NESTING ECOLOGY AND CONSERVATION OF SHRUBLAND BIRDS IN A FRAGMENTED URBANIZED LANDSCAPE IN NORTHEASTERN ILLINOIS

BY

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THESIS

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ABSTRACT

Current declines in shrubland bird populations and habitats in eastern North America highlight the importance of understanding the nesting ecology of shrubland birds. The majority of the literature on shrubland birds has focused on communities in regenerating forest areas following silvicultural practices. Little information exists regarding nesting ecology and success of shrubland birds in fragmented patches in urbanized areas in regenerating agricultural fields. Nesting success/failure may co-vary with factors such as bird species, predator type, weather, microhabitat conditions at the nest, and landscape factors. Although many studies consider avian species-specific differences, most group types of depredation/failure rather than linking specific predators to nesting success/failure and then comparing levels of success/failure to other variables. The purpose of this study was to combine nest observations, video camera technology, and historical point count data to examine the influence of vegetative factors, landscape factors, and types of nest failure/depredation on habitat use and nesting success of shrubland birds in regenerating agricultural fields in an urban/suburban landscape matrix near Chicago, Illinois. A total of 53 active nests of 12 species were monitored at two sites including shrubland patches of various sizes during late May-August 2010. Approximately 39% of nests failed, and the mean percentage of young fledged (of all known eggs/young) was 52%. Many nests failed partially at different times during the nesting cycle. Depredation and weather (particularly high winds associated with thunderstorms) contributed to the most failures, although other factors such as destruction by House Wrens (*Troglodytes aedon*) and/or other bird species, and abandonment due to Brown-headed Cowbird (*Molothrus ater*) parasitism were also documented. All nests experiencing Brown-headed Cowbird parasitism failed (n=5). Red-winged Blackbird (*Agelaius phoeniceus*) was one of the most successful species; Willow Flycatcher (*Empidonax traillii*) was one of the least successful, and failure rates were higher than some reported from rural, agricultural areas in Illinois. Species-specific variation existed in the types of trees and shrubs used for nesting purposes; some species utilized Gray Dogwood (*Cornus racemosa*) exclusively. Percent vegetative cover above nest, area of patch, and distance from the nearest shrubland patch edge did not influence success. Fledgling success increased with increasing nest height, distance from roads, and in some cases, distance from trails. An above average percentage of nests located in trees/shrubs with thorns fledged. No significant relationship existed between patch area and species richness or the number of species confirmed breeding, but larger patches did support higher numbers of individuals. Elucidating how landscape and vegetative factors, depredation ecology, avian behavior, Brown-

headed Cowbird parasitism, and weather affect nest success/failure (particularly as increased urban sprawl causes habitat loss and degradation and climate change contributes to weather-related variation) can benefit conservation and management practices for shrubland birds, including species experiencing declining population trends.

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INTRODUCTION

Shrubland Communities and Bird Population Trends

A number of studies have documented population declines of birds in temperate shrubland communities in North America within the past few decades (Askins 1994; Dettmers 2003; Hunter et al. 2001). In eastern North America, about 70% of shrubland bird species are undergoing recent or long-term declines, with only 10 out of 40 shrubland-associated species exhibiting stable or increasing population trends (Hunter et al. 2001). Nearly one-quarter of shrubland birds in the northeastern U.S. have experienced population declines of 50% or more since the mid-1960s (Dettmers 2003). Uncommon shrubland birds have some of the lowest abundances of any species in the northeastern U.S. (Dettmers 2003). Similar declines are mirrored within the Chicago, Illinois region (*The State of Our Chicago Wilderness: A Report Card on the Ecological Health of the Region* 2006).

Habitat availability is clearly one limiting factor having a direct negative effect on shrubland bird populations in North America (Brooks 2003; Dettmers 2003; Hunter et al. 2001; Thompson & DeGraaf 2001). While regeneration of forest on abandoned farm fields and other cleared areas initially provides appropriate habitat for shrubland birds, natural successional processes eventually change the habitat until it is no longer appropriate for many of these species, usually within 15 years (Krementz & Christie 2000; Litvaitis 2003). Many current shrubland habitats are small, disconnected, or surrounded by other land uses (Brooks 2003; Johnson et al. 2006). Land development, loss of keystone species, disruption of natural disturbances such as fire and flooding, and invasion of exotics are some threats to the conservation and restoration of these habitats (Brooks 2003; DeGraaf & Yamasaki 2003; Hunter et al. 2001).

Unfortunately, shrublands have historically received much less protection and conservation attention than other habitats (Askins 2001). Indications exist that the current amount of early-successional habitat in the northeastern U.S. may be approaching or falling below the levels existing prior to European settlement, which facilitated the creation of such habitat through the process of succession after land clearing (Brooks 2003; DeGraaf & Yamasaki 2003). Therefore, it is likely that continuing conservation and restoration efforts will be needed to maintain shrubland bird populations.

Study Goals and Rationale

Current declines in shrubland bird populations and shrubland habitats highlight the importance of understanding the nesting ecology and success, and thus persistence, of shrubland bird populations. The majority of the literature on shrubland birds has focused on the examination of avian communities in regenerating forest areas following silvicultural practices, reclaimed surface mines, or utility rights of way, but not regenerating agricultural fields, which may be composed of a different plant community than other anthropogenically-modified habitats. Researchers disagree on the influence of area sensitivity and edge effects on shrubland birds, although a few species exhibit area sensitivity, and many species appear to avoid edges (cf. Askins 1994; Askins et al. 2007; Dettmers 2003; Fink et al. 2006; Hunter et al. 2001; Krementz & Christie 2000; Robinson et al. 1999; Rodewald & Vitz 2005; Schlossberg & King 2008). Studies on the influence of patch area and distance from edge on nesting success also differ. Little information exists regarding how landscape factors affect nesting ecology and success, particularly in fragmented, urbanized areas. In addition, a lack of understanding exists regarding the link between predator type and nesting success/failure; few studies have utilized video camera technology to link type of nest failure/depredation with landscape factors in species of shrubland birds. The purpose of this study was to examine the influence of vegetative factors, landscape factors, and types of nest failure/depredation on nesting success of shrubland birds in regenerating agricultural fields located in an urban/suburban landscape matrix. Understanding habitat use, landscape use, and nesting ecology can improve conservation and management practices for shrubland birds, particularly as their habitats experience fragmentation and decline.

LITERATURE REVIEW

Patch Use: Area Sensitivity and Edge Effects

Habitat fragmentation can adversely affect populations of breeding birds, and influence factors such as species richness, abundance, density, and nesting success. Research differs on the presence of area sensitivity (sensitivity of certain species to the size of habitat patches that they require for breeding purposes) in shrubland birds (cf. Askins et al. 2007; Dettmers 2003; Krementz & Christie 2000; Rodewald & Vitz 2005).

Some have suggested that shrubland birds as a whole typically are not as sensitive to patch size as other groups of birds (Askins et al. 2007), and that shrubland birds occur in similar densities and diversity across a wide variety of patch sizes (Dettmers 2003; Krementz & Christie 2000), as long as patch sizes are adequate to support the necessary plant community. For example, some have indicated that patch area does not affect species richness or abundance in early-successional bird communities in regenerating clearcuts (Askins et al. 2007; Krementz & Christie 2000). Results of other studies indicate possible area sensitivity. Rodewald and Vitz (2005) found that frequency of occurrence of shrubland species increased as area increased in regenerating clearcuts. These varying conclusions are due to species-specific differences in area sensitivity. For example, Fink et al. (2006) found that the effect of habitat size on breeding densities varied among shrubland bird species in Missouri. Some shrubland bird species appear to exhibit area-sensitive tendencies, and are thus vulnerable to the effects of habitat fragmentation (Krementz & Christie 2000; Rodewald & Vitz 2005). Both Golden-winged Warblers (*Vermivora chrysoptera*) and Yellow-breasted Chats (*Icteria virens*) show a tendency to select patches at least 10 ha or greater in size (Dettmers 2003), while avoiding patches < 2 ha (Askins 1994; Hunter et al. 2001). The Golden-winged Warbler has been found to increase in occupancy and densities at patch sizes from 12-40 ha (Hunter et al. 2001). Rodewald and Vitz (2005) found Yellow-breasted Chats showed area sensitivity in regenerating clearcuts; abundances were twice as high in large patches as smaller patches. Robinson et al. (1999) found indications of area sensitivity in a number of species in Illinois, many of which were only detected in patches > 6 ha (some > 20 ha), and are also currently species of regional and national conservation concern.

Research also differs regarding the presence of edge sensitivity (sensitivity to edges in fragmented habitat) in shrubland birds. It seems that a number of species have a tendency to avoid edges. For example, Rodewald and Vitz (2005) found that seven of eight shrubland specialists (particularly Field Sparrow [*Spizella pusilla*], Yellow-breasted Chat, Blue-winged

Warbler [*Vermivora pinus*], and Prairie Warbler [*Setophaga discolor*]) avoided edges in regenerating clearcuts in Ohio, which would likely reduce bird densities in small or irregularly shaped patches. Schlossberg and King (2008) found that 17 species of shrubland birds were more abundant in interiors than edges in early-successional regenerating forest habitats in the eastern U.S., and that edge effects were significant for 8 of those species. Fink et al. (2006) found that Blue-winged Warbler, Eastern Towhee (*Pipilo erythrophthalmus*), Prairie Warbler, and Yellow-breasted Chat avoided forest-pasture edge habitats in Missouri and were found in greater densities in glades and regenerating forest habitat types. Shrubland birds that sometimes nest in the understory of mature forest (e.g. Eastern Towhee, White-eyed Vireo [*Vireo griseus*]) showed lower edge avoidance of forest edges, while species that rarely nest in mature forests (e.g. Blue-winged Warbler, Field Sparrow) showed higher avoidance of edges (Rodewald & Vitz 2005; Schlossberg & King 2008). The reasons for edge avoidance are unclear, however. Shrubland birds may or may not be responding to changes in vegetation near edges (Rodewald & Vitz 2005; Schlossberg & King 2008; Woodward et al. 2001), and/or may experience territory restrictions near edges (Schlossberg & King 2008).

Although shrubby utility rights of way have the potential to provide shrubland bird habitat, some species appear to be sensitive to edge effects in rights of way (Confer & Pascoe 2003). Greater diversity of shrubland specialist species has been found on wide utility corridors (61 and 92 m) than narrow corridors, as well as greater abundances of some species (Askins 1994). Other species only appear to be present in wide corridors (Askins 1994). Therefore, narrow utility rights of way and small habitat patches may not provide adequate habitat for edge-sensitive shrubland birds (Rodewald & Vitz 2005).

Some authors have suggested that the adaptability of shrubland birds to small-scale disturbance regimes and the ephemeral nature of transitional habitats facilitates colonization of isolated patches (Askins et al. 2007; Chandler et al. 2009); others believe that small, isolated patches may take longer to be colonized (DeGraaf & Yamasaki 2003; Thompson & DeGraaf 2001). Available evidence indicates that despite the ephemeral nature of these habitats, shrubland birds exhibit levels of site fidelity similar to those of forest species, with adults frequently returning to former breeding sites and yearlings dispersing away from their natal sites (Lehnen & Rodewald 2009; Schlossberg 2009). In some species however, yearlings prefer to settle on patches already occupied by breeding birds, and may be thus influenced by the presence of conspecifics (Schlossberg 2009; Ward & Schlossberg 2004).

In summary, responses to area and edge effects appear to be species-specific (Thompson & DeGraaf 2001; Woodward et al. 2001). More work is needed to determine optimal patch sizes needed to predict species presence and reproductive success in shrubland birds (Dettmers 2003; Hunter et al. 2001). Factors contributing to how shrubland birds select and utilize patches within the landscape need to be further studied, as well as shrubland bird response to habitat patches of various sizes, shapes, and configurations (Askins 1994).

Patch Use and Reproductive Success

Most of the available data on nesting ecology of shrubland birds focuses on anthropogenically-modified habitats such as regenerating forest patches, reclaimed mining areas, and utility rights of way. Since these areas provide the potential to be "reclaimed" and managed as shrubland habitat, reproductive success within such areas, particularly within smaller, isolated patches is an important management concern. Some suggest that shrubland birds can have fairly high reproductive success even in small patches (Dettmers 2003), although results of other studies differ regarding the influence of area and edge effects on reproductive success. Robinson et al. (1999) found nesting success of shrubland birds in Illinois did not increase with shrubland size, suggesting that shrubland bird populations may possibly be maintained in relatively small habitat patches compared to those needed to support grassland and forest bird populations. King and DeGraaf (2004) found that Chestnut-sided Warbler (*Setophaga pensylvanica*) nests were initiated earlier in larger patches of regenerating forest in Massachusetts, suggesting that smaller patches may be less suitable habitat, although patch area and shape were unrelated to number of young fledged or nest predation rates. Area of suitable habitat affects the number of territories that may be accommodated, and may have important implications for shrubland birds that exhibit high levels of conspecific aggregation or extra-pair fertilizations (Rodewald & Vitz 2005).

Some researchers report that edges do not result in increased nest predation rates (DeGraaf & Yamasaki 2003; King et al. 2001). Others have reported increases in nest predation near shrubland edges, however (King & Byers 2002; Rodewald & Vitz 2005; Woodward et al. 2001). Robinson et al. (1999) found that nesting success of shrubland birds did not increase with increasing distance from edge in Illinois, although they also found that shrubby edges (including "soft" edges) and corridors contained high levels of nest predators and nest parasites (Nest predators and parasites were less common in contiguous shrublands of intermediate shrub density). King and Byers (2002) found that Chestnut-sided Warblers in Massachusetts utility rights of way experienced levels of reproductive success sufficient to balance losses from mortality, but that nesting success was reduced near edges. They found that vegetation removal associated with herbicide use in utility rights of way could provide foraging habitats for predators and consequently reduce nesting success, particularly near edges. Woodward et al. (2001) found that nest predation rates were greater closer to edges for Yellow-breasted Chat and Prairie Warbler in Missouri, but that edges did not act as ecological traps for shrubland birds. Some area-sensitive species, such as Yellow-breasted Chats and Prairie Warblers, appear to be edge-sensitive, as well, and have been found to prefer nesting areas >20 m from edges (Woodward et al. 2001).

Studies of nest success rates in shrubland birds show variation from 10-99% (King et al. 2001; King et al. 2009; Schlossberg & King 2007). Schlossberg and King (2007) analyzed 38 studies of nesting success in 22 species of shrubland birds, finding an average Mayfield success rate (Mayfield 1975) of 0.43 ± 0.02. These high levels of variation in nesting success may be due to differences in forest cover, geographic location, differences in the composition of nest predator communities (King et al. 2001), species-specific variations in success (Schlossberg & King 2007), and/or other factors such as yearly variation. Further studies including detailed demographic data are needed to determine how productivity during the breeding season (or lack thereof) contributes to population trends in shrubland birds.

Most studies on nest success group failures when determining factors contributing to nest success; little is known about the importance of individual predator species on patterns of nest success, and how predator ecology may influence patterns of success/failure (Benson et al. 2010). Since type of depredation may differ among various locations and within different landscape matrices, and some predator types may utilize edges more frequently than others, more studies are needed that examine predator type in regard to landscape and region.

METHODOLOGY

Study Sites

The study area was located approximately 50 kilometers west of Chicago, Illinois. Study sites were established at two forest preserves located approximately 25 kilometers apart in DuPage County, Illinois: Herrick Lake Forest Preserve and Greene Valley Forest Preserve (Figures 1-2). These sites were chosen because they are both located within an urban/suburban landscape matrix and contain patches of shrubland habitat primarily consisting of regenerating agricultural fields. Both sites were agricultural homesteads settled in the early to mid-1830s and acquired by the DuPage County Forest Preserve District in the 1920s. Herrick Lake is approximately 350 ha in size, and is situated within a larger corridor of preserved land that is approximately 1497 ha. Approximately 8 kilometers of multipurpose trails connect Herrick with its neighboring preserves. With the exception of a few small patches, only one road divides the preserve. Greene Valley is approximately 559 ha in size and is isolated from other preserved land. It contains about 17 kilometers of multipurpose trails. Two roads and one electrical right of way divide the preserve. Both preserves contain a variety of habitats, including deciduous woodland, wetland, grassland, and shrubland. Where not connected with other preserved land, both preserves are primarily surrounded by residential suburban development.

Specific study areas within the preserves were pinpointed with the aid of the forest preserve district's ecosystem delineation data. In order to divide preserves into smaller management blocks composed of similar habitat, the forest preserve district has delineated various habitat types within each preserve into ecosystem units. Plant community structure is the primary factor in forming these delineations, although wildlife observations also factor into the process. Units designed EHE15 (at Herrick Lake), and EGV07, EGV13, EGV15, and EGV19 (at Greene Valley) were chosen because they were composed of shrubland habitat as well as serving as monitoring point locations for forest preserve bird monitors. For the purposes of this study (e.g. to examine possible patch effects on nesting success), these units were modified so that each could be considered as a separate patch surrounded by roads and/or habitat types other than shrubland (Figures 1-2). Units EGV07 (62.2428 hectares) and EHE15 (68.7667 ha) remained the same. Units EGV15 and EGV19 were combined into a single patch (labeled EGV15/19 [66.3417 ha]) because they are contiguous. Unit EGV13 was separated into two patches (labeled EGV13A [10.8213 ha] and EGV13B [7.45088 ha]), since this unit is separated by the presence of roads. Multipurpose gravel trails were present in each of the study patches. Access roads and/or parking areas were present in EHE15 and EGV15/19.

The habitat type for all units was shrub meadow, with the exception of EGV13A and EGV13B, which were designated as upland reforestation. Shrub meadow units were open habitats composed of trees, shrubs, grasses, and forbs; the upland reforestation unit was similar, but contained less shrub cover. These units are currently managed as shrubland habitat.

Nesting Ecology

Nest searches were concentrated in shrubland habitat located within the designated study patches at Herrick Lake Forest Preserve and Greene Valley Forest Preserve (see Figures 1-2). Searches were conducted May 26-August 23, 2010, primarily between the hours of 9:00 am-12:00 pm. In order to locate nests effectively and protect nests and nestlings, no nest searches or visits were conducted during inclement weather. Meander searches were performed with attempts made to search all shrub species equally, without giving preference to any particular shrub species. Approximately 61.5 hours total were spent searching for nests: 35.5 hours at Herrick Lake Forest Preserve, and 26 hours at Greene Valley Forest Preserve.

Determination of nest activity (or inactivity) was based in part on breeding evidence criteria for confirmed breeders from *The Illinois Breeding Bird Atlas* (Kleen et al. 2004). A nest was considered active or potentially active based on one or more of the following criteria: 1) Adults were seen constructing the nest, or there was evidence of recent construction or depredation (e.g. material was found added to the nest on consecutive visits), 2) A nest was found with an adult on, eggs, or young present, 3) Adult(s) were seen closely defending an empty nest (exhibiting mobbing behavior/agitation), 4) An empty nest with no apparent activity contained eggs or eggshells, 5) An empty nest was found with feces in and/or around the nest, indicating possible fledging, and 6) An empty nest was found with fledglings nearby, and/or adult(s) were found feeding fledglings nearby. In most cases, a combination of the above factors was used to determine nest activity. Inactive nests fit one or more of the following criteria: 1) A nest was found empty, and did not exhibit any of the criteria of an active nest (as listed above), 2) An empty nest was found sagging, collapsed, or in disrepair, and 3) The nest cup was not maintained (i.e. debris was present in the nest cup or it was covered over). As with the criteria for active nests, a combination of the above factors was used to determine inactivity.

At each nest, the following information was recorded: date, location (Herrick or Greene Valley), the four-letter USGS Bird Banding Laboratory band code for the bird species utilizing the nest (if determinable), and species of the principal plant structure supporting the nest. The location of each nest was recorded with a Garmin eTrex H GPS unit (Garmin International, Inc., Olathe, KS, U.S.A). Nest height from ground to eggs (or where eggs would be located, if absent) was recorded in centimeters with the use of a telescoping pole and tape measure. At each nest, the following were also noted: Number of host eggs, number of Brown-headed Cowbird (*Molothrus ater*) eggs, number of host young, number of Brown-headed Cowbird young, and whether or not an adult was present on the nest. Status of eggs/young was ascribed to one of the following categories: 1) Eggs, 2) Naked or downy young (no adult feathers present), 3) Young growing feathers/feather shafts present, or 4) Young nearly fully feathered (flight feathers almost completely grown in). Although efforts were concentrated on monitoring active nests, data on date found, location (Herrick or Greene Valley), bird species, species of plant supporting the nest, GPS coordinates, and nest height were also recorded for inactive nests that could be identified to species to provide additional information regarding microhabitat and vegetative characteristics.

In order to minimize nest disturbance by the observer, as little time as possible was spent at each nest. Nest height and GPS coordinates were taken at the nest, while other information was recorded once the observer had retired to a suitable distance. A Craftsman Professional Extra Long Inspection Mirror (extendible to 130 cm) (Sears Holdings Corporation, Hoffman Estates, IL, U.S.A.) was used to inspect nest contents. This tool aided in checking nests that were too high to properly examine without assistance, as well as to minimize direct human contact with nests and nestlings.

Nests were revisited roughly every 4-5 days until they terminated. Nests were considered terminated when they were found empty (either young fledged and left the nest, or nests had been depredated and/or destroyed). Once nests had terminated, the following information was recorded: Whether the nest was damaged or undamaged, whether the nest had been abandoned (if determinable), whether there were feces present in or around the nest, whether the nest rim was flattened, whether fledglings or adults with young were seen near the nest, whether adults were near the nest and excited, whether egg fragments were present in the nest, estimated number of young fledged, and any other information pertaining to the nest outcome.

To aid in the determination of nest outcomes, time-lapse infrared video camera systems were placed at 10 nests of 6 species, similarly to the methodology described in Benson et al. (2010). Each system consisted of a video camera with built in infrared light-emitting diodes (models PC506IR and PC168-IR; Supercircuits, Austin, TX, U.S.A.) mounted on a 2.2 cm diameter wooden dowel rod near each nest and camouflaged to blend in with the surrounding habitat. Each camera was connected to a digital video recorder and deep cycle battery, housed in a plastic weatherproof container located away from the nest. Video was recorded on secure digital media. Camera systems were installed after the egg laying period to reduce possible nest abandonment due to camera presence. Systems were visited approximately once per week until each nest terminated for maintenance, to change batteries, and to replace camera cards. Species with cameras on nests included American Goldfinch (n=1), American Robin (n=1), Brown Thrasher (n=1), Gray Catbird (n=1), Willow Flycatcher (n=3), and Yellow Warbler (n=3). Cameras were located on 5 nests at Herrick and 5 nests at Greene Valley (Table 1). Nests monitored with video cameras were also manually monitored.

Final nest outcomes were determined using a combination of methods. In some cases, video camera systems provided accurate determinations of nest success or failure. In cases when video cameras were not present or failed to provide accurate information, nest success was determined by examining data collected throughout the nesting cycle, as well as at nest termination. General hatching dates were determined from collected data, and compared with the relative age of young at each nest check, the date of nest termination, and information on each species' earliest fledging dates compiled from three sources: Baicich and Harrison 1997, Harrison 1975, and Poole 2005. After each nest had terminated, determination of nest success was based on one or more of the following factors: 1) Fledged young were seen near the nest, 2) At the previous nest check, young were nearly fully feathered (flight feathers almost completely grown in) and therefore had likely fledged, and 3) Feces were present on the nest rim and around the nest, indicating possible fledging. Determination of nest failure was based on one or more of the following factors: 1) A nest was found damaged or destroyed, 2) Damaged eggs, eggshells, or deceased young were present in the nest, and 3) Eggs and/or early stage young were missing from the nest before earliest possible fledging dates for each nest. In some cases nests experienced partial failure; monitoring was continued until these had fully terminated. Determination of nest outcomes was conservative; if an outcome was unclear, nest success was listed as "unknown."

The tree/shrub species utilized for nesting purposes and percent cover at nest were examined to help determine whether shrubland birds have specific nesting preferences regarding vegetative structure, and if so, to determine what those preferences might be. Information on percent cover at nest and nest heights were examined to determine whether either influenced nesting success. To determine percent vegetative cover at each nest, an image of the vegetation above each nest was taken using a Nikon Coolpix P5100 digital camera (Nikon Inc., Melville, NY, U.S.A.). Images were taken for both active and inactive nests, but after active nests had terminated to avoid disturbing nestlings. The camera was placed with the viewscreen flush with the nest rim, roughly centered above the nest's center, with the lens pointing skyward. Images were taken during the same time period that nest searches and visits were conducted, during clear or partly-cloudy weather conditions. To ensure that all images were as consistent as possible, the following settings were applied: The lens was set at the widest angle (35 mm), image size was set at 12 megapixels (12,000,000 pixels), and image quality was set at "normal." All other settings were automatic.

In order to analyze images, I developed a digital vegetative cover assessment specifically for this study (Modified from *Method to Estimate Vegetative Cover on Army Training Lands*, U. S. Army Corps of Engineers, 2005). Using the selection, color replacement, and desaturation tools in Adobe Photoshop CS3 Extended (Adobe Systems Incorporated, San Jose, CA, U.S.A.), each color image was edited to create a new black/white image in which the sky was composed entirely of uniformly white pixels and the vegetation was composed of uniformly black pixels. Using the "select color range" tool, the black area of the vegetation was selected. The "record measurements" tool was used to measure the area of the selection (in pixels). This information was imported into a Microsoft Excel file. The percent vegetative cover for each image was then calculated by dividing the area of vegetative cover (in pixels) by the total area covered by the image in pixels (12,000,000).

Coordinates for each active nest were entered into a geographic information system (GIS) (ArcGIS 9, ESRI, Redlands, CA, U.S.A.). Utilizing forest preserve spatial data, the following landscape variables were measured in GIS: Distance from each nest to the nearest trail, distance from each nest to the nearest road, and distance from each nest to the nearest patch edge. The patch name and area of the patch where each nest was located were also noted.

Patch Use

Historical point count data collected by volunteer bird monitors and provided by the DuPage County Forest Preserve District was utilized in order to characterize shrubland bird habitat use in the various study patches. Historical point count data were collected between 2007 and 2009 by forest preserve bird monitors for 12 monitoring points within the study areas (Figures 1-2). Point locations were at least 150 meters apart. Each point was visited 4-6 times between sunrise and 9:00 am from June through July. At each visit, the number of each species seen or heard within a 100 meter radius of the point was recorded for a five minute survey period. Breeding evidence was also noted, if observed.

Data Analysis

Nest success was calculated as a proportion of the number of nests succeeding to the number of nests failing. Fledgling success was calculated as a proportion of the number of young fledging to total known clutch size for each nest that fledged young. Nest failure was calculated using a version of the Mayfield method (Mayfield 1975). The Mayfield method accounts for variations in the number of days a nest is under observation before termination. This value is often termed “daily predation rate,” or DPR. Since a number of nests in this study failed due to factors other than predation, however, “failure rate” is a more appropriate term, and is used hereafter. This was determined by taking the number of days until failure divided by the number of days the nest was observed. For this calculation, only nests visited at least twice were included in the analysis. The date of a significant event occurring in the nest cycle (failure or fledging) was taken as the midpoint between the date of the last nest check and the date the event was found to have occurred. Mean failure rate was then determined by species.

Historical point count data from forest preserve district bird monitors was analyzed to determine relative abundance, frequency of occurrence, and species richness at each point. Relative abundance was determined by taking the average abundance for each species by monitoring point divided by the total number of individuals in the community (for each point). Frequency of occurrence was determined by taking the number of detections for each species per point divided by the total number of visits per point. Mean values were then pooled to find relative abundance, species richness, and frequency of occurrence by patch. Historical data were pooled with data from the current season to determine the number of species confirmed breeding at each patch unit. Linear regression was used to examine possible effects of patch area on the number of individuals detected, species richness, mean relative abundance, and the number of species confirmed breeding.

In order to compare nest success/failure with other variables, an *F*-test was conducted for each variable to determine whether or not variances were equal. The appropriate *t*-test (assuming equal variances or unequal variances, respectively) was conducted for each variable to be examined. If a comparison was conducted for more than one group, one-way ANOVA was used instead of a *t*-test. If data were highly abnormally distributed, a nonparametric alternative test (such as a Mann-Whitney *U* test) was used. Linear regression was the primary method used to compare quantitative variables. These tests were conducted to determine the influence of the following on nest success, fledgling success, and/or failure rate: Nest height, percent vegetative cover above nest, patch area, distance from each nest to the nearest trail, distance from each nest to the nearest road, distance from each nest to the nearest patch edge, and storm frequency and wind severity during the nesting period (More detail about which test was used in each instance is provided in the “Results” section). Unless otherwise noted, all statistical analyses assumed a 95% confidence level ($\alpha=0.05$).

RESULTS

Nesting Ecology

A total of 85 nests were found during the nest search period. Of these, 53 were determined to be active or in use during the current breeding season, and 32 were determined to be inactive or from previous years. A total of 48 nests were found at Herrick (35 active, 13 inactive), and 37 at Greene Valley (18 active, 19 inactive). Although more time was spent searching at Herrick, the number of nests found per hour remained the same for both preserves (approximately 1.4/hr.).

Of the active nests, 52 active nests were identifiable to species. Of the inactive nests, 17 were identifiable to species. Nest identification was conservative, with nests only identified to species if there was a high level of certainty regarding the identity of the species utilizing the nest. Active nests were relatively simple to identify to species (due to presence of adults at the nest). In many cases; however, it was difficult to identify inactive nests to species, particularly since many species build nests that closely resemble one another. These nests were only identified to species if the nest was of a type that was easily attributed to a specific species. Therefore, species-related information (such as nest height and percent cover at nest site) that utilizes information from inactive nests contains more records for certain species than others.

Active nests were identified for 12 species (Table 2). These included American Goldfinch (n=7), American Robin (n=13), Bell's Vireo (n=1), Blue-gray Gnatcatcher (n=1), Brown Thrasher (n=2), Cedar Waxwing (n=1), Eastern Kingbird (n=1), Gray Catbird (n=5), Northern Cardinal (n=1), Red-winged Blackbird (n=7), Willow Flycatcher (n=8), and Yellow Warbler (n=5). Inactive nests identifiable to species included American Robin (n=11), Brown Thrasher (n=3), Gray Catbird (n=1), and Orchard Oriole (n=2). Orchard Oriole was the only species for which only inactive nests were located.

Of the 53 active nests, estimated or known outcomes were as follows: 20 fledged completely, 18 failed completely, 8 failed partially, and 7 had unknown outcomes. Of the nests with estimated or known outcomes (n=46), therefore, 39% failed, 17% partially failed, and 43% fledged (Figure 3). Causes of failure or partial failure were attributed to predation (although weather may have also contributed) (54%, n=14), weather (27%, n=7), destruction by House Wrens (*Troglodytes aedon*) or other bird species (eggs were punctured, but not consumed, and House Wrens were seen in the immediate area) (8%, n=2), abandonment due to Brown-headed Cowbird parasitism (7%, n=2), and disease/starvation/parasites (1 young was found dead in nest) (4%, n=1) (Figure 4). Damage to nests during the nesting cycle varied from missing (n=3), knocked down (n=2), partially destroyed or with holes in the side or bottom (n=3), and intact with only the inner lining disturbed (n=2). All damaged or partially damaged nests experienced complete failure, with the exception of one nest that partially fledged despite minor damage. Nests experiencing partial failure were generally missing eggs and/or young early in the nesting cycle, and were often left intact. In some cases, eggs/young went missing at different dates. Of the 10 nests with video camera systems, 40% failed, 40% partially failed, and 20% fledged (Figure 5). The causes of failure included weather (30%, n=3) (In two cases, video cameras showed eggs falling or being blown out of nests due to high winds during thunderstorms), and possibly depredation (50%: 3 partially, and 2 completely), although predator type could not be determined due to camera failure. Although video camera systems did not capture images of predators, possible nest predators such as Garter Snakes (*Thamnophis* spp.), Thirteen-lined Ground Squirrels (*Spermophilus tridecemlineatus*), American Crows (*Corvus brachyrhynchos*), and Blue Jays (*Cyanocitta cristata*) were observed within the Herrick study patch; an American Mink (*Neovison vison*) and Striped Skunk (*Mephitis mephitis*) were noted at one of the Greene Valley study patches. Data on nests with video camera systems showed similar partitioning of failure/success as manually-monitored nests.

A total of 5 nests of 4 species experienced known parasitism by Brown-headed Cowbirds: Bell's Vireo (n=1), Blue-gray Gnatcatcher (n=1), Willow Flycatcher (n=1), and Yellow Warbler (n=2). Responses to cowbird parasitism ranged from nest abandonment (Bell's Vireo, Yellow Warbler), building the nest over the egg (Willow Flycatcher), to no response (Blue-gray Gnatcatcher, Yellow Warbler). Some species actively eject Brown-headed Cowbird eggs from nests; this response was not documented, but it may have occurred. Although nest failure could only be directly attributed to cowbird parasitism in 2 cases of abandonment (Bell's Vireo, Yellow Warbler), all cowbird parasitized nests failed completely (n=4), or partially (n=1).

Nest success and fledgling success were determined for all species (n=12) for which nest outcomes and/or number of young fledged and clutch size were observed. Species nest success was defined as the sum of all nests succeeding for that species/the total number of nests for that species (Partially failed nests were included by dividing them evenly between the "failed" and "succeeded" categories). This resulted in a mean nest success across all species of 55%. Fledgling success for each nest was defined as the number of young fledged/total known clutch size. This was calculated for each nest with at least 1 egg or young and a known outcome. Species fledgling success was defined as the mean of the fledgling success values for each species. Mean fledgling success across all species was 52%.

Further examination of species-specific results regarding nest and fledgling success was limited to species for which 3 or more nests were found (n=6) (Figure 6). As seen in the figure, nest success varied by species, with Red-winged Blackbird experiencing the highest success (71%, n=7), and Willow Flycatcher experiencing the lowest success (0%, n=4). Fledgling success for species with at least 3 nests ranged from 10-50%. Red-winged Blackbird experienced the highest success (50%, n=4), and Yellow Warbler experienced the lowest success (10%, n=3). Willow Flycatcher experienced the second lowest success (40%, n=6).

Failure rates were calculated for 31 nests of 11 species. Failure rates ranged from 0 (nest fledged at least 1 young) to 0.83. Four nests failed within 1 day. Mean failure rates were calculated for species with at least 3 values. Results were as follows: American Goldfinch (0.23, n=5), American Robin (0.26, n=7), Red-winged Blackbird (0.14, n=3), and Willow Flycatcher (0.33, n=6). Mean failure rate across all species was 0.20 (n=31). Although failure rates were lower than data examining proportions of success/failure, results showed similar trends, with Willow Flycatcher exhibiting the highest rate of failure, and Red-winged Blackbird exhibiting the lowest failure rate. Linear regression analysis of nest failure rates over time (number of days until failure/the number of days the nest was observed) indicated that the possibility of nest failure decreased with the number of days each nest was observed (i.e. number of days each nest remained active, or increasing age of nest) (p=2.29^{-5}, R^2=0.67) (Figure 7).

Microhabitat Vegetative Factors and Nesting Ecology

Identification of the plant species serving as the primary nest support structure was determined for 84 of the 85 total nests (active and inactive). Crabapples and Hawthorns were not identified to species, but consolidated into two groups termed Crabapples (*Malus* spp.) and Hawthorns (*Crataegus* spp.). A total of 12 different plant species groups were used for nesting. Approximately 13% of nests utilized vines (Virginia Creeper [*Parthenocissus quinquefolia*] and Riverbank Grape [*Vitis riparia*]), and 20% utilized plants with thorns (Hawthorns and Multiflora Rose [*Rosa multiflora*]). Relative frequency of nests encountered by shrub type was determined by taking the total number of nests per plant species/the total number of nests (84) (Figure 8). Relative frequency was highest for Gray Dogwood (*Cornus racemosa*) (43%), followed by Hawthorns (15%), and Crabapples (14%).

Tree/shrub type used for nesting was also examined in relationship to bird species for both active and inactive nests (Figures 9 and 10). Generally, as number of nests increased per shrub type, bird species diversity also increased, but this was not always the case. Number of nests and bird species diversity were highest in Gray Dogwood, followed by Crabapples.

American Robins exhibited the highest diversity in terms of shrub species used for nesting, followed by Brown Thrasher and Gray Catbird. Some species only utilized certain plants for nesting purposes, however. Orchard Oriole, Red-winged Blackbird, and Willow Flycatcher all nested exclusively in Gray Dogwood. American Goldfinch and Yellow Warbler also utilized Gray Dogwood for the majority of nests.

Vegetation images for calculation of vegetative cover above each nest were obtained for 71 of the 85 nests (active and inactive). Images were not obtained for 11 nests due to height, and for 3 nests due to loss of the nest. One additional inactive nest was found in a dead tree, so no image was taken. Percent cover at nest varied from 15% to nearly 100%. Mean percent cover was 88.8%, with the most commonly occurring value at 97% (Figure 11 [Note: The lowest 5 values are excluded for ease of reading]). Mean percent cover at nest varied slightly by bird species, but most values fell within the 85%-95% range (Figure 12). Low numbers of nests found per species did not allow for significant comparisons, however.

Nest heights were obtained for 83 of the 85 nests (active and inactive) (Figure 13). Heights were not obtainable for one nest due to loss of the nest, and one nest due to height. Heights ranged from 79 cm to 324 cm. Mean height was 162 cm. Mean nest heights varied slightly by species (species utilizing trees for nesting tended to have higher nest heights), although low numbers of nests found per species did not allow for significant comparisons (Figure 14).

Information on nest height and percent cover above nest were analyzed for active nests to determine whether either influenced nest success or fledgling success. Mean nest height and mean percent cover above nest were calculated in three categories: Failed nests, partially failed nests, and fledged nests (Figure 15). Mean percent cover above active nests ranged from 78% to 93% across categories, with percent cover highest at failed nests, and lowest at partially failed nests. A Mann-Whitney *U* Test comparing percent cover at nest of failed nests and succeeded nests was not statistically significant (p=0.34). Mean nest height ranged from 140 cm to 173 cm across categories. Mean height was similar between failed and partially failed nests (142 cm, 140 cm), but was higher for fledged nests (173 cm). A *t*-test conducted to compare nest heights between failed and succeeded nests was not quite statistically significant (p= 0.07). When partially failed nests were included in the “failed” category, however, the *t*-test did produce a significant result (p= 0.04). Linear regression analysis of percent cover above nest and fledgling success was not significant (p=0.16), nor was linear regression analysis of percent cover above nest and failure rates (p=0.13), although predicted success evidenced a downward trend (fledgling success decreased as percent cover above nest increased, and failure rate increased as percent cover above nest increased). Linear regression analysis of nest height and failure rate was not significant (*p*=0.34). Linear regression analysis of nest height and fledgling success was significant (*p*=0.04, R^2=0.13); fledgling success increased with nest height. Predicted fledgling success was approximately 60% at 200 cm, increasing to 80% at 300 cm (Figure 16).

Of active nests, a total of 2 nests were at least partially located in vines (Riverbank Grape, Virginia Creeper), 8 nests were located in invasive species (Common Buckthorn [*Rhamnus cathartica*], Amur Honeysuckle [*Lonicera maackii*], or Multiflora Rose), and 8 nests were located in trees/shrubs with thorns (Hawthorn or Multiflora Rose). Of the nests in vines, 1 failed and 1 succeeded. Of the nests in invasive species with known outcomes, approximately 43% failed and 57% succeeded (n=7). Of the nests with known outcomes located in trees/shrubs with thorns, 20% failed, another 20% partially failed, and 60% fledged (n=5).

Landscape Factors and Nesting Ecology

Active nests found by patch were as follows: EHE15 (n=35), EGV13A (n=3), EGV13B (n=2), EGV07 (n=6), and EGV15/19 (n=7). Nest success by patch was defined as the sum of the total number of nests succeeding for each patch/the total number of nests with known outcomes for that patch. When partially failed nests were added (divided evenly between the "failed" and "succeeded" categories for each patch), nest success for each patch was as follows: EHE15 (60% fledged), EGV07 (58%), EGV13A (50%), EGV13B (25%), and EGV15/19 (17%) (Figure 17). Fledgling success by patch was determined by taking the proportion of fledged young for each nest with a known outcome (number of young fledged/maximum clutch size), and then calculating the mean proportion of fledged young for each patch. Proportions of fledged young by patch were as follows (rounded to the nearest percent): EHE15 (59%, n=25), EGV07 (17%, n=3), EGV13A (0%, n=1), EGV13B (25%, n=2), and EGV15/19 (17%, n=6) (Figure 18). Mean failure rates by patch varied from 0 (EGV07, n=1) to 0.42 (EGV13B, n=2) (Figure 19).

Linear regression comparing distance to the nearest trail and failure rate was not significant (*p*=0.80). One way ANOVA comparing distance to nearest trail among failed nests, succeeded nests, and partially succeeded nests did not produce a significant result (*p*=0.34). Regression analysis comparing proportion of fledged young to distance from nearest trail was not significant (*p*=.51). When nests that experienced 0% or 100% failure were removed from regression analysis; however, leaving only nests with intermediate levels of failure, linear regression analysis was statistically significant (p=0.03, R^2=0.59). In that instance, proportion of young fledged increased as distance from trails increased (Figure 20).

Although larger patches fledged more young (had lower failure rates) than smaller patches, linear regression analysis did not indicate a significant correlation between patch area and the percentage of nests succeeding (p=0.97), or between patch area and the percentage of young fledged (p=0.40). Linear regression analysis also indicated that patch area did not significantly influence failure rate (p= 0.22). Linear regression analysis comparing percentage of young fledged at each nest to the distance to the nearest patch edge was not significant (p=0.54), nor was regression analysis comparing failure rates and distance to the nearest patch edge (p=0.28). Regression analysis of failure rate and distance from the nearest road was not significant (p=0.11). Regression analysis comparing percentage of young fledged at each nest with distance from the nearest road was significant, however (p=0.03, R^2=0.16). Fledgling success increased as distance from roads increased (Figure 21).

Weather and Nesting Ecology

Since a number of nests failed due to weather, particularly high winds associated with storms, the influence of weather-related factors on nest success/failure were examined. Daily weather data from the National Weather Service's Chicago (O'Hare), Illinois Station 60666 (42.0° N 87.9° W) was collected for each day nests were observed. Weather data collected included maximum daily wind speed, maximum daily wind gust speed, and whether or not a thunderstorm occurred that day. The breeding season was divided into weeks, and weekly nest failure was determined by taking the number of nests failing during any given week/the total number of nests terminating (failing or fledging) that week. Weekly storm frequency was determined by taking the number of days with storms per week/the total number of days per week. Maximum weekly wind speed and gust speed were determined by taking the mean of the maximum daily wind speeds and gust speeds for each week. Weekly nest failure was compared to weekly storm frequency, wind speed, and gust speed to see if any correlations occurred. Although results of linear regression analysis indicated that weekly nest failure appeared to be lower with lower storm frequency, wind speed, and wind gusts, none of these results were significant (p=0.27, p=0.10, and p=0.38, respectively).

Patch Use

Historical point count data documented a total of 45 species across all points at Herrick and Greene Valley. Species with the highest relative abundance across all points were Red-winged Blackbird, American Goldfinch, American Robin, and Yellow Warbler, respectively. Lowest abundances tended to be for those species that are primarily associated with other habitat types, such as grassland and woodland (Figure 22). A comparison of mean relative abundance by preserve for each species indicated that although overall species richness was higher at Greene Valley, relative abundances of most species were higher at Herrick Lake (despite the fact that Herrick Lake was monitored less frequently than Greene Valley) (Figure 23). Data on frequency of occurrence for both preserves provided similar results to data on relative abundance. Species most frequently detected included Red-winged Blackbird, American Goldfinch, Field Sparrow, Gray Catbird, Song Sparrow, Yellow Warbler, and American Robin, respectively. Species associated with grasslands and woodlands were some of the least commonly detected. In general, species with the highest relative abundances also were the most frequently detected.

A total of 14 species were detected at all of the shrubland patches monitored (Figure 24). Species encountered at 20% or less of the patches tended to be grassland or woodland specialists, rather than shrubland species. Although larger patches did have higher species richness (Table 3), linear regression analysis of patch area and species richness indicated that there was no significant relationship between patch size and species richness (p=0.16). Generally, the total number of birds seen per patch mirrored species richness; the total number of birds observed was higher in patches with higher species richness. Linear regression analysis of the total number of birds detected and patch area was significant (p= 0.02, R^2=0.87), indicating that the number of birds detected increased with patch area (Figure 25). Mean relative abundance was highest at smaller patches; according to linear regression analysis, this finding was almost statistically significant (p=0.07).

Out of 46 total species observed by monitors and myself, 22 were determined to be confirmed breeders. There were 20 confirmed breeders at Herrick, and 14 at Greene Valley. Although nests were found for most species confirmed breeding, nests could not be located for 6 open-cup nesters designated confirmed breeders: Bobolink, Common Yellowthroat, Eastern Towhee, Field Sparrow, Indigo Bunting, and Song Sparrow. It was difficult to determine the influence of patch size on the number of confirmed breeders since varying amounts of time were spent searching among patches. Since larger patches contained more area, search time was generally increased in larger patches. Although larger patches appeared to contain higher numbers of species confirmed breeding, linear regression analysis indicated that patch area was not a significant indication of the number of species confirmed breeding (p=0.39).

DISCUSSION

Nesting Ecology

The high percentage of nests failing (approximately 50%) during this study highlights the importance of examining factors relating to nesting success/failure in regard to the maintenance of shrubland bird populations, as well as when creating conservation and management plans for shrubland birds. Predation and weather were considered to be the primary causes of nest failure. Unfortunately, video camera systems did not capture images of nest predators, and some nests without cameras believed to be depredated may have in fact failed due to weather or other factors. Analyses comparing weekly nest failure to storm frequency, wind speed, and gust speed were not quite statistically significant (possibly since nests were grouped without determining cause of failure); however, the relationship between weekly max wind speed and nest failure was almost significant. This result mirrors the findings from video footage (that high winds during storms contributed to nest failure), and some nests without video cameras may have failed due to weather, as well. Damage by weather contributed to nest failure directly (high winds associated with severe storms blew eggs, and possibly young, out of the nest), and possibly indirectly (storms and high winds caused nest damage, and thus, nest failure). Possible nest damage by storms may be an important consideration in determining nesting success, since almost all damaged nests failed. Most studies of the impacts of weather on avian populations have not considered the effects of wind and storms (Sæther et al. 2004); however, the results of this study indicate that high winds associated with storms may be an important determiner of nest failure, especially during breeding seasons with high storm frequency and severity. A possible increase in the frequency and severity of severe storms due to global warming (Trapp et al. 2007) may further threaten populations of species susceptible to reproductive losses due to storms.

Overall, failure rates fell within the range of those calculated for other shrubland studies (King et al. 2001; King et al. 2009; Schlossberg & King 2007). In general, nest success and fledgling success were higher in common species, and lower in less common species or species of conservation concern. Of individual species examined, Red-winged Blackbirds experienced the highest levels of nest success (greater than combined species' nest success for this study) and fledgling success, and the lowest failure rates (lower than the mean failure rate across species); they were also the most common species present at both sites. Although Yellow Warbler exhibited the lowest fledgling success, this is probably due to the low number of nests used in analysis. Willow Flycatchers experienced the second lowest levels of both nest success (less than the combined species' nest success for this study) and fledgling success, and one of the highest failure rates (higher than the mean failure rate across species). In addition, none of the Willow Flycatcher nests monitored experienced complete success.

Although Robinson et al. (1999) found that Mayfield failure rates (daily predation rates) were lower in species of conservation concern in Illinois, results of this study documented higher failure rates for Willow Flycatcher. Willow Flycatcher is a less common species at both sites, as well as a species of conservation concern both regionally and nationally (Rich et al. 2004; The Chicago Wilderness Consortium 2006). One possible reason for this difference is that Robinson et al. (1999) primarily conducted their study in central and southern Illinois. Although they examined habitats fragmented by agricultural land uses, most of these habitats were not surrounded by urban/suburban sprawl (as was this study). Higher failure rates have been documented in urban landscapes than in rural landscapes for shrub-nesting forest species in Ohio (Borgmann & Rodewald 2004; Rodewald et al. 2011), and the relationship between reproductive productivity and urbanization varies by species (Rodewald & Shustack 2008). Location of shrubland habitat fragments in an urban/suburban matrix located in a highly-populated area such as northern Illinois may concentrate potential nest predators that capitalize on human activities and anthropogenically-modified landscapes, and it is possible that some species may be more susceptible to causes of depredation/failure associated with urban landscapes. Another possible explanation for the variation between studies could be due to the high nest mortality from storms/high winds in this study. Nesting success may be reduced in years with above average storm activity. Unfortunately, low numbers of nests located by species in this study did not allow for significant conclusions to be drawn regarding failure rates. Further studies conducted during additional field seasons would yield larger sample sizes and enable more accurate conclusions regarding failure rates of shrubland birds in northern Illinois, including the influence of urbanization and seasonal weather variation on nest success/failure.

Another possible reason for the difference in nest success and fledgling success among species is predator-directed antagonistic behavior. Some species, such as Red-winged Blackbirds, exhibit more aggressive nest defense and mobbing behaviors than others, which may positively influence nesting success. Red-winged Blackbirds were certainly witnessed exhibiting antagonistic behavior during this study, particularly towards researchers. Brown Thrashers and Eastern Kingbirds also exhibited very aggressive behavior towards researchers approaching nests, and also experienced high levels of nest and fledgling success, although low numbers of nests found for these species did not allow for species-specific conclusions. Other species, such as Willow Flycatchers, show little or no aggressive behavior at the nest site. For example, when Willow Flycatcher nests were approached during this study, adults would occasionally call and/or clap their bills, but generally left the immediate vicinity of the nest.

Differences in nest and fledgling success among species may also be due to nest and vegetative structure; some species (such as Willow Flycatcher) build nests out of delicate materials, and/or utilize highly flexible vegetative structures, which may be more easily damaged or moved by predators and/or high winds during storms. Other possible reasons for variation in nest and fledgling success by species likely exist, but additional species-specific data, as well as more conclusive data on causes of nest failure would be necessary in order to examine them.

The multiple instances of partial nest failure (individual eggs and/or young, but not others, went missing from nests, often at different times) pose some interesting questions regarding causes of failure. Unfortunately, information from video camera systems provided limited information regarding causes of partial nest failure, although video cameras did capture individual eggs being blown out of nests by high winds during storms, while other eggs were left in the nest. One possibility is that individual young could have also been blown out of nests by high winds during storms. Daily monitoring of an American Robin nest in an Arrowood Viburnum (*Viburnum dentatum*) during the summer of 2011 provided additional evidence of this possibility. A severe storm with winds in excess of 75 mph hit the nest site. Immediately after the storm, a five- to six-day-old young was found on the ground beneath the nest. The nestling was too young to fledge, and flight feathers were not present. The nest bottom was undamaged, so the nestling could not have fallen through the nest bottom. One egg remained present in the nest. High human traffic in the area, coupled with the fact that the nestling was found intact directly after the storm make depredation unlikely (Secker 2011).

Another possible cause of partial nest failure could be predator type(s) that may remove single eggs and/or young from nests without causing nest damage, rather than depredating the entire nest. It seems likely that predators would tend to depredate entire nests rather than leaving eggs/young, however. Brown-headed Cowbirds are known to remove host eggs from nests; video cameras have documented cowbird removal of host young, as well (Benson et al. 2010). A further possibility is that aggressive behavior from adults (such as mobbing) may have been successful in driving predators from the nest site before all eggs and/or young were depredated, although mobbing behavior might also serve to alert predators to the existence of nest sites. The possibility of early fledging is highly unlikely; nests with missing young were only attributed to failure if nestlings had not yet grown flight feathers. Additional studies with video camera systems would be necessary to determine the influence of nest defensive behaviors on predation risk, as well as to elucidate predator feeding ecology at nests.

Although nest parasitism by Brown-headed Cowbirds was not one of the major causes of nest failure in this study, cowbird parasitism remains an important consideration in studies of nest success. All nests parasitized by cowbirds also experienced some form of failure, and most failed completely. Others have confirmed that nests parasitized by cowbirds tend to experience higher levels of predation (Burhans & Thompson 1999; Rodewald & Shustack 2008). While some failures may be attributed directly to cowbird presence (e.g. nest abandonment, cowbird removal of host species' eggs), it is possible that the loud begging calls of cowbird nestlings increase predation risk by drawing predators to nest sites. Most of the species experiencing cowbird parasitism in this study were common, with the exception of Bell's Vireo, which is less common in the study site area, and a species of greater conservation concern (Rich et al. 2004; The Chicago Wilderness Consortium 2006). Bell's Vireo tends to experience high levels of cowbird parasitism, which are often offset by nest abandonment and initiation of additional nest(s) (Kus et al. 2010). Some species have adapted more efficient strategies for dealing with cowbird parasitism than others. Strategies requiring greater investments of energy (such as initiating second nests), coupled with other threats, may reduce population growth and maintenance in species of conservation concern. Cowbird parasitism has been demonstrated to be greater in urban than rural shrublands (Burhans & Thompson 2006), and may be a management concern in fragmented urban areas.

Nest failure due to House Wrens (and possibly other avian predators) also was not a major source of failure in this study, but poses some interesting questions and concerns regarding shrubland management for breeding birds. House Wrens are known to puncture eggs of other species nesting near their territories (Harrison 1975); video camera footage showed a possible House Wren near one nest, and others were sighted near nests containing punctured, uneaten eggs. Other species such as Blue Jays and American Crows have been known to remove eggs and/or nestlings from nests (Poole 2005), and may have done so. Since many of these predators primarily utilize woodlands, proximity of nests to woodlands may influence success/failure in such cases. Small shrubland patches may allow easier access to nests for avian nest predators. Additional video camera documentation of avian-induced nest failures would be needed in order to draw conclusions regarding the influence of shrubland patch size and distance from woodland edge on avian-induced failures.

The probability of nest failure decreased with the increasing number of days each nest was observed (i.e. number of days each nest remained active, or increasing age of nest). It is possible that the probability of a nest succeeding increased with the age of the nest because older nestlings may less susceptible to certain types of depredation than eggs/younger nestlings. Although the possibility exists that human scent spread by researchers attracts or deters predators at nest sites, thus decreasing or increasing chances of nesting success, human scent has not been demonstrated to significantly influence nest success or failure (Skagen et al. 1999; Weidinger 2008). Even if human scent does influence predation rates, attempts to conceal human scent are likely ineffective (Donalty & Henke 2001). Since the number of nest visits increased (and thus possible increased human scent) with the age of each nest, it is encouraging that data from this study indicated that older nests were more likely to succeed. The use of human scent to locate nests may be utilized by some types of predators more than others; in addition, high nest mortality caused by storms in this study may have made the spread of human scent less of a consideration.

Microhabitat Vegetative Factors and Nesting Ecology

Many of the tree/shrub species utilized most heavily for nesting purposes (determined by number of nests by tree/shrub type) were also the most common at the study sites (e.g. Gray Dogwood, Crabapples, and Hawthorns). This would appear to indicate that birds were generally utilizing whichever shrub species provided the appropriate vegetative structure to meet their nesting requirements and were also present and accessible. Studies have indicated that vegetation structure is more important to birds than specific types of plants (Robinson et al. 1999). Since different tree/shrub species exhibit different structural characteristics; however, it might be possible to determine structural preferences for nesting purposes by observing which tree/shrub species certain bird species utilize for nesting purposes. Examination of bird species diversity by tree/shrub type during this study yielded some interesting results. While some birds (e.g. American Robin, Brown Thrasher, and Gray Catbird) utilized a variety of species for nesting purposes, others only utilized Gray Dogwood (i.e. Orchard Oriole, Red-winged Blackbird, and Willow Flycatcher). Other shrub species that were fairly common at study sites (e.g. American Hazelnut [*Corylus Americana*]) did not contain any nests. Difference in structure among tree/shrub species is a likely explanation. Gray Dogwood, Crabapples, and Hawthorns are characterized by branching structures that may be conducive to nest building, but are not present in species such as American Hazelnut (which is composed of many small upright stems). Data gathered on percent vegetative cover above nests indicates that shrubland birds generally preferred high levels of cover (89-97%); this information did not vary considerably among species. While the apparent preference of some species for Gray Dogwood may be coincidental, or an artifact of the high numbers of Gray Dogwood present at the study sites, it is also possible that Gray Dogwood provides preferred nesting structure for these species. Knowledge of the tree/shrub species utilized for nesting purposes holds important implications for conservation, since bird conservationists often must work in tandem with ecological restorationists, who may have different goals. Determining the preferred nesting structure and percent cover above nest by examining structure of various tree/shrub species may allow bird conservationists to determine which shrubs provide appropriate structure while also meeting the goals of restoration practitioners.

It was hypothesized that nest success would be greater at nests with higher percent cover, since increased cover would limit the possibility of visual detection of nests, as well as provide possible physical barriers to predation. Percent cover above nest was not a significant predictor of success, however. Although some have shown evidence that increased cover decreases predation rates (Heske et al. 2001), others have noted higher levels of predation with increasing vegetative cover (Robinson et al. 1999). Such variation may reflect variations in predator type and foraging ecology; some predators may utilize methods for locating nests (e.g. sense of smell, watching movements of adults) that do not rely heavily on visual location, and/or cover at nest may not provide a physical barrier to predation for these species. Further information would be necessary to determine the influence of varying levels of vegetative cover at the nest on nest success/failure in regard to different types of nest predators.

The data supported the hypothesis that nests located higher in their supporting structures would experience greater levels of success, perhaps since they would tend to be less out of the reach of ground predators. One study of nest success in urban shrublands confirms this conclusion (Burhans & Thompson 2006). It is possible that this result was just barely statistically significant since nests of all species were grouped (height of nest can vary with bird species) and nests were also grouped by cause of failure (some causes of failure are more likely to be influenced by height than others). In cases where winds blew eggs out of nests, high nest placement could actually be detrimental to success, especially in instances where nests were located in thin support structures. One of the highest nests in the study lost eggs during high winds.

Although information was collected on the number and success of nests utilizing vines and invasive species, low numbers of nests did not allow for significant conclusions to be drawn regarding nest success in relation to these factors. Since percent cover above nest was not a significant indicator of success, it is possible that the added cover of vines would also not affect success. Multiple researchers have found that the presence of exotic, invasive vegetation may impact birds negatively (Borgmann & Rodewald 2004; D'Antonio & Meyerson 2002; Johnson et al. 2006; King et al. 2009). Nests located in tree/shrubs with thorns experienced above average levels of success, which indicates that thorns may provide a physical barrier to predation.

Landscape Factors and Nesting Ecology

Examination of failure rates and the proportion of young fledged by patch appeared to indicate that birds fledge more young and experience lower failure rates in larger patches than in smaller ones, but results were not statistically significant. Although a larger percentage of nests fledged in larger patches, patch EGV15/19 experienced relatively low success compared with patches of similar size. Most of the nests in this patch were located close to a paved road and parking area, which experienced high levels of human traffic. It is possible that increased accessibility and the presence of trash receptacles may have drawn predators to these nests, resulting in lower nesting success. Results comparing percentage of young fledged at each nest to distance from the nearest road were statistically significant (percentage of young fledged increased as distance from the nearest road increased); therefore, roads may negatively impact populations of breeding birds in shrublands. Nest distance to edge of the shrubland patch did not significantly affect the percentage of young fledged or failure rates. Most of the shrubland patches in this study were surrounded by woodland habitat; it appears that other factors influenced nest success/failure in this study more than distance from woodland edges.

Although initial analysis did not indicate a correlation between distance to nearest trail and nest success, when nests with partial success were removed from analysis, results were significant, and nest success increased with distance from trails. It is possible that these results may be indicating the presence of predator type(s) that tend to remove individual eggs/nestlings from nests on different occasions, and may be more likely to utilize trails to access nests. Few studies have examined the influence of trails on nest success/failure in shrubland birds; further studies are needed.

Grouping results comparing success/failure and distance to trails, roads, and habitat edges may lead to erroneous conclusions; some predator species may utilize trails, roads, and/or habitat edges to access nests, while others may not. Conclusions drawn regarding landscape effects (such as area and edge effects) on nest success/failure may simply be artifacts of variations in predator species and predator ecology. Future studies may be strengthened by deploying more video camera systems in order to determine exact causes of nest failure, comparing results by type of failure/depredation, then analyzing the effects of landscape variables. Further data on predator types and foraging behavior would help elucidate the effects of landscape variables on depredation ecology.

Patch Use

A comparison of species richness and relative abundance between sites indicated that although overall species richness was higher at Greene Valley, relative abundances of most species were higher at Herrick Lake. The high species richness at Greene Valley may be at least partially explained by the higher diversity of habitats, interspersed with smaller shrubland patches; it is possible species from other habitats were also utilizing shrublands at Greene Valley. Herrick contained a large area of contiguous shrubland habitat, which may explain the higher abundances of species encountered there than at Greene Valley. Species richness and the number of species confirmed breeding did not vary significantly with patch area. Although mean relative abundances were higher in smaller patches than in larger ones, the relationship between relative abundance and patch size was not quite significant. The total number of birds detected per patch varied significantly with patch area; as patch area increased, the number of birds detected increased. Therefore, larger patches of contiguous shrubland likely support greater numbers of individuals. This is reasonable, considering that larger areas would allow for more territories to be accommodated. Small patches may not support the nesting requirements of some species, and most likely support smaller numbers of individuals and territories. Small patches may serve as population sinks; however, the possibility that smaller patches may benefit populations of shrubland birds by providing adjacent foraging habitat during the breeding season would be an interesting subject for further study.

Study Limitations

A number of limitations may have affected this study. Nests of some species are easier to locate than others; it was not possible to collect information on nesting ecology of a number of species confirmed breeding, simply because nests were not located for those species. Conclusions drawn regarding types of nest failure gleaned from observation alone in some cases were less reliable than conclusions drawn from information gathered from video camera systems. In some cases, especially when individual eggs and/or young went missing from nests at different times during the breeding cycle, it was difficult to determine whether depredation, weather, or some unknown factor was the cause. Although such cases were primarily attributed to depredation (usually due to the presence of nest damage), high winds blowing individual eggs/nestlings from nests may have been the true cause, and weather related mortality may have been a greater factor in nest failure than was documented. Nests could have partially fledged or failed before they were found by researchers, thus affecting results and conclusions drawn regarding success/failure. Insufficient numbers of nests located by species required some results regarding success/failure to be grouped; however, probability of success would likely vary among species due to differences in nesting ecology and behavior (such as aggressiveness of predator defense strategies). For the purposes of this study, failure rates were not calculated separately by stage of nesting cycle; however, failure rates can differ by stage (Mayfield 1975). In order to help mitigate some of the effects of these limitations, efforts were made to standardize information collected and conclusions drawn regarding outcomes of nests without video cameras (as described in the "Methodology" section). Future studies could be improved by the deployment of additional video camera systems, reducing the necessity of drawing conclusions from observations of nests without cameras. Possible yearly variation may be accounted for by conducting multi-year studies. More accurate conclusions regarding the effects of landscape factors on nest success/failure could likely be drawn if greater numbers of nests could be located, and bird species and type of failure were taken into consideration in analyses.

CONCLUSIONS

Nesting success/failure may co-vary with factors such as bird species, predator type, weather, stage of the nesting cycle, microhabitat conditions at nest, and landscape factors. For example, species-specific differences in predator-directed antagonistic behavior may influence nesting success positively or negatively. Different predators may utilize the landscape differently, thus causing spatial and temporal variation in patterns of depredation. Future studies of nest success/failure could be improved by utilizing video camera systems to determine types of failure, then comparing cause of failure to landscape variables for each species/type of failure. Elucidating how depredation ecology and landscape use vary with predator type, as well as how various species respond to nest predators could provide insights that would benefit management practices for breeding shrubland birds. Additional studies on how shrubland birds utilize the landscape during the breeding season, and how microhabitat characteristics and weather influence nest success/failure would also be beneficial. Species-specific studies of nesting ecology could provide information that would benefit management practices for shrubland species of concern and/or those experiencing declining population trends. Additional studies of depredation ecology and nesting success are particularly important as urban sprawl continues to increase the number of small, isolated habitat patches.

A comparison of the literature to the results of this study yields some important management recommendations. Since studies differ on the effects of patch area and edges on shrubland birds, preserving larger patches of shrubland habitat while minimizing edges may benefit the greatest number of species and individuals. Since fledgling success increased with increasing distance from roads (and in some cases, trails), limiting the number of trails and roads intersecting shrubland patches may also be advantageous, although further studies may be warranted. If smaller patches are necessary, they could be concentrated around larger patches in order to provide additional foraging habitat. Planting high-density shrub species with multiple branching stems may provide additional nesting sites, since many high-density species were utilized for nesting purposes. Maintaining some tall trees and/or shrubs (200-300 cm, or approximately 6-10 ft.) may help increase nesting success by providing nesting sites out of the reach of ground-based predators; sturdy shrubs may provide nesting sites less susceptible to the effects of high winds. Planting or maintaining species with thorns may also be beneficial, due to above average success in species with thorns. Since some birds appear to prefer certain tree/shrub species for nesting purposes (such as Gray Dogwood), planting or maintaining these species could be beneficial, particularly if they are not found to significantly contribute to reduced nesting success.

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APPENDIX A: BIRD SPECIES

Common Name	Scientific Name	Band Code
American Goldfinch	*Spinus tristis*	AMGO
American Robin	*Turdus migratorius*	AMRO
Baltimore Oriole	*Icterus galbula*	BAOR
Barn Swallow	*Hirundo rustica*	BARS
Bell's Vireo	*Vireo bellii*	BEVI
Black-capped Chickadee	*Poecile atricapillus*	BCCH
Blue Jay	*Cyanocitta cristata*	BLJA
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN
Bobolink	*Dolichonyx oryzivorus*	BOBO
Brown Thrasher	*Toxostoma rufum*	BRTH
Brown-headed Cowbird	*Molothrus ater*	BHCO
Cedar Waxwing	*Bombycilla cedrorum*	CEDW
Chestnut-sided Warbler	*Setophaga pensylvanica*	CSWA
Chimney Swift	*Chaetura pelagica*	CHSW
Common Grackle	*Quiscalus quiscula*	COGR
Common Yellowthroat	*Geothlypis trichas*	COYE
Downy Woodpecker	*Picoides pubescens*	DOWO
Eastern Bluebird	*Sialia sialis*	EABL
Eastern Kingbird	*Tyrannus tyrannus*	EAKI
Eastern Meadowlark	*Sturnella magna*	EAME
Eastern Towhee	*Pipilo erythrophthalmus*	EATO
European Starling	*Sturnus vulgaris*	EUST
Field Sparrow	*Spizella pusilla*	FISP
Gray Catbird	*Dumetella carolinensis*	GRCA
House Wren	*Troglodytes aedon*	HOWR
Indigo Bunting	*Passerina cyanea*	INBU
Mourning Dove	*Zenaida macroura*	MODO
Northern Cardinal	*Cardinalis cardinalis*	NOCA
Northern Flicker	*Colaptes auratus*	NOFL
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	NRWS
Orchard Oriole	*Icterus spurius*	OROR
Red-bellied Woodpecker	*Melanerpes carolinus*	RBWO
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL
Ring-necked Pheasant	*Phasianus colchicus*	RNPH
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	RBGR
Ruby-throated Hummingbird	*Archilochus colubris*	RTHU
Song Sparrow	*Melospiza melodia*	SOSP
Tree Swallow	*Tachycineta bicolor*	TRES
Warbling Vireo	*Vireo gilvus*	WAVI
White-breasted Nuthatch	*Sitta carolinensis*	WBNU
Willow Flycatcher	*Empidonax traillii*	WIFL
Yellow Warbler	*Setophaga petechia*	YWAR
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU
Yellow-breasted Chat	*Icteria virens*	YBCH
Yellow-throated Vireo	*Vireo flavifrons*	YTVI

APPENDIX B: PLANT SPECIES

Common Name	Scientific Name
American Hazelnut	*Corylus americana*
Amur Honeysuckle	*Lonicera maackii*
Arborvitaes	*Thuja* spp.
Arrowood Viburnum	*Viburnum dentatum*
Box Elder	*Acer negundo*
Common Buckthorn	*Rhamnus cathartica*
Crabapples	*Malus* spp.
Eastern Red Cedar	*Juniperus virginiana*
Elderberry	*Sambucus canadensis*
Gray Dogwood	*Cornus racemosa*
Hawthorns	*Crataegus* spp.
Multiflora Rose	*Rosa multiflora*
Olives	*Elaeagnus* spp.
Red Oak	*Quercus rubra*
Redosier Dogwood	*Cornus stolonifera*
Riverbank Grape	*Vitis riparia*
Shingle Oak	*Quercus imbricaria*
Virginia Creeper	*Parthenocissus quinquefolia*
Wild Plum	*Prunus americana*

FIGURES AND TABLES

Figure 1. Greene Valley Forest Preserve Study Patches

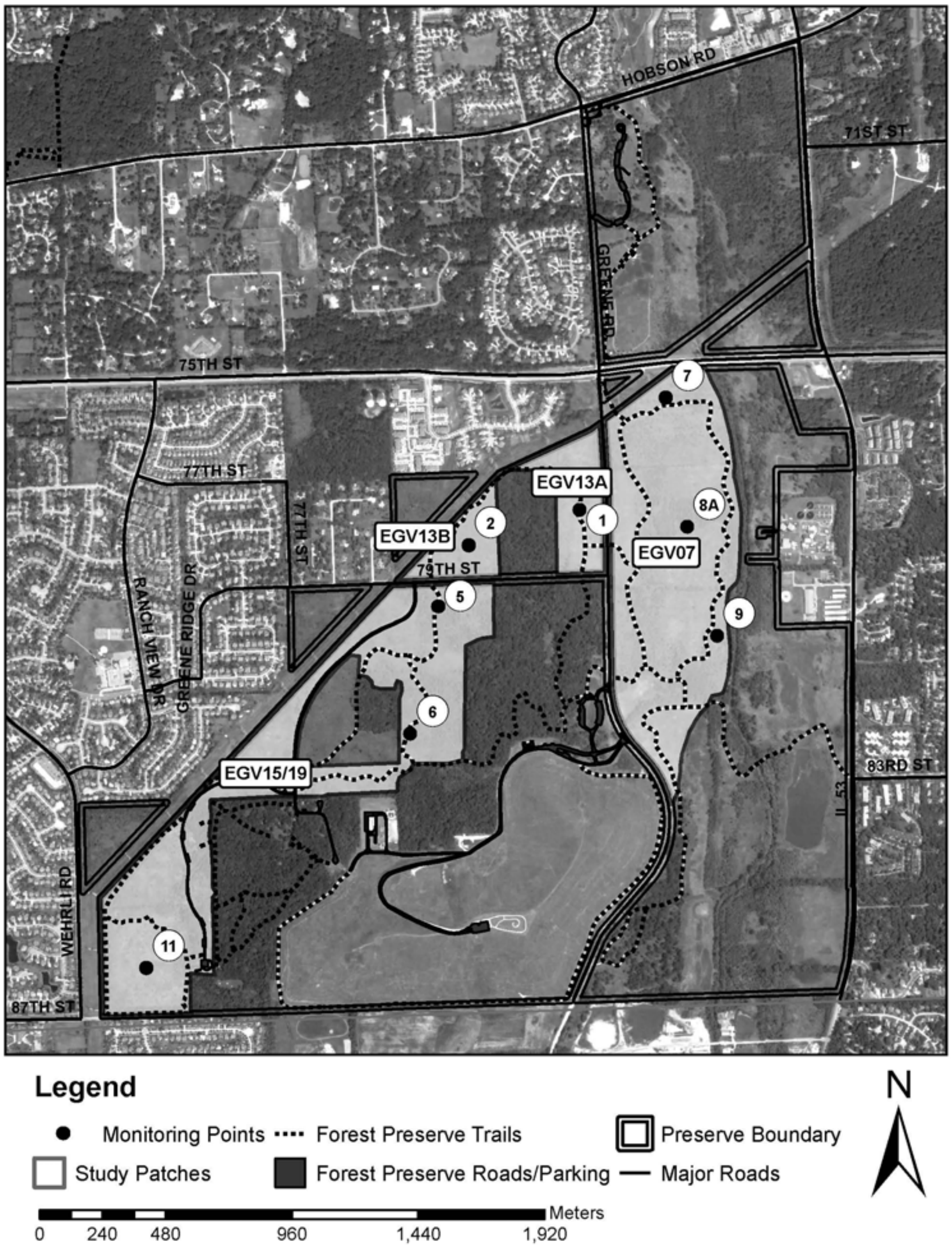


Figure 2. Herrick Lake Forest Preserve Study Patch

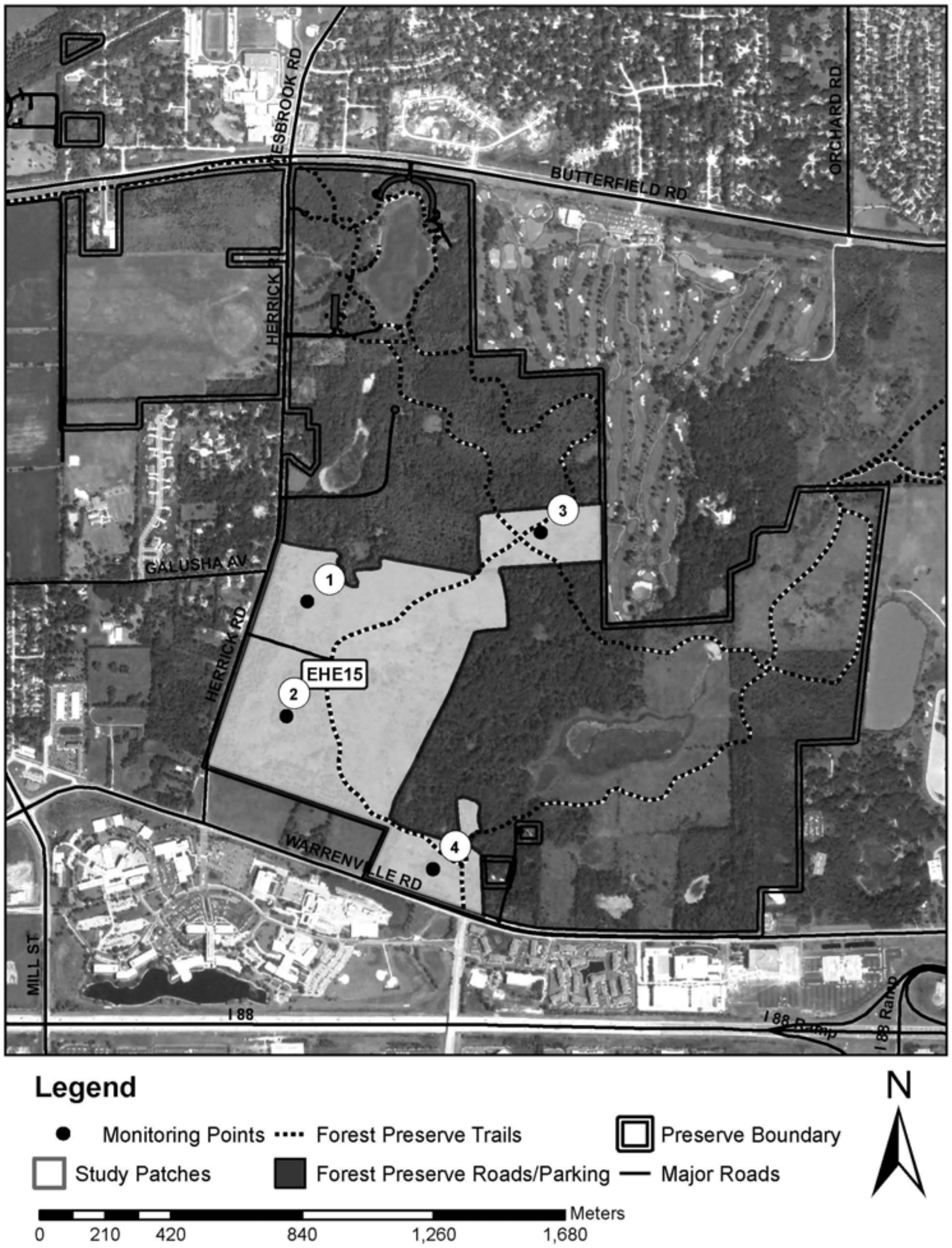


Table 1. Nests with Video Camera Systems

		Greene Valley	Herrick Lake	Totals
American Goldfinch	*Spinus tristis*		1	**1**
American Robin	*Turdus migratorius*	1		**1**
Brown Thrasher	*Toxostoma rufum*		1	**1**
Gray Catbird	*Dumetella carolinensis*	1		**1**
Willow Flycatcher	*Empidonax traillii*	1	2	**3**
Yellow Warbler	*Setophaga petechia*	2	1	**3**
Totals		**5**	**5**	**10**

Table 2. Active Nests by Species (Includes Nests with Video Camera Systems)

		Greene Valley	Herrick Lake	Totals
American Goldfinch	*Spinus tristis*		7	**7**
American Robin	*Turdus migratorius*	8	5	**13**
Bell's Vireo	*Vireo bellii*		1	**1**
Blue-gray Gnatcatcher	*Polioptila caerulea*	1		**1**
Brown Thrasher	*Toxostoma rufum*		2	**2**
Cedar Waxwing	*Bombycilla cedrorum*		1	**1**
Eastern Kingbird	*Tyrannus tyrannus*		1	**1**
Gray Catbird	*Dumetella carolinensis*	1	4	**5**
Northern Cardinal	*Cardinalis cardinalis*		1	**1**
Red-winged Blackbird	*Agelaius phoeniceus*	3	4	**7**
Willow Flycatcher	*Empidonax traillii*	2	6	**8**
Yellow Warbler	*Setophaga petechia*	3	2	**5**
Unknown			1	**1**
Totals		**18**	**35**	**53**

Figure 3. Total Nest Outcomes (Of Known, n=46)

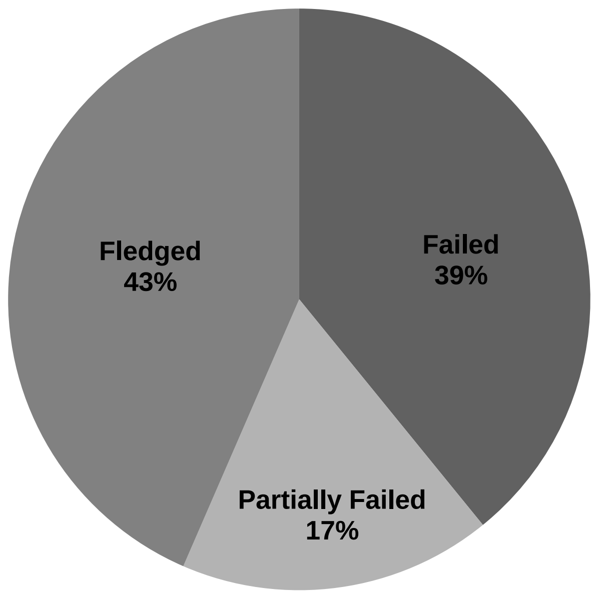


Figure 4. Causes of Nest Failure (n=26)

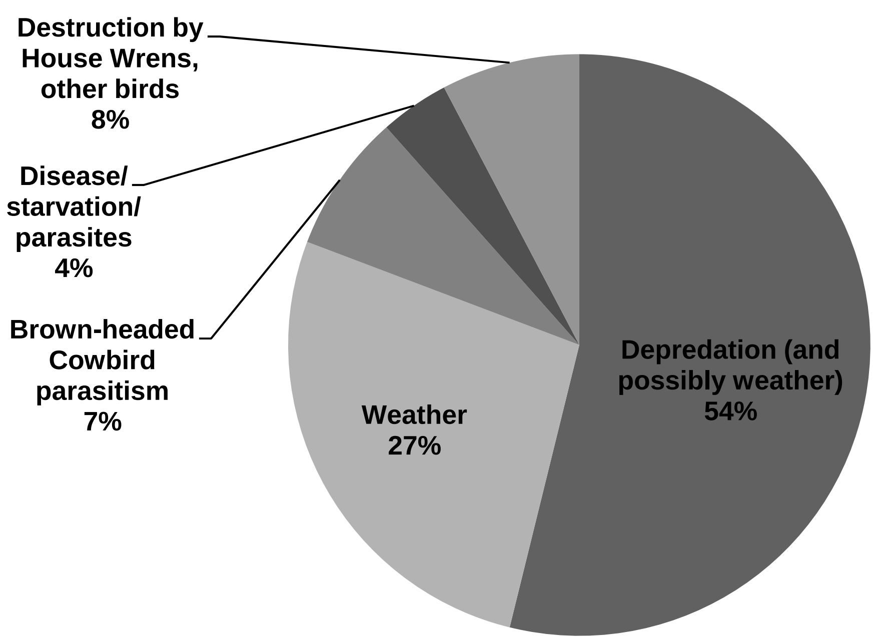


Figure 5. Outcomes of Nests With Video Camera Systems (n=10)

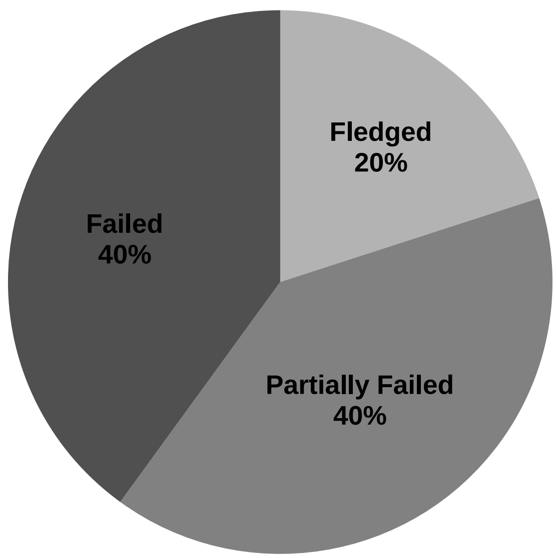
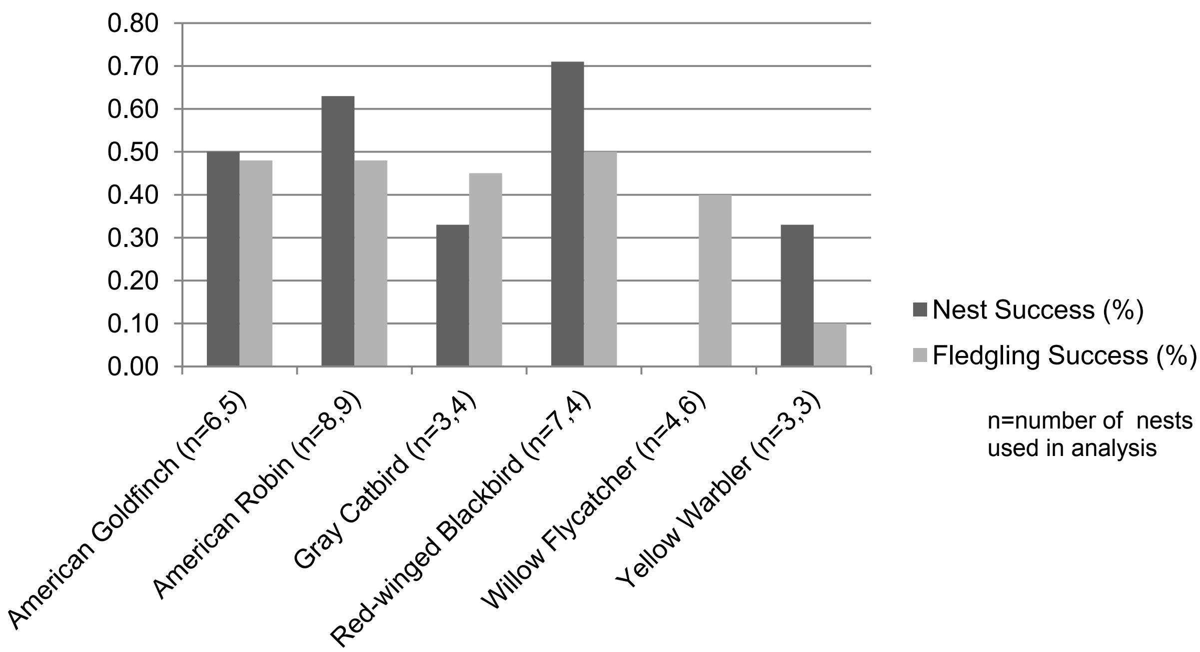


Figure 6. Nest and Fledgling Success by Species



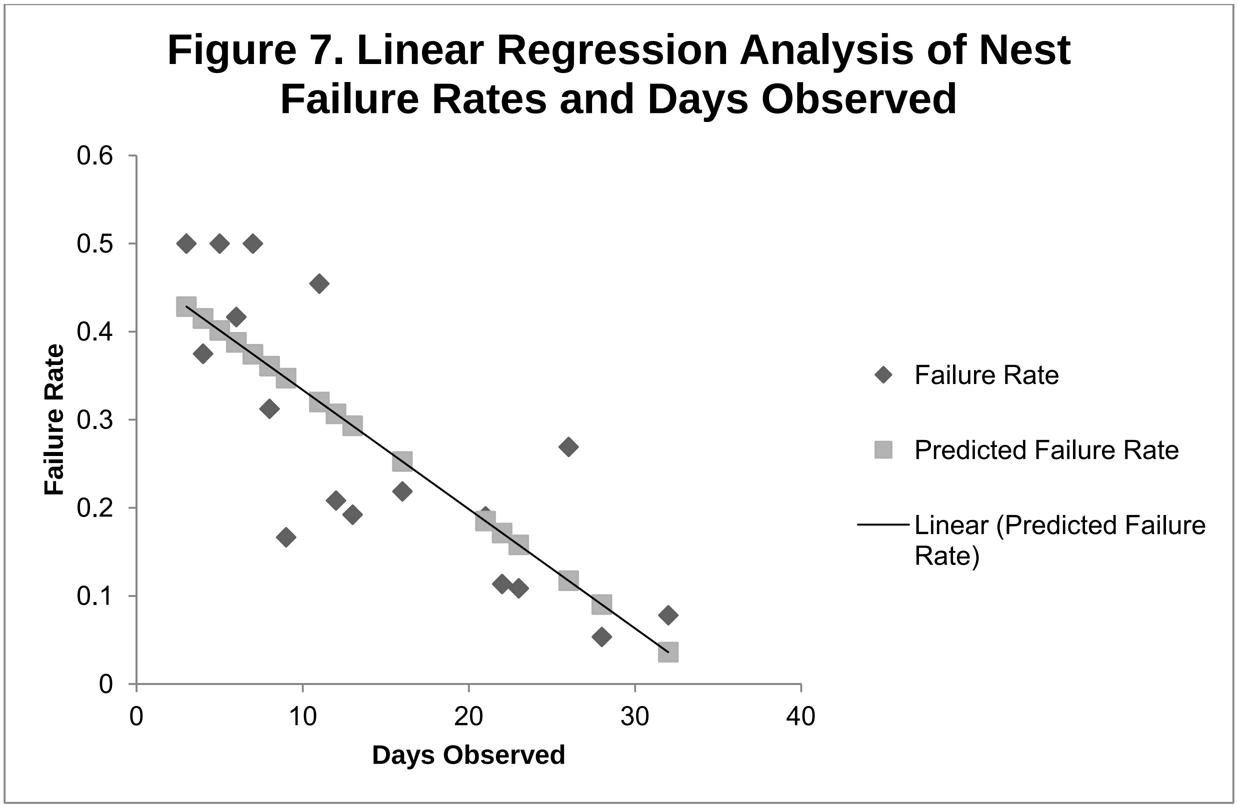


Figure 7. Linear Regression Analysis of Nest Failure Rates and Days Observed
Failure Rate
Days Observed
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
Failure Rate
Predicted Failure Rate
Linear (Predicted Failure Rate)

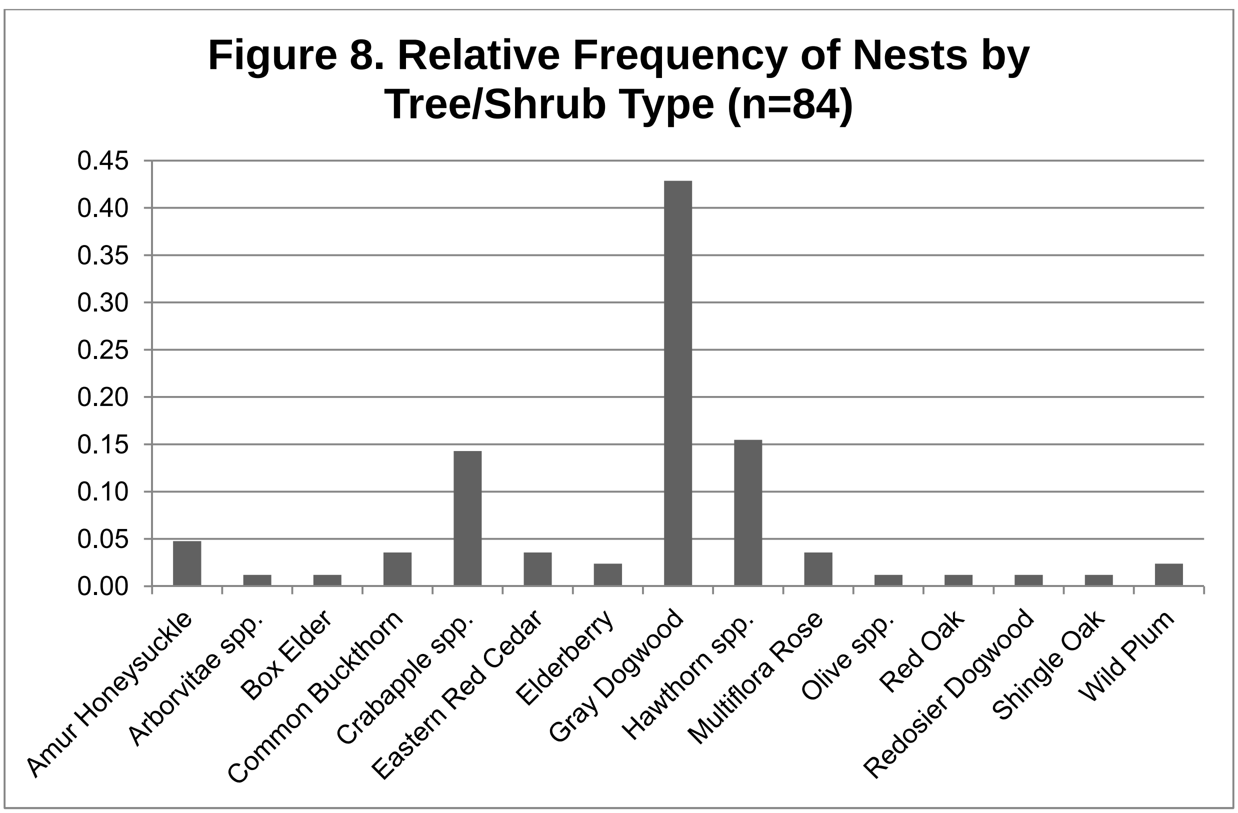


Figure 8. Relative Frequency of Nests by Tree/Shrub Type (n=84)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Amur Honeysuckle
Arborvitae spp.
Box Elder
Common Buckthorn
Crabapple spp.
Eastern Red Cedar
Elderberry
Gray Dogwood
Hawthorn spp.
Multiflora Rose
Olive spp.
Red Oak
Redosier Dogwood
Shingle Oak
Wild Plum

Figure 9. Tree/Shrub Species Diversity and Number of Nests by Bird Species

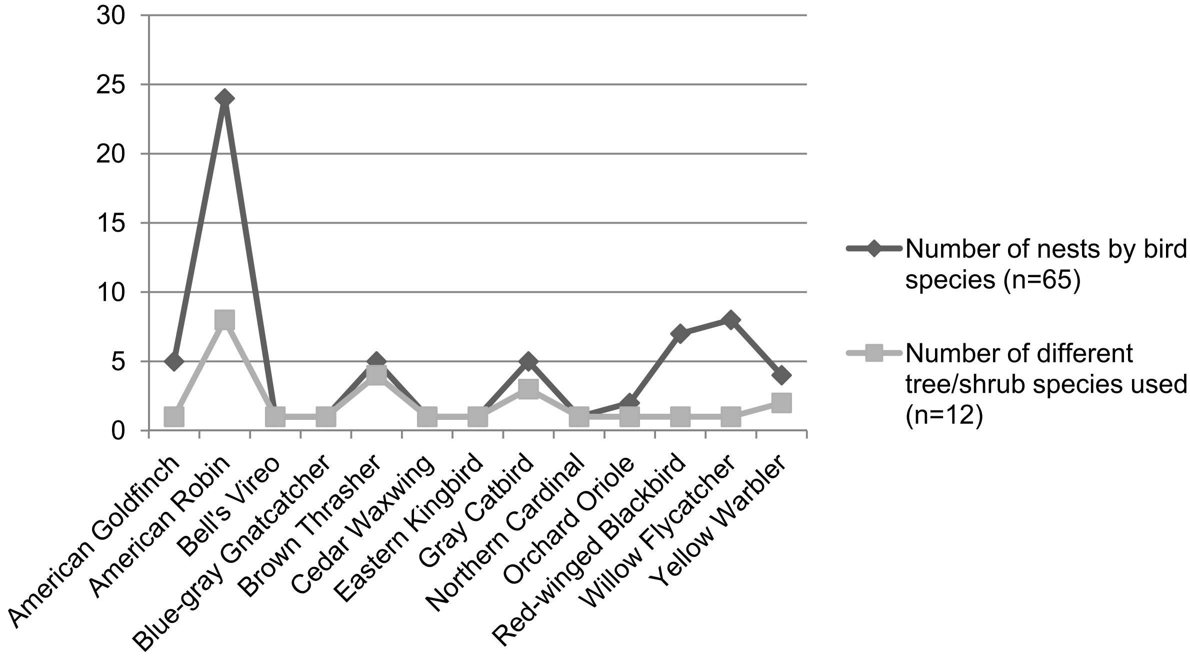
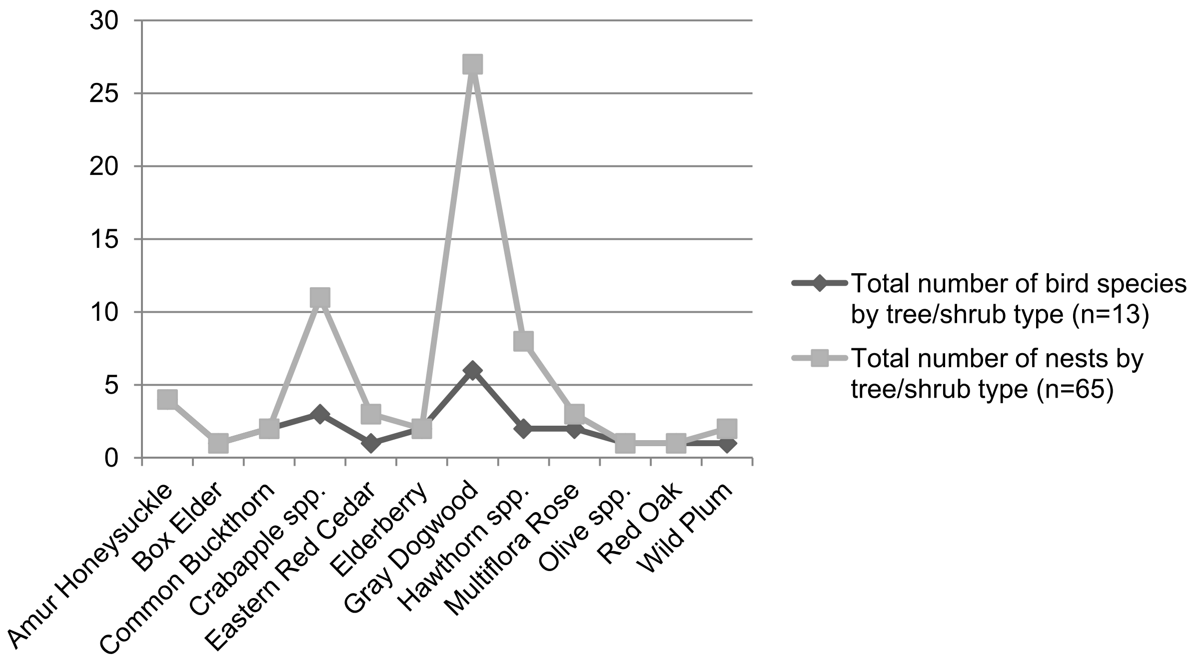


Figure 10. Bird Species Diversity and Number of Nests by Tree/Shrub Type



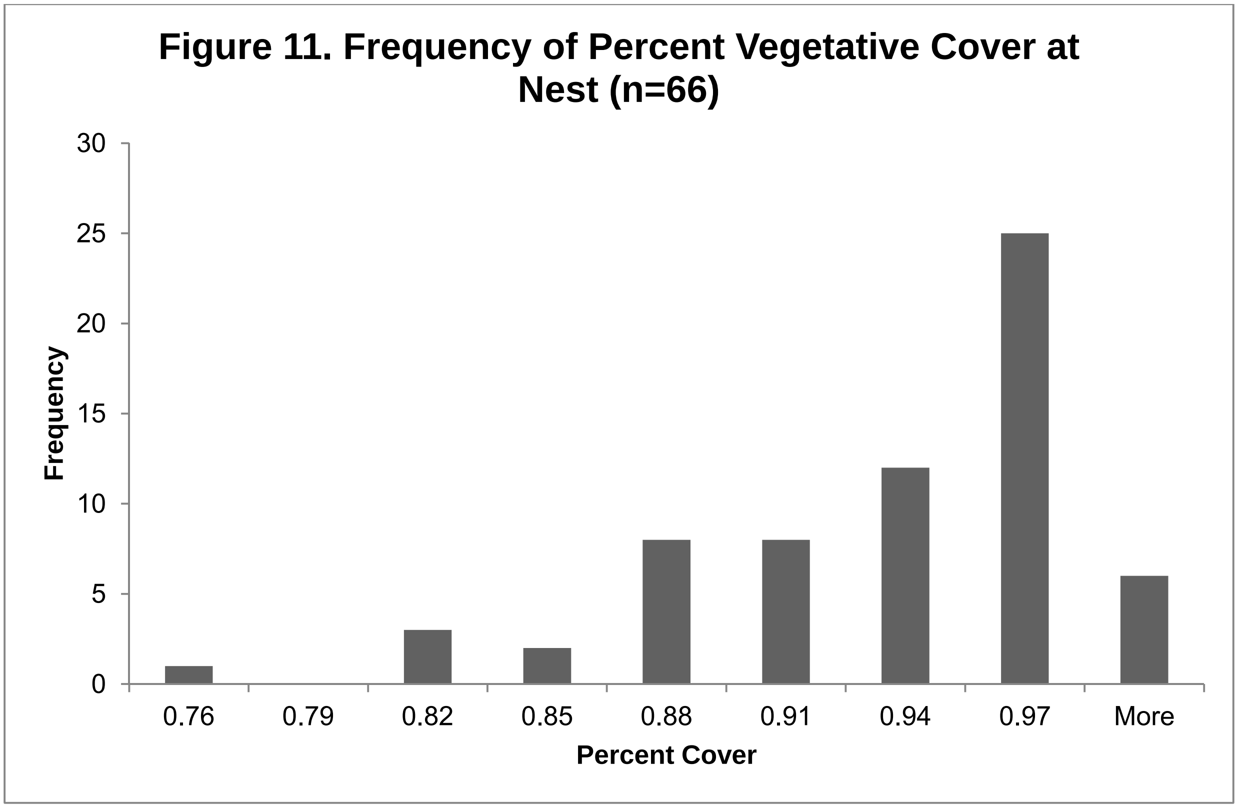


Figure 11. Frequency of Percent Vegetative Cover at Nest (n=66)
Frequency
30
25
20
15
10
5
0
0.76
0.79
0.82
0.85
0.88
0.91
0.94
0.97
More
Percent Cover

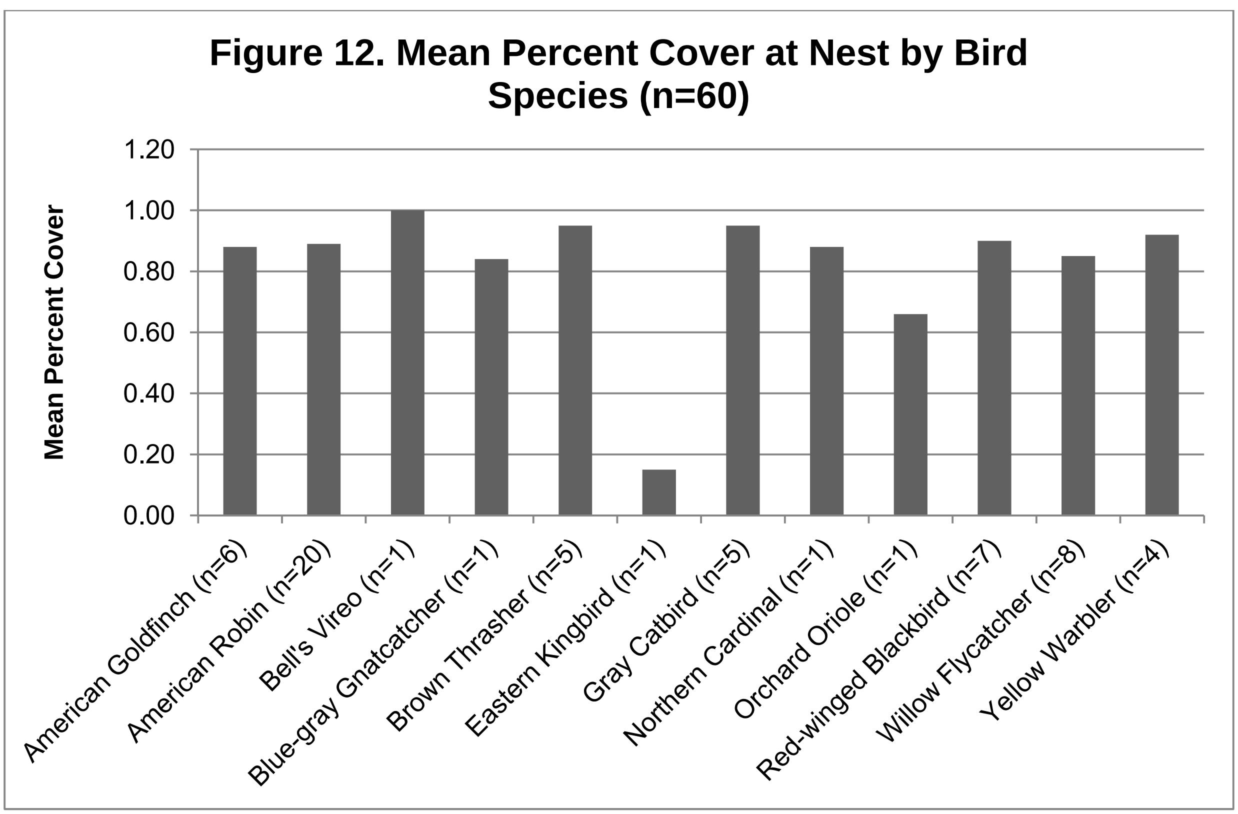


Figure 12. Mean Percent Cover at Nest by Bird Species (n=60)
Mean Percent Cover
1.20
1.00
0.80
0.60
0.40
0.20
0.00
American Goldfinch (n=6)
American Robin (n=20)
Bell's Vireo (n=1)
Blue-gray Gnatcatcher (n=1)
Brown Thrasher (n=5)
Eastern Kingbird (n=1)
Gray Catbird (n=5)
Northern Cardinal (n=1)
Orchard Oriole (n=1)
Red-winged Blackbird (n=7)
Willow Flycatcher (n=8)
Yellow Warbler (n=4)

Figure 13. Shrubland Nest Height Distribution (n=83)

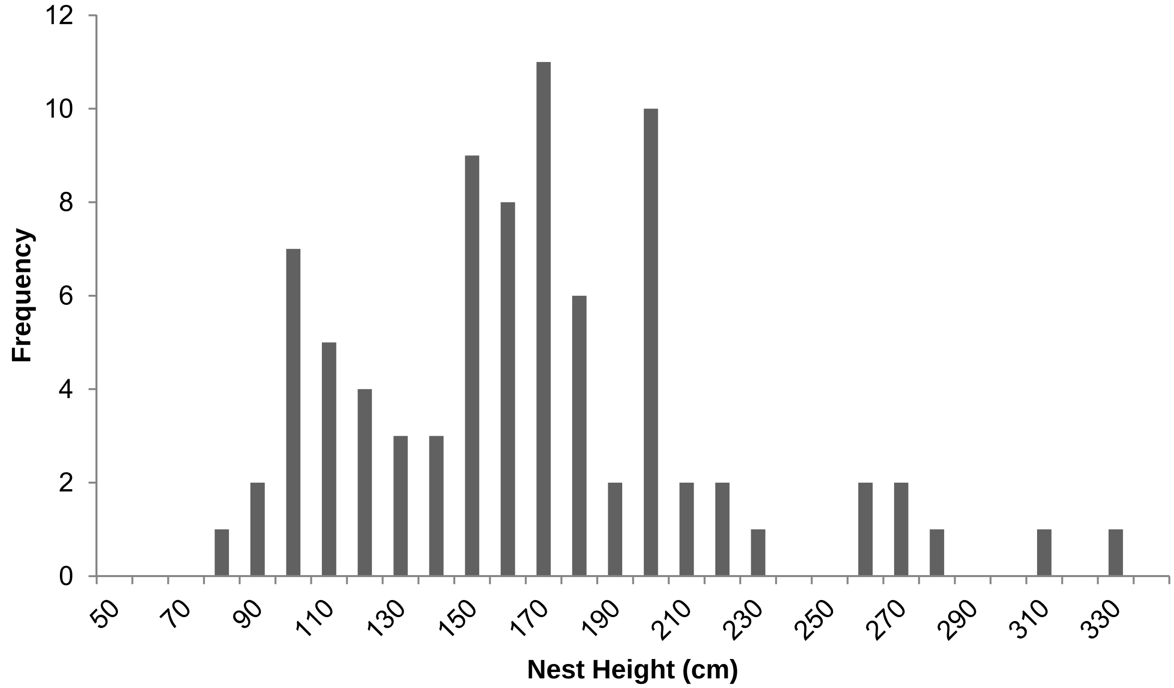
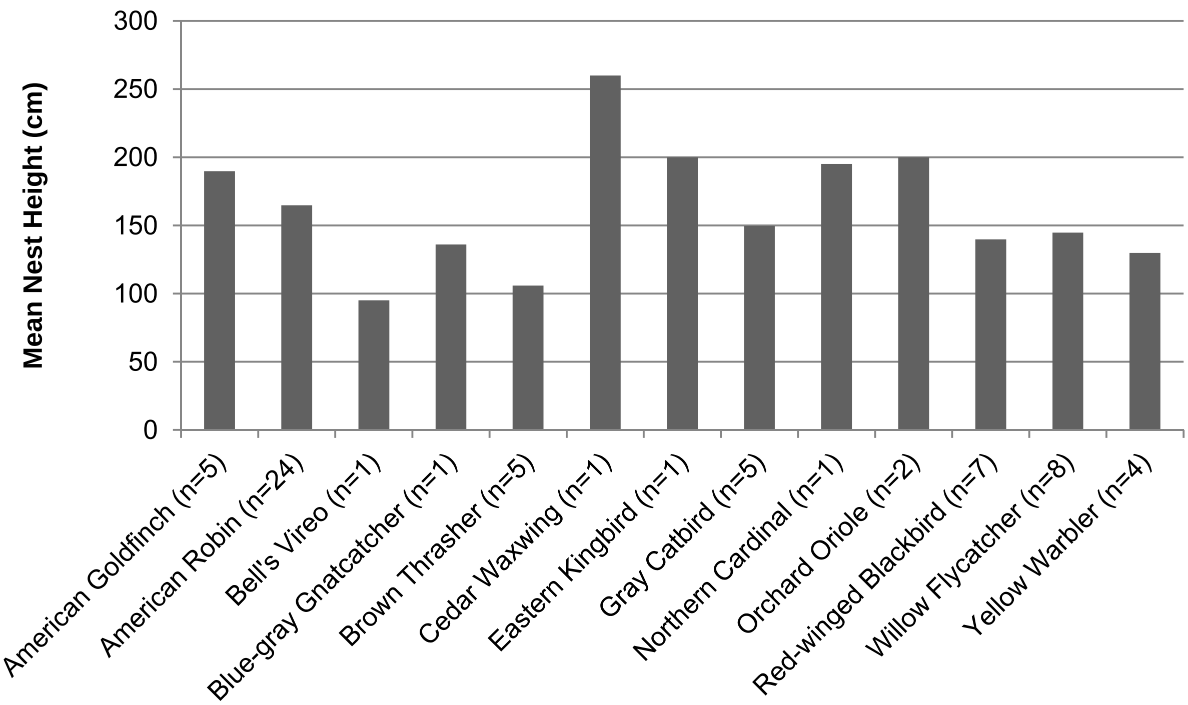


Figure 14. Mean Nest Height by Bird Species (n=65)



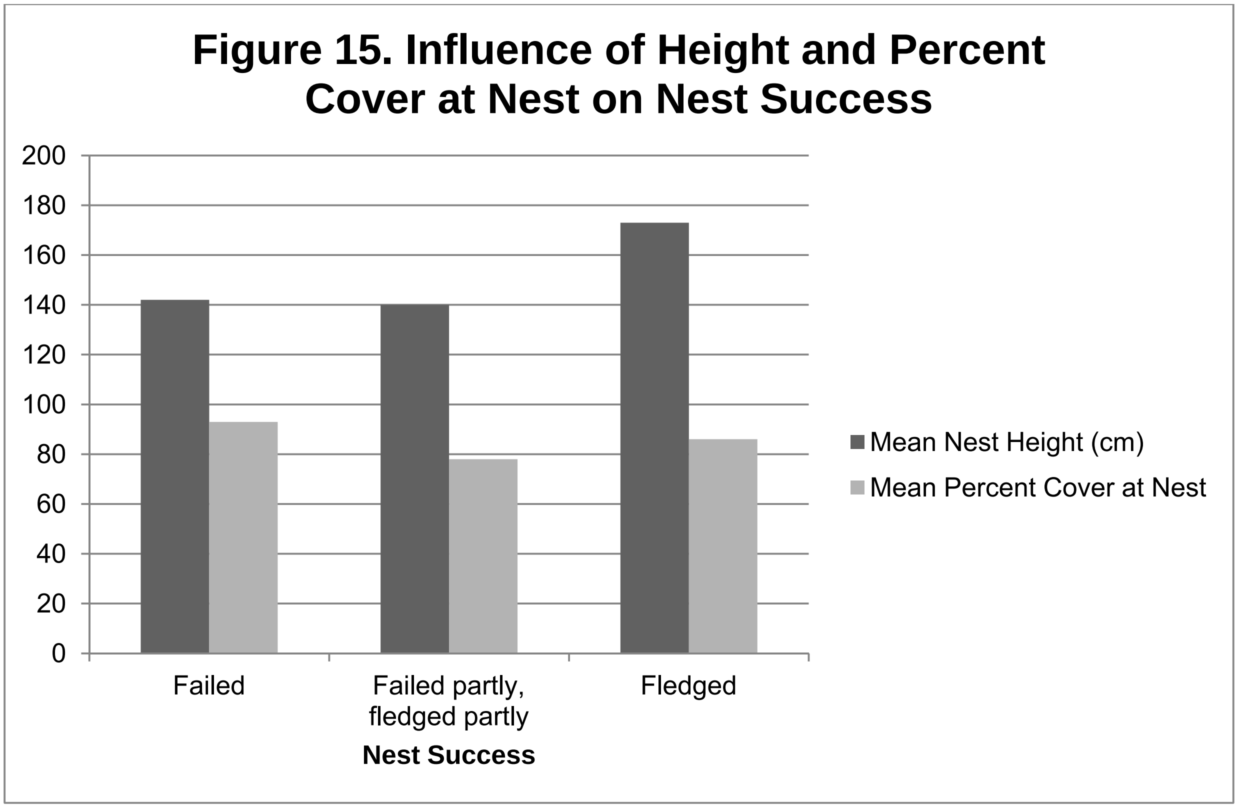


Figure 15. Influence of Height and Percent Cover at Nest on Nest Success
200
180
160
140
120
100
80
60
40
20
0
Failed
Failed partly, fledged partly
Fledged
Nest Success
Mean Nest Height (cm)
Mean Percent Cover at Nest

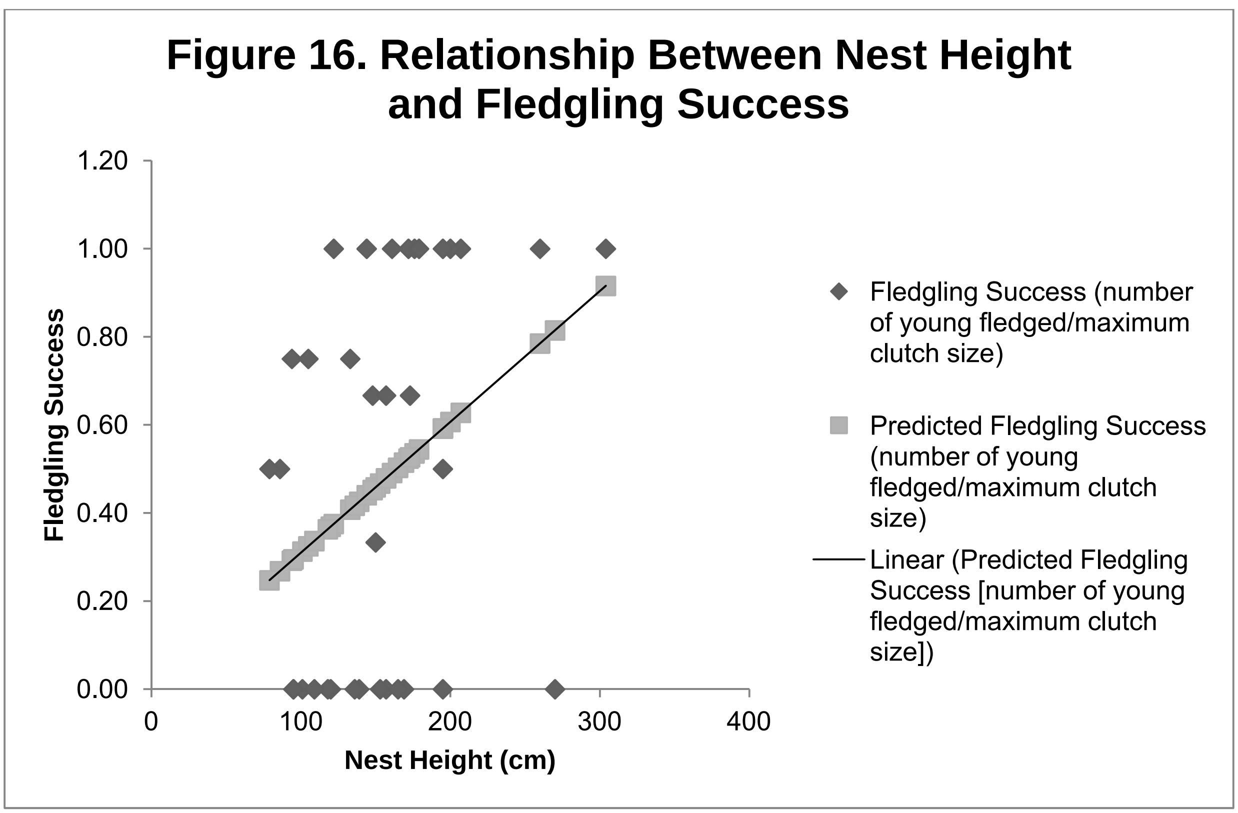


Figure 16. Relationship Between Nest Height and Fledgling Success
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Fledgling Success
0
100
200
300
400
Nest Height (cm)
Fledgling Success (number of young fledged/maximum clutch size)
Predicted Fledgling Success (number of young fledged/maximum clutch size)
Linear (Predicted Fledgling Success [number of young fledged/maximum clutch size])

Figure 17. Nest Success by Patch

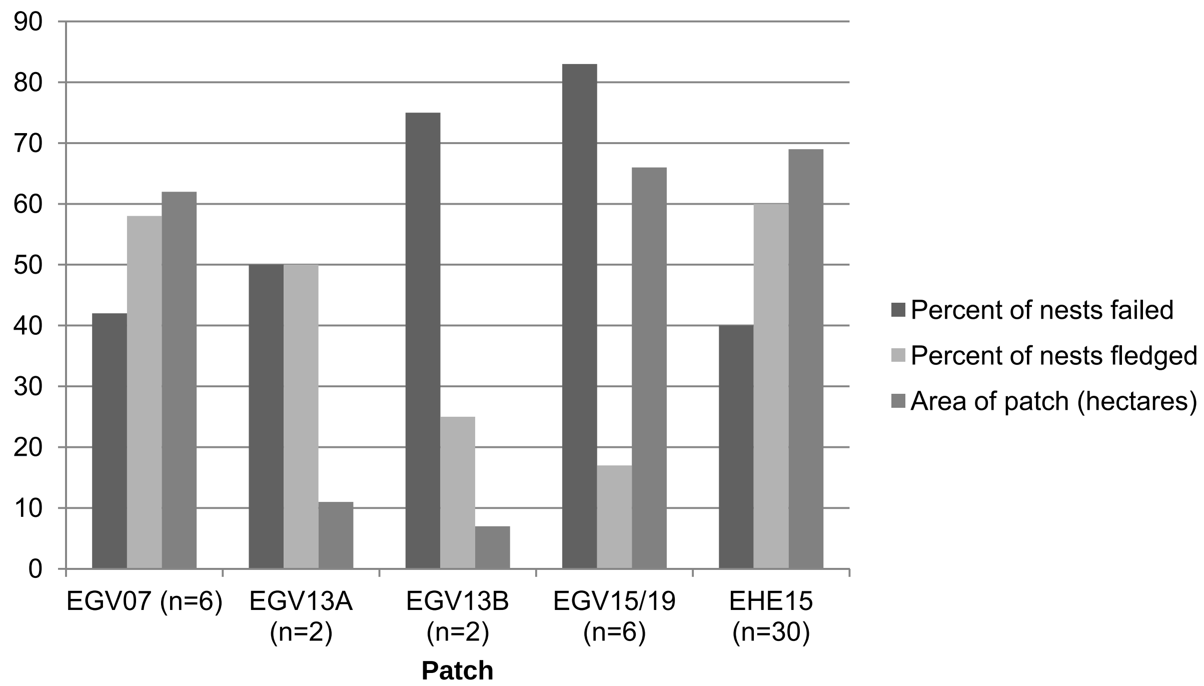
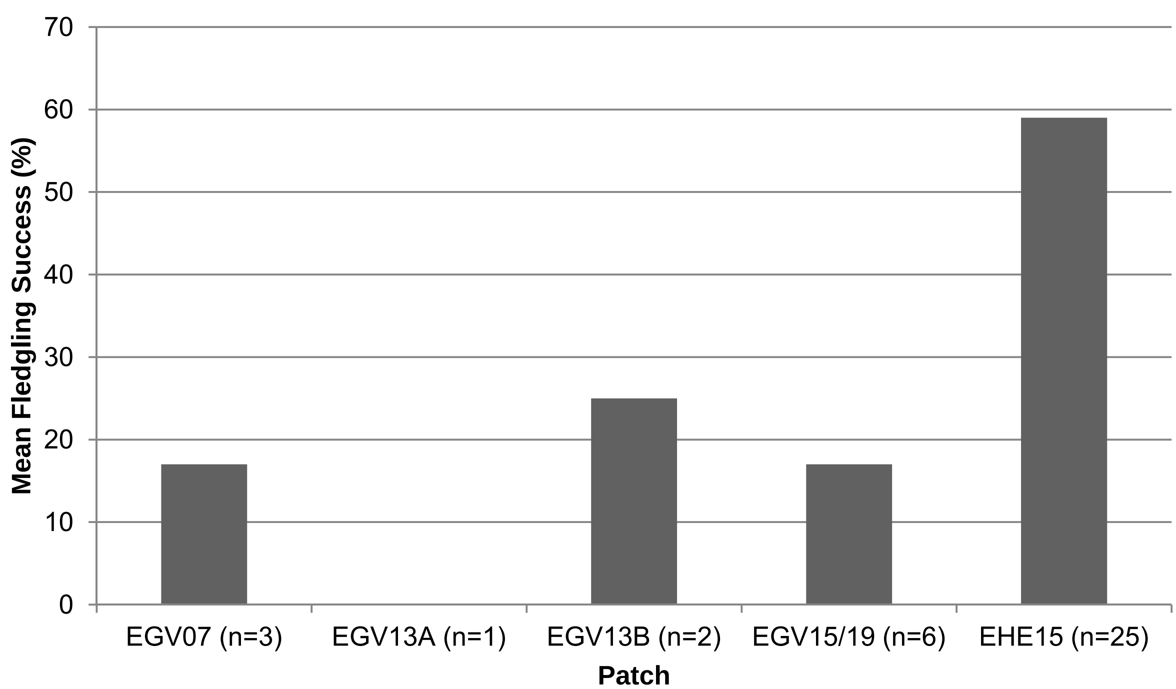


Figure 18. Mean Fledgling Success by Patch



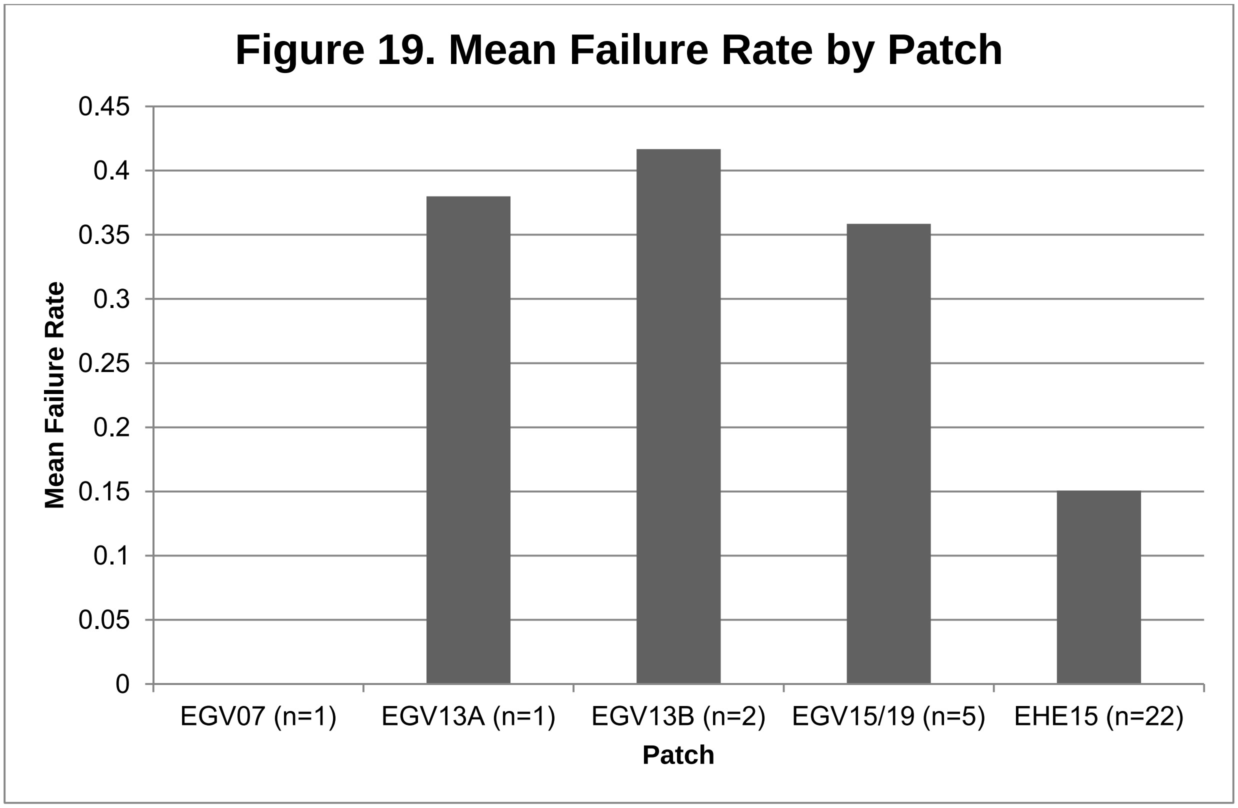


Figure 19. Mean Failure Rate by Patch
Mean Failure Rate
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
EGV07 (n=1)
EGV13A (n=1)
EGV13B (n=2)
EGV15/19 (n=5)
EHE15 (n=22)
Patch

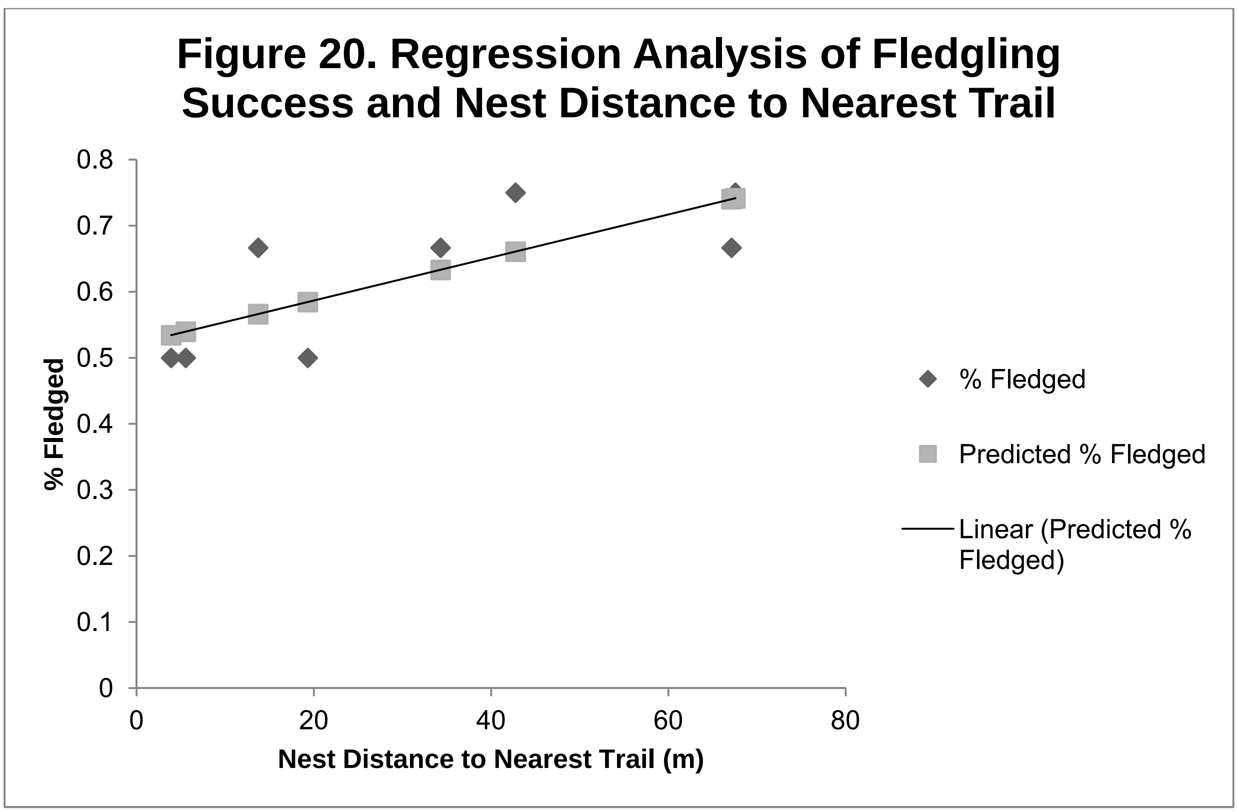


Figure 20. Regression Analysis of Fledgling Success and Nest Distance to Nearest Trail
% Fledged
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
Nest Distance to Nearest Trail (m)
% Fledged
Predicted % Fledged
Linear (Predicted % Fledged)

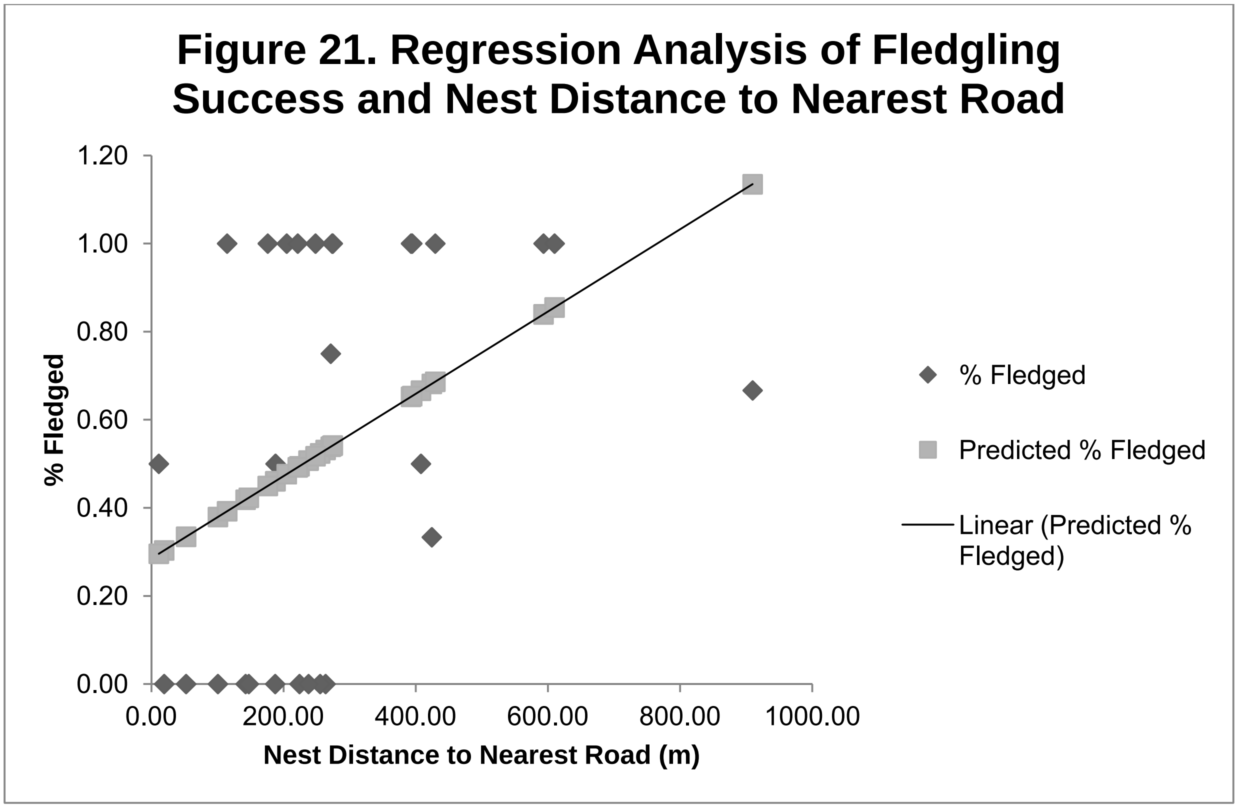


Figure 21. Regression Analysis of Fledgling Success and Nest Distance to Nearest Road
1.20
1.00
0.80
0.60
0.40
0.20
0.00
% Fledged
0.00
200.00
400.00
600.00
800.00
1000.00
Nest Distance to Nearest Road (m)
% Fledged
Predicted % Fledged
Linear (Predicted % Fledged)

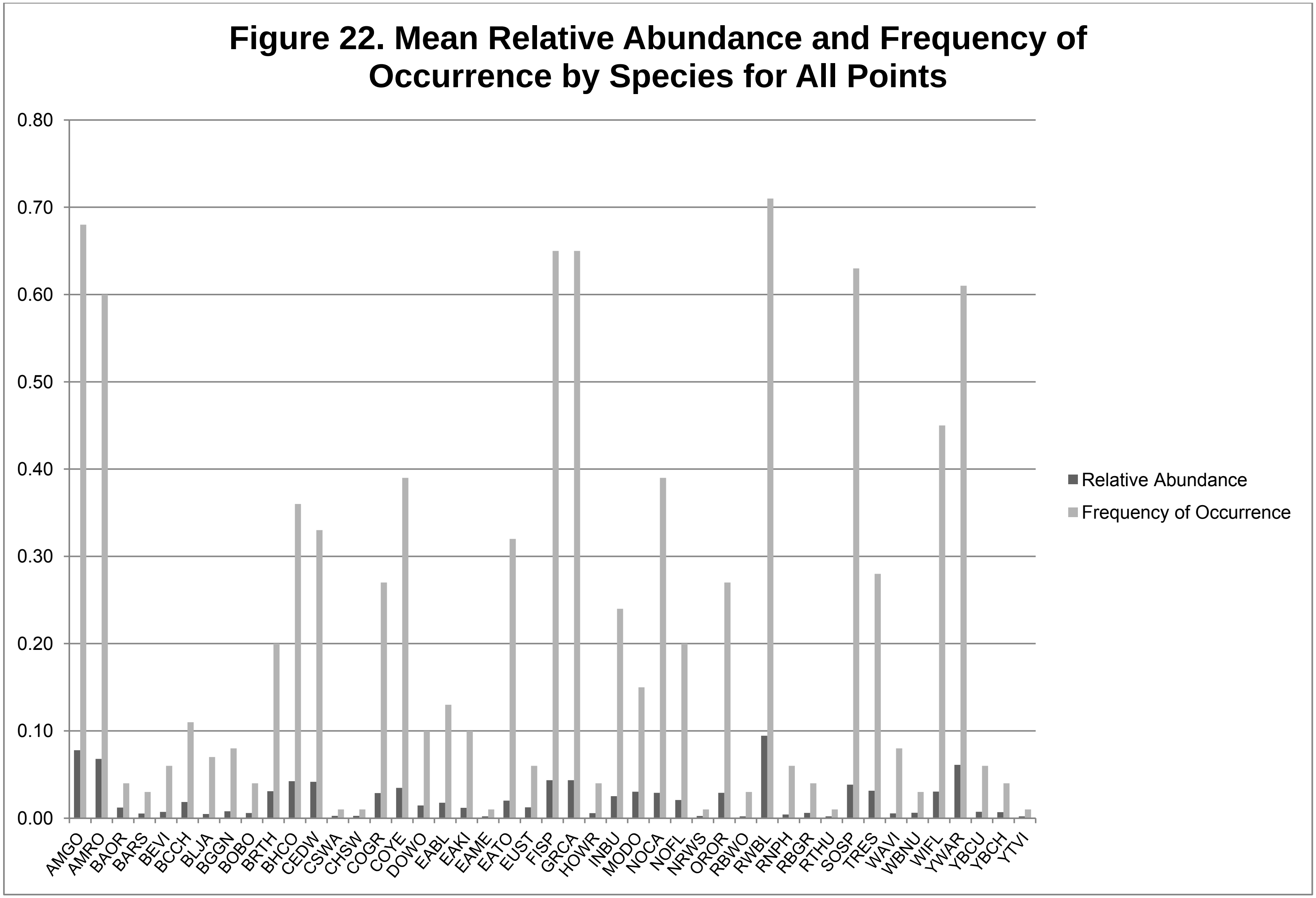


Figure 22. Mean Relative Abundance and Frequency of Occurrence by Species for All Points
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
AMGO
AMRO
BAOR
BARS
BEVI
BCCH
BLJA
BGGN
BOBO
BRTH
BHCO
CEDW
CSWA
CHSW
COGR
COYE
DOWO
EABL
EAKI
EAME
EATO
EUST
FISP
GRCA
HOWR
INBU
MODO
NOCA
NOFL
NRWS
OROR
RBWO
RWBL
RNPH
RBGR
RTHU
SOSP
TRES
WAVI
WBNU
WIFL
YWAR
YBCU
YBCH
YTVI
Relative Abundance
Frequency of Occurrence

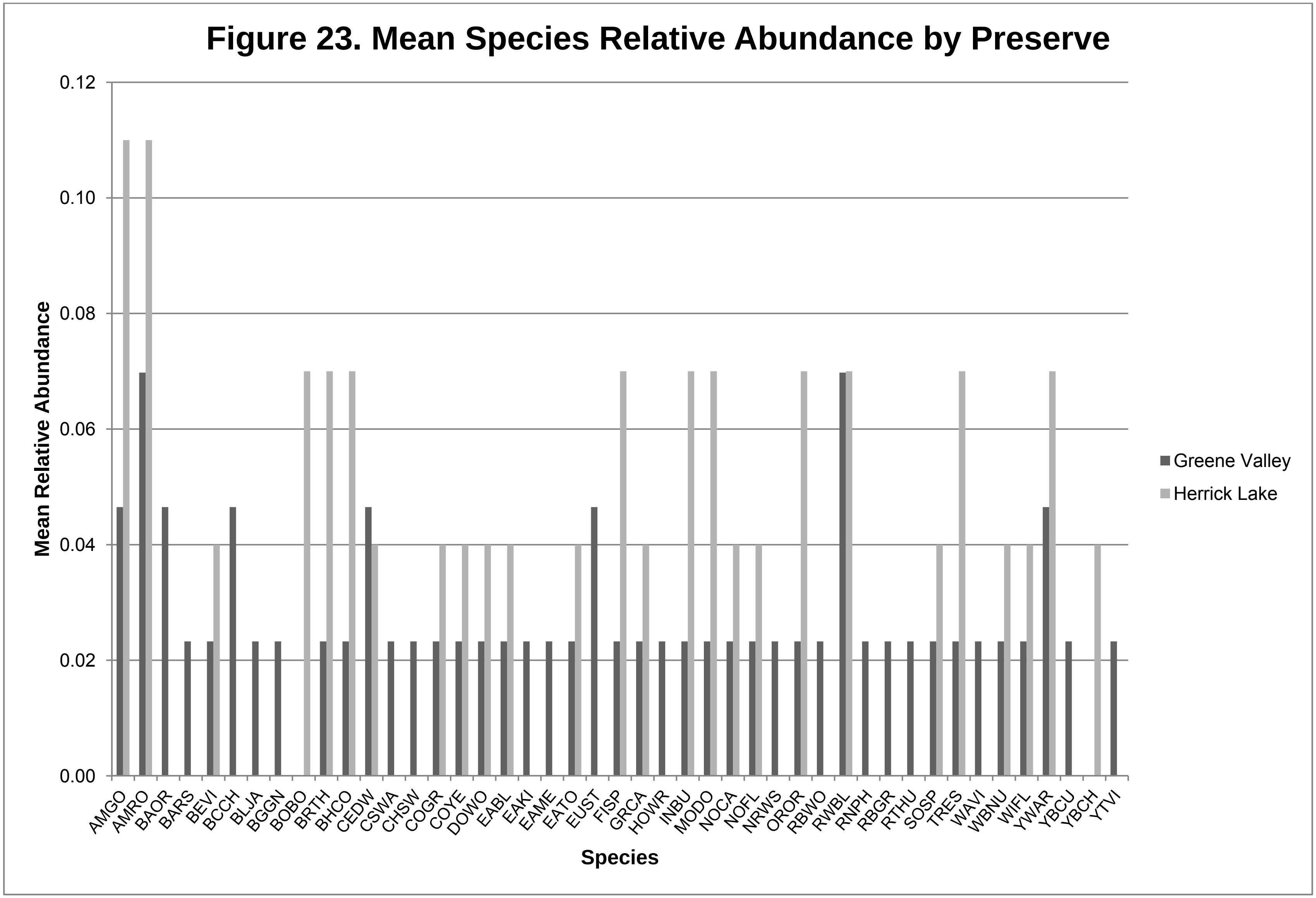


Figure 23. Mean Species Relative Abundance by Preserve
Mean Relative Abundance
0.12
0.10
0.08
0.06
0.04
0.02
0.00
AMGO
AMRO
BAOR
BARS
BEVI
BCCH
BLJA
BGGN
BOBO
BRTH
BHCO
CEDW
CSWA
CHSW
COGR
COYE
DOWO
EABL
EAKI
EAME
EATO
EUST
FISP
GRCA
HOWR
INBU
MODO
NOCA
NOFL
NRWS
OROR
RBWO
RWBL
RNPH
RBGR
RTHU
SOSP
TRES
WAVI
WBNU
WIFL
YWAR
YBCU
YBCH
YTVI
Species
Greene Valley
Herrick Lake

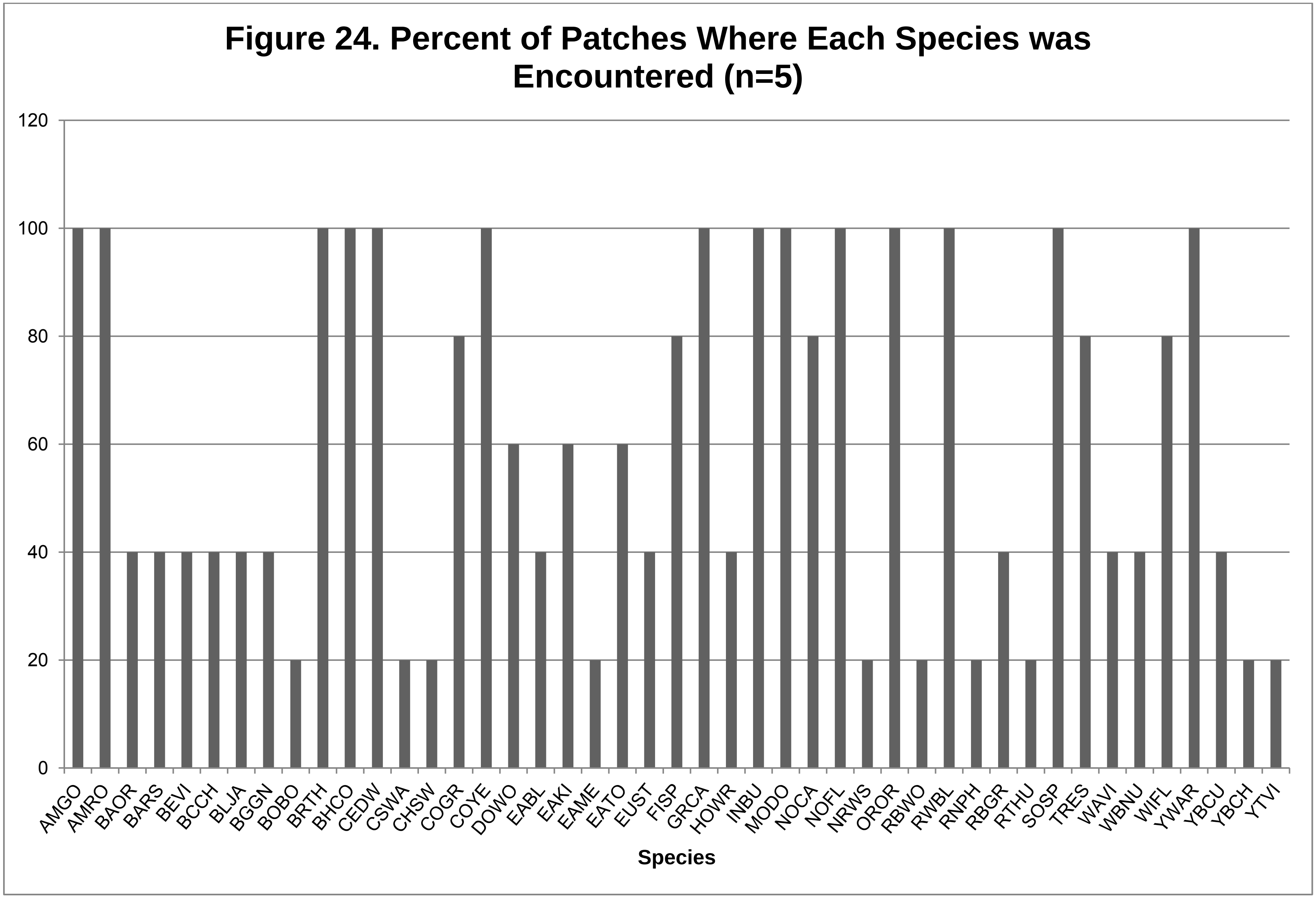


Figure 24. Percent of Patches Where Each Species was Encountered (n=5)
120
100
80
60
40
20
0
AMGO
AMRO
BAOR
BARS
BEVI
BCCH
BLJA
BGGN
BOBO
BRTH
BHCO
CEDW
CSWA
CHSW
COGR
COYE
DOWO
EABL
EAKI
EAME
EATO
EUST
FISP
GRCA
HOWR
INBU
MODO
NOCA
NOFL
NRWS
OROR
RBWO
RWBL
RNPH
RBGR
RTHU
SOSP
TRES
WAVI
WBNU
WIFL
YWAR
YBCU
YBCH
YTVI
Species

Table 3. Bird Monitoring Data by Patch

Patch ID	Patch Area (Hectares)	Number of Species	Total Number of Birds	Mean Relative Abundance	Mean Frequency of Occurrence
EGV07	62.2428	37	153	0.03	0.26
EGV13A	10.8213	21	40	0.05	0.26
EGV13B	7.45088	22	44	0.04	0.22
EGV15/19	66.3417	29	129	0.03	0.23
EHE15	68.7667	26	112	0.04	0.16

Figure 25. Regression Analysis of Number of Birds and Patch Area