ABUNDANCE, NEST PLACEMENT, AND NEST SUCCESS OF THE GRAY VIREO
(VIREO VICINIOR) IN THE SEVILLETA NATIONAL WILDLIFE REFUGE

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ABSTRACT

The Gray Vireo is a small songbird native to arid pinyon-juniper savannas across the Southwestern United States. Although they are federally listed as a bird of conservation concern, many unknowns remain concerning their preferred habitat, population size, nesting success, or the impacts of brood parasitism by the Brown-headed Cowbird (*Molothrus ater*) on nest success. In the spring and summer of 2014, we performed audio playback surveys, nest searching, nest monitoring, and vegetation sampling for breeding Gray Vireos across three study sites on the Sevilleta National Wildlife Refuge (NWR) located near Socorro, New Mexico. We found seven nests in steep canyons of the Los Piños Mountains, and twelve nests on an expansive plateau. We found that minimum vireo abundance was comparable to other Gray Vireo populations in central New Mexico but lower than most populations in California, Colorado, Texas, or other parts of New Mexico. We found nineteen Gray Vireo nests, of which seven successfully fledged Gray Vireos, four were parasitized by cowbirds, six were predated, and two failed for other reasons. Vireos in the canyon sites were less densely populated, but experienced greater nest success due to an absence of cowbird parasitism. Vireos on the plateau were more densely populated and experienced lower overall nest success. Future research is needed to determine if dense populations in flat areas commonly exhibit lower nest success than sparse populations in canyons. Gray Vireo nests occurred in large juniper trees in dense stands of juniper. These characteristics were associated with greater likelihood of nest success. Habitat managers should consider forestry techniques that increase juniper abundance and preserve the largest, oldest trees.
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Chapter 1

Introduction

The Gray Vireo (*Vireo vicinior*) is a small migratory songbird that breeds in arid pinyon-juniper woodlands and savannas across the American Southwest and winters in Northwestern Mexico (Barlow *et al.* 1999). Gray Vireos are geographically limited and sparsely distributed, contributing to their listing as an endangered species in New Mexico and a bird of conservation concern at the federal level (NMDGF 2006, USFWS 2008). Although they have garnered scientific and conservation attention since their listing, the body of knowledge on Gray Vireos is small compared to most other North American birds. Breeding bird survey data, which provides our only long-term index of Gray Vireo abundance across their range, inconclusively indicates increases in population since 1966 (Sauer *et al.* 2011). However, this likely reflects a gradual recovery from drastic range reductions caused by the cattle ranching boom of the early 20th century, coupled with an increased survey effort (Raitt & Pimm 1978, Barlow *et al.* 1999). Studies have detected small or nonexistent populations in historically documented or otherwise suitable Gray Vireo habitat, suggesting their population has failed to recolonize many habitats within their range (DeLong & Williams 2006, Hargrove & Unitt 2014).

Gray Vireos typically arrive to their breeding grounds in central New Mexico and begin breeding in early May. Males arrive first to establish and defend territories; females arrive later and quickly pair monogamously with males (Barlow *et al.* 1999). Nest construction begins immediately after pair formation, and continues for five to six days. Because of frequent parental traffic, nests are relatively easy to find in the construction phase. Incubation begins upon the
laying of the first egg, though the female lays one egg a day until she reaches a typical brood of three to five eggs. Incubation continues for thirteen to fourteen days. Though parents alternate incubation, the female takes primary responsibility for incubation while the male primarily defends the territory from intruders (Barlow et al. 1999). Nests in the incubation phase are more difficult to find, as incubating birds typically are still, quiet, and only leave to feed themselves. Once the eggs hatch, nestlings grow for thirteen to fourteen days before fledging the nest. Nests with nestlings are typically easier to find, as both parents make frequent trips to obtain food for their young (Barlow et al. 1999).

![Gray Vireo](image)

**Figure 1 – A male Gray Vireo, photographed by Benjamin Vizzachero in the Sepultura Flats region of the Sevilleta NWR, Socorro, NM, June 2014.**

Like many North American songbirds, Gray Vireos are threatened by habitat loss and degradation (Barlow et al. 1999). This includes land development for both construction and resource extraction as well the relatively less destructive effects of cattle ranching, wildfire, and other habitat management efforts (Wickersham & Wickersham 2006, Hawks Aloft 2007). Because Gray Vireos are obligate inhabitants of pinyon-juniper savannas, they have suffered as large sections of this habitat type have been destroyed or severely degraded. Between 1950 and
1961, more than 5000 square kilometers of pinyon-juniper savannah were destroyed in Arizona alone (Little 1977). Pinyon-juniper savannahs, though occurring in arid areas, are only moderately drought tolerant and continue to degrade as climate change stimulates the increased frequency and severity of drought in the western United States (Short & McCulloch 1997).

Some Gray Vireo populations nest almost exclusively in juniper, but this varies across their range. One New Mexico study reports 27 of 43 nests occurring in juniper trees, and 11 of 43 in oaks (Hawks Aloft 2007). Another New Mexico study reported 26 of 27 nests in juniper trees (Hutchins and Leukering). DeLong and Williams III (2006) report in their comprehensive review of the Gray Vireo in New Mexico that 65 of 80 nests were in a Juniperus species. The preference for juniper is not so strong outside of the four corner states. A study from California and another from Big Bend National Park in Texas both reported zero nests in juniper trees (Wauer 1971, Hargrove & Unitt 2014).

Gray Vireo presence is often related to shrub density, but researchers have found that this varies across elevational gradients. We observed early in data collection that Gray Vireos often place nests along arroyos, the rocky gullies that drain canyons during intense rainstorms. Shrubs typically occur more densely along these drainages, which may increase their favorability to Gray Vireos (Frei 2008). Gray Vireos are thicket foragers, who glean insects from leaves and branches of shrubs and small trees (Barlow et al. 1999). A study in central New Mexico found that juniper tree density was nearly three times greater near vireo nests than random points (DeLong and Cox 2005). Schlossberg (2006) found Gray Vireo abundance and elevation are negatively correlated, but explains that this pattern is driven by vegetation characteristics including juniper abundance, sagebrush abundance, and overall shrub density. Giroir (2001) found that Gray Vireos separate themselves from closely-related Plumbeous Vireos (Vireo
plumbeus) by vegetation characteristics, which were influenced by elevation. Gray Vireos occupied areas with greater deciduous shrub density and lower pinyon pine and juniper density, which often occurred at lower elevation or in canyon bottoms (Giroir 2001). Johnson et al. (2011) suggest maintaining healthy juniper-dominated savannahs on hills and low slopes is critical for Gray Vireo habitat management, and emphasizes distinguishing juniper savannahs from pinyon-juniper woodlands.

Songbirds of many species place their nests to minimize thermoregulatory stress, but few researchers have investigated these topics specifically for Gray Vireos (Bergin 1991). Barlow et al. (1999) state that Gray Vireos often place nests in west- or north-facing tree forks, but do not cite original data. One study in California very clearly documented a tendency for Gray Vireos to place their nests on south-facing slopes in the south side of trees; they suggested that vireos simply prefer to nest on the downslope side of trees (Hargrove & Unitt 2014). We aim to determine if this pattern exists outside of Southern California. We speculate that Gray Vireos would place their nests in order avoid the direct afternoon sun and associated heat stress, as Warbling Vireos (Vireo gilvus) are also known to do so in the American Southwest (Walsberg 1981). This would mean that nests are less likely to occur on south facing slopes or the south-facing part of the tree, contrary to the findings of Hargrove and Unitt (2014).

Nest placement and concealment also influence the likelihood of nest success. Martin’s (1992) comprehensive review of breeding birds suggests an overall association between greater nest concealment and lower predation rates, but his study is too broad in terms of habitats and species studied to make specific inferences about Gray Vireos. The importance of concealment depends on the nest predator, as the nest must be concealed from that predator’s angle of attack; a nest that is well-concealed to avian predators may be easily visible to a snake (Burhans and
Thompson III 1998). Since female Brown-headed Cowbirds detect nests by observing host species, the concealment of a nest does not affect the likelihood of that nest being parasitized. (Norman & Robertson 1975). We observed early in data collection that Gray Vireo nest trees are often old and sparsely foliated, and aim to test the hypothesis that Gray Vireo nest trees have sparser foliage on average. Many species are known to select cover in a manner that optimizes the tradeoff between concealment (the extent to which the animal is hidden) and visibility (the ability to spot approaching threats) (Camp et al. 2013).

Gray Vireos typically have low overall nest success, documented as low as 18% of 95 nests (Hargrove & Unitt 2014). Cowbird parasitism is often a cause of nest failure, with rates as high as 71% of 19 nests in some sites (Hawks Aloft 2006). The commensal relationship between Brown-headed Cowbirds and large grazing mammals is well documented, but the effect of cattle presence on cowbird parasitism rates is a continuing topic of research (Lowther et al. 1993). Several studies confirm that Brown-headed Cowbirds strongly prefer to forage near cattle in a variety of habitats, including the arid grasslands and pinyon-juniper savannahs of New Mexico (Goguen & Mathews 1999, Harper et al. 2002). Researchers have documented a clear association between grazing and increased brood parasitism rates in the Midwestern tall-grass prairies and the Sierra Nevada Mountains, but fewer studies investigate proximity to offsite ranching operations, specifically in the Southwestern United States (Verner & Ritter 1983, Airola 1986, Goguen & Mathews 2000, Patten et al. 2006). Since female Brown-headed Cowbirds have been recorded regularly commuting ten kilometers a day between feeding grounds and breeding sites, a single ranching operation may have far-reaching effects in surrounding wilderness (Curson et al. 2000). For this reason, we expect to see higher rates of brood parasitism in sites located closer to off-site cattle ranching operations. Fortunately, Gray Vireos possess the ability to recognize a
cowbird egg, as the majority of documented parasitized nests are abandoned (Figure 2) (Hanna 1944, Hawks Aloft 2006, Hawks Aloft 2007, Hargrove and Unitt 2014). Unfortunately, insufficient data exists to determine the population-level impact of brood parasitism on the Gray Vireo.

![Image of a nest containing two Gray Vireo eggs and one Brown-headed Cowbird Egg](image)

**Figure 2 - A Gray Vireo nest containing two Gray Vireo eggs and one Brown-headed Cowbird Egg that can be identified by the larger size. This nest was abandoned within days of the cowbird egg being laid. Photo taken by Benjamin Vizzachero in the Sepultura Flats region of the Sevilleta NWR, Socorro, NM, June 2014.**

The other prevalent cause of Gray Vireo nest failure is predation. A study in Southern California indicates the Western Scrub-Jay (*Aphelocoma californica*) as a prominent nest predator of the Gray Vireo, responsible for one third of all recorded predation events (Hargrove & Unitt 2014). Other common predators that occur in New Mexico include the Northern Mockingbird (*Mimus polyglottos*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Loggerhead Shrike (*Lanius ludovicianus*), Scott’s Oriole (*Icterus parisorum*), Bewick’s Wren (*Thryomanes bewickii*), and a variety of non-venomous snakes (Barlow *et al.* 1999).

By studying breeding Gray Vireos within the Sevilleta NWR, we intend to determine the impacts of nest predation and cowbird parasitism on this local population, and to identify factors
relating to nest placement that influence nest success. Given there are few past studies of this kind, we also aim to hone the set of procedures used to measure abundance and locate nests. This information can be used in the future to more efficiently study Gray Vireos and to identify habitat management methods that would benefit Gray Vireo populations.
Chapter 2

Objectives

We conducted this study in order to meet the following objectives:

1. Assess the status of the Gray Vireo Population on the Sevilleta NWR in terms of relative abundance and nest success; describe the impacts of nest predation and brood parasitism.

2. Test the hypothesis that rates of brood parasitism by the Brown-headed Cowbird are higher at sites closer to cattle ranching operations.

3. Describe the placement of Gray Vireo nests on the Sevilleta NWR in terms of vegetation characteristics and topography. Test the hypotheses that Gray Vireos prefer to nest in more sparsely foliated juniper trees, and that Gray Vireos place their nests to avoid direct sunlight.

4. Identify which nest placement factors influence the likelihood of a nest successfully fledging Gray Vireo young.

5. Gain information to add to a small but growing body of knowledge used to assess the Gray Vireo’s conservation status and aid in potential management decisions on the Sevilleta NWR or other wild lands.
Chapter 3

Study Area

No past scientific publication has studied in detail the population of Gray Vireos contained within the Sevilleta NWR, about 20 miles north of Socorro, New Mexico. The USFWS founded this refuge in 1973, following roughly a century of intensive cattle ranching. Our study took place during the summer of 2014 and focused on the Gray Vireo population in the Los Piños Mountains on the eastern edge of the refuge. We selected three sample sites: Piños Canyon, Bootleg Canyon, and Sepultura Flats (Figure 3). Piños Canyon (2.93 km²) and Bootleg Canyon (1.35 km²) are topographically similar, consisting of dry, rocky arroyos running along the base of steep slopes rising up to rocky mountain peaks (Figure 4). Sepultura Flats (5.36 km²), as the name implies, is a relatively flat basin surrounded by mesas and a canyon to the north.

Immediately across the north border of the refuge is a cattle ranch. We aim to determine if proximity to cattle ranching operations is associated with rates of brood parasitism by the Brown-headed Cowbird. Piños Canyon is approximately 1.5 km from this ranch, Bootleg Canyon is approximately 6 km away, and Sepultura Flats is a minimum of 11 km away. Previous researchers selected and delineated these three study sites to provide a gradient of distance to this ranch, but also for their accessibility.
Figure 3 – Left: Map of the three 2014 survey sites within the Sevilleta NWR near Socorro, NM. Study sites are outlined in red with the location of audio playback survey points inscribed. Piños Canyon is the northernmost, Bootleg Canyon is central, and Sepultura flats is southernmost. Right: Location of the Sevilleta NWR in the state of New Mexico. Images generated from public domain satellite imagery and shapefiles using ArcMap 10.3 by Benjamin Vizzachero, 2016.

Given a field crew of only two people, it was necessary to concentrate resources on a smaller area that could be surveyed thoroughly, rather than disperse our efforts over the entire refuge’s area. All Study sites could be reached by a combined driving and hiking time of less than 90 minutes. The boundaries of these regions were delineated to avoid any insurmountable obstacles (i.e. cliffs, canyon walls) or hikes more than 2.5 kilometers in distance. These regions are by no means the only Gray Vireo habitat on the refuge; there are large sections of pinyon-juniper savannah difficult to access within the Los Piños Mountains and on the far west side of the Sevilleta NWR on the foothills of the Ladron Mountains. West of the Los Piños Mountains is a large arid grassland on the Sevilleta NWR. To the east of the refuge, there are the foothills of the Los Piños Mountains, which are owned by various private landholders and have been used for cattle grazing to various extents in the past.
Figure 4 - The three survey sites where Gray Vireo audio-playback surveys and nest searching occurred. Sepultura Flats (top left) was the largest site, an expansive flat area surrounded by plateaus and bordered by a canyon to the north. Bootleg Canyon (top right) and Piños Canyon (bottom) are topographically similar canyons in the Los Piños Mountains, where steep slopes rise from arroyos to rocky cliffs. All photos taken by Benjamin Vizzachero in the Sevilleta NWR, Socorro, NM, June and July of 2014.

Ecologically, this area is considered a pinyon-juniper savannah. There are over 72 million acres of similar habitat across the Southwestern United States, largely concurrent with the Gray Vireo’s range (Figure 5) (West 1999, Barlow et al. 1999). In the Sevilleta NWR, the savannah is dominated by one-seed juniper (Juniperus monosperma) with two-needle pinyon pine (Pinus edulis) occurring at higher elevations. There is also a significant presence of various shrubby oak species (Quercus gambelii, Quercus grisea, hybrids thereof), shrubs such as winterfat (Krascheninnikovia lanata) and creosote bush (Larrea tridentata), and desert succulents like yucca (Yucca spp.), prickly pear (Opuntia spp.), and cholla (Cylindropuntia spp.).
Figure 5 – Left: The distribution of pinyon-juniper woodlands and savannas in the Southwestern United States (West 1999). Right: The distribution of the Gray Vireo (Barlow et al. 1999).
Chapter 4
Methods

Audio Playback Surveys

Within the Los Piños Mountains, previous researchers delineated three large sample sites and overlaid a 300x300m grid of points using GIS software. The sites, Piños Canyon, Bootleg Canyon, and Sepultura Flats, include 38, 16, and 53 points, respectively. We began audio playback surveys on May 29th, 2014, alternating between sample sites each day and continuing until all points within each site were surveyed. We based this survey methodology on the methodology published by DeLong and Williams III (2006). Audio surveys consisted of two to five minutes of listening immediately after arriving at a point, followed by 30-60 seconds of playback at maximum volume on the speakers of an iPhone 4S, using the recording of the Gray Vireo territorial song from The Sibley eGuide to Birds. After an additional two to five minutes of listening, we repeated 30-60 seconds of playback, followed by two to five final minutes of listening.

Nest Searching

If we heard a Gray Vireo at any point during the survey or while travelling in or near the sample site, we located that vireo as quickly as possible. We did not pursue vireos that appeared to be associated with a known nest or territory. Though Gray Vireos cannot be sexed by visual cues, behavior often revealed the sex. Male birds typically would respond vocally to the lure, singing loudly and closely approaching the source of the playback. Female birds rarely sing more
than three syllables of the song, but often made scolding alarm calls. We would watch the male
until it revealed the location of the nest by flying directly to it, or until we spotted the female.
The female typically visits the nest more frequently, and thus reveals its location more readily.

If the bird disappeared and was not seen or heard for at least ten minutes, we performed
two or three rounds of playback (one “round” consisting of 30-60 seconds of playback and two
to five minutes of listening). If the bird remained unresponsive for 30 minutes, or if we
abbreviated the search due to time constraints, we took a GPS waypoint and returned within the
next week to continue the nest search. If we spotted a fledgling being attended to by the adults,
we took a GPS waypoint and noted the species of the fledgling (Gray Vireo or Brown-headed
Cowbird). If we found a nest, we took a GPS waypoint and placed flagging at least three meters
away to indicate the nest location.

Nest Monitoring

We revisited all nests every three to five days, with occasional longer lapses caused by
weather or logistical constraints. We observed and recorded the contents of every nest upon
initial detection and each revisit, counting the number of eggs and nestlings of Gray Vireos or
Brown-headed Cowbirds. Most nests were above eye level, so we used a mirror mounted on the
end of an extendable pole to view their contents (Figure 6). Birds found sitting on the nest were
typically flushed by the proximity of the researchers or the mirror pole, but sometimes were
more reluctant to leave. In some instances we could not flush the incubating vireo or record the
nest’s contents.
Figure 6 – We used an extendable pole with a small mirror mounted on the end to check the contents of nests that were above eye level. Photo by Sze Wing Yu, used with permission, taken on the Sevilleta NWR, Socorro, NM, July 2014.

Vegetation Measurements

After we surveyed all of the grid points within all sample sites, we began sampling vegetation. Vegetation surveys were all centered around juniper trees, including the nineteen nest trees and the closest trees to each of 34 randomly selected audio-playback survey points. This includes nine randomly selected points from Piños Canyon, four from Bootleg Canyon, and twenty-one from Sepultura Flats. We based these vegetation methods on that of Anderson and Ohmart (1986). We measured the height and canopy diameter of each tree. We measured canopy diameter at the widest part of the tree and again at a 90° angle to this, and averaged these two numbers. We constructed a one-meter square board of ten-centimeter checkerboard tiles to estimate each tree’s foliage density (Figure 7). One researcher held the board one meter above
the ground on one side of the tree, while the observer would stand on the opposite side of the tree and estimate the percent of the board visible through the tree. We took this measurement twice per tree along the same two axes that were measured for canopy diameter, always by the same researcher, and results were averaged for each tree. For nest trees only, we took the nest’s vertical height above the ground and the orientation of the nest from the center of the tree. For all points on sloped ground, we took a compass bearing to measure the direction immediately downslope.

Figure 7 – This one-meter square board was used to estimate the “sparseness” (foliage density) of juniper trees. While one researcher held the board as pictured, the other researcher stood on the opposite side of the tree and estimated the number of unobscured tiles. Photo taken by Benjamin Vizzachero on the Sevilleta NWR, Soccorro, NM, July 2014.

In order to assess the local vegetation community, we evaluated four one-meter square ground cover plots, placed ten meters from the tree in each of four cardinal directions. We recorded estimates of ground cover in these categories: bare ground, grass, forb, shrub,
succulent, dead forb, dead succulent, tree. We considered dead litter and debris as bare ground. “Succulent” includes both cacti (cholla and prickly pear) and various types of yucca. We tallied bare ground as the remaining area uncovered by other vegetation types. We averaged percent cover in each category for the four quadrats at each point. Lastly, we identified to genus and counted all succulents and woody shrubs over 50 cm tall within a ten-meter radius of every survey tree.

After the field season, additional variables were measured using GIS software. I visually estimated canopy coverage within a 50-meter radius of each nest and vegetation point, as a percentage in increments of ten percent, using publically available satellite imagery. For each nest, I measured distance to the audio-playback survey point where it was detected and distance to the nearest arroyo. I identified arroyos using publically available digital elevation models and satellite imagery.

Analysis

I assessed vireo abundance by two means. I calculated the percentage of survey points where vireos responded, and used this as an index for abundance. I also calculated the minimum density of vireo pairs within each sample site by calculating the total number of known territories in each site and dividing by that site’s area. Territories include both the in-bounds nests and all family groups for which nests were not found. Though the audio-playback surveys alone did not constitute a census of these sites, frequent traversing of the sample sites to perform nest checks and vegetation measurements brought us in contact with every section of each site throughout the season. I am confident that few, if any active territories went completely undetected.
I performed the majority of statistical analyses in JMP Pro 12 including nest placement and nest success models (SAS Institute Inc. 2016). I began the analysis of nest placement by conducting a series of two sample t-tests to determine if these variables were significantly different between nest points and random points. These variables included nest height, tree height, canopy diameter, sparseness, canopy cover, number of junipers within ten meters, percent ground cover occupied by grass, and the sum of all woody shrub counts within ten meters.

We calculated nest success in terms of the daily survival rate in accordance with the methods described in Mayfield 1972 by using the modeling tools available in program MARK, published by Phi-dot software (Rotella 2016). Because of our small sample size, we lacked power to perform analyses of which factors influence nest success in program MARK. Instead, I used traditional modeling methods and constructed a binomially distributed general linear model to predict nest success or failure in JMP Pro 12. Using the seven aforementioned variables, I then followed standard stepwise model reduction techniques. Beginning with the predictor whose effect test had the least significant p-value, I removed that predictor from the model and compared the corrected Aikake’s Information Criterion (AICc) between the full and reduced model. If the removal of a predictor caused AICc to decrease by two or more, I removed that predictor from the final model.

I performed the analysis of nest orientation within the tree and slope face orientation beneath the nest tree in Minitab 16 Statistical Software (Minitab, Inc. 2016). For both nest and slope orientation, I tallied the number of nests into four categories: N (315°-360°, 0°-44°), E (45°-134°), S (135°-224°), and W (225°-314°). I tested this distribution against the null hypothesis that nests are evenly distributed between all eight categories.
Chapter 5

Results

Audio Playback Survey

Vireo abundance varied considerably by site (Table 1). Piños Canyon had the fewest responses to playback. This survey region contained a large swath of land that was devoid of vireos, on the west-facing slope of the Los Piños Mountains. It also included areas high on steep slopes where juniper trees were absent. Bootleg Canyon had more responses to playback, even though this study site contained a large, flat, sparsely vegetated area at the mouth of the canyon where we found no vireos. Sepultura Flats had by far the most responses, with vireos responding at nearly one third of survey points.

Table 1 – Number of Gray Vireos detected on audio playback surveys for each study site, number of audio playback survey points per site, and the percent of points where Gray Vireos were detected. Sevilleta NWR, Socorro, NM, May through July 2014.

<table>
<thead>
<tr>
<th>Site</th>
<th>Gray Vireos Detected</th>
<th>Number of Survey Points</th>
<th>Percent of point with Gray Vireos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piños Canyon</td>
<td>2</td>
<td>38</td>
<td>5.26%</td>
</tr>
<tr>
<td>Bootleg Canyon</td>
<td>2</td>
<td>16</td>
<td>12.50%</td>
</tr>
<tr>
<td>Sepultura Flats</td>
<td>17</td>
<td>53</td>
<td>32.08%</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>107</td>
<td>19.63%</td>
</tr>
</tbody>
</table>
We found nineteen nests, and Appendix A summarizes their means of detection. We initially detected thirteen of these nests during audio playback, and six while travelling through the sample region for other reasons. Of thirteen nests found by playback, we found nine nests on the same day as initial detection, and had to revisit the other four before finding a nest. Of six nests detected without playback, we incidentally encountered five while in the field; the other one was the second attempt of a pair whose first nest failed. Of five incidental encounters, two were outside the survey area. The other three were not detected at any of the nearby survey points, constituting the only nests that were missed by our detection method.

In addition to 19 nests, there were four additional groups of birds with no nest associated included in minimum territory density calculations (Table 2). One of these occurred in Piños Canyon, where we found a pair of Gray Vireos feeding a single Brown-headed Cowbird chick. In Sepultura Flats, there was a similar pair of Gray Vireos feeding a fledgling cowbird, along with a family group of four or five vireos not detected prior to fledging. Sepultura flats also hosted one pair of vireos for which no nest was found, and this pair was not present upon later visits. Three nests were out of the survey bounds and not included in minimum territory count, two in Piños Canyon and one in Sepultura Flats.

### Table 2 – The minimum number of territories for each site, representing the sum of all in-bounds detected nests, family groups, and lone pairs. This was divided by the area of each site, in square kilometers, to produce the minimum territory density for each site in terms of territories per square kilometer. Sevilleta NWR, Socorro, NM, May through July 2014.

<table>
<thead>
<tr>
<th>Site</th>
<th>Minimum Territories</th>
<th>Area of Site (km²)</th>
<th>Minimum Territory Density (territories/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piños Canyon</td>
<td>4</td>
<td>2.93</td>
<td>1.37</td>
</tr>
<tr>
<td>Bootleg Canyon</td>
<td>2</td>
<td>1.35</td>
<td>1.48</td>
</tr>
<tr>
<td>Sepultura Flats</td>
<td>13</td>
<td>5.36</td>
<td>2.61</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>11.15</td>
<td>1.79</td>
</tr>
</tbody>
</table>
Though the stage of the nest upon detection varied, thirteen of nineteen nests were found containing eggs. Four of these were still in the egg-laying stage, the other nine being incubated. Three nests were found while under construction, two were found containing partially-feathered nestlings, and one was found containing fully-feathered nestlings.

Of the thirteen nests initially detected from the audio playback survey, ten were detected at the survey point closest to the nest, the remaining three were missed at a closer survey point before being detected from a further point. Examining the distribution of nests by distance from detection point reveals that the majority of nests were within a 175-meter radius of their detection point (Figure 8).

![Figure 8 - Distribution of thirteen Gray Vireo nests by distance from point of initial detection in meters. Six nests not initially detected during audio playback survey are not included. Sevilleta NWR, Socorro, NM, May through July 2014.](image-url)
Nest Placement

Of nineteen nests, all were placed in juniper trees (*Juniperus* spp.). Nests were at an average height of 2.38 meters, though this ranged considerably from 0.45 to 3.50 meters. Juniper trees chosen by vireos as nest sites were larger on average than our random sample, both in terms of canopy diameter and height (Table 3). We found no statistical support for the hypothesis that nest trees are more sparsely foliated on average. Canopy cover and the number of junipers within ten meters were both significantly greater at nest sites, but the number of junipers within ten meters was only significant by a one-tailed test. These variables are both proxies for the shrub density surrounding the nest; they are correlated to each other with an $R^2$ of 0.21. The total number of shrubs within 10 meters is also related to overall shrub density, but did not display any significant difference between nest and random sites. The percent of ground cover occupied by grass is also significantly higher at nest sites.

Table 3 – Vegetation variables around Gray Vireo nest sites and random vegetation points on the Sevilleta NWR, Socorro, NM, May through July 2014. *Indicates significance at $\alpha=0.05$. **Number of junipers within 10m and Grass are significant at $\alpha=0.05$ ($p=0.0273$, 0.0467 respectively) by a one-tailed t-test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average for Nests (n=19)</th>
<th>Average for Random Points (n=33)</th>
<th>t-ratio</th>
<th>Degrees of freedom</th>
<th>p-value (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height (cm)</td>
<td>378.1±16.8</td>
<td>307.1±17.5</td>
<td>-2.89</td>
<td>47.13</td>
<td>0.0058*</td>
</tr>
<tr>
<td>Canopy Diameter (cm)</td>
<td>536.0±43.7</td>
<td>411.2±28.1</td>
<td>-2.40</td>
<td>32.77</td>
<td>0.0220*</td>
</tr>
<tr>
<td>Sparseness (% of 1m² board visible)</td>
<td>5.39±1.17</td>
<td>4.27±6.64</td>
<td>-0.67</td>
<td>45.32</td>
<td>0.5065</td>
</tr>
<tr>
<td>Number of junipers within 10m</td>
<td>5.79±1.30</td>
<td>2.97±0.50</td>
<td>-2.02</td>
<td>23.40</td>
<td>0.0546**</td>
</tr>
<tr>
<td>Total Shrubs within 10m</td>
<td>21.32±3.68</td>
<td>19.52±3.41</td>
<td>-0.35</td>
<td>43.97</td>
<td>0.7212</td>
</tr>
</tbody>
</table>
Our documentation of all shrubs greater than 50 cm tall in a ten-meter radius of each
vegetation point demonstrated the differences in vegetation by site. The average ten-meter radius
counts for all species by site and nest/random point are included in Appendix B. All sites had a
significant juniper component with an average of at least two juniper stems per point, but
junipers were typically more abundant in Sepultura Flats than the canyon sites. Some shrubs such as algerita (*Berberis haematocarpa*), *Ribes* spp., and pinyon pine (*Pinus edulis*) were
similarly present at low abundances across all sites. In the canyon sites, oaks were as abundant as
junipers, in addition to a strong presence of apache plume (*Fallugia paradoxa*), tree cholla
(*Cylindropuntia imbricate*) and various *Yucca* species. Only oak (*Quercus* spp.) and mountain
mahogany (*Cercocarpus* spp.) were noticeably different between the two canyon sites, with
both being more than twice as abundant at Piños Canyon. Sepultura Flats, in the absence of any
oaks or apache plume, and much lower numbers of yucca and cholla, hosted high numbers of
creosote bush (*Larrea tridentata*) and amaranth shrubs such as winterfat (*Krascheninnikovia
lanata*) and saltbush (*Atriplex* spp.).
Figure 9 - The distribution of all vegetation points by canopy cover. Both have a similar bell-shaped distribution, but average canopy cover at nest points (25%) is eleven percent higher than average canopy cover at non-nest vegetation points (14%). Sevilleta NWR, Socorro, NM, May through July 2014.

Canopy cover within a 50-meter radius averaged at 25% for nest sites and 14% for random points, a significant difference (Figure 9). Our measurements of ground cover revealed that Gray Vireo nest sites had an average of 40% of the ground covered by grass, as opposed to 30% for random points. This difference is significant by a one-tailed t-test. No other ground cover classification was significantly different between nest and random sites. Average ground cover for nest and random points at all sites is provided in Appendix C.

The orientation of a nest within a tree and of the slope beneath a nest tree suggest that vireos avoid placing their nest on the east side of trees, or in trees on south facing slopes (Figure 10). I analyzed each variable separately with a chi-square goodness-of-fit test, and determined them not to be significantly different from a completely random distribution (Table 4)
There was also a noticeable tendency for Gray Vireos to place their nests near rocky arroyos. Half of all nests were within 55 meters, and one quarter of nests were within 15 meters. This trend varied considerably across sites; all nests in Piños Canyon and Bootleg Canyon were within 40 meters of an arroyo, while some nests in Sepultura Flats were as far as 500 meters from the nearest arroyo.

**Nest Survival**

Of nineteen nests, eight nests fledged young, seven of them fledging Gray Vireos and one (Sepultura Flats nest nine) fledging only a single cowbird chick (Table 5). Six nests experienced premature disappearance of eggs or young, presumed to be predation. Four nests were
parasitized by cowbirds, and three of these nests were abandoned (parents were not seen incubating). After abandonment, two of them were then predated (remaining eggs suddenly disappeared). One nest (Sepultura Flats nest seven) had all but one egg disappear. We continued to revisit the nest for several weeks; though the egg remained, we never saw a parent present and concluded the nest was abandoned. At Sepultura Flats nest two, we saw parents incubating for an entire month, indicating that these eggs were not viable given a typical incubation period of two weeks (Barlow et al. 1999). Upon the final check the nest was destroyed, apparently caused by structural collapse but possibly the result of predation. We found Sepultura Flats nest eight while it was actively being constructed, but this nest was never completed for reasons unknown.

Table 5 – The fate of all Gray Vireo nest detected within three sites on the Sevilleta NWR, Socorro, NM, May through July 2014.

<table>
<thead>
<tr>
<th>Region</th>
<th>Nest</th>
<th>Fate</th>
<th>Secondary Fate</th>
<th>Cowbird</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piños Canyon</td>
<td>1</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Predated</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Bootleg Canyon</td>
<td>1</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Predated</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Sepultura Flats</td>
<td>1</td>
<td>Partially Predated</td>
<td>Abandoned</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Failed</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Abandoned</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Predated</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Predated</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Partially Predated</td>
<td>Abandoned</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Incomplete</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Parasitized</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Predated</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Abandoned</td>
<td>Predated</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Fledged</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
We calculated the daily survival rate as 0.9555, meaning that each nest has a 95.55% chance of surviving until the next day. Given that the typical nest cycle lasts 32 days (four days of egg laying, 14 days of incubation, and 14 days as nestlings before fledging), the chance of any given nest fledging young can be calculated as $(0.9555)^{32}=0.2330$; this means each nest has a 23% chance of succeeding.

The final binomially distributed general linear model to predict success includes the following significant predictors of nest success: Nest tree height ($p=0.0026$), canopy diameter ($p=0.0283$), ten-meter radius juniper count ($p=0.0039$), and sparseness ($p=0.0121$) (Appendix D). Nest tree height is the only factor with a negative parameter estimate, suggesting that nests in shorter trees are more likely to succeed. All other factors were positively associated with nest success.
Chapter 6
Discussion

Vireo Abundance and Density

Our sites seem to host Gray Vireos at abundances comparable to many other highly active sites. Piños Canyon hosts 1.37 minimum territories per square kilometer (territories/km²), Bootleg Canyon has 1.48 territories/km², and Sepultura Flats holds 2.61 territories/km². Three other studies measured vireo abundance in terms of territory density. Delong and Williams III (2006) report densities of 0.5, 0.75, 1.75 for three sites also within Socorro county, along with 1.75 and 2.25 territories/km² for two sites in Santa Fe and Bernalillo counties, respectively. Other studies report 1.5 territories/km² in the Providence Mountains of California, and 1.92 and 2.07 for two consecutive years at the Colorado National Monument (Johnson et al. 1948, Giroir 2001).

A handful of studies have estimated density of individual vireos using point counts and distance sampling without playback. They arrived at estimates of 6.4 birds/km² for pinyon-juniper woodlands across the Colorado Plateau, 5.6 birds/km² in pinyon-juniper woodlands in Northwest New Mexico, and 4 birds/km² found in Deep Canyon of California’s Santa Rosa Mountains (Weathers 1983, Schlossberg 2006). Considering that almost every territory contains a breeding pair, along with zero to five young fledging throughout the breeding season, I multiplied minimum number of territories by two to create the approximate minimum individual bird density; these values are 2.74, 2.96, and 5.22 birds/km² for Piños Canyon, Bootleg Canyon,
and Sepultura Flats respectively. Though our use of audio playback does increase the detection rate, my density estimates are minimum values that do not account for detectability as is done when using distance sampling.

Though the observed densities for Piños and Bootleg Canyons are lower than most other reported densities, they are most similar to the three sites in Socorro County, New Mexico (the location of the Sevilleta NWR) reported by Delong and Williams III (2006). This area in central New Mexico represents the northernmost reaches of the Chihuahuan Desert Biome, and it is possible that the arid climate and rugged, mountainous terrain limits potential nest sites and requires vireos to forage over larger territories. These factors may both depress the territory density in mountainous sites of central New Mexico.

**Nest Detection**

Considering that we did not detect a six of nineteen nests at any of the nearest survey points, one may conclude that our audio playback survey methodology is not ideal. The distribution of distance from detection point (Figure 8) suggests that the grid size is not the cause of the problem. Given a 300-meter grid of survey points, no nest could be more than ~212 meters from the nearest survey point, unless it was located peripheral to the surveyed regions. We regularly detected nests within a 212-meter radius, and we detected two nests from over 350 meters away. This is much further than the 100-meter radius of reliable playback response reported by DeLong and Williams (2006). Of the four nests located more than 225 meters from their detection point, three were not detected at a closer survey point and one was located
peripheral to the surveyed region. I have also determined that there is no significant difference in average distance to closest survey point between nests that were and were not detected on the survey. This suggests that these nests were not missed because they happened to be further from survey points, and further confirms that our grid size of 300 meters is appropriate to effectively detect vireo nests.

One could improve this survey method by increasing survey frequency; one should visit each survey point more than once per breeding season. Multiple researchers identified all occupied territories by the end of May, then revisited each as frequently as twice a week, or at least twice a month, until mid-July (Hawks Aloft 2006, Hawks Aloft 2007, Hargrove and Unitt 2014). In New Mexico, Delong and Williams III (2006) report early, median, and late dates for initiation of incubation as May 5, May 27, and July 5. Our surveys and nest searching began on May 29, 2014, after the median date. Our audio playback surveys were not completed until July 26, so many areas within the study sites were not visited at all until after the peak of the breeding season. Once an area was surveyed, we usually returned for either nest monitoring or vegetation monitoring. However, we did not visit many areas for any reason until June or July, so these areas may have contained nests that were completed before we had a chance to survey. There is no clearer evidence than Piños Canyon nest one, which was well into the egg incubation stage when we found it on the first day of fieldwork.

The topography also affected our ability to detect nests. In Piños Canyon, we found only two nests, and encountered the other three incidentally. Though two of those incidental encounters were out of the survey bounds, we simply failed to detect the other one on the survey. In Bootleg Canyon, we initially detected two nests on the survey, but difficulties in searching forced us to revisit them both. In Sepultura Flats, we detected nine of twelve nests on the survey
and found seven of those on the first try. Of two incidental encounters, one was out of bounds, leaving only one nest in Sepultura Flats that we failed to detect on the survey. In this flat area, it was much easier to identify the source of vireo songs heard, and much easier to quickly traverse the terrain. The steep canyons deflected the songs of the Gray Vireo, making their source harder to locate.

There is limited evidence that the stage of nesting affects the male’s responsiveness to the audiolure. Of thirteen nests detected on the survey, all but one were in the egg-incubation stage or earlier. However, two of the six nests found by other means were in the fledgling stage, and three under construction. During egg incubation, the male vireo may have more time to defend the territory from intruders and keep lookout for Brown-headed Cowbirds. During the nest construction and nestling stages, parents are very active collecting nest materials or food.

**Nest Placement**

The body of literature on Gray Vireo nest sites consistently suggests a preference for juniper trees and greater shrub density, consistent with our observations that Gray Vireos prefer nest sites with greater canopy cover and juniper abundance. However, no previous study also can show that vireo nest trees are taller and wider than the average available tree. Frei (2008) reports that Gray Vireos prefer to nest in juniper trees of intermediate age. The average nest tree observed was 3.78 meters tall; this is larger than previously reported mean nest tree heights of 3.5 meters in central New Mexico or 1.8 meters in Southern California (Frei 2008, Hargrove & Unitt 2014). The average nest height of 2.38 meters is higher than previously reported numbers.
of 2.06 meters or 2.29 meters, and this is probably because nest trees were larger than many previous studies (Hawks Aloft 2007, Frei 2008).

Though there is no evidence to support the hypothesis that Gray Vireos prefer more sparsely foliated nest trees, sparseness is positively associated with nest success. Consistent with this premise, the average sparseness for successful nests (4.9) was much less than that of predated nests (6.5), excluding nests that failed due to parasitism or other reasons. Unfortunately, these sample size are too small for statistical analyses. This still suggests that vireos benefit from nesting in more sparsely foliated trees, as they may be able to spot approaching predators and defend their nest. I am dubious that our method of estimating the percent of a one-meter square board visible through the foliage is the most accurate way to quantify sparseness. Trees that appeared sparser overall often did not have a higher percent of the board visible, and instead the girth of the canopy and placement of main trunks seemed more influential on the reading.

Perhaps we could better detect this trend by pairing nest trees with random trees of very similar sizes, and adapting a new method of measuring sparseness, such as with a canopy densitometer. In addition to sparser trees, Gray Vireos often selected nest sites near tall dead branches that provided singing perches. This would be an interesting variable to document in future studies.

The orientation of nests within the tree and the orientation of the slope beneath nest trees were not statistically significant, but given a sample size of fifteen this analysis most likely statistical lacked power. Our data in no way support Hargrove and Unitt’s (2014) data suggesting Gray Vireos tend to nest on South-facing slopes in the southern part of the tree, but neither support nor dispute Barlow et al.’s (1999) claim that vireos prefer to nest in west- or north-facing branches. We observed a complete lack of nests on south-facing slopes; this is consistent with the expectation that Gray Vireos place their nests to avoid excessive direct sunlight and
associated heat stress (Walsberg 1981). There is also a distinct lack of nests on the east side of trees. Bergin (1991) reports that some birds in open habitats place their nests on the leeward side of trees to avoid excessive wind. These winds can cause heat loss, but may also escalate during severe weather and cause the physical destruction of a nest (Bergin 1991). Though wind direction on the Sevilleta NWR is quite variable, southwest winds prevail, so it is unlikely that wind affects the placement of Vireo nests (K. Granillo, personal communication). Hargrove and Unitt (2014) suggest that vireos may simply be selecting the downslope side of the tree, but of fourteen nests placed on slopes, only four nests were within 45° of directly downslope.

Previous studies have noted the Gray Vireo’s affinity for nesting along arroyos. Giroir (2001) reported that “of the Gray Vireo territories, 60% were in canyon bottoms and 40% were on plateau tops.” This is potentially a reflection of their altitudinal preferences, as Gray Vireos are infrequently found at sites above 2000 meters above sea level and their abundance is negatively correlated with elevation (Hargrove and Unitt 2014, Schlossberg 2006). The arroyos of Piños and Bootleg Canyon bottom out at less than 1800 m, while the surrounding slopes rise to peaks as high as 2286 meters. Meanwhile, almost all of Sepultura flats lies below 1900 meters, explaining the lack of preference for low elevation nest sites. This closely matches the previously reported band of vireo occupancy between 1800 and 2000 meters, which may relate to tracking ideal juniper growing conditions (Schlossberg 2006, Frei 2008) However, since these arroyos were our preferred footpaths when traversing the canyon sites throughout the field season, this sample bias may have exaggerated the pattern.
Nest Survival

Rates of nest success and cowbird parasitism varied considerably by site. As previously stated, Gray Vireos were noticeably less abundant in Piños and Bootleg Canyon. There were only seven nests distributed across 5.8 square kilometers of canyons surveyed, but only two of these nests failed to fledge Gray Vireos. Sepultura Flats had much greater vireo abundance, but lower nest success. Of twelve nests distributed across 11.2 square kilometers of plateau, only two successfully fledged Gray vireos, with one other nest fledging a Brown-headed Cowbird. Sample sizes are too small for a statistical analysis of differences in nest survival by site. Predation rates were relatively stable across all sites: 28% in the canyon sites and 33% in Sepultura Flats.

Instead, brood parasitism by the Brown-headed Cowbird drove the difference in survival by site, as all parasitism events occurred in Sepultura Flats. This directly contradicts the hypothesis that Piños Canyon would have the highest parasitism rate due to its proximity to a cattle ranch. Since this ranch is only eleven kilometers from Sepultura flats, it is within range for a female Brown-headed Cowbird to commute daily (Curson et al. 2003). Female cowbirds perform this commute to take advantage of the dense population of vireos and other nesting songbirds; Sepultura Flats had roughly twice as many vireos in terms of minimum territory density, playback response rate, and number of nests. This depends on the assumption that cowbirds are exclusively feeding near cattle, when they are not completely dependent on grazing mammals for foraging grounds (Lowther 1993). Cowbirds are known to prefer open grassland habitats and woody edges for both foraging and breeding, so they may inhabit open areas across the Sevilleta NWR but avoid canyons due to the unfamiliar terrain (Lowther 1993).

It appears in the Sevilleta NWR that the canyons may be a source population, where relatively few vireos experience high nest success. There are many miles of similar habitat in the
Sevilleta NWR that we were unable to survey. Sepultura Flats, however, is potentially a population sink, where breeding Gray Vireos occur at higher densities but experience very low nest success. Additional research is needed to determine if this pattern occurs at other sites and to elucidate what drives the relationship between Gray Vireo nest success, territory density, and topography.

Few other studies calculate daily survival rate of Gray Vireos by Mayfield’s (1972) method. An unpublished study in New Mexico reported a 43.6% probability of nest success, much greater than the 23% chance of surviving to fledging that we observed (Hargrove and Unitt 2014). Hargrove and Unitt (2014) suggest that their observed daily survival rate of 92% is insufficient to sustain the population, but do not justify this claim. Our survival rate of 95.55% is very similar, and this suggests that the Gray Vireo population on the Sevilleta NWR is in decline or sustained by immigration. Two thirds of predation events observed by Hargrove and Unitt (2014) were performed by Western Scrub-Jays, which are abundant at the Sevilleta NWR and likely responsible for several of our predation events. Other possible nest predators of the Sevilleta NWR include a variety of non-venomous snakes, Northern Mockingbird, Pinyon Jay, Loggerhead Shrike, Scott’s Oriole, and Bewick’s Wren (Barlow et al. 1999).

The positive association between the count of junipers within ten meters and likelihood of nest success indicates that denser juniper stands provide shelter for nests, making them harder to find for predators and Brown-headed Cowbirds. Nest tree height is the only factor with a negative parameter estimate, suggesting that nests in shorter trees are more likely to succeed. Considering Gray Vireos selected trees larger than average, this result suggests some mismatch between the preferred and ideal nest sites selected by vireos. However, canopy diameter and sparseness were positively associated with nest success. The apparent significance of our data on
sparseness is difficult to explain, since it was not a significant factor in nest placement. Canopy diameter and the count of junipers within ten meters both strongly influence nest placement, and they are both also associated with greater likelihood of nest success. I am left to conclude that a Gray Vireo’s ideal nest site is in an old, outwardly sprawling juniper tree surrounded by many other junipers of various sizes. Having both large, old junipers to nest in and many small younger junipers to provide forage and cover is important for Gray Vireo populations (Hawks Aloft 2007). If looking to provide Gray Vireo nesting habitat, managers should consider ways to maintain a healthy juniper population, through wildfire suppression or selective harvesting practices (Hawks Aloft 2007).

**Conclusion**

We found that Gray Vireos are present on the Sevilleta NWR at abundances similar to other sites within central New Mexico but lower than populations in other areas. Gray Vireos were more densely populated in Sepultura Flats, where they experienced lower nest success because of brood parasitism by the Brown-headed Cowbird. Gray Vireos did not experience cowbird parasitism when nests were distributed more sparsely along the bottoms of Piños and Bootleg Canyons, but predation rates were similar. This directly contradicts our expectation that cowbird parasitism would be more frequent at sites closer to cattle ranching operations, and suggests that female cowbirds will make long daily commutes to take advantage of dense populations of nesting songbirds.

We found that Gray Vireo nests were placed in large, sparsely-foliated, sprawling juniper trees surrounded by dense stands of juniper, and that these characteristics were associated with
greater nest success. Nesting Gray Vireos must achieve a balance between visibility while sitting on the nest and concealment of the nest from predators. Habitat managers seeking to benefit Gray Vireos should begin by focusing on canyon sites, which appear to offer Gray Vireos greater protection from brood parasitism by the Brown-headed Cowbird. Within these sites, they should pursue habitat management practices that increase the overall density of juniper shrubs and enhance the preservation of the largest, oldest juniper trees.
Appendix A

List of all Gray Vireo nests by site and detection method

Of the six nests that were not initially detected on the audio-playback survey, five were found either by incidental encounter while travelling through the sample region, and one was found because it was the second nesting attempt of a previously detected pair. Of thirteen nests detected on the survey, nine nests were located on the same day as initial detection, while four had to be revisited at a later date to locate the nest. Of four out of bounds nests, three were detected on the survey and one was encountered incidentally. Three nests were found during construction, four during egg-laying, nine during egg incubation, two were found with partially-feathered nestlings, and one with fully-feathered nestlings. * Indicates nests where, upon initial detection, contents could not be viewed due to parental presence, and stage upon detection was inferred from later visits.

<table>
<thead>
<tr>
<th>Site</th>
<th>Nest Number</th>
<th>Detection method</th>
<th>In bounds?</th>
<th>Nesting Stage, when found</th>
<th>Date Found</th>
</tr>
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<tbody>
<tr>
<td>Piños Canyon</td>
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<td>2</td>
<td>survey</td>
<td>no</td>
<td>Egg incubation*</td>
<td>June 2</td>
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<tr>
<td>Piños Canyon</td>
<td>3</td>
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<td>no</td>
<td>Nest construction</td>
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<td>Egg-laying</td>
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Appendix B

Table of Average Ten-meter Radius Shrub Counts for Nest and Random Points in All Sites

For all woody vegetation, the average number of plants at least 50 centimeters tall within a 10 meter radius of the vegetation for all sites.

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<th>Random</th>
<th>Nest</th>
<th>Random</th>
<th>Nest</th>
<th>Random</th>
<th>Nest</th>
<th>Random</th>
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<th>Random</th>
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<td>2.00</td>
<td>6.60</td>
<td>1.20</td>
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<tr>
<td></td>
<td>Latin</td>
<td>Cylindropuntia</td>
<td>Opuntia</td>
<td>Yucca</td>
<td>Ribes</td>
<td>Fallugia</td>
<td>Berberis</td>
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</table>
Appendix C

Table of Average Ground Cover for Nest and Random Points in All Sites

For all nest and random vegetation points in all sites, the average percent of ground covered by all of the following categories.

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<tr>
<th>Site</th>
<th>Point</th>
<th>Bare ground</th>
<th>Grass</th>
<th>Forb</th>
<th>Shrub</th>
<th>Succulent</th>
<th>Yucca</th>
<th>Dead Forb</th>
<th>Dead Succulent</th>
<th>Tree</th>
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<tr>
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<td>86.55%</td>
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<td>87.25%</td>
<td>8.50%</td>
<td>1.03%</td>
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Appendix D

Output for General Linear Model

---

**Generalized Linear Model Fit**

- *Response:* Nest Success
- *Modeling P(Nest Success = 0)*
- *Distribution:* Binomial
- *Link:* Logit
- *Estimation Method:* Maximum Likelihood
- *Observations (or Sum Wgts) = 19*

**Whole Model Test**

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<thead>
<tr>
<th>Source</th>
<th>-LogLikelihood</th>
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<td>Reduced</td>
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</tbody>
</table>

**Goodness Of Fit Statistic**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>ChiSquare</th>
<th>DF</th>
<th>Prob&gt;ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>8.6158</td>
<td>14</td>
<td>0.8549</td>
</tr>
<tr>
<td>Deviance</td>
<td>9.7573</td>
<td>14</td>
<td>0.7797</td>
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</tbody>
</table>

**AIC**

24.3726

**Convergence Failure**

Maximum Iterations Exceeded

Norm(Gradient) 4.01659202

Evidence of perfect fit for some data points detected, and the Hessian matrix suggests quasi-complete separation of the data.

Fit and results are of questionable value. Proceed with caution.

Try running the model again using the bias-adjusted estimates.

**Effect Summary**

<table>
<thead>
<tr>
<th>Source</th>
<th>LogWorth</th>
<th>PValue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height</td>
<td>2.587</td>
<td>0.00259</td>
</tr>
<tr>
<td>Juniper</td>
<td>2.412</td>
<td>0.00387</td>
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<tr>
<td>Sparserness</td>
<td>1.915</td>
<td>0.01215</td>
</tr>
<tr>
<td>Canopy</td>
<td>1.549</td>
<td>0.02827</td>
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</table>

**Effect Tests**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>ChiSquare</th>
<th>Prob&gt;ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height</td>
<td>1</td>
<td>9.0777381</td>
<td>0.0026</td>
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<tr>
<td>Canopy</td>
<td>1</td>
<td>4.8113905</td>
<td>0.0283</td>
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<tr>
<td>Juniper</td>
<td>1</td>
<td>8.3430521</td>
<td>0.0039</td>
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<tr>
<td>Sparserness</td>
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<td>6.2890538</td>
<td>0.0121</td>
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**Parameter Estimates**

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate</th>
<th>Std Error</th>
<th>ChiSquare</th>
<th>Prob&gt;ChiSq</th>
<th>Lower CL</th>
<th>Upper CL</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>19.799843</td>
<td>12.987952</td>
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<tr>
<td>Tree Height</td>
<td>-0.105583</td>
<td>0.0692806</td>
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<tr>
<td>Canopy</td>
<td>0.0226259</td>
<td>0.0168199</td>
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<tr>
<td>Juniper</td>
<td>1.42002</td>
<td>0.9300045</td>
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<tr>
<td>Sparserness</td>
<td>0.5257802</td>
<td>0.3437939</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


New Mexico Department of Game and Fish (NMDGF). 2006. Threatened and endangered species of New Mexico, 2006 biennial review. New Mexico Department of Game and Fish, Santa Fe, New Mexico.


Education: The Pennsylvania State University
Major: Wildlife and Fisheries Science
Minor: Biology
With Honors

Thesis Title: Surveying and Nest Monitoring of the Gray Vireo (*Vireo vicinior*) in the Sevilleta NWR
Thesis Supervisor: Margaret C. Brittingham, Ph.D.

Work Experience:

January 2015 to Present
Trip Guide
Plan and guide a variety of outdoor excursions for Penn State students including backpacking, hiking, canoeing, climbing, and more.
Penn State Adventure Recreation
Danny Williams, Program Coordinator

May to August 2015
Field Technician for Doctoral Study
Worked outdoors daily in grasslands of Iowa and Missouri, performed territory mapping and behavioral nest searching of Dickcissels along with avian transect surveys, vegetation sampling, and arthropod sampling.
Iowa State University
Jaime J. Coon, Doctoral Fellow and Scott B. Nelson, Doctoral Fellow

May to August 2014
Sevilleta LTER Research Experience for Undergraduates Program
Conducted audio playback surveys, nest searching, and nest monitoring of the Gray Vireo along with vegetation sampling and avian transect surveys in association with this publication.
University of New Mexico and the US Fish and Wildlife Service
Kathy Granillo, Refuge Manager

May to July 2013
Field Assistant for Doctoral Study
Conducted avian point counts and sampled for emergent insects and aquatic invertebrates while working outdoors daily in the frequently adverse conditions of the Izembek NWR in Cold Bay, Alaska.
The Pennsylvania State University and the US Fish and Wildlife Service
Didem Ikis, PhD. Candidate

Awards:

- Theloa F. Thevaos Honors Scholarship (2014-Present)
- Robert T. Billin Memorial Scholarship (2014-Present)
- Schreyer Honors College Academic Excellence Scholarship (2012-Present)
- Gerard L. Bayles Memorial Scholarship (2012-Present)
- Oswald Scholarship (2013-2014)
- Irvin C. Reigner Endowment Scholarship (2013-2014)
- R. F. Russell Memorial Scholarship (2012-2013)
- Wilbur W. Ward Memorial Scholarship (2012-2013)

Presentations:

Surveying and Nest Monitoring of the Gray Vireo (*Vireo viciinior*) in the Sevilleta NWR. Student Research-in-Progress Poster Session
The Wildlife Society 21st Annual Conference
October 2014, Pittsburgh PA

Community Service Involvement:

- September 2012 to Present
  Bird Bander
  Working alongside a diverse team of University and community volunteers, we band and process a variety of local songbirds while also providing educational interpretation to school groups and other visitors
  The Arboretum at Penn State

- October to November of 2009 to 2011 and 2015
  Northern Saw-Whet Owl banding assistant
  Alongside a diverse crew of volunteers, we capture, band, and process Northern Saw-Whet Owls and provide educational interpretation to a variety of visitors.
  The Ned Smith Center or Nature and Art