COMPARATIVE DEMOGRAPHY AND BEHAVIORAL COMPARISON OF THE BLUE-GRAY GNATCATCHER (Polioptila cerulea) AND THE CERULEAN WARBLER (Setophaga cerulea)

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science, with a major in Biological Sciences.

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Christopher M. Rogers Committee Chair

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DEDICATION

This work is dedicated to Maria Martino, Administrative Assistant, Advisor, Masterful Coordinator and Super Hero.

Each species is a *masterpiece* of evolution, offering a vast source of useful scientific knowledge.
-E.O. Wilson

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ABSTRACT

The Neotropical-migratory Cerulean Warbler (Setophaga cerulea) is one of North America's strongest declining songbirds. Alterations of breeding ground habitat are a potential primary cause of decline, versus wintering and migration habitat alterations being a primary factor driving population decline. Evaluating the influence of these hypotheses on population trends could reallocate the limited resources of conservation efforts. For the Cerulean, two studies show that annual adult migration survival reflects the range expected for non-declining species (40-60% winter/migration survival), whereas annual reproductive output is very low throughout its breeding range. This suggests a strong role for events on the breeding grounds in its population decline. As an independent test of this qualitative model, annual survival and reproduction were measured in a non-declining Blue-gray Gnatcatcher (Polioptila cerulea). Annual survival of the Blue-gray Gnatcatcher was predicted to be similar to that of the Cerulean, but reproduction of the Gnatcatcher to be significantly higher. Results from two field seasons (April-August 2011 and 2012) of Blue-gray gnatcatcher data were rigorously compared to six field seasons of data on the Cerulean warbler collected by Christopher M. Rogers (May-June 2003-2008). All statistical measures that were assessed regarding were contrary to original predictions. Cerulean warblers had higher nest success, equal nest output per successful nest, a higher number of female fledglings per female within the study populations and a higher rate of survival over wintering and migration. It is speculated that there was a great influence of drought on the two field seasons of Blue-gray gnatcatcher data collection.

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CHAPTER 1

INTRODUCTION

The Cerulean Warbler (*Setophaga cerulea*), CERW, from the Family *Parulidae* (New World warblers), is one of the most rapidly declining Neotropical-migratory songbirds in the U.S.; 3.04-4.0% per year since 1966 [1, 2]. Conservation biologists are attempting to understand the factors bringing about the sharp decline of this beautiful songbird that is listed as a threatened species in the state of Michigan [3] and as a vulnerable species by the International Union for Conservation of Nature [4]. A recent model of five geographically separate populations of Cerulean warblers based on within season sampling of nest survival and fledgling success found all five populations to be sinks, where annual reproduction was consistently less than apparent annual adult mortality [5]. In this study, we focused on discerning between the influences of two decline hypotheses. One is the breeding grounds hypothesis, and the other is the migration hypothesis.

The breeding grounds hypothesis posits that events on the breeding grounds cause annual reproduction to be less than annual survival. A possible cause for decline on the breeding grounds is lack of appropriate heterogeneity in mature growth cover [6]. Loss of floodplain forests in the United States has resulted in limited nesting habitat for an already stressed population, and the resulting fragmentation and isolation of large tracts of mature deciduous species have isolated the remaining habitat [7]. Increasing the number of large forest tracts with high percentage of forest cover could greatly improve nest success, more so than managing to reduce local edges and eliminating small openings within forest tracts [8].

A second hypothesis, the migration hypothesis, presumes that conditions along the migratory path, such as, fragmentation and reduction in quality of habitat used during migration drive annual survival to be less than annual reproduction. An Ontario study performed from 1994-2002 suggests that adult mortality impacts population growth more significantly than seasonal fecundity and cites that most adult mortality occurs during migration and on the wintering grounds [9]. Recent studies of at least three parulids show migration to be the greatest contributing time-period of adult mortality, whereas the stationary seasons hold the least risk for adult mortality [10]. A great deal of funds over the last decade has been focused on management plans and building higher carrying capacities of lands in Latin America, rather than on research and monitoring. However, we do not have the knowledge of the regional ecology to manage most species in most regions effectively [11].

With this study it is our hope to bring scientific attention back to ground-truthing population models and theories by completing season long fecundity research and monitoring of the Blue-Gray gnatcatcher (Polioptila cerulea) or BGGN on their breeding grounds and comparing the demographic variables to those of our declining species the Cerulean warbler (Setophaga cerulea) or CERW. This research gives a novel look into what might be driving the steep decline of the CERW. With limited conservation resources available, comparing and contrasting survivorship and fecundity of our declining species (CERW) to that of a non-declining species (BGGN) may elucidate where conservation efforts will have the greatest positive impact towards population stability.

Due to research location and similarity to the CERW, the non-declining species selected for comparison was the Blue-Gray Gnatcatcher (Polioptila cerulea), BGGN, from the Family Polioptilidae (Gnatcatchers). The Blue-Gray Gnatcatcher is a unique Neotropical migratory songbird that is increasing in population, as well as, expanding its range over the last two decades[12, 13]. The Blue-gray Gnatcatcher is from the same Order, Passeriformes, as is the

CERW and has many shared characteristics such as, but not limited to, body size, body shape and coloration. Both of the studied passerines are insectivorous, and both species have cup nests of similar size and shape [12, 14, 15]. CERW and BGGN are also long distance migrants with similar preferred habitat characteristics. If in our comparison between our decliner CERW and our non-decliner BGGN we discover the migratory/ wintering survivorship is similar, then we can advocate the idea that the decline of the CERW results primarily from events on the breeding grounds. With adequate comparison of seasonal fecundity and inter-seasonal survivorship, we can draw sound scientific conclusions that will be of benefit to conservation efforts and justify more impetus on protecting the breeding grounds right here in the United States.

A secondary comparison in life history traits and behavioral traits (see Table 1) was done to uncover the differences between species that potentially explain the propensity or vulnerability towards certain population trends: BGGN to not decline and CERW populations to steeply decline. Traits such as feeding guild can influence life-span by impacting safety from predators and food availability. A demographic analysis through mark-resight and nest monitoring paired with a behavioral analysis will help determine which traits dictate population trajectory and whether they follow predictive trends [16]. Migrants that are able to readily modify their breeding phenology with longer laying periods and advanced arrival dates are more likely to have a non-declining population; flexibility in habitat and diet also buffer against decline [17]. A comparison of traits potentially allows us to flag certain risk factors that make populations more susceptible or resilient against decline such as cooperation, territoriality, and parental care.

CHAPTER 2

RESEARCH DESIGN AND METHODOLOGY

The WSU Biological Field Station, Ninnescah Reserve consists of 133 hectares located along the Ninnescah River in southwestern Sedgwick County, Kansas (37°32'N 97°41'W). The site includes remnants of unplowed mid-latitude grasslands, restored midgrass prairie, and 6.9 hectares of riparian woodland that were the study location for the Blue-Gray gnatcatcher. The Ninnescah Reserve's riparian habitat is dominated by cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), box elder (*Acer negundo*) and Siberian elm (*Ulmus pumila*) [18]. The Ninnescah Reserve provides adequate habitat to accommodate approximately 18-20 breeding pairs per year of Blue-gray Gnatcatchers, making it a prime research site for this study. Our materials and methods followed the established protocols of the Cerulean Warbler studies completed in Michigan [19, 20]. We used black, six meter, four shelf, 30mm mesh mist nets to capture a total of 18 BGGN. Each of the 5-7g birds were delicately disentangled from the mesh netting and banded for future resighting identification. A light-weight aluminum band with a unique identification number issued by the U.S. Fish and Wildlife Services was placed on one leg. A single color band or combination of two color bands was placed on the opposite leg. The smallest commercially available color band size, XF from A.C. Hughes, is too large for the Blue-gray gnatcatcher's leg. Therefore, to insure a proper fit we trimmed the bands with an X-Acto knife, shaving approximately one millimeter from the split of the band. The color bands were smoothed with an emory board to ensure there were no jagged edges. During banding acetone was applied to the split to ensure proper bonding of the modified band [21]. With the unique combination of which leg the aluminum band had been placed on, as well as, the color combinations used, we were then able to correctly re-identify each banded BGGN and establish territory maps and boundaries between territories throughout the breeding season. See Appendix C for complete list of the color codes used and the coordinates at which every BGGN was banded. To get the Blue-gray gnatcatchers into the nets we used a targeted banding technique, playing an edited version (narrator voice removed) of Blue-gray gnatcatcher song and call [22]. An MP3 player was buried under leaf litter directly below the net with the song/call set on loop for 15 minutes. A BGGN model made from Sculpey II Modeling clay (see Fig. 1) was set in or near the net. A vast combination of models and placements of models were used: female model alone, male model alone, and male and female model placed close to net. Several models were adapted to have nesting material near the leg base and were perched on a ¼" diameter dowel rod, making it possible to manipulate the model from afar using a pull string attached to the dowel rod. Nets were not placed within 20 meters of a known nest to reduce the possibility of nest abandonment. Attempts to band within the same territory were limited to one hour per week. Resightings of banded birds within field season were also used to attribute nest ownership. Territories were extensively searched throughout the breeding season every 3-4 days (0.25-2.0 hr/visit) following a grid pattern of transects. I carefully avoided following established deer paths and taking familiar routes to nests so as to avoid predictability of my behavior, hoping to minimize my influence on BGGN behavior and minimize attraction of predators to the nesting sites. The presence of active nests or newly fledged young was detected mostly through auditory cues with profuse adult defense calls or loudly begging fledges. On rare occasions of luck and diligence nests of silent incubators were found within a territory. Territories were observed from 0600-1200, with occasional

Figure 1 Sculpey Model made by Anna Balthazar 2012

evening visits from 1600-2030, to maximize observation times that avoided the hottest part of the day when BGGN activity was undetectable. All nests were monitored every 2-4 days during nest building and incubation, and every two days as fledging neared. A successful nest is a nest that fledged one or more BGGN young; failed nests fledge no BGGN young. Due to lack of experience in identifying fledgling begging calls to species all fledgling calls were followed and identified to species [19]. There was a great amount of similarity to my novice ears in fledgling calls between the study species (BGGN) and those of Tufted titmice (Baeolophus bicolor) and Eastern kingbirds (Tyrannus tyrannus). By tracking down the source of all begging calls throughout all territories and identifying to them all to species we minimized the potential for missing any BGGN young in our fledgling count data. There is a bias towards detecting the more boisterous fledglings using this system of monitoring though. A silent BGGN is nearly undetectable hidden high within the foliage.

Due to timeliness in the field and desiring to minimize human influence within each territory, data was taken down quickly on notecards and later analyzed against a nesting cycle timeline [23] developed from several sources predicting the days necessary for BGGN stages from nest building to successful fledge [12]. The initial nest-building attempt can take as long as two weeks until completion, whereas re-nesting attempts can produce a finished and lined nest in as little as 3 calendar days [24] [and personal field observations].

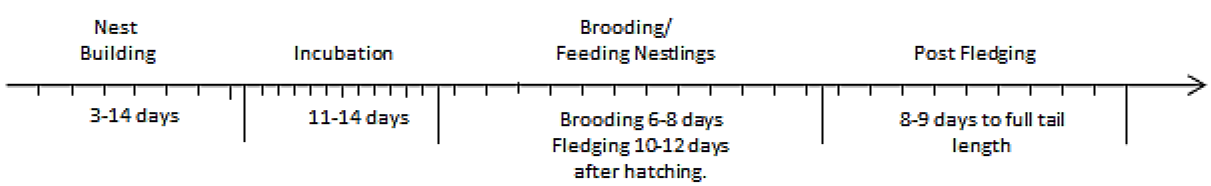

FIGURE 2.1 BGGN NESTING CYCLE TIMELINE [12, 25]

The timeline was then evaluated against established criteria (see Table 2) for determining nesting outcome, also referred to as nest fate. This formal evaluation of each nest's data and timeline allowed for increased accuracy and objectivity in evaluating nesting outcome. In most instances the nest fate was clear due to the impossibility of fledging young in between observation dates, though the cause of nest failure was often difficult to ascertain.

Table 2.1 Nest Fate Criteria. The outcome of nests was considered known if they met one or more of the following criteria. The fates of nests that did not meet any of the noted criteria were determined to be unknown [23].

Evidence for Successful Nest (a nest producing one or more BGGN fledgling).	Evidence for Nest Failure
1. Fledglings seen or heard outside of nest.	1. Nest Damaged or inactive longer than 45 minutes.
2. Chicks bulging out of nest or stretching wings at last visit.	2. Contents of nest gone during egg laying, incubation, or early nestling stages, before fledging is possible.

CHAPTER 3

RESULTS

Collecting annual survival data through mark-resight methods and fecundity data through season-long pair monitoring, we were able to evaluate the possible divergence in demography. This analysis paired with behavioral and life history traits emphasized areas to concentrate our conservation efforts though our collected data on fecundity and survivorship is limited currently to two years of field research. Overall, we were able to band a total of 18 Blue-gray gnatcatchers in two full field seasons. Two were excluded from data interpretation, because the area in which they were banded was not able to be searched adequately the following field season due to time constraints and labor investment limitations. Inter-seasonal Survival for BGGN was 18% with an apparent 82% mortality over winter and migration to and from the nesting grounds. It is prudent to mention that there is no way to distinguish between mortality and dispersal at this point in the study. With one more field season of data, we are able to then calculate an error rate in re-sighting data. This will assign a more definitive percentage to survival, and account for the number of birds that are still alive, but never re-sighted due to stealth, as well as the birds that choose to disperse. The cerulean data had a much higher rate of survival settling at 54%. Due to the lack of large enough sample sizes for BGGN the difference in survival was not statistically significant within a 95% confidence, again highlighting the need for more data to be collected. However, the difference is significant at 90% confidence. Table 3.1 summarizes the results below. The mean number of fledglings per successful nest was statistically equal for BGGN (2.44) that in the CERW data (2.33). The percentage of nests that succeeded was significantly higher in the declining CERW population at 46.15% of nests fledgling one or more CERW young. In our non-declining model species nest success was 18.75%. The number of female fledglings per female, an important component of demographic comparison as it measures the overall ability of reproductive females to replace themselves within a population, was significantly higher for CERW, .61 female fledglings per female per year versus .32 female fledglings per female per year BGGN (Z= -2.17 p= 0.015).

Another interesting comparison is the number of nesting attempts per BGGN pair versus that of the CERW. BGGN nesting attempts significantly outnumbered the number of nesting attempts completed by CERW pairs (Z=2.823 p-value =.0024) using the Wilcoxon Rank Sum Test. BGGN were incredibly persistent re-nesters. The maximum number of BGGN nesting attempts that were observed within a single breeding season was 5 nests in a single territory. The maximum number of CERW re-nesting attempts was three, in all six field seasons of observations. Thus, suggesting a high nest success rate in CERW due to high investment of effort for each nest.

Table 3.1: Demographic Comparison of BGGN and CERW
ǂ latitude independent measures of fecundity ♦ influence of latitude unknown

	BGGN	CERW	Statistical Analysis
Annual Survival♦	n=16 0.18	n=102 0.54 [20]	χ^2 =3.240 Crit. Value=3.841
Mean # Fledglings/Successful Nestǂ	n = 9 2.44	n = 45 2.33	Wilcoxon Rank Sum Test Z= 0.264 p= 0.396
% Nest Successǂ	n=48 18.75	n=104 46.15	χ^2 =10.25 Crit. Value=3.841
# Female Fledges/ Female/ Year♦	n= 34 .32	n=88 .61	Wilcoxon Rank Sum Test Z= -2.17 p= 0.015

Table 3.2: Behavioral Comparison of Blue-Gray Gnatcatcher to the Cerulean Warbler
ǂlatitude independent characteristics *latitude influenced characteristics

	Blue-Gray Gnatcatcher (*Polioptila cerulea*)	**Cerulean Warbler** (*Setophaga cerulea*)
Feeding Niche	Insectivore [26]ǂ	Insectivore [14] ǂ
Prey Capture	Hovering, hawking, and gleaning, all heights of tree, trunk and ground cover. [12]ǂ	Almost exclusively gleaning within crown of tree. [Rogers unpublished observations]. ǂ
Nest building	Males and females mutually build nests as a cooperative effort.[12] ǂ	Female exclusively construct nests.[14] ǂ
Cooperative Brooding and Incubation	24% of incubation and brooding was done by males (n=46). [unpublished observations][27] ǂ	No male assistance with incubation, or brooding.[5] ǂ
Nestling Care	Both male and female feed nestlings and defend nest from predation. [24]ǂ	Both male and female feed nestlings[19] . ǂ
Double Brooding	Attempted regularly, highest rates of double brooding at southern regions of breeding range.[12] *	Rarely Attempted. [28]ǂ
Nest Height	9.9±5mǂ Calculated from observations See Appendix D	18-20m ± 2 [summarized from [19]].ǂ
Territorial Behavior	Males singing, some chasing of competitor mated pairs occurs [unpublished observations]. ǂ	Males extremely aggressive. Visible conflicts between intraspecific competitors. Females will also attack competitor females [19]. ǂ
Length of Breeding Season	Late March to Late August [unpublished observations].*	Mid-May to Late June [28].*

CHAPTER 4

DISCUSSION

The Summer of 2011 was a record breaking drought year for the mid-western United States from Kansas down to Texas. The Summer of 2012 was also ridden by high temperatures and extremely low rainfall [29]. There are immediate responses to drought such as increased temperature resulting in higher metabolic costs to keeping cool and decreased resources for water and food resulting in poor foraging efficiency. These effects may demand that parents have longer foraging bouts and thus spend less time defending the nest from predators and underfed nestlings would be noisier, overall increasing the likelihood of predation [30].

As observations were made for a study on Blue-gray Gnatcatcher reproduction, there was a distinct lack of activity as early as 9am observed for the 2011 field season, whereas there was a drop in activity at 11am the previous year. This lack of ability to forage efficiently in high heat could have led to the low percentage of successful nests, as well as, the lowered output of fledglings per nest that was indeed successful. When we began the study we expected there to be four to five fledglings per successful nest, but our data reflected a much lower yield at 2.44 fledglings on average per successful nest. Since both field seasons were impacted by drought it is impossible to ascertain the true influence of the drought on our data as we have no data from a non-drought year. The number of BGGN fledglings was 2.44 per nest versus 2.33 CERW per nest; basically they were equal. Though this was not a statistically significant difference, the CERW data has been consistently held over many field seasons and has been replicated in several other studies [31], whereas, BGGN with more temperate conditions could potentially have a much greater output in non-drought years.

A study on Rufus-crowned sparrows illustrated a direct positive correlation between rainfall and the number of fledglings produced per year. As well as, significantly decreased nesting attempts across four separate species of passerines studied in a drought year [32]. Rainfall was also found to be the key component of population growth in the critically endangered Razo lark, due to increased reproductive output rather than increased adult survivorship [33]. This study was done over many consecutive seasons to arrive at these correlations. Only more time and labor in the field will yield the truth of fecundity and survivorship and their influence on population trends for BGGN. The amount of field time necessary for establishing population trends is 6-10 years of data collection according to U.S. Fish and Wildlife Services Avian Monitoring Programs [34].

Another integrated, collaborative study analyzing the plant/herbivore/predator interactions in regards to the effects of environmental change was done using the Oak-Winter Moth-Tit food chain as a model. During high heat, but plentiful nutrient and water availability there was decreased growth and increased tannin in leaves of oak trees making them less appetizing to the winter moth caterpillars. The timing of bud eruption in oak and caterpillar reproduction was sped up with temperature increases, impacting the food availability for successful reproduction in Tits [35]. The impacts of low water and high temperatures combined were not tested in this study, however the complexity and completeness of temperature impact alone was clearly illuminated. The breeding flexibility of Tits and ability to predict and coincide with caterpillar reproduction would highly impact their ability to successfully adapt to global climate change. In the early field season late April through May, there was a fungal disease that seemed to be attacking caterpillars. This may have reduced the number of adult moths available later in the field season.

Drought impacts producers as well as consumers having huge bottom-up impacts on successful reproduction. As plants struggle to survive drought tolerant, invasive plants can potentially out-compete native herbaceous plants decreasing diversity of herbaceous plants which, in turn, impacts seed and foraging diversity for insects and higher trophic levels such as song birds [36]. After just one season of drought there was a visible increase, though not quantified, of cacti throughout the grass dominated areas of the WSU field station. Insect populations were visibly lower due to drought effects during the 2011 and 2012 field season, decreasing food availability for insectivorous Blue-gray Gnatcatchers. Food availability is a critical factor in timing of nest initiation, nest success, and double brooding behavior. All of which can significantly impact population dynamics for these songbirds [37].

Endocrine plasticity allows birds to respond to variation in temperature, rainfall, and food availability by stimulating gonadal regression and the start of molt. A process usually primarily directed by photoperiod is malleable in times of drought [38]. Molting was observed as early as July 1, 2012 in Blue-gray Gnatcatchers three weeks in advance of the previous year's observations of molt. This is an acknowledgement that the breeding season was effectively shorter than it had been in previous record.

There were a high number of instances of nest predation of nestlings possibly due to low food availability for the higher trophic levels and decrease in cover because of plant wilt and leaf loss. There was increased abandonment in incubation phase most likely due to low food availability and poor foraging efficiency. Overall reproductive success was far below expected numbers.

The WSU field station site impacted by severe drought experienced reduction in quality of habitat and reduced nesting success: the impacts of which carry over to future breeding seasons. Reproductive success influences breeding site fidelity as there are decision guidelines on whether an adult will return or disperse to a new breeding ground based on their reproductive success and that of their neighbors [39]. With a third field season of recorded returns we can evaluate an error rate for lack of resighting a surviving individual using the program MARK. This would greatly increase the power of our model in correctly interpreting dispersal versus mortality. Drought impacts could in turn, show a reduction in site fidelity for several of the coming breeding seasons. Which we have already observed in Blue-gray Gnatcatcher returns in 2012. We can assume within season survival on the breeding grounds was high as all banded birds were re-sighted throughout the 2011 breeding season. However, there is no way to quantify or differentiate survivorship during migration and on the wintering grounds; Nor can we distinguish between mortality or dispersal. The re-sighting of banded BGGN has been well below what was expected (18% with 50% expected n=16). It is unclear whether survival or nest site fidelity, or both are contributing to the low numbers. Age structure can be impacted as a result of drought effects, as adults disperse to better territories there may be increased recruitment of yearling birds. This may impact breeding success even with more temperate conditions, as yearlings often exhibit lower reproductive success when compared to older birds [40, 41].

The impacts of drought are dubiously intricate. Understanding these interwoven seasonal interactions that act together to produce long term fluctuations in migratory song bird populations is of great benefit to understanding the world around us and protecting vulnerable species of concern as increased climate volatility is predicted for the foreseeable future.

With the longer breeding season and the re-nesting persistence of the Blue-gray gnatcatcher we expected that reproductive success would be much higher in the gnatcatcher populations than in ceruleans. However, the Cerulean warbler, a declining species, had a significantly higher percentage of nest success and higher numbers of female fledges per female per year than the

Blue-gray gnatcatchers in the populations studied. One behavioral trait that could contribute to BGGN to have lower nest success could be that it is an edge adapted species. In a study on avian nest success in Midwestern forests fragmented by agriculture, the lowest rates of nest success were seen by open-cup nesters, Neotropical migrants, species that reject Brown-headed Cowbird eggs (Molothrus ater) eggs, and nesters that nest along forest edge [42]. The BGGN meet all four of these criteria. In our study there was only one instance where a Cowbird nestling was suspected and the nest was predated before fledging was possible. In an Illinois study of BGGN 80% of parasitized nests (n = 20) were abandoned, those that were not abandoned did not produce any BGGN young [13]. It is fair to say that BGGN have a great many contributing factors towards population decline, at least in the agriculturally dominated area in which this study was completed.

The WSU Biological Field Station, Ninnescah Reserve is riparian edge habitat that is surrounded by agricultural fields. These agricultural field edges behave as corridors for nest predators and nest parasitizers [43]. Many common avian nest predators such as American crow (Corvus brachyrhynchos), Common Grackle (Quiscalus quiscula) and Blue Jays (Cyanocitta cristata) were observed quite regularly throughout both field seasons; as well as, mammalian nest predators such as the opossum (Didelphis virginiana) and raccoon (Procyon lotor). Hypothetically, parents may choose to raise fewer young due to the increased risk of attracting predators with larger, noisier broods [44]. It did seem that past the initial stages of establishing territories, the BGGN males did not call or sing nearly as frequently and stealth of all BGGN from June onward seemed to be the norm. These observations could speculatively be attributed to BGGN knowledge of predation risk and adapting behavior to increase survival of young BGGN. With this level of stealth fledglings could have been missed or under-represented in field observations. I think this bias in the data would be minimal however, as the fledglings that were found were quite vocal and had distinct and frequent begging calls.

This was, however, the first field ecology undertaking I have experienced as a researcher. From season 1 to field season 2, I as a researcher made many improvements in technique including more proficiency in field note-taking, binocular use, recognition of blue-gray gnatcatcher song, calls, behaviors and daily rhythms. With this thesis and the infrastructure of the study now in place, it is my hope that the study continues on with future graduate and undergraduate assistants to measure the demography of our non-declining species. To detect the subtleties of fecundity, behavioral traits, and survivorship we must have more data over a longer time period to tease out the impacts of drought and other temporary conditions of the landscape and establish long-term patterns that contribute most greatly to population trends.

A key question remains: Does ecology determine a species' life history, or does life history determine a species' ecology? Further comparative demographic studies paired with behavioral analysis and geographic region analysis will help us to determine the life history and behavioral traits that may make a species more susceptible to ecological changes [16]. By furthering understanding of this dynamic relationship we will be able to maximize conservation efforts for the Ceruleans and many other declining species on Earth.

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APPENDICES

APPENDIX A

Table A: Chi-Square Tables for Nest Success and Annual Survival for BGGN and CERW.

Nest Success

	Successful	Failed	Total
CERW	48	57	105
	39.117647	65.88235	
	2.0168952	1.197532	
BGGN	9	39	48
	17.882353	30.11765	
	4.4119582	2.6196	
Total	57	96	153

$\chi 2$	critical value from table
10.25	3.841
α =.05	

Survival

	Yes-Return	No-Return	total
BGGN	3	13	16
	6.3396226	9.660377	
	1.7592655	1.154518	
CERW	60	83	143
	56.660377	86.33962	
	0.1968409	0.129177	
Total	63	96	159

$\chi 2$	critical value from table
3.240	3.841
α =.05	

APPENDIX B

Table B: Comparative Demography Data   This data for CERW was collected by Christopher M. Rogers 2003-2008 and for BGGN by Taryn R. Cipra in 2011-2012 field seasons.
CERW=Cerulean Warbler   BGGN= Blue-gray Gnatcatcher   BSGA=Barry State Gaming Area
FCTU= Fort Custer U.S. Army Michigan National Guard Reservation
Year of Study = The number of consecutive years the study had been done.
Effort/Attempt=The number of consecutive nesting attempts completed by a nesting pair within the current field season.
Found n/f= Whether the nest was found prior to or during nestling phase, or whether fledgling counts were made post-fledging.
Territory = The unique code assigned to each nesting pair, utilized throughout the field season to identify nest ownership. Fledglings= The number of BGGN or CERW fledglings found
Female Fledglings= The number of BGGN or CERW fledglings found divided by 2 using Fisher's Principle.
Cowbird= The number of fledges found that were Brown-headed Cowbirds (Molothrus ater)
Nest Code= A number assigned to categories of nest failure for evaluation in a statistical program. Key to nest codes= Explanation of the nest fate in words.

Bird	Site	Calender year	Year of study	Territory	Effort/ Attempt/ nest #	Fledglings	Female fledglings	Cowbird	key to nest codes
CERW	bsga	2003	1	12a	1	4	2	0	nest successful
CERW	bsga	2003	1	13a	1	2	1	1	nest successful bhco
CERW	bsga	2003	1	10a	1	0	0	0	nest failed:known predation
CERW	bsga	2003	1	14	1	0	0	0	nest failed:known predation
CERW	bsga	2003	1	16	1	0	0	0	nest failed:probable predation
CERW	bsga	2003	1	17	1	0	0	0	nest failed:probable predation
CERW	bsga	2003	1	11a	1	.	.	.	nest successful
CERW	bsga	2006	4	10a	1	2	1	0	nest successful
CERW	bsga	2006	4	4	1	2	1	0	nest successful
CERW	bsga	2006	4	5a	1	2	1	0	nest successful
CERW	bsga	2006	4	9	1	2	1	0	nest successful
CERW	bsga	2006	4	11	1	3	1.5	0	nest successful
CERW	bsga	2006	4	5	1	0	0	0	nest failed:probable predation
CERW	bsga	2006	4	6	1	0	0	0	nest failed:unknown cause
CERW	bsga	2006	4	6	2	0	0	0	nest failed:unknown cause
CERW	bsga	2006	4	7	1	0	0	0	nest failed:probable predation
CERW	bsga	2006	4	7	2	0	0	0	nest failed:unknown cause

Bird	site	calender year	year of study	territory	effort/ attempt/ nest #	fledglings	female fledglings	cowbird	key to nest codes
CERW	bsga	2006	4	8	1	0	0	0	nest failed:probable predation
CERW	bsga	2006	4	8	2	0	0	0	nest failed:probable predation
CERW	bsga	2006	4	9c	1	0	0	0	nest failed:probable predation
CERW	bsga	2006	4	10	1	0	0	0	nest failed:weather (rain)
CERW	bsga	2006	4	10	2	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	2	1	3	1.5	0	nest successful
CERW	bsga	2007	5	3	1	1	0.5	1	nest successful bhco
CERW	bsga	2007	5	7	1	4	2	0	nest successful
CERW	bsga	2007	5	10	2	1	0.5	0	nest successful
CERW	bsga	2007	5	11	1	2	1	0	nest successful
CERW	bsga	2007	5	4	1	2	1	0	nest successful
CERW	bsga	2007	5	4a	1	3	1.5	0	nest successful
CERW	bsga	2007	5	4b	1	2	1	0	nest successful
CERW	bsga	2007	5	5	1	1	0.5	0	nest successful
CERW	bsga	2007	5	13a	1	2	1	0	nest successful
CERW	bsga	2007	5	15	1	2	1	0	nest successful
CERW	bsga	2007	5	17a	1	2	1	0	nest successful
CERW	bsga	2007	5	6	1	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	7a	1	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	7a	2	0	0	0	nest failed:unknown cause
CERW	bsga	2007	5	9	1	0	0	0	nest failed:unknown cause
CERW	bsga	2007	5	10	1	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	10a	1	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	13	1	0	0	0	nest failed:probable predation
CERW	bsga	2007	5	14	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	1	1	0	0	0	nest failed:known predation
CERW	bsga	2008	6	1	2	0	0	0	nest failed:unknown
CERW	bsga	2008	6	2	1	2	1	0	nest successful
CERW	bsga	2008	6	3	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	4	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	4	2	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	4	3	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	5	1	0	0	0	nest failed:unknown cause
CERW	bsga	2008	6	5	3	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	6a	1	4	2	0	nest successful
CERW	bsga	2008	6	6c	1	3	1.5	0	nest successful

Bird	site	calender year	year of study	territory	effort/ attempt/ nest #	fledglings	female fledglings	cowbird	key to nest codes
CERW	bsga	2008	6	7a	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	7a	2	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	8	1	0	0	0	nest failed:unknown cause
CERW	bsga	2008	6	8	2	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	8a	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	10	1	2	1	0	nest successful
CERW	bsga	2008	6	11	1	3	1.5	0	nest successful
CERW	bsga	2008	6	12	1	0	0	0	nest failed:known predation
CERW	bsga	2008	6	13	1	0	0	0	nest faled:unknown cause
CERW	bsga	2008	6	13	2	2	1	0	nest successful
CERW	bsga	2008	6	13a	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	13a	2	4	2	0	nest successful
CERW	bsga	2008	6	14	1	0	0	0	nest failed:probable predation
CERW	bsga	2008	6	16	1	0	0	0	nest failed:probable predation
CERW	ftcu	2004	2	3	1	2	1	1	nest successful bhco
CERW	ftcu	2004	2	5	2	0	0	1	nest successful bhco
CERW	ftcu	2004	2	7	1	2	1	0	nest successful
CERW	ftcu	2004	2	12	2	2	1	0	nest successful
CERW	ftcu	2004	2	4	1	3	1.5	0	nest successful
CERW	ftcu	2004	2	16	1	1	0.5	0	nest successful
CERW	ftcu	2004	2	17	1	2	1	0	nest successful
CERW	ftcu	2004	2	1	1	0	0	0	nest failed:probable predation
CERW	ftcu	2004	2	3a	1	0	0	0	nest failed:known predation
CERW	ftcu	2004	2	5	1	0	0	0	nest failed:known predation
CERW	ftcu	2004	2	8a	1	0	0	0	nest failed:weather(rain)
CERW	ftcu	2004	2	8a	2	0	0	0	nest failed:probable predation
CERW	ftcu	2004	2	12	1	0	0	0	nest failed:known predation
CERW	ftcu	2004	2	18a	1	0	0	0	nest failed:known predation
CERW	ftcu	2005	3	2	1	2	1	0	nest successful
CERW	ftcu	2005	3	2a	2	1	0.5	1	nest successful bhco
CERW	ftcu	2005	3	3	1	3	1.5	0	nest successful
CERW	ftcu	2005	3	3a	1	3	1.5	0	nest successful
CERW	ftcu	2005	3	6	2	2	1	0	nest successful
CERW	ftcu	2005	3	7	1	0	0	1	nest failed:brood parasitism
CERW	ftcu	2005	3	8	1	3	1.5	0	nest successful
CERW	ftcu	2005	3	11	1	3	1.5	0	nest successful

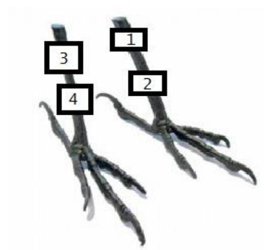
Bird	site	calender year	year of study	territory	effort/ attempt/ nest #	fledglings	female fledglings	cowbird	key to nest codes
CERW	ftcu	2005	3	14	2	3	1.5	0	nest successful
CERW	ftcu	2005	3	5	1	2	1	0	nest successful
CERW	ftcu	2005	3	9	1	2	1	0	nest successful
CERW	ftcu	2005	3	13	1	2	1	0	nest successful
CERW	ftcu	2005	3	16	1	3	1.5	0	nest successful
CERW	ftcu	2005	3	18	1	2	1	0	nest successful
CERW	ftcu	2005	3	2a	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	4	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	4a	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	5a	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	6	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	6b	1	0	0	0	nest failed:known predation
CERW	ftcu	2005	3	6b	2	0	0	0	nest failed:weather (wind)
CERW	ftcu	2005	3	14	1	0	0	0	nest failed:probable predation
CERW	ftcu	2005	3	15	1	0	0	0	nest failed:known predation
BGGN	wsufs	2011	1	1	1.1	0	0	0	.
BGGN	wsufs	2011	1	1	1.2	0	0	0	.
BGGN	wsufs	2011	1	2	2.1	0	0	0	.
BGGN	wsufs	2011	1	2	2.2	0	0	0	.
BGGN	wsufs	2011	1	4 A	4A.1	0	0	0	.
BGGN	wsufs	2011	1	4b	4B.1	4	2	0	.
BGGN	wsufs	2011	1	6	6.1	0	0	0	.
BGGN	wsufs	2011	1	6	6.2	0	0	0	.
BGGN	wsufs	2011	1	6	6.3	1	0.5	0	.
BGGN	wsufs	2011	1	6a	6A.1	0	0	0	.
BGGN	wsufs	2011	1	6a	6A.2	0	0	0	.
BGGN	wsufs	2011	1	6b	6B	0	0	0	.
BGGN	wsufs	2011	1	7	7.1	0	0	0	.
BGGN	wsufs	2011	1	8	8.1	0	0	0	.
BGGN	wsufs	2011	1	8	8.2	0	0	0	.
BGGN	wsufs	2011	1	8	8.3	3	1.5	0	.
BGGN	wsufs	2011	1	8a	8A.1	0	0	0	.
BGGN	wsufs	2011	1	9	9.1	0	0	0	.
BGGN	wsufs	2011	1	9	9.2	0	0	0	.
BGGN	wsufs	2011	1	9a	9A	2	1	0	.

Bird	site	calender year	year of study	territory	effort/ attempt/ nest #	fledglings	female fledglings	cowbird	key to nest codes
BGGN	wsufs	2011	1	9b	9B	1	0.5	0	.
BGGN	wsufs	2011	1	10	10.1	0	0	0	.
BGGN	wsufs	2011	1	10 a	10A. 1	3	1.5	0	.
BGGN	wsufs	2011	1	12	12.1	0	0	0	.
BGGN	wsufs	2011	1	12	12.2	0	0	0	.
BGGN	wsufs	2011	1	12	12.3	0	0	0	.
BGGN	wsufs	2011	1	12	12.4	0	0	0	.
BGGN	wsufs	2011	1	12 a	12A	0	0	0	.
BGGN	wsufs	2011	1	13	13.1	0	0	0	.
BGGN	wsufs	2011	1	13	13.2	0	0	0	.
BGGN	wsufs	2011	1	14	14.1	0	0	0	.
BGGN	wsufs	2011	1	14	14.2	0	0	0	.
BGGN	wsufs	2011	1	15	15.1	0	0	0	.
BGGN	wsufs	2012	2	2	2.1	0	0	0	
BGGN	wsufs	2012	2	2	2.2	0	0	0	probably blew down
BGGN	wsufs	2012	2	2	2.3	0	0	0	.
BGGN	wsufs	2012	2	4	4.1	0	0	0	.
BGGN	wsufs	2012	2	4	4.2	0	0	0	.
BGGN	wsufs	2012	2	5	5.1	4	2	0	.
BGGN	wsufs	2012	2	5	5.2	0	0	0	predation
BGGN	wsufs	2012	2	6 A	6A.1	0	0	0	.
BGGN	wsufs	2012	2	7	7.1	0	0	0	.
BGGN	wsufs	2012	2	7	7.2	0	0	0	.
BGGN	wsufs	2012	2	7	7.3	0	0	0	predation
BGGN	wsufs	2012	2	7	7.4	0	0	0	.
BGGN	wsufs	2012	2	9	9.1	0	0	0	.
BGGN	wsufs	2012	2	9	9.2	0	0	0	.
BGGN	wsufs	2012	2	10	10.1	0	0	0	blew down
BGGN	wsufs	2012	2	10	10.2	0	0	0	.
BGGN	wsufs	2012	2	11	11.1	2	1	0	.
BGGN	wsufs	2012	2	12	12.1	2	1	0	.
BGGN	wsufs	2012	2	12	12.2	0	0	0	.
BGGN	wsufs	2012	2	14	14.1	0	0	0	.
BGGN	wsufs	2012	2	14	14.2	0	0	0	.

Bird	site	calender year	year of study	territory	effort/ attempt/ nest #	fledglings	female fledglings	cowbird	key to nest codes
BGGN	wsufs	2012	2	15	15.1	0	0	0	.
BGGN	wsufs	2012	2	16	16.1	0	0	0	.
BGGN	wsufs	2012	2	17	17.1	0	0	0	.
BGGN	wsufs	2012	2	18	18.1	0	0	0	.
BGGN	wsufs	2012	2	18	18.2	0	0	0	.

Appendix C

Table C: Banding Data for BGGN

						GPS Coordinates	
A=Aluminum	number	Aluminum Band	M/F	Bands	Date Banded	North	West
G= Dark Green	1		M	AOBO	7/10/2010		
S = Black	2		M	AOCO	7/10/2010		
P= Pink	3		M	AOJO	4/18/2011	37˚32.145	97˚40.807
L = Light Blue	4		M	AOLO	4/26/2011	37˚32.307	97˚40.473
W = White	5		M	AOMO	4/11/2011	37˚32.335	97˚40.644
J = Light Green	6		M	AOPO	4/14/2011	37˚32.287	97˚40.417
Y=Yellow	7		M	AORO	5/10/2011	37˚32.316	97˚40.448
M=Mauve (purple)	8		M	AOSO	4/5/2011		
C=Orange	9		M	AOWO	5/10/2011	37˚32.401	97˚40.899
R=Red	10		F	AOYO	4/14/2011	37˚32.388	97˚40.796
B=Royal Blue	11		F	AOOO	4/13/2011	37˚32.239	97˚40.512
O=no band at that location	12		M	BOAO	5/16/2011	37˚32.161	97˚40.801
	13		M	LOAO	5/23/2011	37˚32.347	97˚40.819
	14		M	MOAO	5/16/2011	37˚32.391	97˚40.839
	15		M	POAO	5/25/2011		
	16		M	ROAO	6/8/2011	37˚32.931	97˚37.259
	17		M	SOAO	4/12/2011	37˚32.309	97˚40.330
	18		F	BAOO	5/2/2011	37˚32.112	97˚36.907
	19	262079801	M	BCAO	4/25/2012	37˚32.284	97˚40.970
	20	262079802	M	RPAO	5/2/2012	37˚32.214	97˚40.624
	21	262079803	M	PYAO	6/7/2012	37˚32.296	97˚40.258
	22	262079804	fledge	RCAO	7/13/2012	37˚32.283	97˚40.549

Appendix D

Table D: Nest Height Data BGGN

Field Season	Nest	Nest Height (meters)	Tree
2011	1.1		
	1.2		Hackberry
	2.1		Osage Orange
	2.2	10	Honey Locust
	4A	7	Osage Orange
	6.1	14	Hackberry
	6.2	17	Siberian Elm
	6A.1	11	Black Locust
	6A.2	15	Osage Orange
	6B	10	
	7.1	3	Hackberry
	8.1	17	Hackberry
	8.2	11	Black Locust
	8.3		
	8A	8	Honey Locust
	9.1	20	Cottonwood
	10	24	Cottonwood
	10A	5	Box Elder
	12.1	11	Osage Orange
	12.2	7	Hackberry
	12.3	5	Hackberry
	12.4	10	Osage Orange
	12A	6	Hackberry
	13.1	5	Siberian Elm
	13.2	3	Box Elder
	14.1	4	Siberian Elm
	14.2	5	Hackberry
	15	6	Osage Orange

Field Season	Nest	Nest Height (meters)	Tree
2012	2.1	10	Green Ash
	2.2	20	Hackberry
	2.3	8	Box Elder
	4.1	15	Siberian Elm
	4.2	19	Hackberry
	5.1	10	Hackberry
	5.2	12	Hackberry
	6A	5	Honey Locust
	7.1	15	Cottonwood
	7.2		
	7.3	6	Box Elder
	7.4	4	Box Elder
	9.1	12	Hackberry
	9.2	13	Cottonwood
	10.1	12	Osage Orange
	10.2	10	Black Locust
	12.1	9	Box Elder
	12.2	12	Osage Orange
	14.1	7	Box Elder
	14.2	8	Box Elder
	15	6	Hackberry
	16		
	17	4	Osage Orange
	18.1	13	Hackberry
	18.2	5	Box Elder
Average Nest Height		10	
Standard Deviation		±5.0	