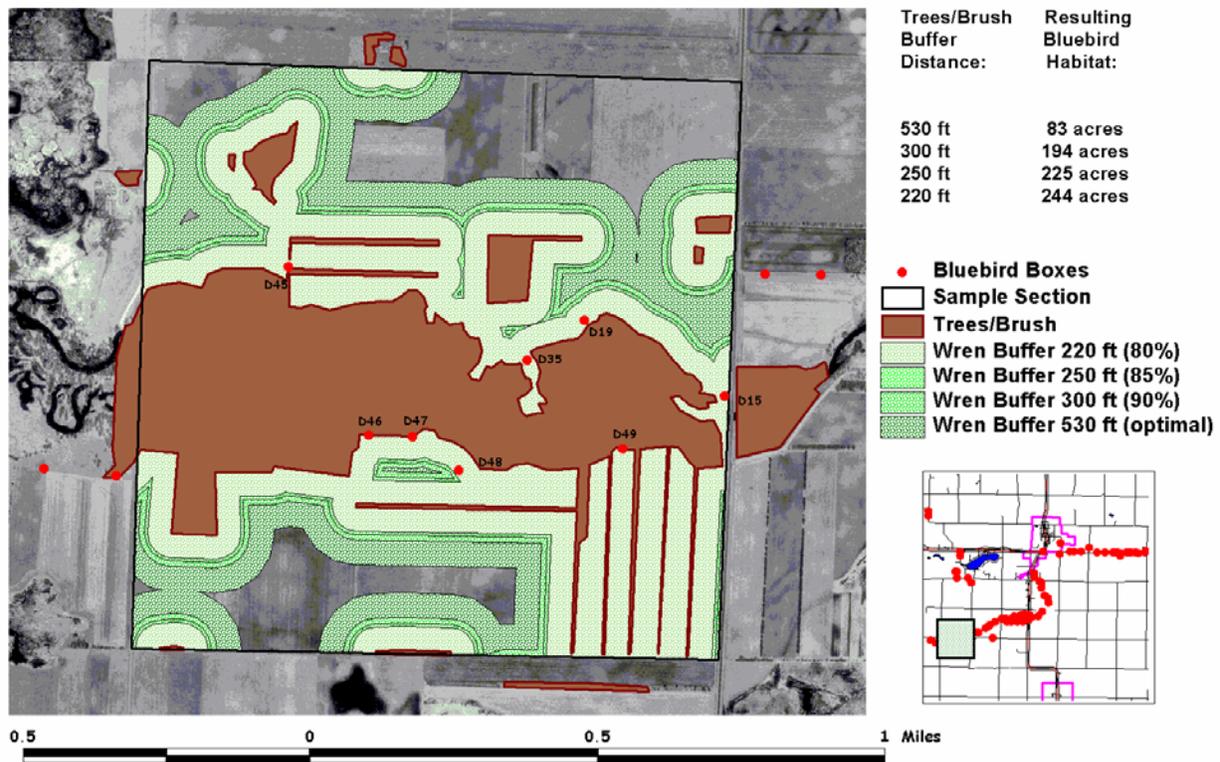


Figure 5: Adjusted safe distances' from wrens

House Sparrows

Perhaps the biggest avian threat to the success of bluebirds is the house sparrow (*Passer domesticus*), one of the most abundant and aggressive bird species in the United States. Ever since their introduction in New York in the 1850s, these “thick-billed, mainly seed-eating weaver finches” have followed the pioneers west across this United States (Summers-Smith, 1976). Sparrow researcher W. B. Barrows perhaps said it best back in 1889, “like a noxious weed transplanted to a fertile soil, it has taken root and become disseminated over half a continent before the significance of its presence has come to be understood” (Summers-Smith, 1976). Because of its noisy and aggressive nature, capability to survive in all climatic conditions, ability to nest in many different sites and situations, lack of natural competitors, and its preference for human settlement, the house

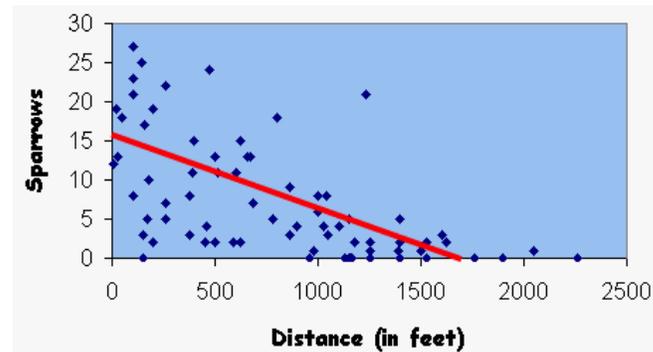
sparrow quickly took up residence throughout the U.S. In fact, “the bird spread from town to town along railway lines in box cars” (Summers-Smith, 1976). Since its optimal habitats included buildings located in close proximity to each other as well as near a source of food (mainly seeds and grains – especially spilled grain for horses and cattle), the house sparrow thrived anywhere humans went (Summers-Smith, 1976).

The house sparrow’s effect on bluebirds has been anything but healthy. With the introduction of house sparrows came competition for the precious few natural nesting cavities. Although not an exclusive cavity nester, the house sparrow often chooses to nest in such sites when they are available. In fact, male house sparrows are so protective over a nest site that they may actually select a site during the winter with hopes of using it in the spring (Eno, 1996). If a sparrow should decide to use a

nest site that a bluebird has already claimed, it will take over by force. Using its sharp beak, the house sparrow can easily pierce the skull of an adult bluebird during combat. Often, however, the house sparrows just kill the bluebird young (including breaking and removing any eggs) or construct their own messy nests over the existing bluebird nests. Fortunately, the house sparrow is not a federally protected species and can be killed at will. The other avian bluebird competitors and their eggs (tree swallows and wrens) must be left alone. Fittingly, the house sparrow was the only competitor that had a statistically significant effect on bluebird nesting success rate (successful bluebird attempts per total number of bluebird attempts). By their presence wrens and tree swallows took away chances for bluebirds to use nest boxes, whereas sparrows actually affected the bluebirds' use of those nest boxes.

The only sure way to make a bluebird trail safe from sparrows is by moving the boxes far enough away from man-made structures. In this study, the distance of each box to the nearest building was measured and entered in the GIS. The distance of each box from buildings was plotted against the number of sparrow encounters and some degree of correlation was exhibited. However, like the wren data, a number of anomalies existed. After consulting the Fiedlers once again, it was learned that many of the boxes had an interesting past. This included being next to cow corrals, pasture areas, buildings, or other human-induced disturbances that harbored house sparrows. In fact, by keeping track of these boxes' data year after year, it was quickly apparent when the boxes were moved or the land practices changed. After removing these anomalies, the data were tested and found to have a strong correlation between distance from buildings

and sparrow use. The same linear regression analysis used with the wren data was used here to find the safe distance from buildings. Plotting this in SPSS gave an x-intercept, or safe distance, of approximately 1710 feet (Figure 6).



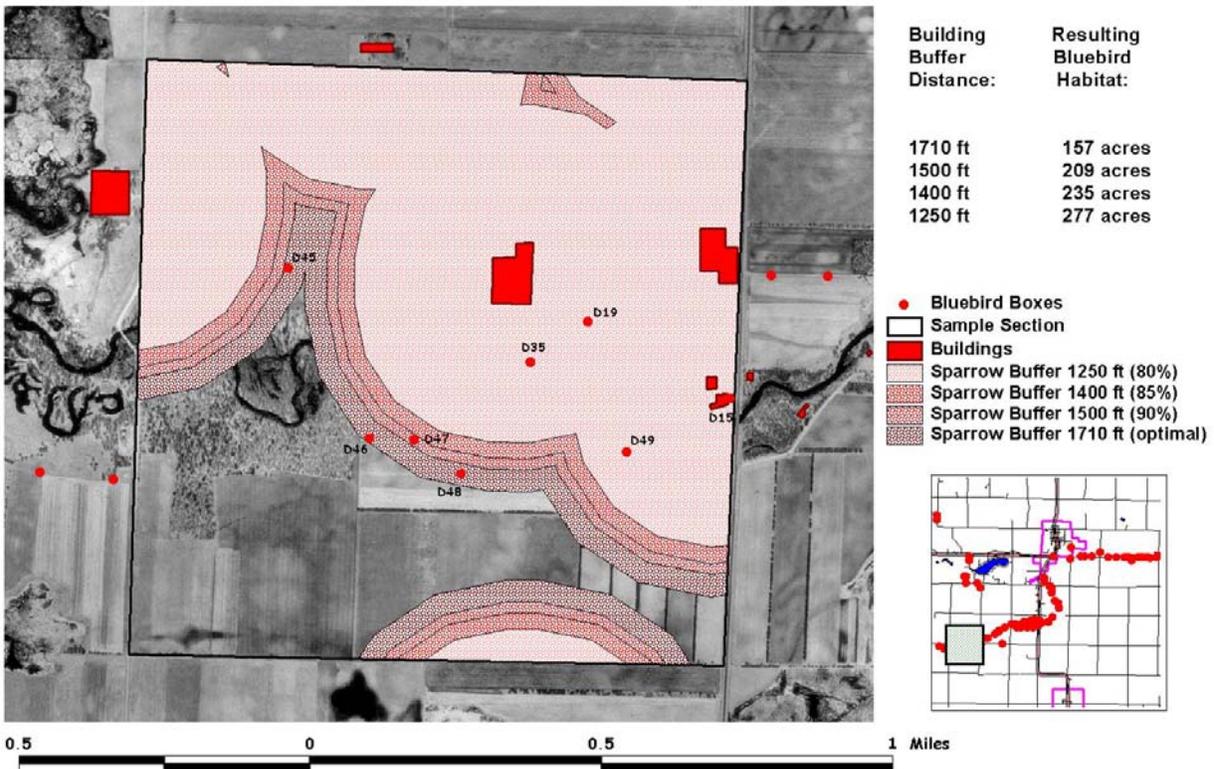


Figure 7: Adjusted safe distances from sparrows

swallows in the Fiedlers' study did not seem to have an adverse affect on bluebird nesting success (successful attempts/total attempts) as there was no significant ($p < 0.05$) statistical correlation between the two.

Not only do they occasionally steal nest boxes from bluebirds, but they are much more versatile in their habitat preferences, making it impossible to isolate one or two variables in order to test for correlations. To the tree swallows, it did not seem to matter where they were in relation to any of the five landscape variables (trees, roads, boxes, water, buildings) and, thus, no safe distance was developed.

It seems that no matter where a box is placed, swallows may find it. Of all the bluebird's competitors, tree swallows are the most acceptable. In fact, some studies have indicated that putting up two nest boxes in one location (pairing) can solve the problem by giving both species ample opportunity to

nest (Grooms and Peterson, 1991). However, this theory was developed after the Fiedlers started their study.

Combined Competitor Analysis

To apply the optimal distances from wrens and sparrows, a 1 square mile sample area was selected in the Fiedlers' study area. First, all the buildings in the sample area were digitized followed by all areas with trees/brush. These layers were then buffered with the appropriate safe distance (530 ft for the trees/brush layer and 1710 feet for the buildings layer) using an ArcView extension called XTools. The resulting map showed much of the section to be unsuitable for bluebird box placement, with only 27.3 of the 640 total acres being outside the buffered area for wrens and sparrows (Figure 8). If the Fiedlers were going to put up more bluebird boxes and had permission

to use the land, this area outside the combined buffer zone would be the top priority (at least in terms of eliminating avian competitors). However, if the Fiedlers chose to use the adjusted safe distance of 80%, the total land outside the combined buffered zone would be 75 acres (Figure 9).

Cats and mammalian predators

Cats also pose problems to bluebirds because they can jump up to a box and reach in for an easy meal. Farm cats left to themselves become wild animals roaming the countryside. Where bluebirds interacted with cats in the Fiedlers’ study, the result for bluebirds was nearly always fatal. A dozen or so cat occurrences were noted (and many

more suspected) in the Fiedlers’ study area. Distances to the nearest building ranged from less than 100 feet to nearly 1920 ft. Since it is virtually impossible to place boxes in areas cats do not frequent (especially in farm country), there are a number of ways to keep them from preying on bluebirds. Placing boxes as high as possible on smooth metal poles and away from overhangs is a good place to start. Placing PVC baffles and sheet metal cones around the poles and using coon guards (such as the Noel Guard) will make boxes almost impossible for cats and mammalian predators to get into (North American Bluebird Society, 2002).

In addition to the previously mentioned competitors and predators, a

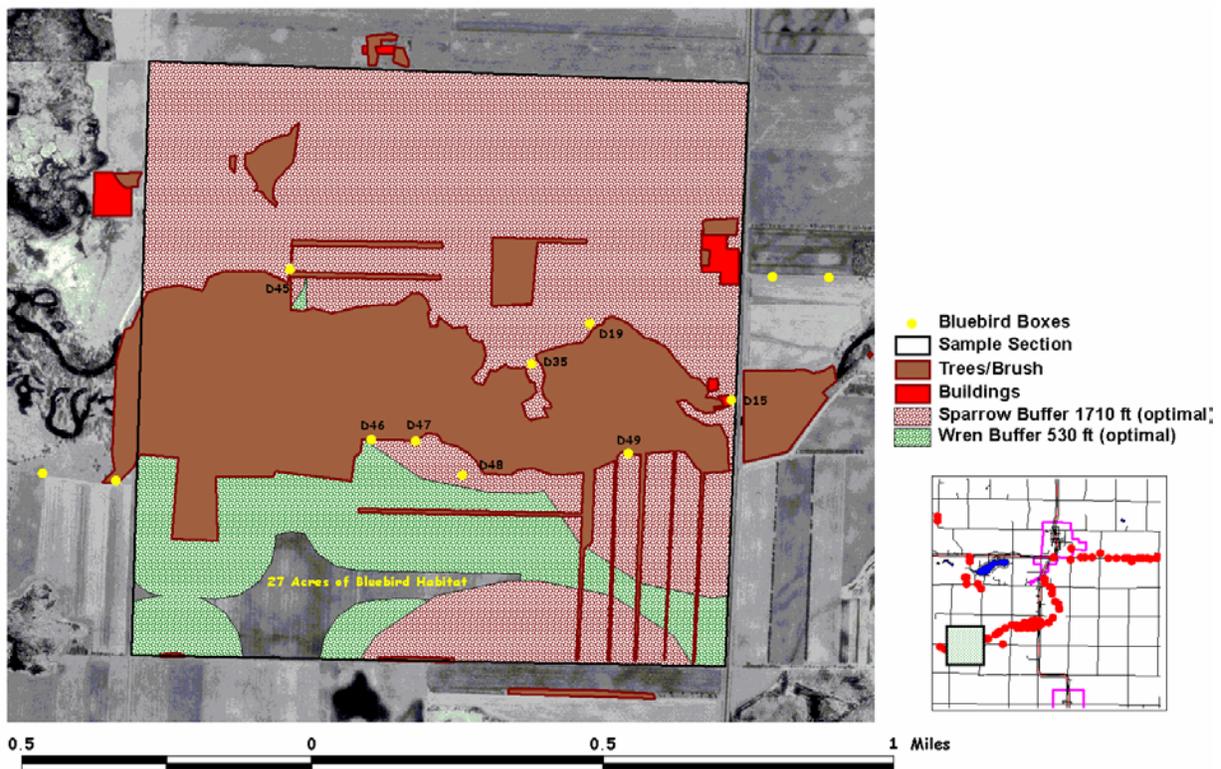


Figure 8: Optimal bluebird habitat in 1 square mile sample area

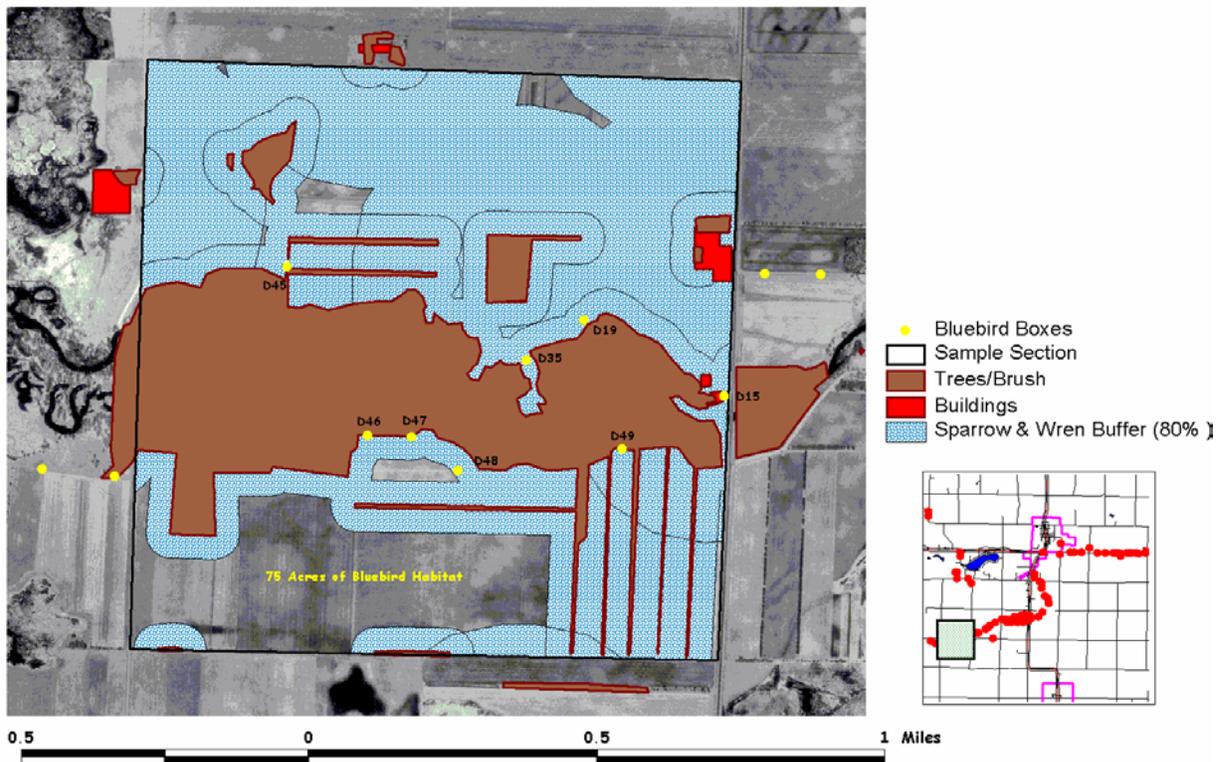


Figure 9: Adjusted buffer distance for avian competitors (using 80% of the bluebird data)

number of other animals were found in the Fielders' study area, including chickadees, starlings, flying squirrels, and mice. However, since these were rare occurrences, they were not factored into this study.

Other Analysis

A number of other factors were also analyzed to determine their affect on bluebirds. No correlation existed between the distance to the nearest water source and bluebird attempts or success. In addition, there was no connection between the distance to nearest roads and bluebird nest attempts. Analyzing bluebird attempts versus the distance to the nearest nest box indicated a positive correlation ($r = .317$, $p < 0.01$): bluebird attempts increased as the distance between boxes increased (Figure 10). Finally, the direction the nest box faced was also analyzed. It proved to have little or no effect, since the bluebird success rates for

each direction were within one standard deviation of each other.

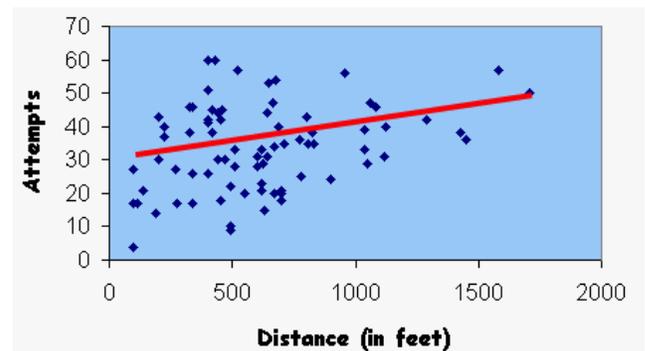


Figure 10: Linear regression of bluebird attempts vs. the distance the nearest nest box

Another interesting part of this study was analyzing bluebird nesting success (or lack thereof) over time. Rectified aerial photographs from the 1970's, 1980's, and 1990's were used. Instead of re-measuring the distances from bluebird boxes to each landscape element for each year/decade, the

analysis was centered on those areas where change has been known to occur (or where identified using the imagery). In addition, a data matrix was created to visually compare bluebird nesting statistics year by year. This allowed for easy identification of any change in a box's historical trend. For example, if a particular box was 2/2, 1/2, 2/3, 1/1, 2/2 (success/attempts) during a five-year period and was suddenly 0/2, 1/2, 0/2, 0/1, 0/2 with a high number of sparrows, a good chance existed that the box was either moved to an area near buildings or structures were built near the box. Both instances occurred throughout the Fiedlers' study. Box 27, located on a fence post bordering the Pierz Municipal Golf Course, enjoyed an open grassy surrounding for the first few years of the study, until houses were built on Park Avenue directly behind the box in the early 1970's. As a result, the box went from 15 bluebird attempts in the first seven years to 12 attempts during the next 30, due to sparrow competition. The same result can be said of boxes 32 and 25 when chicken barns were built nearby (Figure 11). This analysis, coupled with the anomaly identification performed during correlation testing, showed where the landscape had changed, boxes were moved, and other problems were encountered.

Conclusions

Using a GIS to add the spatial element to the Fiedlers' bluebird study was unique in that it focused on the relationship between bluebird nesting success, elements of the landscape, and the competitors' relationship to that landscape. Although many studies have been conducted and many books written on ways to help the bluebird, few have offered the empirical evidence to support where exactly to place a bluebird box in a spatial context.

In summary, ideal buffer distances

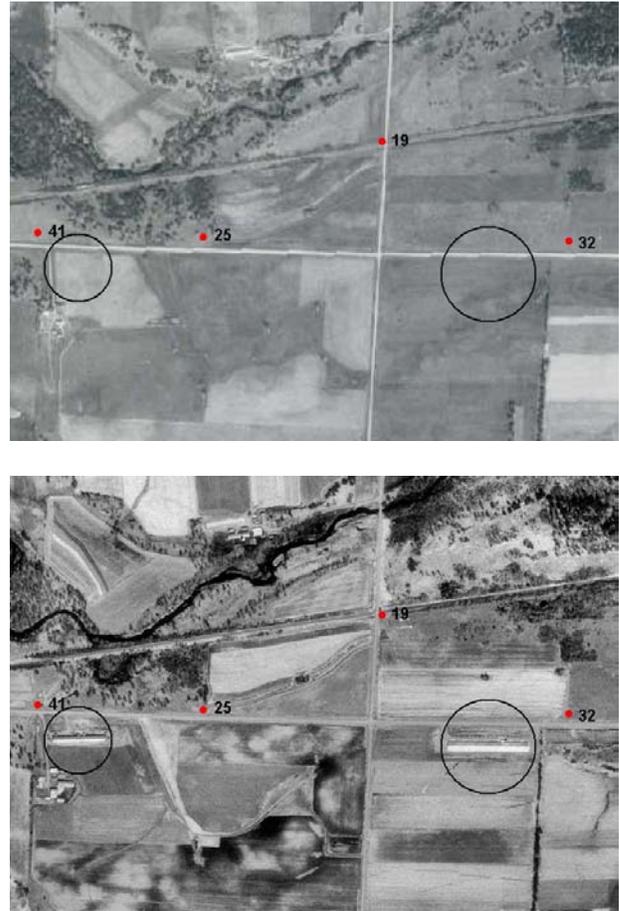


Figure 11: Addition of chicken barns to the landscape between 1970 and 1990.

were developed for 2 of the 3 primary bluebird competitors. The results of this study of optimal bluebird habitat indicate boxes need more of a buffer from wrens than the traditional 100 ft recommended in many bluebird guide books (Stokes, 1991, Grooms and Peterson, 1991). The general recommendation to keep sparrows at least a quarter mile away (1320 ft) was also slightly exceeded (1710). However, when using the 80, 85, and 90 percent-tile, these buffer distances drop significantly and seem to offer a more reasonable alternative to an average landowner who wants to put up a few boxes. In either case, these numbers are

only guides to ideal nest box placement since they could easily vary in other areas and situations. For example, the Fiedlers' most successful box (in terms of both attempts and success rate) is only about 120 feet from trees/brush, much closer than the safe distance developed in this study (Figure 12).

Recommendations for Further Research

A continuation of this project could include an analysis of vegetation type/height as well as crop history to see if vegetation and crop rotation had any effect on bluebird nesting success. Further analysis of tree swallow nesting and habitat preferences would also be beneficial to this study, especially the effects of pairing on bluebird nesting success. Carol Fiedler set up a study area

with over 100 boxes to study just the tree swallow and its nesting habits. A GIS analysis could be useful with her study.

Since a strong correlation existed between bluebird success and the numbers of predators (many of them unknown), it seems wise to identify the sources of predation. The Fiedlers are thinking about video-recording some of the boxes to see if the unknown predators are raccoons, cats, or other mammals.

Ultimately, if time permitted, other buildings and trees/brush (both in the study area and beyond) could be digitized and buffered using the safe distances obtained in this study. In addition, the Fiedlers suggest studying the effects of the presence of high-line wires on bluebird nesting success (see photo below).



Figure 12: The Fiedlers' most used and most successful box was #11.

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