

RECOVERY OF CAPE SABLE SEASIDE SPARROW – SUBPOPULATION A



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CONTENTS

| | | |
|------------|---|-----------|
| 1.0 | EXECUTIVE SUMMARY..... | 4 |
| 2.0 | DEMOGRAPHIC MONITORING | 10 |
| 2.1 | INTRODUCTION | 10 |
| 2.2 | SUBPOPULATION A | 11 |
| 2.2.1 | Study Area..... | 12 |
| 2.2.2 | Sparrow Numbers | 13 |
| 2.2.3 | Reproduction..... | 14 |
| 2.2.4 | Mark-Recapture Data | 16 |
| 2.3 | SUBPOPULATION B | 17 |
| 2.3.1 | Study Area..... | 18 |
| 2.3.2 | Sparrows Numbers..... | 18 |
| 2.3.3 | Reproduction..... | 19 |
| 2.3.4 | Mark-recapture Data..... | 20 |
| 2.4 | SUBPOPULATION D | 21 |
| 2.4.1 | Study Area..... | 21 |
| 2.4.2 | Sparrow Numbers | 22 |
| 2.4.3 | Reproduction..... | 22 |
| 2.4.4 | Mark-recapture Data | 23 |
| 2.5 | COMPARATIVE DATA..... | 23 |
| 2.5.1 | Population Trends..... | 24 |
| 2.5.2 | Sex Ratios..... | 26 |
| 2.5.3 | Reproduction..... | 28 |
| 2.5.4 | Survival..... | 30 |
| 2.6 | CONCLUSIONS..... | 30 |
| 2.7 | TABLES AND FIGURES | 33 |
| 3.0 | JUVENILE CAPTURE TECHNIQUES..... | 39 |
| 3.1 | INTRODUCTION | 39 |
| 3.2 | CAPTURE TECHNIQUES..... | 40 |
| 3.2.1 | Aging Sparrows..... | 40 |
| 3.2.2 | Juvenile Flocks..... | 41 |
| 3.2.3 | Mist Netting..... | 42 |
| 3.3 | SEXING JUVENILES | 43 |
| 3.3.1 | Morphometric Sexing..... | 43 |
| 3.3.2 | Genetic Sexing..... | 44 |
| 3.3.3 | Results: Genetic-Morphometric Sexing..... | 46 |
| 3.4 | CONCLUSIONS..... | 48 |
| 3.5 | TABLES AND FIGURES | 49 |

| | | |
|------------|--|-----------|
| 4.0 | SPATIALLY-EXPLICIT POPULATION ESTIMATOR | 56 |
| 4.1 | INTRODUCTION | 56 |
| 4.2 | TERRITORY SIZES | 57 |
| 4.2.1 | <i>Home Range Analysis.....</i> | <i>58</i> |
| 4.2.2 | <i>Results.....</i> | <i>59</i> |
| 4.2.3 | <i>Discussion</i> | <i>60</i> |
| 4.3 | SEX RATIOS | 62 |
| 4.3.1 | <i>Overview.....</i> | <i>62</i> |
| 4.3.2 | <i>Results.....</i> | <i>63</i> |
| 4.3.3 | <i>Discussion</i> | <i>63</i> |
| 4.4 | DENSITY ESTIMATION | 64 |
| 4.4.1 | <i>Distance Sampling</i> | <i>65</i> |
| 4.4.2 | <i>Results.....</i> | <i>68</i> |
| 4.4.3 | <i>Discussion</i> | <i>69</i> |
| 4.5 | CONCLUSIONS..... | 70 |
| 4.6 | TABLES AND FIGURES | 72 |
| 5.0 | LITERATURE CITED..... | 87 |

1.0 EXECUTIVE SUMMARY

The following report presents research on the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) conducted under a grant from the U.S. Fish & Wildlife Service (USFWS) through the Endangered Species Conservation – Recovery Implementation Funds (CFDA 15.657). Supplemental funding for Cape Sable seaside sparrow (CSSS) research was provided by the South Florida Water Management District (SFWMD), with additional support provided by Everglades National Park (ENP). Funding under these awards was provided to meet three main objectives: (1) development of a spatially-explicit population estimator for the CSSS, (2) conduct intensive monitoring of CSSS subpopulations A, B and D, and (3) refine techniques to capture juvenile CSSS for potential future translocation. Each of these objectives was meant to provide information necessary to aid recovery efforts of CSSS subpopulation A. This report is broken down into five sections as follows:

Section 1.0 is an Executive Summary of this report. **Section 2.0** provides an overview of demographic monitoring conducted in CSSS subpopulations A, B and D in 2015 and presents current breeding conditions. This is followed by **Section 3.0** which provides a review of juvenile capture techniques refined during demographic monitoring and methods to sex juvenile sparrows. **Section 4.0** provides a summary of our initial analyses to develop a spatially-explicit population (SEP) estimator for the CSSS. This section presents preliminary analyses of historical data needed to develop the SEP estimator and offers suggestions for future development of the estimator. Our original goal was to develop the population estimator this year; however, we determined that additional data were required in order to develop a robust SEP estimator and thus do not provide a population estimate in this report. Finally, **Section 5.0** presents literature cited throughout the report. Following is a more detailed summary of each of the three main sections of our report.

Section 2.0 Demographic Monitoring

During 2015 we continued to focus field research on intensive nest monitoring in small sparrow subpopulation A. This subpopulation has reported a decline in sparrow numbers in recent years and is subject to current management changes, or proposed changes, and thus near real-time information on where sparrows are nesting and the status of individuals in this area is needed to help direct water management if necessary. In 2015, we also continued intensive nest monitoring in a study plot in subpopulation B so that we could collect data from a large sparrow subpopulation for comparison with data collected from the small subpopulation. Also in 2015, we conducted demographic monitoring in subpopulation D under a separate grant agreement with the South Florida Water Management District, and results from this study are included in this report for further comparison. Finally, during 2015 we also continued a long-term mark-recapture study by banding individuals in subpopulations A, B and D, and resighting previously banded individuals in these subpopulations.

Overall, the 2015 sparrow breeding season was an average to slightly below average year in regards to overall nest success rates in subpopulations A, B and D. Subpopulation A actually had a more successful season in 2015 than reported in the past several years; however, overall productivity and total recruitment remain very low. The mean hatch rate observed in subpopulation A also continues to be substantially lower than the hatch rate in subpopulations B and D. Subpopulation B reported lower overall productivity in 2015 than in 2014, possibly due to an ill-timed flooding event before the majority of the first nesting attempts had fledged. Recruitment levels were also lower in subpopulation B in 2015 despite a strong effort to band juveniles and nestlings in 2014. Overall productivity and recruitment remain very low in subpopulation D due to the small population size and an extremely male-biased sex ratio. The only evidence of multi-brooding by breeding pairs this season was in subpopulation B; however, there was one late-season nest in subpopulation A that was not monitored until completion.

The total number of sparrows in subpopulation A remains very low with 14 adult sparrows detected in 2015. Subpopulation B increased slightly with 34 adults, and subpopulation D

declined slightly with 12 adults. The continued decline in subpopulation A is a major concern; numbers first dropped from 2010-2011 largely due to a reduction in females on our study plot, and numbers dropped again from 2012-2014 due to a reduction in males this time. We are concerned that subpopulation A could be approaching a minimum threshold necessary to promote settlement of breeding sparrows, perhaps due to a lack of enough conspecific cues. The past low nest success rates and current low return rates in subpopulation A raise alarm that this subpopulation may face continued declines unless the causes of the lower demographic rates here can be identified and managed. We suggest that monitoring should continue to be conducted in a large sparrow subpopulation in conjunction with monitoring in small subpopulation A for comparative purposes in order to quickly recognize potential Allee effects in the small subpopulations that could lead to rapid population declines.

Two other areas of major concern remain the highly-skewed adult sex ratio and very low recruitment rates observed in small sparrow subpopulation A. The adult sex ratio did become more balanced in 2014 and 2015; however, due to the already small population size this subpopulation should be monitored closely for future changes as the current sex ratio balance may not be stable. The return rate of previously banded adult female sparrows was alarmingly low in small subpopulations A and D. Return rates were substantially higher for adult males in subpopulation A and adults of both sexes in large subpopulation B. Highly skewed adult sex ratios increase a species' risk of extinction (Dale *et al.* 2001). This process was observed during the extinction of a closely-related species, the Dusky seaside sparrow (*A. m. nigrescens*), when ultimately all of the remaining sparrows in the wild were males (Delaney *et al.* 1981). Thus it is critical that the skewed sex ratio in small sparrow subpopulations be monitored closely to assess the rangewide status of the Cape Sable seaside sparrow in the future. Future research should continue to document sex ratios in small subpopulations, but should also continue to examine sex ratios in a large sparrow subpopulation for comparison to potentially capture early warning signs of a rangewide pattern that could be very detrimental to overall Cape Sable seaside sparrow population viability.

With generally lower nest success and limited dispersal in subpopulation A, we are concerned that this important sparrow subpopulation may be subject to continued declines in the near term. Local recruitment and dispersal rates alone will unlikely be enough to enable this isolated sparrow subpopulation to persist. It has previously been suggested that conservation managers should consider translocation of female sparrows into subpopulation A to achieve an adequately-sized breeding population for its persistence, and that the time to do this was likely becoming critical as the existing male sparrows in this subpopulation continued to age (Virzi and Davis, 2012). Although the high return rate for male sparrows observed in subpopulation A in 2015 is encouraging, the extremely low return rate of female sparrows is problematic, as is the low recruitment of new birds. It is possible that we may already be very close to the critical mass necessary for this subpopulation to persist. While translocation of birds may seem like a viable management option for this subpopulation at this time, we caution that until we more fully understand the mechanisms causing reduced demographic rates (e.g., low hatch rates) and recent population declines in our study plot in subpopulation A there is considerable risk associated with the translocation of sparrows. We suggest that sparrows breeding in subpopulation A should be monitored closely to determine if the population continues to decline, and that the best method to monitor the subpopulation is to conduct intensive ground surveys and nest monitoring with similar effort to that conducted in recent years. Finally, we strongly recommend that a detailed translocation plan be developed before any sparrows are translocated into subpopulation A.

Section 3.0 Juvenile Capture Techniques

During the course of our demographic monitoring, we refined techniques to capture juvenile sparrows and developed methods to sex individuals based on morphometric measurements and genetic techniques. Proper sex determination of individuals captured (e.g., juvenile sparrows) is critical so conservation managers can select the desired individuals for translocation, and so researchers have additional information to study the success of translocations. In order to rapidly assess the sex of individuals captured for translocation, we

developed a field method for sex determination based solely on morphometric measurements. Our results indicate that juvenile sparrows may be accurately sexed in the field based on wing chord and tail length measurements with an acceptable degree of precision. Thus, we are confident that using morphometrics to provide a rapid assessment of sex in the field will enable researchers to select the desired individuals for translocation without the need to wait for lab results to determine sex. To validate our field method, we also sent feather samples to a genetics lab, Avian Biotech, to sex juvenile sparrows using genetic sexing techniques. Avian Biotech was able to develop markers to accurately sex Cape Sable seaside sparrows using DNA extracted from feather samples, so researchers can still obtain very reliable sex determination of translocated birds at a later time to validate sex determinations originally based on morphometric measurements.

Section 4.0 Spatially-Explicit Population Estimator

A central part of our research in 2015 was to develop a spatially-explicit population estimator for the CSSS. While we did not accomplish our original goal of developing a spatially-explicit population estimator, we did make great strides towards the development of this estimator in 2015. We analyzed 10 years of historic CSSS data to test several assumptions made in the derivation of the current 16x multiplier used to estimate CSSS population size based on the ENP rangewide helicopter survey data. Significant findings included: (1) CSSS territory sizes are much larger in small subpopulations, (2) sex ratios are much more highly male-biased in small subpopulations, and (3) detection probability appears lower in small subpopulations. We also successfully used line transect surveys incorporating distance sampling to provide estimates of CSSS density and detection probability. These results provide invaluable information that can inform continued development of a spatially-explicit population estimator and provide insight into ways to improve the ENP rangewide helicopter surveys to better estimate population size. We suggest that in 2016 additional data be collected to fill information gaps needed to complete development of the population estimator, and that new survey methods (e.g., time-

of-detection sampling) be tested in the field in a continued attempt to improve the ENP rangewide helicopter surveys.

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2.0 Demographic Monitoring

2.1 Introduction

In 2015, we continued demographic monitoring in Cape Sable seaside sparrow (CSSS) subpopulation A which has been ongoing since 2009 (Virzi *et al.* 2009). Subpopulation A continues to be one of the most important CSSS subpopulations to track because historically it was one of the two largest subpopulations before significant population declines in the 1990s. Therefore, it holds the potential for significant recovery, even as it remains extremely vulnerable due to its small population size and its downstream position west of Shark River Slough, which exposes it to freshwater management decisions during the breeding season. Monitoring is needed in this area because it is subject to current water management actions, and thus near real-time information on where sparrows are nesting and the status of individuals in this area is needed to help direct water management, if necessary.

In contrast to subpopulation A, CSSS subpopulation B contains the largest number of sparrows, has maintained relatively stable population trends since the early 2000s, and apparently supports demographic rates that produce an annual population growth rate > 1.0 . As such, it serves as a high-quality reference population for comparison of demographic parameters with small subpopulation A. For this reason, in 2015 we continued demographic monitoring in this large, reference subpopulation which has been ongoing since 2012 (Virzi and Davis 2012).

Also in 2015, we conducted demographic monitoring in CSSS subpopulation D as part of a separate grant from the South Florida Water Management District (SFWMD) to monitor this small subpopulation (Virzi *et al.* 2015). Subpopulation D is one of the smallest sparrow populations, and is located outside of the boundary of Everglades National Park on land managed by SFWMD. Demographic monitoring has been ongoing in subpopulation D since 2006, with intensive monitoring for SFWMD since 2011 (Virzi *et al.* 2011a). We present data from our monitoring in subpopulation D in this report to provide additional data from a second small CSSS subpopulation for further comparison.

Monitoring in these CSSS subpopulations is needed to maintain continuity with previous research and monitoring, and to evaluate and consider new opportunities for recovery as new restoration actions are being proposed. The Central Everglades Planning Project (CEPP) is the next generation of proposed projects to be implemented under the Comprehensive Everglades Restoration Plan (CERP). One goal of CEPP is to identify and plan for projects on land already in public ownership to allow more water to be directed south to the central Everglades, Everglades National Park (ENP), and Florida Bay. Although this project is expected to produce large-scale hydrological benefits to the ecosystem, there is also concern about its potential impact on endangered species, including the Cape Sable seaside sparrow, whose range is extremely limited and population very small.

In this section, we report on our demographic monitoring conducted in subpopulations A (**Section 2.2**), B (**Section 2.3**), and D (**Section 2.4**) following methods established in 2012-2013 (Virzi and Davis 2013, 2012) and continued in 2014 (Slater *et al.* 2014; Virzi and Davis 2014). We conducted intensive nest searching on existing demographic study plots and continued banding adult and juvenile sparrows, which has been ongoing since 1994 (Pimm *et al.* 2002). During 2015, as part of our demographic research we also sought to improve methods for capturing and sexing juvenile sparrows providing information to help inform possible future translocation of sparrows, possibly into subpopulation A from subpopulation B (see **Section 3.0**).

2.2 Subpopulation A

At one time considered part of the ‘core’ habitat for the sparrow (along with subpopulation B), subpopulation A experienced a very noticeable, and consequently controversial, decline between 1992 and 1995 (Curnutt *et al.* 1998). Persistent unnatural flooding during consecutive breeding seasons caused this subpopulation to decline substantially in occupancy and numbers, leading to legal actions requiring a change in water management so that less water was delivered into subpopulation A during the peak of the sparrow’s breeding season (Pimm *et al.* 2002). While these water management efforts appear to have resulted in relatively stable sparrow occupancy since 1996, at least until recently based on ENP rangewide survey data, this

subpopulation continues to show little sign of recovering to pre-1990 occupancy levels (Cassey *et al.* 2007) and has apparently declined in numbers since 2008. Demographic monitoring began in subpopulation A in 2008 after a fire burned through the West Camp area.

Observations of several large juvenile flocks indicated that breeding may have been very successful in that year. More intensive demographic monitoring has been ongoing since 2009, although observations of large juvenile flocks, as seen in 2008, have not been seen again. The goal of our research in subpopulation A is to better understand why the subpopulation continues to show no sign of recovery, and to identify possible management actions to aid in recovery. Two specific objectives include: 1) to keep water managers abreast of current nesting conditions, and 2) to continue collecting basic demographic information.

2.2.1 Study Area

Intensive nest searching was concentrated in the area near West Camp (within 3 km). From 2009-2014, intensive ground surveys for breeding sparrows in subpopulation A had generally been conducted in a 5 km² square study area between the following ENP helicopter survey sites: shark-40 (near West Camp), shark-28 to the north, shark-105 to the east, and shark-108 to the south (Slater *et al.* 2014). In 2015, however, our effort was concentrated in the area known as the Lower Meadow located between shark-32, shark-36, shark-69, and shark-82 (**Figure 2.1**). Overall, the total area surveyed in 2015 covered approximately 1.6 km² and was thus substantially smaller in size than the area surveyed in previous years.

The size of our demographic study plot in subpopulation A was first reduced in 2014 due to funding limitations and access issues. Subpopulation A can only be accessed by helicopter, and limited funding combined with logistical constraints has historically made consistent monitoring of this remote CSSS subpopulation difficult. For this reason, in 2015 we decided to continue to monitor a smaller study plot in subpopulation A in order to ensure that we obtain adequate survey coverage over the entire plot throughout the CSSS breeding season. Also contributing to our decision to drop the Upper Meadow area from our demographic monitoring in 2015 was the fact that no sparrows were observed in this area in the previous year (Slater *et al.* 2014).

Finally, we made changes to our survey methods in 2015 that required us to better delineate the boundaries of our study plots in all subpopulations monitored, and thus led to a reduction in the size of all of our demographic study plots. We modified our survey methods to include line transect surveys using distance sampling to estimate sparrow density on our study plots (see **Section 4.4**).

2.2.2 Sparrow Numbers

In 2015, monitoring in subpopulation A did not begin until late-April, approximately three weeks later than in subpopulation B, due to logistical constraints affecting access to the site. Territory mapping began on 21 April and ended on 10 July. We documented eight territorial male sparrows and six breeding female sparrows (**Table 2.1; Figure 2.1**). The number of breeding pairs ($n = 6$) in 2015 was identical to the previous three years. The number of territorial males was equal to the number seen during the 2014 season; however, this number was lower compared to previous years (2013: $n = 10$; 2012: $n = 17$). The number of female sparrows was consistent with previous years. Due to the recent decline in males in subpopulation A, the sex ratio crept closer to 1:1 in 2014 and remained at the same level in 2015 (0.57; **Table 2.1**). Male-biased sex ratios have been observed in all the sparrow subpopulations studied, although ratios have historically been more imbalanced in small sparrow subpopulations. Sex ratios reported in all CSSS subpopulations are examined more closely below (see **Section 4.3**).

Territory maps in **Figure 2.1** reflect an average of 44.4 GPS points per individual tracked. In 2015, we conducted more systematic territory mapping than in previous years in order to obtain a more precise estimate of sparrow density on our study plots, and to better map male territories for comparison of territory sizes among subpopulations (see **Sections 4.2 and 4.4**). The density of sparrows on our West Camp study plot in subpopulation A was 8.8 birds per km² based on territory mapping. This density estimate is substantially higher than the previous three years (**Table 2.1**); however, this is not an indication of an increase in population size in 2015. Rather, the higher density estimate is a function of our smaller study plot – reduced in

size from 5 km² to 1.6 km² – which was intentionally placed in the highest known density of breeding sparrows in the West Camp area (i.e., the Lower Meadow).

As seen in past years, most sparrows continued to remain outside of the area in the Lower Meadow that burned in 2008, despite the apparent recovery of vegetation in this area. Nearly one-third of the newly-defined study plot was in the old recovered burn area, but no sparrows held territories entirely within this area. Two to three territories were on the edge and went into the burn area a small amount (**Figure 2.1**). This lack of recolonization of the recovered burn is in direct contrast to the re-establishment of breeding pairs in a healthy subpopulation (E) following the Lopez Fire in 2001 (La Puma *et al.* 2007). The eight male CSSS territories found on our study plot were stable for the duration of the 2015 field season with the exception of one male that completely disappeared; this was likely due to mortality because he left behind a female and fledglings.

2.2.3 Reproduction

We located and monitored the fate of 12 sparrow nests; four were early-season nests (i.e., hatched before June 1st) and eight were late-season nests. The first nest was located on 16 Apr, and the last nests were found on 10 July. The timing of nest initiation by sparrows in subpopulation A was consistent with previous breeding seasons (Boulton *et al.* 2011). All monitored nests were located in the Lower Meadow in our newly-defined study plot. The Upper Meadow area was not visited at all during 2015.

Pairs in 2015 tended to stay on the same territory for the entire season, similar to the 2014 breeding season, but unlike in 2013 when sparrows moved across the study area to re-nest in drier areas after the onset of rainy season (Virzi and Davis 2013). This may have been due to the delayed onset of water level rise and overall reduced water levels in 2015 and 2014 compared to 2013. Pairs stayed together throughout the 2015 season, with the exception of a male that disappeared right after his nest fledged in May, leaving behind a female and fledglings. Polygyny was later confirmed for the neighboring male of the male that disappeared. The ‘widowed’ female remained on the territory feeding the fledglings and the neighboring male

began to interact with her. By 10 July she was incubating a clutch of 4 eggs and was seen interacting with the remaining male when she left the nest. This male was also seen the same day feeding nestlings with his original mate. It is interesting to note that no new male took up residence with the 'widowed' female, even though there were two unpaired males elsewhere on the study site. The lack of wandering sparrows in and out of our study plot suggests that this cluster of breeding sparrows may have become isolated from other sparrows breeding in subpopulation A – if any exist.

Mean clutch size was 3.6 eggs per nest, which is similar to estimates in previous years (**Table 2.1**). Six of the 12 nests survived the full incubation period (13 days) to hatching (hatch rate = 0.50); three from early-season nests, which generally have higher success rates (Baiser *et al.* 2008), and three from late-season nests. A fourth late-season nest was only monitored for one day; it is unknown whether this nest hatched or not. The hatch rate was below the rate of 0.57 reported in 2013 (Virzi and Davis 2013), but better than the rate of 0.43 reported in 2014 (Slater *et al.* 2014). The mean hatch rate over the past four years (0.49) is well below the rate of 0.71 reported in 2011 (Virzi *et al.* 2011b) – the last time this small subpopulation reported a healthy hatch rate comparable to rates reported in other subpopulations.

Overall nest success (% nests that produced ≥ 1 fledged young) was 0.33; however, this is 'apparent' success and we expect that real success was even lower since it does not take into account nests that failed prior to being located. The dataset of 12 nests does include three July nests with unknown outcomes due to the inability to continue monitoring in subpopulation A past this point. Thus, the apparent nest success rate of 0.33 could be somewhat higher if these nests were successful. Our continued use of Thermochrom iButton dataloggers in nests proved to be very helpful for interpreting nest fates and timing of transitions (i.e., time of nest failure or fledging) in 2015, particularly as nest visits were irregular due to the helicopter schedule. Two nests failed due to abandonment; one after a single egg was depredated and the other after the female had incubated in excess of 15 days without hatching. The three other confirmed failed nests were due to predators taking eggs; data suggests one may have been

depredated by a rodent (e.g., chew marks on iButton) and the other two predators are unknown.

In all, six nestlings were confirmed as fledged from monitored nests in subpopulation A in 2015, and at least one (range = 1-4) additional nestling fledged from an additional nest that was found post-fledge without a prior count of nestlings. Thus, the number of young confirmed fledged in 2015 (range = 7-10) was similar to 2014 ($n = 9$), and was more than what was observed during the previous two breeding seasons (2013: $n = 5$; 2012: $n = 3$). The mean number of young fledged per pair and young fledged per successful nest were 1.2 and 1.5, respectively. With such small sample sizes it is hard to interpret these estimates, but they are generally similar to previous years (**Table 2.1**). Finally, we documented no multi-brooding in subpopulation A in 2015 for the fourth consecutive year, with the following caveat: of the three July nests that were not monitored to final outcome two were from pairs that had successful nests earlier in the season.

2.2.4 Mark-Recapture Data

During 2015, we newly banded six adult sparrows (two males and four females), but no nestlings or juvenile sparrows (**Table 2.2**). Of the 13 banded adults present in subpopulation A in 2014, we resighted five males and one female this season, yielding an adult return rate of 0.46. This rate is in line with the rates observed in 2014 (0.43) and 2013 (0.48), but substantially lower than the rates observed in 2012 (0.56) and 2011 (0.64; Virzi *et al.* 2011b). While return rates are not directly comparable to survival rates, the observed return rate in 2015 was below the range of apparent adult survival estimate generated by Boulton *et al.* (2009) from 2002-2009 (mean = 0.59; 95% CI = 0.52-0.68). The adult return rate in subpopulation A is biased heavily towards males with five of seven males returning while only one of six females returned in 2015. The return rate for males was actually quite high (0.71) compared to the rate for females (0.17). While female survival is expected to be approximately 14-19% lower than for males (Boulton *et al.* 2009), the reported disparity in male-female return rates in subpopulation A is worrisome even though sample size is small.

In 2015, we resighted none of the nestling sparrows ($n = 3$) banded in 2014. We did not band any free-flying juveniles in 2014; however, the two juveniles banded in 2013 returned as breeders for the second season in a row. Mean return rates for nestlings and juveniles can be calculated over the 4-year period reported; however, the very small sample sizes due to a lack of enough breeding sparrows in our study plot in subpopulation A make these rates difficult to interpret. Nonetheless, return rates appear too low to bolster the breeding population via local recruitment alone.

We documented no between-subpopulation dispersal events involving subpopulation A in 2015. In fact, no dispersal events have been reported in subpopulation A since demographic monitoring began in 2008. While our study plot represents a very small area within the boundary of potential breeding habitat for the CSSS in subpopulation A, it is concerning that no dispersal events have been observed over this period. We interpret this as evidence that dispersal into this isolated subpopulation is likely very limited, possibly at a rate that is too low to aid in the recovery of this critical sparrow subpopulation.

2.3 Subpopulation B

Subpopulation B currently holds the largest number of sparrows and is considered part of the core habitat for the CSSS (along with subpopulation E). It is generally protected from flooding and incendiary fires by Long Pine Key, contributing towards making this subpopulation a stronghold for the CSSS (Curnutt *et al.* 1998). During 2015, we continued demographic monitoring in subpopulation B, which was initiated in 2012, so that demographic rates could be compared among subpopulations with subpopulation B being considered a high-quality reference site (Virzi and Davis 2012). Intensive nest monitoring in subpopulation B was initiated in 2013, thus data on reproductive rates for comparison only goes back three years (Virzi and Davis 2013).

Another object of the research in subpopulation B in 2015 was to gain information about sparrows breeding in a large CSSS subpopulation that might be useful in the future if conservation managers decide to translocate sparrows from a large subpopulation into small

subpopulation A to aid its recovery. We also continued to refine our methods to capture free-flying juvenile sparrows in subpopulation B, which are potential candidates for translocation, and explored methods to sex juvenile sparrows (see **Section 3.0**).

2.3.1 Study Area

Monitoring was conducted in the Dogleg Study Plot (DL plot) off Main Park Road, a small part of subpopulation B that is easily accessible by car/foot. Selection of this site also allowed us to continue to collect mark-recapture data in this core sparrow subpopulation in an area where sparrows were banded from 1994 to 2008 (through the work of Dr. Stuart Pimm) and since 2012 (Virzi and Davis 2012). Overall, the total area surveyed in the DL plot in 2015 covered approximately 0.68 km². Similar to our West Camp study plot in subpopulation A, in 2015 we reduced the size of our DL study plot in subpopulation B as part of the new survey protocols established this year. Thus, our 2015 study plot in subpopulation B was smaller than the study plots monitored in 2012-2014, which were approximately 1.5 km².

2.3.2 Sparrows Numbers

During 2015 we located 34 adult sparrows (18 males and 16 females; **Table 2.1; Figure 2.2**). The numbers of male and female sparrows were slightly higher than numbers observed in 2012-2014 (Slater *et al.* 2014). Territory mapping began on 17 March and ended on 4 August; territory maps in **Figure 2.2** reflect an average of 47.1 GPS points per individual tracked. The density of sparrows on the DL plot was 50.0 sparrows per km² based on territory mapping. As discussed for the 2015 density estimate in subpopulation A, the high density estimate reported here is more a function of the reduction in size of our study plot combined with its placement in the area with the highest known density of sparrows. Thus, the 2015 density estimate in the DL plot is not an indication of an increase in population size this year (although numbers did increase slightly).

We observed a nearly equal sex ratio in our study plot in subpopulation B in 2015 (0.53; **Table 2.1**). The sex ratio appears to be trending closer to a 1:1 ratio each year, with the ratio declining from 0.59 in 2013 and 0.57 in 2014. The highly-imbalanced sex ratio of 0.64 reported in 2012 is

likely a function of the lower survey effort this year, which was the first year that demographic monitoring was initiated in the DL plot – without intensive nest monitoring which likely resulted in lower detection of female sparrows.

2.3.3 Reproduction

We located 32 sparrow nests, of which 17 were early-season nests and 15 were late-season nests. The earliest nest was located on 26 March, and the latest nest was found on 14 July. Territories were relatively evenly distributed across the DL plot, with a slightly greater density of birds towards the north end (**Figure 2.2**). A maximum of 18 males held territories at some time in 2015, with 15 confirmed pairs (**Table 2.1**). Three males went missing after initial resights early in the season and one older prominent female was not seen after May. Three out of the four birds that disappeared early in the season were banded as adults in 2012, and were seen every year since then; thus these birds may have reached the end of their lifespans. The fourth missing bird was a second-year male who was single on the DL plot but was later found on the opposite side of Main Park Road with a mate and nest. The other territorial males were very stable throughout the season, and all were paired eventually, although two did not get mates until late and at least one other male lost his mate. The total female count in the DL plot for 2015 was 16. New females came onto the site later in the season, so emigration rather than mortality may be a factor with the disappearance of younger birds. One male was possibly polygynous, but he was never seen with both females at the same time so this could not be confirmed.

Mean clutch size was 3.3 eggs per nest, which is consistent with previous years. Twenty-three of the 32 nests found in subpopulation B survived to hatching (hatch rate = 0.72); 14 were early-season nests (61%) and 9 were late-season nests (39%). Ten of the 23 hatched nests survived to fledge young (fledge rate = 0.43); 5 were early-season nests (50%) and 5 were late-season nests (50%). The overall fledge rate per nest was 0.31 (10 of 32 nests found fledged at least one young). The mean number of young fledged per breeding pair and young fledged per successful nest were 1.7 and 3.1, respectively. Importantly, we documented evidence of multi-

brooding in subpopulation B in 2015 (20% of the pairs multi-brooded). Overall, 25 young fledged from monitored nests in subpopulation B in 2015.

Nests were initiated in late March and early April, but a severe storm event on 29 April flooded all nests being monitored at the time, and likely most other nests active elsewhere in the local area. The DL plot went from completely dry to 100% covered with water within 24 hours. A few nests had fledged or failed prior to the storm. This event may have caused the birds to be unusually synchronized for the next two nest attempts, with nearly all pairs on nests in late-May to early-June, and again in late-June and the first half of July. The rest of the summer was relatively dry, and water levels dropped back down to 50% coverage or less for most of June and nearly all of July. This may have contributed to a relatively successful late nesting attempt for some pairs in subpopulation B.

2.3.4 Mark-recapture Data

In 2015, we newly banded three adult males and five adult female sparrows in our study plot in subpopulation B (**Table 2.2**). We needed to band few adults because of the high number of returning adults from previous seasons. Of the 29 banded adults in subpopulation B in 2014, 16 were resighted in 2015 yielding a return rate of 0.55. The observed return rate in subpopulation B was within the range of the apparent adult survival estimate generated by Boulton *et al.* (2009) from 2002-2009 (mean = 0.59; 95% CI = 0.52-0.68). The return rate for males (0.59) was slightly higher than for females (0.50), which is also in line with expectations based on Boulton *et al.* (2009) who found that females had approximately 14-19% lower survival rates (with similar recapture rates) to males. By the end of the 2015 breeding season all 18 of the adult male sparrows and 15 of the 16 adult female sparrows found in our study plot in subpopulation B were color-banded.

In 2015, we resighted five of the 23 juvenile sparrows banded in 2014 (return rate = 0.22) and only one of the 37 nestlings banded in 2014 (return rate = 0.03). The return rate for nestlings rises to 0.08 when only known fledged nestlings are considered, but is still much lower than that observed for birds banded as free-flying juveniles, which is typical. The combined return

rate for juveniles and fledged nestlings was 0.13, which is lower than the combined return rate observed in 2014 (0.27; Slater *et al.* 2014) but still in line with expectations based on survival analyses (Gilroy *et al.* 2012a; Boulton *et al.* 2009).

No between-subpopulation dispersal events were documented in subpopulation B in 2015. This is not an unusual observation, even in this large sparrow subpopulation, because dispersal among subpopulations is limited. A review of demographic data collected in several study plots in subpopulation B over the past decade reveals that dispersal events are documented approximately every other year. In our Dogleg plot, we last recorded a between-subpopulation dispersal event in 2014 and previously in 2012.

2.4 Subpopulation D

Although demographic monitoring in CSSS subpopulation D was not part of our award agreement from USFWS, we present a summary of results reported to the SFWMD under a separate award agreement to monitor this small sparrow subpopulation. Subpopulation D is a very small and ephemeral CSSS subpopulation, and is the only known subpopulation located outside the boundary of ENP on land managed by SFWMD. Annual monitoring in this subpopulation has been conducted since 2006, originally funded by ENP and USFWS (Lockwood *et al.* 2010). In 2011, SFWMD began funding more intensive research in this subpopulation to gather baseline demographic data about sparrows breeding there and to study potential effects caused by hydrologic changes anticipated to occur as a result of the C-111 SC Project, which could have detrimental effects on sparrow habitat in this area (Virzi *et al.* 2011a). We present results from demographic research conducted in subpopulation D in this report to provide further comparative data from a second small sparrow subpopulation. We refer readers to the 2015 annual report to SFWMD provided by Ecostudies Institute for a more detailed summary of this research (Virzi *et al.* 2015).

2.4.1 Study Area

Demographic monitoring was in the core area in sparrow subpopulation D east of Aerojet Road and south of the East-West Road, intensely surveying the area between the following ENP

helicopter survey sites: rprse-22 to 24 and rprse-31 to 33 (**Figure 2.3**). In 2015, our demographic study plot in subpopulation D was reduced in size, as described previously for subpopulations A and B, in order to standardize our survey areas and meet the goals of our new research design. Overall, the total area surveyed in 2015 covered approximately 1.6 km² and was thus substantially smaller in size than the area surveyed in previous years. As described in our other study plots in other subpopulations, we placed our study plot in the area of the highest known density of breeding sparrows in subpopulation D. Thus, our survey area was more compact than in previous years but still covered most of the occupied habitat in this area.

2.4.2 Sparrow Numbers

During 2015 we located 11 territorial male sparrows in our study plot in subpopulation D, which is a slight decline from the 14 males detected in 2014 (**Table 2.1; Figure 2.3**). Still, the number of males in subpopulation D remains higher than we have seen historically. Unfortunately, we only detected one female in 2015 creating a highly-imbalanced sex ratio of 0.92. This has been a persistent problem in this small sparrow subpopulation, and in 2015 the low number of females reversed a trend of increasing numbers in recent years. Territory mapping began on 19 March and ended on 2 July (territory polygons shown in **Figure 2.3** reflect an average of 43.6 GPS points per individual tracked).

2.4.3 Reproduction

Despite continuing to hold very few sparrows, for the fourth consecutive year sparrows nested successfully in subpopulation D. We located three sparrow nests in our study plot in 2015, all from a single breeding pair. The only successful nest attempt was the first attempt, which was an early-season nest. Both of the late-season nest attempts at a second brood failed. For the third year in a row, all of the nests in subpopulation D hatched with all nest failure occurring during the brooding period. In total, two young fledged from the single successful nest in subpopulation D. Thus, overall productivity in this subpopulation was very low. Further, productivity declined from levels reported in 2013-2014.

2.4.4 Mark-recapture Data

During 2015 we resighted seven of the 13 color-banded adult sparrows (7 of 11 males; 0 of 2 females) that were present in the breeding population in 2014 (**Table 2.2**). Thus, we observed a return rate of 0.54 for adult sparrows, which is in line with the rate expected (~ 0.60) based on previous CSSS research (Boulton *et al.* 2009, Gilroy *et al.* 2012a). The lack of returning females continues to be a persistent problem in subpopulation D every year.

We observed two between-subpopulation dispersal events in subpopulation D from 2012-2015. One was a female sparrow that dispersed from subpopulation D into subpopulation B after a failed breeding attempt in 2012. The second was a male sparrow originally banded as a nestling in subpopulation B in 2012 that was resighted in subpopulation D in 2014. These dispersal events show that there is some connectivity between large subpopulation B and small subpopulation D, even though our study plots in these subpopulations are approximately 25 km apart.

2.5 Comparative Data

This section of our report summarizes and compares data collected in CSSS subpopulations A, B and D during the 2015 sparrow breeding season. **Tables 2.1 and 2.2** present data collected in these subpopulations from 2012-2015. For small subpopulation A, we present data for the past 4 years from our study plot near West Camp in order to show trends in demographic parameters over recent breeding seasons. We monitored subpopulation A with similar effort in each of these years making these data comparable (albeit with somewhat reduced effort in 2014-2015 as described previously). Monitoring effort in small subpopulation D was also similar among years. For large subpopulation B, we present data collected in our Dogleg study plot off Main Park Road from 2012-2015. Survey effort was similar in all years and nest monitoring effort was similar in 2013-2015; we did not intensively monitor nests in this subpopulation in 2012. The objective of this section is to highlight some of the important differences we observed in the data from subpopulation A compared to another small subpopulation (D) and a large reference subpopulation (B).

2.5.1 Population Trends

Figure 2.4 shows trends in abundance of Cape Sable seaside sparrows on our study plots in small subpopulations A and D compared with trends in large subpopulation B from 2008-2015. We included abundance estimates for subpopulation A for the period since 2008 because these data were available, and because these data are useful to show an apparent decline in numbers in this subpopulation over recent years. We show abundance estimates in our study plot in subpopulation D over the same period to compare trends in subpopulation A with a second small sparrow subpopulation over the same period. We only show abundance estimates for the Dogleg study plot in large sparrow subpopulation B since 2012 because this is when intensive ground surveys were reinitiated in this area. We should note that abundance estimates remain comparable in 2015 despite a reduction in the size of our demographic study plots because we placed our plots in the core breeding areas where sparrows were located in recent years.

One apparent pattern observed in the trend analysis is that the number of birds on our study plot in subpopulation A has declined since 2010, while numbers in our study plot in subpopulation B have increased moderately over the same period (**Figure 2.4**). From 2010-2011 there was a slight decline in the number of males (from 19 to 16) and a substantial decline in the number of females (from 10 to 6) in our study plot in subpopulation A (Virzi *et al.* 2011b). Numbers in subpopulation A appeared stable in 2012, but declined again in 2013. Interestingly, the large decline from 2012-2013 was due to a substantial decline in the number of males (from 17 to 10) not females. In 2014, the number of males in subpopulation A declined again (from 10 to 7) while the number of females increased (from 5 to 6). Numbers in subpopulation A remained stable in 2015. In large subpopulation B, the number of males on our study plot remained relatively constant over the 2012-2015 period while the number of females has actually increased each year.

Comparing the population trend in subpopulation A to another small subpopulation (D) shows another interesting pattern. While numbers in subpopulation A appear to be declining, numbers in subpopulation D have been increasing. While the sample size in each subpopulation

is very small, we should not ignore the fact that trends in subpopulation D more closely resemble recent trends in subpopulation B. Thus, there appears to be some local factors in subpopulation A that are limiting population growth. Environmental conditions (e.g., local rainfall or water depths) were relatively similar in all three breeding populations over the period examined so local annual recruitment should be expected to be similar in all three subpopulations monitored. In fact, local conditions during the core CSSS breeding season (Apr-Jul) in subpopulation A were typically better than in the other subpopulation monitored.

While the plot in subpopulation B has been near-saturated with breeding territories (density = 50.0 sparrows/km²), the density of breeding territories in A has been low (density = 8.8 sparrows/km²), even though large areas of apparently suitable habitat exist. Subpopulation D reports a similar density to A (density = 7.5 sparrows/km²), and numbers have been increasing there possibly as new individuals arrive to take advantage of available unoccupied habitat. The inability of the sparrow population in A to reverse recent declines when apparently suitable habitat is available has been a major question to land managers. Unfortunately because the population size is small, our sample sizes for estimating demographic rates are also small, making it difficult to make strong inferences about limiting factors. It seems likely that several factors are working congruently to stem population recovery. One pattern that appears when looking at the comparable data is that the demographic rates that drive population growth – reproduction, survival, and recruitment (juvenile survival) rates – have been generally lower in subpopulation A compared to subpopulations B and D. However, we have little information on the habitat factors (e.g., vegetation, predators, food availability) that influence these demographic rates in subpopulation A, and thus no way to develop strategies aimed at improving vital rates. An expanded demographic monitoring effort could help answer these questions and should be considered for future research.

One area on our study plot in subpopulation A where sparrows were expected to recolonize is the area that burned in the southern portion of the Lower Meadow in 2008. This area supported numerous breeding territories prior to the burn based on previous research (La Puma *et al.* 2007); sparrows can reoccupy burned patches two to three years post-fire. Prairie

vegetation in this area has recovered and appears suitable for sparrows. However, if population growth rates within the study plot and the subpopulation remain < 1.0 , there may be no surplus birds capable of immigrating into this area. It is also possible that sparrows have not moved into the recovered habitat near West Camp due to strong philopatry to the Lower Meadow, where sparrows have been breeding in recent years, or due to the influence of stronger conspecific attraction in those same areas (Virzi *et al.* 2012).

Subpopulation A is not likely to see a substantial increase in numbers through immigration from other subpopulations. Subpopulation A is certainly the most isolated sparrow subpopulation, being the only subpopulation located west of the Shark River Slough. Sparrow dispersal probability declines greatly over longer distances and thus the likelihood of sparrows from other subpopulations dispersing into subpopulation A is low (Gilroy *et al.* 2012a; Van Houtan *et al.* 2010). In fact, no between-subpopulation dispersal events have been documented into the study plot in subpopulation A from 2008-2015. Since 2012, we have documented two dispersal events between subpopulations B and D indicating that there is better connectivity between these subpopulations.

2.5.2 Sex Ratios

Our data suggests that there is consistently a more highly-skewed sex ratio in the small sparrow subpopulations than in large subpopulations (also see **Section 4.3**). The mean sex ratios in subpopulation A (0.65) and subpopulation D (0.76) over the period from 2012-2015 are well above the mean reported in large subpopulation B (0.58) over the same period (**Table 2.1**). However, in 2015 the sex ratio in subpopulation A (0.57) was only moderately above the ratio observed in subpopulation B (0.53) for the second year in a row. This is in contrast to the extremely imbalanced sex ratio reported in small subpopulation D (0.92) in 2015. While on the surface this seems like a good development, the more moderately skewed sex ratio was achieved through a reduction in the number of male sparrows detected in subpopulation A in recent years rather than an increase in females. We do not have an explanation for this shift, although we suspect it is temporary based on previous data that shows small CSSS

subpopulations, and other threatened species, tend to have male-biased sex ratios (Virzi *et al.* 2011b, Donald 2007).

Possible explanations for male-biased sex ratios in sparrows are the effects of inbreeding (Liker and Szekely 2005), lower female survival rates (Gruebler *et al.* 2008) or sex-specific dispersal patterns (Steifetten and Dale 2005). Small, isolated populations may be particularly vulnerable to skewed sex ratios because natal dispersal is usually female-biased (Dale *et al.* 2001). Adult female survival is slightly lower than adult male survival in CSSSs, although not dramatically (Boulton *et al.* 2009). It is unknown at this time why the sex ratio is so skewed in these small sparrow subpopulations, but the consequences can be severe, as was the case with the now extinct Dusky seaside sparrow (*A. m. nigrescens*). More research is needed to understand the factors that drive the sex-ratio bias in CSSSs. In addition, conservation techniques to address this problem, such as translocating female sparrows from a larger and more stable subpopulation should be considered. It is important to recognize the inherent risk of moving birds, however, translocation should be considered if for no other reason than to ensure the short-term persistence of this important sparrow subpopulation. However, due to the current dearth of information regarding factors affecting demographic rates in subpopulation A we suggest that further monitoring and research be conducted in this subpopulation before any attempt to translocate female sparrows be conducted.

Finally, we should point out that there has been a sharp decline in the number of male sparrows and very low return rates for both sexes in subpopulation A over the years analyzed (see **Section 2.5.4** below), although the return rate for color-banded males between 2014 and 2015 in subpopulation A (0.71) was the highest rate recorded in the last four years. The female return rate in 2015, however, was much lower at 0.17 and was well below the 0.50 rate observed in 2013-2014. Although the sex ratio has come closer to a 1:1 ratio in subpopulation A, it is due to a reduction in the number of male sparrows rather than an increase in the number of females. The continuing imbalanced sex ratio contributes towards low overall annual productivity in subpopulation A. The small population size and unbalanced sex ratio could also lead to lower recruitment rates due to a lack of enough conspecific cues in the

subpopulation to encourage settlement by sparrows (Virzi *et al.* 2012). It is possible that subpopulation A could be dropping below a critical threshold necessary to attract settling males. Regardless of the cause, the low return rate for female sparrows observed in subpopulation A in 2015 is alarming and should be monitored closely.

2.5.3 Reproduction

It is difficult to make statistical comparisons of nest success data among CSSS subpopulations due to small sample sizes; however, we note the following observations. First, it is clear that sparrows breeding in large subpopulation B have generally been more successful than sparrows breeding in small subpopulation A. Second, sparrows breeding in small subpopulation D have also reported higher nest success rates than sparrows in subpopulation A in recent years. Thus, it appears that factors other than possible Allee effects – which were not shown to occur in another study by Gilroy *et al.* (2012b) – may be causing the lower reproductive rates in subpopulation A.

One troubling pattern seen in the reproductive data is that the hatch rate has been much lower in subpopulation A than in subpopulations B or D. The mean hatch rate from 2012-2015 in subpopulation A was only 0.49, compared to mean rates of 0.76 and 0.92 in subpopulations B and D, respectively. For nests that hatch, the proportion that fledge is actually higher in subpopulation A (mean = 0.67), compared to subpopulations B (mean = 0.62) or D (mean = 0.58) over the 4-year period analyzed. Predation is thought to be the primary cause of CSSS nest failure so it is possible that nest predation rates at the incubation stage are higher in this subpopulation. One hypothesis for increased predation in A is a greater abundance of predators, such as rice rats, in the region; however, this remains untested. It is also possible that predator movements are more influenced by fluctuations in water levels caused by water management decisions affecting subpopulation A resulting in more chance encounters with nests.

Overall productivity remains low in small subpopulation A compared to large subpopulation B, partially explained by the continued low density of breeding pairs in subpopulation A. During

2015, mean clutch size and overall nest success rates were comparable between the two subpopulations. However, as mentioned previously, the hatch rate was substantially lower in subpopulation A. Further, the total number of nestlings fledged per breeding pair continued to be lower in subpopulation A (1.2) compared to subpopulations B (1.7) and D (2.0). Thus, overall productivity and local recruitment for subpopulation A remains extremely low.

The other important observation in our 2015 data is that no multi-brooding was confirmed in small subpopulation A (although the fates of three July nests were unknown); however, 20% of the sparrows in large subpopulation B were able to successfully raise a second brood.

Interestingly, water levels were generally higher in subpopulation B breeding areas compared to subpopulation A throughout the entire breeding season, and the breeding areas in subpopulation A never had substantial water coverage. The subpopulation B study area was flooded in a late-April storm and water levels late-season never reached the depth or coverage seen in the weeks immediately after this storm. Since multi-brooding is predicted to be critical for the population viability of the CSSS it is vitally important to identify the factors that lead to successful multi-brooding. Data from past seasons (Slater *et al.* 2014) indicate that low water levels may not be the sole factor necessary for sparrows to multi-brood. It is possible that water management decisions that affect the rate and quantity of late-season flow into subpopulation A could be limiting late-season breeding opportunities by affecting predator movements and thus increasing nest predation rates, but this hypothesis remains untested.

Over the period analyzed, sparrows were able to multi-brood in subpopulation B every year, and in subpopulation D in 2014, while sparrows in subpopulation A never multi-brooded. Although Gilroy *et al.* (2012b) previously found no Allee effects associated with nest success rates among CSSS subpopulations, it is still possible that there could be an unrecognized Allee effect in small sparrow subpopulations leading to a lack of multi-brooding, again perhaps due to a lack of sufficient conspecific cues in the small subpopulations as one hypothesis (Virzi *et al.* 2012). We suggest that this is an area of research that deserves far more attention, which would require extending the field season to monitor late-season breeding attempts to completion.

2.5.4 Survival

The return rate for adult sparrows in subpopulation A (0.46) was below the rate observed in subpopulation B (0.55) and subpopulation D (0.54) in 2015 (**Table 2.2**). Interestingly, in 2015 the return rate for male sparrows in subpopulation A (0.71) was quite high, rebounding after a three-year decline, but the return rate for females (0.17) plummeted to the lowest rate recorded in the past three years resulting in the overall low adult return rate. The low female return rate reported in subpopulation A is a major concern since this small subpopulation is already on the brink of extirpation. The low return rates observed in subpopulation A could be the result of lower survival rates or the dispersal of individuals to areas off our study plot. Long-distance dispersal is rare for the CSSS so this is unlikely to be the cause for low return rates; however, we cannot rule out that short-distance dispersal is going undetected due to the small size of our study plot. We suggest that further research is needed to better understand the cause for the low return rates observed in subpopulation A, perhaps intensifying surveys to include areas off-study plot to detect dispersing individuals. Dispersal patterns and potential causes for the male-biased sex ratios seen in small sparrow subpopulations remain critical factors that need more understanding in order to better assess the rangewide status of the Cape Sable seaside sparrow.

2.6 Conclusions

Overall, the 2015 sparrow breeding season was an average to slightly below average year in regards to overall nest success rates in subpopulations A, B and D. Compared to the other subpopulations monitored, nests in subpopulation A continue to experience the lowest mean hatch rate. The low hatch rate in subpopulation A is clearly an issue that deserves more attention. Future demographic research should include measures to better identify nest predators since predation rates appear higher in subpopulation A than in either of the other subpopulations being monitored. One field technique that could be considered is the deployment of nest cameras to identify predators. More detailed nest survival analysis of existing data may also be warranted to better understand success rates at various stages, and to compare differences among subpopulations being monitored. Sample sizes continue to be a

problem limiting such analyses due to small population sizes, small plot sizes and a limited number of demographic study plots currently being monitored annually. We suggest that demographic monitoring efforts be increased by adding additional study plots where possible; increasing the sizes of current plots is not possible due to the distribution of sparrows in these areas (i.e., plots are already covering the areas of highest CSSS density).

An important observation is that multi-brooding, which is necessary for CSSS population viability, is not occurring in subpopulation A. Multi-brooding occurred regularly in large subpopulation B over the 4-year period analyzed, and occurred once in small subpopulation D. We cannot explain why we are not observing any multi-brooding in subpopulation A at this time. It is possible that there is some undetected Allee effect occurring in this small CSSS subpopulation, but if this is the case we would expect to see a similar Allee effect in subpopulation D. It is also possible that late-season breeding conditions in subpopulation A are being negatively affected by managed water releases into the system, but since these do not typically occur until after 15 Jul, after our demographic monitoring is usually completed, we would expect to observe some multi-brooding before this date but do not. Further research is needed to understand why multi-brooding is not occurring in subpopulation A, and this may require a longer field season to monitor late-season breeding attempts until completion.

Overall productivity and recruitment remain very low in subpopulation A due to the small population size and limited dispersal into this isolated CSSS subpopulation. We have not observed any dispersal into subpopulation A since monitoring began there in 2008. While dispersal events into subpopulation A have occurred (Van Houtan *et al.* 2010), these events are certainly quite rare and likely not occurring at a rate necessary to sustain this subpopulation and promote recovery. Local productivity and recruitment rates also appear to be too low to sustain this subpopulation and prevent extinction without sufficient immigration into the subpopulation. We suggest that translocation of sparrows into subpopulation A may be necessary at this time to avoid extinction of this critical subpopulation.

The low return rate of female sparrows in subpopulation A in 2015 raises alarm that dispersal or survival rates may be lower for females in this area. In the past, we have suggested translocation of females as the best management option for bolstering subpopulation A. However, overall sparrow numbers may have declined to the point where both males and females should be considered for translocation at this time. Before conducting any translocations, we suggest that survival analyses be re-examined now that more data is available – the last analysis was conducted by Gilroy *et al.* (2012a) – to better understand if there is an issue with female survival in subpopulation A. We also continue to recommend that efforts be made to better understand the causes of low demographic rates (especially hatch rates) in subpopulation A before translocating sparrows there. Finally, a detailed translocation plan should be developed before moving any birds.

2.7 Tables and Figures

TABLE 2.1: Demographic data for Cape Sable seaside sparrows breeding in small subpopulations A and D compared with data from large subpopulation B (2012 - 2015). Nests were not monitored in subpopulation B in 2012. Sex Ratio = male bias in subpopulation (Males / Total Population); Density = number of sparrows per square km; Chicks Fledged/S.Nest = Chicks Fledged / Nests Fledged; Chicks Fledged/Pair = Chicks Fledged / Breeding Pairs. Mean and standard deviation (SD) reported for all demographic parameters, except density estimates which are not meaningful due to changes in sizes of study plots in 2015 (see footnote).

| | Pop A | | | | | | Pop D | | | | | | Pop B | | | | | |
|-------------------------|-------|------|------|--------------------|------|------|-------|------|------|--------------------|------|------|-------|------|------|---------------------|------|------|
| Parameter | 2012 | 2013 | 2014 | 2015 | Mean | SD | 2012 | 2013 | 2014 | 2015 | Mean | SD | 2012 | 2013 | 2014 | 2015 | Mean | SD |
| Total Population | 22 | 15 | 14 | 14 | 16 | 4 | 8 | 5 | 14 | 12 | 10 | 4 | 28 | 27 | 30 | 34 | 30 | 3 |
| Breeding Pairs | 6 | 6 | 6 | 6 | 6 | 0 | 2 | 2 | 3 | 1 | 2 | 1 | 8 | 11 | 13 | 15 | 12 | 3 |
| Males | 17 | 10 | 8 | 8 | 11 | 4 | 6 | 3 | 11 | 11 | 8 | 4 | 18 | 16 | 17 | 18 | 17 | 1 |
| Females | 5 | 5 | 6 | 6 | 6 | 1 | 2 | 2 | 3 | 1 | 2 | 1 | 8 | 11 | 13 | 16 | 12 | 3 |
| Sex Ratio | 0.77 | 0.67 | 0.57 | 0.57 | 0.65 | 0.10 | 0.75 | 0.60 | 0.79 | 0.92 | 0.76 | 0.13 | 0.64 | 0.59 | 0.57 | 0.53 | 0.58 | 0.05 |
| Density ^(a) | 4.4 | 3.0 | 2.8 | 8.8 ^(a) | na | na | 4.0 | 2.5 | 7.0 | 7.5 ^(a) | na | na | 18.7 | 18.0 | 20.0 | 50.0 ^(a) | na | na |
| Nests | 9 | 7 | 7 | 12 | 9 | 2 | 3 | 2 | 4 | 3 | 3 | 1 | 9 | 14 | 26 | 32 | 20 | 11 |
| Mean Clutch Size | 3.8 | 3.0 | 3.3 | 3.6 | 3.4 | 0.4 | 3.7 | 3.0 | 3.3 | 3.7 | 3.4 | 0.3 | na | 3.2 | 3.2 | 3.3 | 3.2 | 0.1 |
| Nests Hatched | 4 | 4 | 3 | 6 | 4 | 1 | 2 | 2 | 4 | 3 | 3 | 1 | na | 11 | 20 | 23 | 18 | 6 |
| Hatch Rate | 0.44 | 0.57 | 0.43 | 0.50 | 0.49 | 0.06 | 0.67 | 1.00 | 1.00 | 1.00 | 0.92 | 0.17 | na | 0.79 | 0.77 | 0.72 | 0.76 | 0.03 |
| Nests Fledged | 2 | 2 | 3 | 4 | 3 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | na | 9 | 12 | 10 | 10 | 2 |
| Fledge Rate/Hatched | 0.50 | 0.50 | 1.00 | 0.67 | 0.67 | 0.24 | 0.50 | 1.00 | 0.50 | 0.33 | 0.58 | 0.29 | na | 0.82 | 0.60 | 0.43 | 0.62 | 0.19 |
| Fledge Rate/Nest | 0.22 | 0.29 | 0.43 | 0.33 | 0.32 | 0.09 | 0.33 | 1.00 | 0.50 | 0.33 | 0.54 | 0.32 | na | 0.64 | 0.46 | 0.31 | 0.47 | 0.17 |
| Chicks Fledged | 3 | 5 | 9 | 7 | 6 | 3 | 1 | 6 | 7 | 2 | 4 | 3 | na | 27 | 33 | 25 | 28 | 4 |
| Chicks Fledged/S.Nest | 1.5 | 2.5 | 3.0 | 1.5 | 2.1 | 0.8 | 1.0 | 3.0 | 3.5 | 2.0 | 2.4 | 1.1 | na | 3.0 | 3.0 | 3.1 | 3.0 | 0.1 |
| Chicks Fledged/Pair | 0.5 | 0.8 | 1.5 | 1.2 | 1.2 | 0.4 | 0.5 | 3.0 | 2.3 | 2.0 | 2.0 | 1.1 | na | 2.5 | 2.5 | 1.7 | 2.2 | 0.5 |
| Pairs Fledging >1 Brood | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | na | 3 | 3 | 3 | 3 | 0 |
| %Fledging >1 Brood | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.08 | 0.17 | na | 0.27 | 0.23 | 0.20 | 0.23 | 0.04 |

^(a)Density estimated as number of sparrows per km² based on territory mapping data from study plots. Note that study plots were reduced in size in 2015, and were placed in highest density areas within former study plots. Therefore, higher density estimates reported in 2015 do not indicate an increase in sparrow density compared to previous years.

TABLE 2.2: Mark-recapture data for Cape Sable seaside sparrows breeding in small subpopulations A and D compared with data from large subpopulation B (2012 - 2015). Banded

Adults = total number of banded adults in subpopulation at year end (birds banded current year + resights); Resights = total number of resights of banded individuals found in breeding population in prior year; Return Rate = Resights / Banded Birds (from prior year, by age class). Return rates not calculated in years where there were no color-banded individuals in any age class in the prior year. Mean and standard deviation (SD) reported for all demographic parameters.

| | Pop A | | | | | | Pop D | | | | | | Pop B | | | | | |
|-------------------------|-------|------|------|------|------|------|-------|------|------|------|------|------|-------|------|------|------|------|------|
| Data | 2012 | 2013 | 2014 | 2015 | Mean | SD | 2012 | 2013 | 2014 | 2015 | Mean | SD | 2012 | 2013 | 2014 | 2015 | Mean | SD |
| Banded Adults | 21 | 14 | 13 | 13 | 15 | 4 | 8 | 5 | 13 | 11 | 9 | 4 | 28 | 25 | 29 | 33 | 29 | 3 |
| Males | 17 | 10 | 7 | 8 | 11 | 5 | 6 | 3 | 11 | 10 | 8 | 4 | 18 | 16 | 17 | 18 | 17 | 1 |
| Females | 4 | 4 | 6 | 5 | 5 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 8 | 9 | 12 | 15 | 11 | 3 |
| Juveniles | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 23 | 13 | 12 | 8 |
| Nestlings | 3 | 3 | 3 | 0 | 2 | 2 | 3 | 5 | 12 | 0 | 5 | 5 | 16 | 17 | 37 | 0 | 18 | 15 |
| Resights - Adults | 10 | 10 | 6 | 6 | 8 | 2 | 2 | 2 | 3 | 7 | 4 | 2 | 5 | 15 | 11 | 16 | 12 | 5 |
| Resights - Males | 10 | 8 | 4 | 5 | 7 | 3 | 2 | 2 | 2 | 7 | 3 | 3 | 2 | 11 | 8 | 10 | 8 | 4 |
| Resights - Females | 0 | 2 | 2 | 1 | 1 | 1 | na | 0 | 1 | 0 | 0 | 1 | 3 | 4 | 3 | 6 | 4 | 1 |
| Return Rate - Adults | 0.56 | 0.48 | 0.43 | 0.46 | 0.48 | 0.05 | 0.33 | 0.25 | 0.60 | 0.54 | 0.43 | 0.17 | na | 0.54 | 0.44 | 0.55 | 0.51 | 0.06 |
| Return Rate - Males | 0.67 | 0.47 | 0.40 | 0.71 | 0.56 | 0.15 | 0.33 | 0.33 | 0.67 | 0.64 | 0.49 | 0.18 | na | 0.61 | 0.50 | 0.59 | 0.57 | 0.06 |
| Return Rate - Females | 0.00 | 0.50 | 0.50 | 0.17 | 0.29 | 0.25 | na | 0.00 | 0.50 | 0.00 | 0.17 | 0.29 | na | 0.50 | 0.33 | 0.50 | 0.44 | 0.10 |
| Resights - Juveniles | 3 | na | 2 | na | 3 | 1 | na | na | na | na | na | na | na | 2 | 3 | 5 | 3 | 2 |
| Resights - Nestlings | 1 | 1 | 0 | 0 | 1 | 1 | na | 0 | 1 | 1 | 1 | 1 | na | 0 | 3 | 1 | 1 | 2 |
| Return Rate - Juveniles | 1.00 | na | 1.00 | na | 1.00 | 0.00 | na | na | na | na | na | na | na | 0.25 | 0.60 | 0.22 | 0.36 | 0.21 |
| Return Rate - Nestlings | 0.13 | 0.33 | 0.00 | 0.00 | 0.11 | 0.16 | na | 0.00 | 0.20 | 0.08 | 0.09 | 0.10 | na | 0.00 | 0.18 | 0.03 | 0.07 | 0.10 |

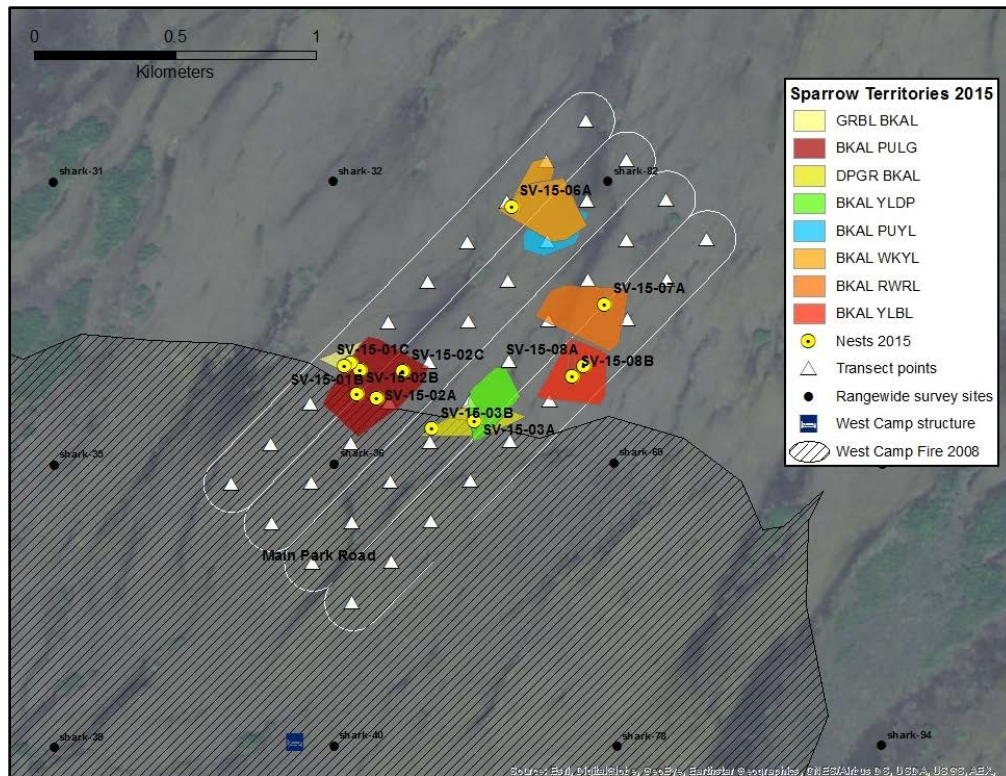


FIGURE 2.1: Location of Cape Sable seaside sparrow territories in subpopulation A during the 2015 breeding season. Black circles correspond to Everglades National Park helicopter survey sites. Eight male sparrows were observed singing on apparent territories during 2015. Territories are color-coded by unique color-band combinations for each male sparrow; red-yellow tones indicate breeding males and blue-green tones indicate single males. Yellow circles correspond to locations of sparrow nests monitored during 2015. Hatched area represents boundary of fire that burned near West Camp in 2008.

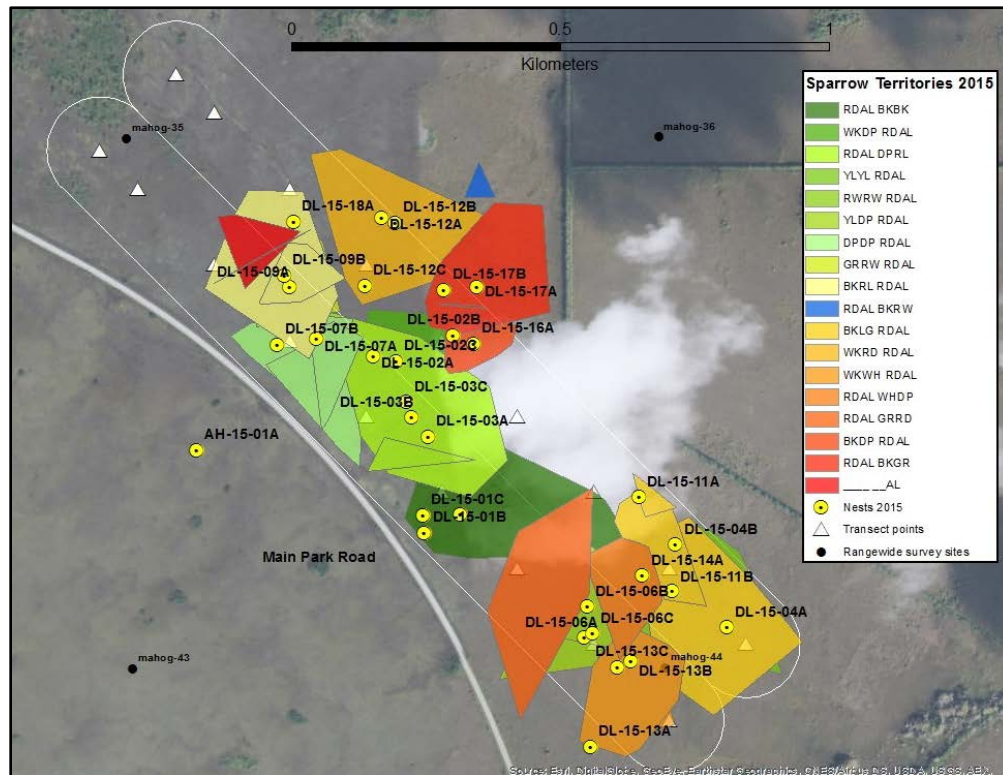


FIGURE 2.2: Location of Cape Sable seaside sparrow territories in the Dogleg Study Plot northeast of Main Park Road in subpopulation B during the 2015 breeding season. Black circles correspond to Everglades National Park helicopter survey sites. Eighteen male sparrows were observed singing on apparent territories during 2015, although all birds were not present throughout the season. Territories are color-coded by unique color-band combinations for each male sparrow; red-yellow tones indicate breeding males and blue-green tones indicate single males. Yellow circles correspond to locations of sparrow nests monitored during 2015.

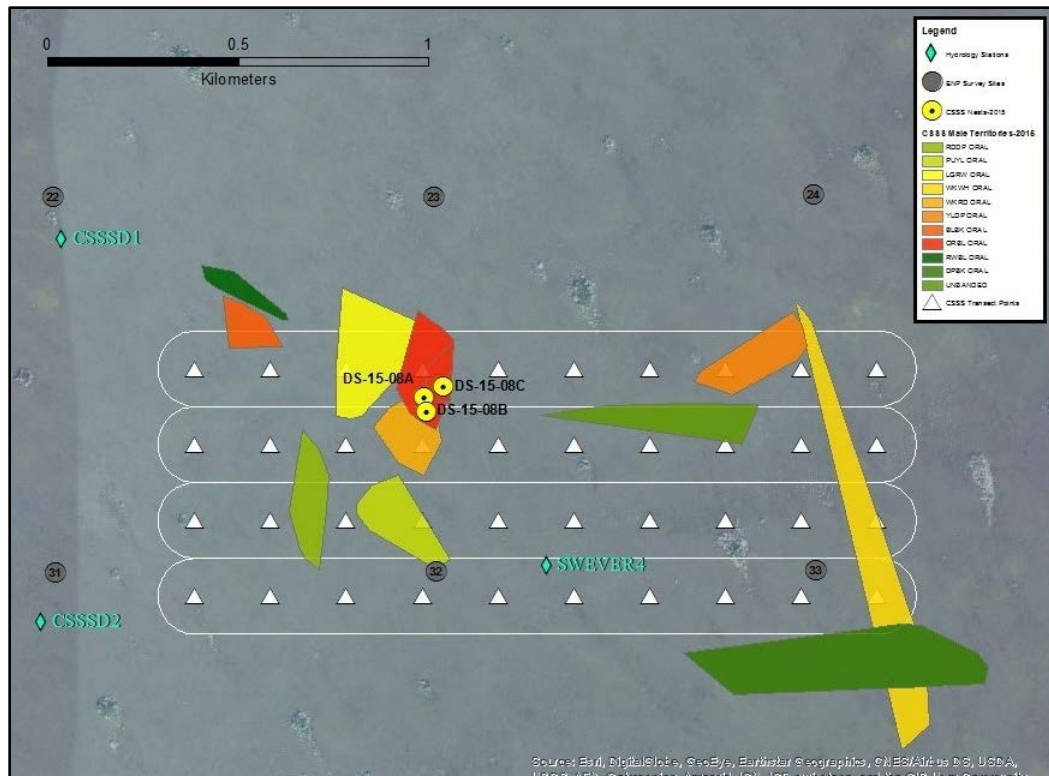


FIGURE 2.3: Location of Cape Sable seaside sparrow territories in subpopulation D study plot east of Aerojet Road during the 2015 breeding season. Gray circles correspond to Everglades National Park helicopter survey sites. Eleven male sparrows were observed singing on apparent territories during 2015. Territories are color-coded by unique color-band combinations for each male sparrow; red-yellow tones indicate breeding males and blue-green tones indicate single males. Yellow circles correspond to locations of sparrow nests monitored during 2015.

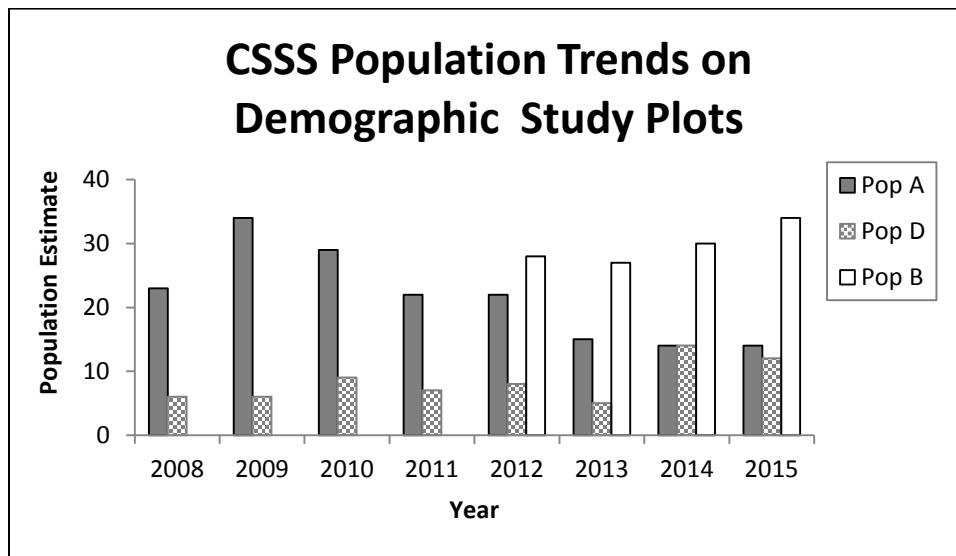


FIGURE 2.4: Number of Cape Sable seaside sparrows on demographic study plots in subpopulations A, B and D (2008-2015). Data from 2008-2011 provided by Slater *et al.* (2014). Study plots in small subpopulations A and D were surveyed annually during the 2008-2015 breeding seasons (Mar-Jul). The study plot in large subpopulation B (Dogleg Plot) was surveyed with similar effort from 2012-2015 only. Total area surveyed within each study plot was consistent from 2008-2014; in 2015 study plots were reduced in size, however, core areas where most sparrows were present in previous years were surveyed with similar effort making population data comparable.

3.0 Juvenile Capture Techniques

3.1 Introduction

As part of our research in 2015 we continued to capture and band free-flying juvenile sparrows on our demographic study plots. Juvenile sparrows present on our study plots are typically captured late in the breeding season as they begin to form age-specific flocks. These flocks likely include juveniles that fledged from monitored nests on our study plots, but also may include juveniles dispersing into our study plots from nearby areas. Flocks may also include adult sparrows, possibly parents of fledged juveniles. In 2015, we chose not to band nestlings to minimize the risks associated with handling pre-fledged birds. Thus, the only sub-adult sparrows banded in 2015 were these free-flying juveniles.

Color-banding juvenile sparrows is conducted as part of our demographic research for multiple reasons. First, color-banding individuals allows us to study juvenile survival and dispersal patterns as part of our long-term mark-recapture study of the CSSS to gain much needed information on this age class. Annual survival is often the most important demographic parameter influencing population viability (Doak *et al.* 1994; Roche *et al.* 2010), and despite the level of CSSS research that has been conducted in recent years there remains a dearth of information on juveniles including survival rates and dispersal and recruitment rates among subpopulations.

Second, the skewed sex ratios reported in small CSSS subpopulations, including subpopulation A, are of major concern. At present, we do not know the cause for the extremely male-biased sex ratios being observed in small subpopulations. Possible causes include lower survival rates for females in small sparrow subpopulations, lower dispersal rates or shorter dispersal distances for female sparrows, or unbalanced sex ratios in juvenile sparrows. Capturing and sexing juvenile sparrows provides a first look at sex ratios for juveniles, which may help answer the question regarding imbalanced sex ratios in small subpopulations.

Finally, we decided to focus on capturing and banding free-flying juvenile sparrows because these individuals are likely candidates for future translocation of sparrows to subpopulation A. Due to the highly male-biased sex ratios historically reported in subpopulation A, we are concerned that if more female sparrows do not recruit into the subpopulation we will see a continued and perhaps rapid decline in sparrow numbers in this already very small sparrow subpopulation as the remaining males senesce. We suggest that translocation of sparrows, perhaps weighted towards females, from a larger and more stable subpopulation into small subpopulation A should be considered at this time in order to ensure persistence of this critically important sparrow subpopulation. Thus, during 2015 we refined our methods to capture free-flying juveniles to provide information necessary to guide managers towards eventual translocation of sparrows from a larger, more stable subpopulation (B) to subpopulation A (**Section 3.2**).

Since we are interested in potentially translocating more female sparrows to subpopulation A, we need to be able to accurately and rapidly sex juvenile sparrows being considered for translocation. Our previous research has led us to believe that juvenile sparrows may be rapidly sexed in the field by taking simple morphometric measurements such as wing chord length and tail length. In order to test this hypothesis we collected feather samples from all juvenile sparrows captured in 2015 for later genetic sexing (**Section 3.3**). These results could then be compared with field sexing based on morphometrics to test our ability to rely on this field method. As a further analysis, we also examined historic mark-recapture data to identify any banded juveniles that later returned to study plots to breed. These individuals could then be sexed accurately based on behavioral observations (e.g., males singing) and compared with predicted sex based on original morphometric measurements.

3.2 Capture Techniques

3.2.1 Aging Sparrows

Juvenile sparrows fledged from current year nests are easy to distinguish from adult sparrows in the field (**Figure 3.1**). Juveniles have buffy undertones and are paler overall compared to

adults. It is possible to age second year birds, distinguishing them from older birds; second year birds will usually show a stark contrast in color between their flight and other wing feathers while flight and wing feathers of after second year birds will be more evenly dark. However, hatch year juveniles are still easy to distinguish from second year birds. Many juveniles begin to molt into adult feathers in early-August, and most birds cannot be confidently aged to second year by the following spring. In summary, juveniles captured by early-August should be easy to identify as hatch year birds (i.e., current year free-flying juveniles) in the hand.

3.2.2 Juvenile Flocks

Towards the end of the CSSS breeding season (late-June to early-July), juvenile sparrows fledged from the current year will begin to gather in loose flocks across the landscape, often remaining near natal breeding areas for the remainder of the season. Free-flying juvenile sparrows tend to congregate in large sawgrass clumps or near small hardwood hammocks (**Figure 3.2**). They forage nearby in shorter grass and bare ground areas, but can escape to this cover when they feel threatened. Based on our previous experience the best time to catch free-flying juveniles is mid-June through the end of July; activity tapers off rapidly in August. It may be easier to locate and catch juveniles earlier in the season when there are still adults nesting since they are attracted to the activity. Juveniles are most active from sunrise to around 0800, and can be difficult to locate after 0900.

Recently-fledged young can be hard to locate for the first month after they leave the care of their parents. Older juveniles become more obvious and often travel in pairs, trios and small flocks, wandering across the landscape investigating the activities of nearby adult sparrows. Flocks of up to 20 individuals have been observed in years with successful breeding. Juvenile sparrows in subpopulation B do not shy away from using hammocks and shrubs as cover, but sparrows in other subpopulations (e.g., A and E) generally stay clear of hardwoods. Flocks may congregate in the same areas for a period of days to weeks allowing ample time for researchers to return to capture juveniles after flocking locations are initially discovered.

Free-flying juvenile sparrows are captured using mist nets. They can be herded into the net, passive-netted, or occasionally drawn in using song playback. Nets are set in or near thick cover, especially in the larger sawgrass clumps that they return to repeatedly. Nets can be set before sunrise in areas where juveniles are known to congregate, and birds can be captured when they become active. The act of setting the net tends to drive the birds out of sawgrass clumps, and they may or may not return. One to three nets can be used at different vegetation clumps, but nets should never be left unattended. Juveniles should not be aggressively chased (herded) by researchers unless they are very close to a net, as they can quickly lose their naiveté and become difficult to capture in the future. Working in teams of 2-3 researchers is recommended to improve efficiency of herding juveniles into nets.

3.2.3 Mist Netting

Target mist netting was used to capture free-flying juvenile sparrows at our demographic study site in subpopulation B (Dogleg plot) in 2015 (**Figure 3.3**). The basic set-up is similar to most other types of mist netting, but the steps are described below:

Gear needed:

1. One set of aluminum banding poles (top and bottom halves)
2. Mist net (length = 12 m; height = 2.6 m; mesh size = 33 mm)
3. Four metal stakes, flagged, with guidelines

Steps for setting up nets:

1. Stick bottom banding pole (without guidelines) vertically into the ground, and place a set of banding loops onto the pole, ensuring that the loops are in order.
2. Attach the top banding pole. Stake guidelines into the ground at $\sim 120^\circ$ angles from the intended direction of the net.
3. Carefully stretch out the net. Trample vegetation a small amount to create a net lane (only if needed).

4. Stick the second bottom banding pole vertically into the ground and place banding loops (in correct order) onto the pole. Attach the top pole and stake the guidelines into the ground as before.
5. Slowly raise loops on both sides. If working alone, you may need to go back and forth between the two sets of poles.

Scouting areas for setting up nets before capture days is recommended to increase efficiency. Knowing where juvenile flocks like to congregate allows you to set the mist net next to their favorite sawgrass clump while it's still dark and capture birds right at sunrise, which will increase your success rate. Setting nets up in the dark may keep you from needing to herd juveniles into the net, which can be done but makes capturing them more difficult. You can also keep the net open while banding and more juveniles may get caught in the net. Juveniles often fly slowly so they don't get as tangled in the net which reduces risk of injury; however, they also may escape or bounce out more easily so having one researcher closely monitor open nets at all times is important.

Not knowing a flock's favored vegetation clump in advance makes catching juveniles much more difficult, but it can sometimes still be done. If you happen across a juvenile (or multiple juveniles), try to figure out what sawgrass clump(s) they tend to prefer and set up the net next to the clump as quickly as you can. Keep an eye on where the juvenile(s) go. They will often get close and watch you, but because of their short attention spans, they may start wandering again before you finish setting up. Sometimes it can be helpful to herd (gently encourage) these juveniles towards the net. Remember, the key to herding is not to surprise or scare them so that they stay naïve. Rather, have one or more researchers slowly herd the juveniles towards the net. This will take some practice and patience to master.

3.3 Sexing Juveniles

3.3.1 Morphometric Sexing

Our previous field research suggests that juvenile CSSS may be sexed in the field using morphometrics (M. Davis, personal communication). Morphometric measurements such as

wing chord length and tail length are ordinarily collected during sparrow banding (**Figure 3.4**). In the past, these measurements have been used to predict the sex of juvenile sparrows; however, statistical analysis has not been previously conducted. Rather, predictions have simply been compared to the actual sex of individuals determined later based on field observations of returning individuals to our study plots. There is some evidence that juvenile male sparrows have longer wings and tails than females suggesting that these morphometrics may be used rapidly predict the sex of juvenile sparrows in the field.

In 2015, we continued to collect morphometric measurements on all sparrows captured and banded. We used these data to predict the sex of juvenile sparrows, and compared our predictions to actual sex determined based on genetic sexing methods (**Section 3.3.2**). We also reviewed historic mark-recapture data to locate data on returning individuals originally banded as juveniles to analyze sex determination based solely on morphometrics to see if this method can be used to accurately predict sex in the field. We used a two-sample Student's *t*-test assuming equal variances to analyze differences in mean wing chord and tail lengths between male and female sparrows. Results are reported with standard errors (SE), lower 95% confidence intervals (LCI), and upper 95% confidence intervals (UCI).

3.3.2 Genetic Sexing

Sexing individuals using genetic material has become commonplace in avian ecology. Polymerase chain reaction (PCR) techniques to amplify a single or few copies of DNA across several orders of magnitude to generate millions of copies for analysis are regularly used by molecular biology labs for many purposes including genetic sexing. We worked with a well-established and highly regarded molecular biology lab, Avian Biotech, which specializes in avian genetic research (<http://www.avianbiotech.com>). Avian Biotech, based in Tallahassee, FL, has developed an efficient and accurate DNA assay for sexing birds from tissue which can be extracted from feathers.

DNA sexing may be done from blood or feather samples with similar results. Avian Biotech worked out a method in 1994 that allows researchers to use a few small, freshly-plucked breast

feathers from birds for genetic analysis. Using breast feathers rather than flight feathers or blood helps to reduce stress on birds, eliminates unnecessary bleeding and minimizes the chance of infection without compromising the accuracy and reliability of the results. Since we wanted to be as cautious as possible handling juvenile sparrows, we decided to try to sex individuals using only 3-6 breast feathers as our sample. We did not want to remove any of the growing flight feathers from juveniles, nor did we want to subject the young birds to the handling required for blood removal. Extracting breast feathers provided us with a very low stress method for collecting the necessary genetic material for analysis.

Genetic material is extracted from the tissue in the calamus of the feather (i.e., the portion of the feather shaft underneath the skin). Each tissue cell contains a nucleus from which a small amount of genomic DNA may be extracted. DNA-based sexing uses PCR to distinguish the differences in the genes or chromosomes of male and female birds. Male birds carry a ZZ chromosome pair while female birds carry a ZW chromosome pair, which determines the sex of offspring. Using PCR a region of the DNA that differs in size between the Z and W chromosomes is amplified. This method yields one marker for males and two markers for females, making visual determination of sex easy (and highly accurate) in the lab. After discussing the procedure with Avian Biotech, it was determined that the lab could produce the most accurate markers for CSSS if we could initially provide feather samples from known sex individuals. As such, we sent the lab feather samples from one known adult male and one known adult female sparrow so that genetic markers could be worked out before attempting to sex juvenile sparrows.

During 2015, we captured free-flying juvenile sparrows and collected breast feather samples from each individual. We tried to collect approximately six freshly-plucked breast feathers from each juvenile handled because the exact amount of feathers required to obtain enough genetic material for analysis was unknown. We were instructed that it is always better to obtain feathers with blood tips, but this is not absolutely necessary. All feathers must be freshly-plucked from the bird (i.e., no feathers that fall out naturally during handling should be collected). Feather samples were stored in kits provided by Avian Biotech, and each sample was labeled with the USGS band combination as the identifier. Researchers cleaned their hands with

disinfectant between handling each bird and avoided touching the ends of feather shafts to avoid contamination issues. Samples were promptly sent to Avian Biotech for processing, and results were typically provided within seven days.

3.3.3 Results: Genetic-Morphometric Sexing

During 2015, we captured 23 free-flying juvenile sparrows and collected feather samples for genetic sexing (**Table 3.1**). Of the 23 juvenile sparrows sexed genetically, 12 were males and 11 were females. Thus, we could include these individuals in our analysis using morphometric measurements to sex sparrows because sex was confirmed for all individuals via genetic sexing (see below). Interestingly, the sex ratio for juvenile sparrows sexed genetically was fairly balanced. This may be expected in large subpopulation B where these juveniles were captured since we typically observe a balanced adult sex ratio in this subpopulation. However, we caution that this is still a rather small sample size. Further, it is possible that our capture technique biases our capture rate towards males since we sometimes use song playback to capture juvenile sparrows. Thus, readers should not place too much importance on the observed sex ratio in this small sample. Still, it is interesting to note the balanced sex ratio in this small sample of juvenile sparrows.

We also reviewed our historic mark-recapture database to identify any sparrows originally banded as free-flying juveniles that later returned to our study plots and thus could subsequently be positively sexed based on breeding status and behavior. Between 2007 and 2015, we identified 50 individuals that were originally banded as juveniles that returned to breed on our study plots. This brings the total number of juvenile sparrows used in our morphometric sexing analysis to 73 individuals with known sex, determined via genetic sexing or later breeding status observations. This provided us with a larger dataset to examine the accuracy of using morphometrics to sex juvenile sparrows because in all cases the sex of these juveniles was positively confirmed at a later time.

We conducted a two-sample *t*-Test assuming equal variances to compare wing chord and tail measurements taken from 73 juvenile sparrows to examine differences between male and

female sparrows (**Table 3.2**). We found that there was a significant difference between males and females for both morphometrics. In general, juvenile females had shorter wings and tails than juvenile males. Mean wing length was 53.5 mm (SE = 0.19, LCI = 53.1, UCI = 53.9) for juvenile females and 56.3 mm (SE = 0.17; LCI = 56.0, UCI = 56.6) for juvenile males. Mean tail length was 43.2 mm (SE = 0.29; LCI = 42.6, UCI = 43.8) for juvenile females and 46.3 mm (SE = 0.37; LCI = 45.5, UCI = 47.0) for juvenile males.

Wing chord appears to be the better morphometric for rapid field sexing because there is less variation among individuals. Thus, we suggest that wing chord length be considered the primary morphometric for field sexing. However, our data suggests that for those individuals with wing chord measurements of 55 mm accurate sexing based on this morphometric alone may not be possible. In these instances, we suggest that tail length measurements be used as a secondary morphometric to more accurately sex individuals in the field. In these instances, it appears that individuals with tail lengths below 45 mm will likely be females.

Sexing juvenile sparrows using morphometrics alone will always have some level of error due to individual variation, difficulties accurately aging individuals that might affect measurements, and potential inconsistencies with the measurements themselves. Still, following the guidelines outlined here should provide a useful method for rapid field sexing of juvenile sparrows. To test the accuracy of this field method for sexing juvenile sparrows we conducted an *a priori* validation of our sexing data by comparing predicted sex vs. known sex via genetic sexing or later behavioral observations (**Figure 3.5**). We found that 93% of the individuals included in our analysis were sexed correctly using the guidelines set forth. Using wing chord length alone resulted in accurate sexing of 78% of individuals. Of the 23 juvenile sparrows sexed genetically in 2015, we were able to predict sex based on morphometrics alone for 20 individuals (87%). Of the three individuals that were sexed incorrectly based on morphometrics, one was very young and likely was too small for proper sexing with this method. The other two were individuals with morphometric measurements in the region of overlap identified, and these types of errors are unavoidable using this rapid field method for sex determination but are considered within an acceptable level of error.

3.4 Conclusions

Our results indicate that juvenile sparrows may be accurately sexed in the field based on morphometric measurements with an acceptable degree of precision. Most individuals can be sexed simply based on wing chord length measurements, with males tending to have longer wings than females. For those individuals with wing chord length measurements in the area of overlap (length = 55 mm), tail length may be used as a secondary morphometric measurement to improve precision of sex determination because males also tend to have longer tails than females. Thus, we are confident that using morphometrics to provide a rapid assessment of sex in the field will enable researchers to select the desired individuals for translocation without the need to wait for lab results to determine sex. However, since our genetics lab (Avian Biotech) was able to develop markers to accurately sex Cape Sable seaside sparrows using DNA extracted from feather samples, researchers can still obtain very reliable sex determination of translocated birds at a later time to validate sex determinations originally based on morphometric measurements.

3.5 Tables and Figures

Table 3.1: Sex ratio (Ω) of juvenile sparrows captured in CSSS subpopulation B (2015) based on genetic sexing.

| Sex | <i>n</i> |
|------------|-----------------|
| M | 12 |
| F | 11 |
| Total | 23 |
| Ω | 0.52 |

Ω = sex ratio [n_{males} / n_{total}].

Table 3.2: Summary statistics and *t*-Tests comparing morphometric measurements (wing chord length and tail length) between male and female Cape Sable seaside sparrows. Data used in analysis includes juveniles captured and sexed genetically in 2015 (*n* = 23) and known-sex juveniles captured in previous years that returned as breeders in later years (*n* = 50).

| WING LENGTH | | | | TAIL LENGTH | | | |
|-------------|-------|------------|------|-------------|-------|------------|------|
| F | | M | | F | | M | |
| Mean | 53.5 | Mean | 56.3 | Mean | 43.2 | Mean | 46.3 |
| SE | 0.19 | SE | 0.17 | SE | 0.29 | SE | 0.37 |
| Median | 53.5 | Median | 56 | Median | 43.5 | Median | 46 |
| Mode | 54 | Mode | 56 | Mode | 44 | Mode | 46 |
| SD | 1.00 | SD | 1.10 | SD | 1.54 | SD | 2.38 |
| Var | 1.00 | Var | 1.20 | Var | 2.37 | Var | 5.67 |
| Kurtosis | -0.97 | Kurtosis | 0.21 | Kurtosis | -0.86 | Kurtosis | 0.26 |
| Skewness | 0.00 | Skewness | 0.40 | Skewness | -0.19 | Skewness | 0.22 |
| Range | 3 | Range | 5 | Range | 6 | Range | 11 |
| Min | 52 | Min | 54 | Min | 40 | Min | 40 |
| Max | 55 | Max | 59 | Max | 46 | Max | 51 |
| <i>n</i> | 28 | <i>n</i> | 44 | <i>n</i> | 28 | <i>n</i> | 42 |
| CI (95.0%) | 0.39 | CI (95.0%) | 0.33 | CI (95.0%) | 0.60 | CI (95.0%) | 0.74 |
| LCI | 53.1 | | 56.0 | LCI | 42.6 | | 45.5 |
| UCI | 53.9 | | 56.6 | UCI | 43.8 | | 47.0 |

***t*-Test: Two-Sample (Equal Variances)**

| WING | F | M |
|--------------------------------|---------|------|
| Mean | 53.5 | 56.3 |
| Variance | 1.00 | 1.20 |
| Observations | 28 | 44 |
| Pooled Variance | 1.12 | |
| H ₀ : mean diff = 0 | 0 | |
| df | 70 | |
| t Stat | -10.909 | |
| P(T<=t) one-tail | 0.000 | |
| t Critical one-tail | 1.667 | |
| P(T<=t) two-tail | 0.000 | |
| t Critical two-tail | 1.994 | |

***t*-Test: Two-Sample (Equal Variances)**

| TAIL | F | M |
|--------------------------------|--------|------|
| Mean | 43.2 | 46.3 |
| Variance | 2.37 | 5.67 |
| Observations | 28 | 42 |
| Pooled Variance | 4.36 | |
| H ₀ : mean diff = 0 | 0 | |
| df | 68 | |
| t Stat | -6.097 | |
| P(T<=t) one-tail | 0.000 | |
| t Critical one-tail | 1.668 | |
| P(T<=t) two-tail | 0.000 | |
| t Critical two-tail | 1.996 | |



FIGURE 3.1: Photo comparing juvenile and adult Cape Sable seaside sparrows. Note the buffy, drab appearance of the juvenile sparrow (left) compared to the adult sparrow (right).



FIGURE 3.2: Photo showing sawgrass clumps (black arrows) used by juvenile Cape Sable seaside sparrows as refugia during the post-fledging period.



FIGURE 3.3: Photo showing example of mist net deployment for capture of juvenile Cape Sable seaside sparrows.



(a)



(b)

FIGURE 3.4: Example of (a) wing chord and (b) tail length measurements used to rapidly sex juvenile Cape Sable seaside sparrows in the field using morphometrics.

| Predicted Sex: Based on Morphometric Measurements | | | |
|---|------------------------------------|---|---|
| Wing < 55 = F | *Wing UCI (F) = 53.9 (mean = 53.5) | } | Primary morphometric measurement (mm) |
| Wing = 55 (see Tail) | *Region of overlap | | |
| Wing > 55 = M | *Wing LCI (M) = 56.0 (mean = 56.3) | | |
| Tail < 45 = F | *Tail UCI (F) = 43.8 (mean = 43.2) | } | Secondary morphometric measurement (mm) |
| Tail >= 45 = M | *Tail LCI (M) = 45.5 (mean = 46.3) | | |

FIGURE 3.5: Schematic showing morphometric method for sexing juvenile sparrows in the field. Cut-off points are based on upper and lower confidence intervals (UCI, LCI) for morphometric measurements (wing chord and tail length) used in sexing analysis. Using these cut-off points for morphometrics results in 93% accuracy of predicted sex compared to actual sex based on genetic sexing ($n = 22$) and/or observations of returning individuals ($n = 50$). Using wing chord measurement alone results in 78% accuracy.

4.0 Spatially-explicit Population Estimator

4.1 Introduction

One of our main objectives in 2015 was to develop a spatially-explicit population estimator to improve upon the current CSSS population estimator being used by agencies. At present, agencies continue to make significant management decisions based on a CSSS population estimate derived by multiplying the unadjusted count data from annual ENP rangewide helicopter surveys using a 16x multiplier (Pimm *et al.* 2002). This method has been shown to be invalid in small sparrow subpopulations where many of the assumptions about breeding sparrows relied upon to develop the estimator are not met (Virzi *et al.* 2009). However, we believe that this multiplier may also not hold in large sparrow subpopulations for similar reasons despite previous evidence suggesting otherwise (Curnutt *et al.* 1998). The ENP rangewide survey data is still useful to examine trends, but the data was not intended to be used for population estimation the way that the surveys were originally designed. One recognized problem is the lack of error estimation surrounding any population estimate based on the current method (Walters *et al.* 2000). We believe that having a more reliable population estimate based on sound methods, with some estimate of precision, is paramount to understanding the current status of the CSSS across its range.

While we did not ultimately derive a new CSSS population estimate at this time, in 2015 we made major strides towards the development of a spatially-explicit population estimator. We plan to continue to develop the estimator in 2016, and will collect additional field data to help in its development. This report provides a summary of our effort towards developing the spatially-explicit population estimator at this time. The rest of this section is broken down into sub-sections describing several problems with the current population multiplier and our actions to address these problems with currently available CSSS data, including demographic data collected in 2015 and historic data over the past decade compiled for analyses herein.

4.2 Territory Sizes

One of the major assumptions made in the derivation of the original 16x multiplier is related to the average size of male sparrow territories. Pimm *et al.* (2002) derived the 16x multiplier based on the assumption that the average territory size for male sparrows is 2 ha. More recent demographic research provides some evidence supporting this estimate, but only in large sparrow subpopulations (Virzi *et al.* 2009). In small CSSS subpopulations, territory sizes are now known to be much larger in areas with lower sparrow density. Further, single male sparrows tend to exhibit even larger territories than their mated counterparts, and there are more single male ‘floaters’ in small subpopulations. Thus, the assumption that the average male CSSS is 2 ha does not hold throughout the sparrows’ entire range. Thus, a multiplier based on assumptions made solely on data collected in large sparrow subpopulations is invalid. If territories are indeed much larger in small subpopulations, then the area component of the multiplier to convert count data to population estimates must be far smaller. Using a multiplier based on a 2 ha mean territory size would tend to overestimate the population size in small sparrow subpopulations.

To address this concern, we reviewed historic territory data collected during demographic monitoring over the 10-year period from 2006-2015. Using GPS data collected to map territories for male sparrows as part of annual demographic monitoring we developed a geodatabase in ArcGIS 10.2.2 to consolidate these data. We then mapped home ranges for male sparrows and compared sizes among subpopulations, and between paired and single individuals. Historically, territory mapping was conducted as part of annual demographic monitoring without standardized protocols. In 2015, we standardized protocols to ensure that sampling effort was consistent for all individuals mapped and among subpopulations (see **Section 4.4**). Historic territory data was cleaned before analysis to remove any individuals with low or questionable sampling effort; for data to be included in our home range analysis we required at least 10 GPS points collected over multiple days.

4.2.1 Home Range Analysis

An organism's home range may be estimated from a dataset of point locations taken for the animal over time. The home range may be defined as the area where the animal spends the majority of its time, often estimated as the 95% kernel density estimate (95% isopleth) of point locations collected (Samuel *et al.* 1985, Worton 1989). The 95% isopleth represents the area where there is a 95% probability of finding the animal during surveys. The home range may be further broken down into the 'core' area where the animal moves, which is estimated as the 50% kernel density estimate (50% isopleth) of points. Thus, the core range is the area where there is a 50% probability of finding the animal during surveys. The average CSSS territory size estimated by Pimm *et al.* (2002) should be thought of as the 'core' home range estimate for sparrows. For purposes of our analysis, we estimated both the home range (95% isopleths) and core range (50% isopleth) of male sparrows.

All spatial analyses were conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment (GME; Beyer 2015) which is a plug-in toolset for spatial analysis. Male CSSS home ranges (95% isopleths) and core ranges (50% isopleths) were estimated using the several GME tools, and CSSS average territory sizes were then calculated and summarized by subpopulation and compared between large and small subpopulations. Further, home ranges were compared between paired and single males. The first step in the analysis used the kernel density (KDE) estimation tool to provide an estimate for a probability density function corresponding to the individual's utilized distribution. All model parameters were applied consistently among KDE estimates for individuals; bandwidth = SCV, cell size = 10 m, extent = subpopulation boundary. Once the KDE estimate for each individual was calculated, we used the isopleth analysis tool to calculate the 95% home range and 50% core range for each individual. The isopleth analysis provided home range maps for each individual, and these were used to estimate home range sizes (ha) for all male sparrows included in our analyses.

4.2.2 Results

We estimated home ranges for 373 male sparrows from territory data collected in all six CSSS subpopulations from 2006-2015 (**Tables 4.1 and 4.2**). Of these, 208 males were from large subpopulations (B and E) and 165 were from small subpopulations (A, C, D and F). Most home range estimates were for paired males ($n = 266$), however, our data also included estimates for single males ($n = 107$). As expected, the proportion of single male sparrows was substantially higher in small subpopulations (45%) than in large subpopulations (16%).

The mean CSSS home range size (HR_{95}) was substantially smaller in large subpopulations ($HR_{95} = 7.2$ ha; SE = 0.5) than in small subpopulations ($HR_{95} = 42.1$ ha; SE = 5.6) (**Table 4.1**). Further, there was more variation in home ranges for sparrows in small subpopulations. Paired males also reported smaller home ranges ($HR_{95} = 14.4$ ha; SE = 1.6) than single males ($HR_{95} = 43.3$ ha; SE = 7.9). However, it is interesting to note that paired and single males generally reported similar home range sizes in large subpopulations, while there was a substantial difference in home range sizes between paired and single males in small subpopulations.

Core home range sizes (HR_{50}) were also substantially smaller and exhibited lower variation in large CSSS subpopulations ($HR_{50} = 1.7$ ha; SE = 0.1) than in small subpopulations ($HR_{50} = 10.3$ ha; SE = 1.5) (**Table 4.2**). It is interesting to note that the mean core home range size for male sparrows in large subpopulations is very close to the 2 ha estimate used by Pimm *et al.* (2002) in their derivation of the 16x multiplier. However, our results strongly suggest that this assumption regarding CSSS territory size does not hold in small subpopulations. Further, similar to our findings for overall home ranges estimates, core home range sizes vary considerably between paired ($HR_{50} = 6.7$ ha; SE = 1.0) and single ($HR_{50} = 14.6$ ha; SE = 3.1) males in small sparrow subpopulations, with single males reporting core home ranges that are more than twice the size of paired males in the same areas. This is a trend that is observed in all small sparrow subpopulations included in our analysis (**Figure 4.1**), and is most pronounced in subpopulation A.

Visual inspection of CSSS home range maps show the extent to which home ranges vary among subpopulations of different sizes (**Figures 4.2 – 4.4**). **Figure 4.2** presents home ranges for paired and single male sparrows in our demographic study plot in large CSSS subpopulation B in 2015. This map depicts an area with the likely maximum density possible for sparrows in any subpopulation (see **Section 4.4**). Comparison with home range maps for small CSSS subpopulations A (**Figure 4.3**) and D (**Figure 4.4**) reveals some interesting patterns. First, despite the obviously lower density of sparrows in subpopulation A there is a similar clumping of sparrow territories within our study plot as witness in subpopulation B. Most sparrows on both study plots were paired, and territories generally are clumped together without much overlap in core home ranges. Keeping in mind that our demographic study plot in subpopulation A is twice the size of our plot in B, our results suggest that there is available space in A that is going unutilized. We have not collected data on micro-site habitat conditions so we cannot rule out that not all habitat is suitable in A; however, our field observations suggest that there is suitable habitat there that is currently not occupied.

Second, the map for home ranges in small subpopulation D (**Figure 4.4**) shows a very different distributional pattern to A or B. Since most males in this subpopulation were not paired, territory sizes and distances traveled were much larger than in either of the other subpopulations being studied. This is a good example of distributional patterns observed in areas with highly male-biased sex ratios; males tend to move over much greater areas likely trying to locate females. It is also possible that habitat is less suitable in these areas requiring males to have much larger territories; however, we do note that when paired males are present in subpopulation D they tend to have similar territory sizes to paired males in other subpopulations suggesting that habitat is not less suitable than other subpopulations.

4.2.3 Discussion

Our results indicate that CSSS territories are substantially larger for single males than for paired males. Further, the proportion of single males to paired males is substantially greater in small CSSS subpopulations. Thus, overall male CSSS territory sizes are expected to be much larger in

small sparrow subpopulations. These results support the conclusion that the 16x multiplier used in population estimation is not accurate for estimating CSSS numbers in small subpopulations, and likely significantly overestimates numbers in these areas. This problem may be compounded by the more highly imbalanced sex ratios found in some small subpopulations (see **Section 4.3**). We do not provide a recommendation as to the correct multiplier to use in small CSSS subpopulations because there are other issues with using the ENP helicopter survey data to estimate population size; for example, there is currently no estimate of detection probability associated with the sparrow counts used for population estimation (see **Section 4.4**), and the current sampling design of the surveys does not allow for strong inference for the overall population.

The issue of detectability is critically important to consider in any attempt to use count data to estimate population size (Murray *et al.* 2011; MacKenzie & Kendall 2002; Walters *et al.* 2000). We address this issue in greater detail below (see **Section 4.4**). However, in the context of the home range analysis here it is important to point out one potential ramification of the variability in male territory sizes among CSSS subpopulations. In small subpopulations where there are a higher proportion of single male sparrows with larger territories, the distribution of males would likely reduce encounter rates during surveys and potentially decrease detection probabilities. Male sparrows move over much larger areas and thus there is a higher probability of individuals being in parts of their home range outside of survey areas during point counts (MacKenzie *et al.* 2005). This would tend to underestimate counts by creating false negative detections. However, the large distances traveled by single male sparrows as they move across their home ranges in small subpopulations may also increase the probability of double-counting individuals on multiple survey points. This latter potential issue would result in counts that overestimate population size further. Thus, the best method for using count data collected during the ENP helicopter surveys to estimate population size would be to incorporate some measure of detection probability directly in the point counts to take these factors into consideration on a population-by-population basis which would account for variation in CSSS density. Incorporating an estimate of detection probability directly into the ENP rangewide

helicopter surveys is not a new idea; incorporating detection probability into the ENP surveys has already been strongly suggested by both Cassey *et al.* (2007) and Walters *et al.* (2000) in past reviews of the surveys.

4.3 Sex Ratios

4.3.1 Overview

The second major assumption made by Pimm *et al.* (2002) in the derivation of the original 16x multiplier is that for every male sparrow detected there is a female sparrow. In other words, the sex ratio in the CSSS population is perfectly balanced. Based on mean CSSS territory sizes estimated by Pimm *et al.* (2002), which as shown in **Section 4.2** above may not be valid, the count data would require a multiplier of 8x to estimate the total number of males in the area surrounding each survey point. This multiplier was then simply doubled to 16x assuming that all males were paired. This assumption would likely fail even without examination of CSSS demographic data since there are often floater males in any breeding population, and thus there is often some level of male-bias in sex ratios in passerines (Donald 2007; Walters *et al.* 2000).

Annual demographic research has shown that there is indeed a male-biased sex ratio in all CSSS subpopulations monitored, and that the bias is more extreme in small sparrow subpopulations (Slater *et al.* 2014; Virzi *et al.* 2009). Thus, surveys designed to capture only singing males cannot simply be doubled to estimate the total population size. Exacerbating the problem is that sex ratios are not consistent among subpopulations, so the error will be compounded in small subpopulations that exhibit more highly male-biased sex ratios. In other words, population estimates in small subpopulations will be overstated to a higher degree than in large subpopulations. To examine differences in sex ratios among CSSS subpopulations we reviewed 10 years of demographic data (2006-2015). We calculated the annual sex ratio (Ω) as the number of male sparrows present on demographic study plots divided by the total population size on each plot. A balanced sex ratio (1:1 ratio) would be indicated by $\Omega = 0.50$, while male-biased sex ratios would be indicated by $\Omega > 0.50$. We conducted an analysis of variance

(ANOVA) to compare sex ratios among subpopulations, and to determine if there is a significant difference between sex ratios found in large and small CSSS subpopulations.

4.3.2 Results

Using the same demographic data described previously to estimate CSSS home range sizes, we were able to estimate sex ratios for large (B and E) and small (A, C, D and F) subpopulations from 2006-2015 (**Table 4.3**). Sex ratios could not be estimated in all subpopulations in all years because in some years there were either no demographic study plots in some subpopulations, or there was insufficient survey effort and/or data to confidently estimate Ω . Sex ratios were male-biased in all CSSS subpopulations monitored, and were more imbalanced in small subpopulations (**Figure 4.5**).

The results of our ANOVA indicated that there was a significant difference in sex ratios among CSSS subpopulations ($F = 4.655$; $p = 0.004$) (**Table 4.5**). Further, results of an *a priori* Student's t-Test to examine group differences indicated that there was a significant difference between mean sex ratios reported in large and small CSSS subpopulations ($\Omega_{\text{large}} = 0.556$, $SE = 0.032$; $\Omega_{\text{small}} = 0.714$, $SE = 0.126$; $p = 0.000$) (**Table 4.6**). There is much greater variability in mean Ω among small CSSS subpopulations (e.g., $\Omega_A = 0.638$; $\Omega_D = 0.769$) (**Table 4.5**); however, all small subpopulations reported significantly higher sex ratios than large subpopulations B and E, which reported more balanced sex ratios ($\Omega \sim 0.50$).

4.3.3 Discussion

Due to the highly imbalanced sex ratios consistently reported in small CSSS subpopulations, the 16x multiplier clearly fails to accurately estimate total population size in these areas. The moderately male-bias sex ratios found in large CSSS subpopulations would result in somewhat overstated population estimates in these areas as well, but the problem is greatly amplified in small subpopulations. If a multiplier were to be calculated to estimate population size based on the ENP helicopter survey count data it would need to be adjusted appropriately to account for the male-biased sex ratios found in all CSSS subpopulations. However, a better method for using the count data to estimate population size would be to design surveys to detect both

male and female sparrows, recognizing that detection probability would be far lower for females. Properly designed surveys could estimate detection probability separately for males and females lending the data more useful for population estimation. At a minimum, if annual surveys continue to be designed to detect only singing male sparrows, then subpopulation specific sex ratios must be determined annually (e.g., on intensively monitored demographic study plots) so that counts may be corrected for imbalanced sex ratios, especially in small CSSS subpopulations.

4.4 Density Estimation

As part of our demographic monitoring in 2015, we modified our survey methods to enable us to better estimate the density of CSSS found on our study plots. In past years, observers typically wandered around demographic study plots with poorly-delineated boundaries in search of breeding pairs working under the assumption that all pairs would be encountered and detected at some point over the course of the field season. While it is likely that most or all breeding pairs were indeed detected at some point, the lack of well-defined plot boundaries did not allow for consistent density estimation across years because there was uncertainty as to the exact area surveyed in any given year. Further, there was never any estimation of detection probability and thus the assumption of perfect detection could not be validated. If not accounted for, the imperfect detection in surveys may lead to biased parameter estimates and abundance estimates will always be biased high (MacKenzie *et al.* 2005).

In 2015, we solved both of these sampling issues by conducting line transect surveys over our entire study plots to better delineate annual plot boundaries and incorporated distance sampling to enable estimation of detection probability and plot density. We continued to conduct spot mapping of CSSS territories during our demographic monitoring; however, we did modify our sampling methods for territory mapping as well to better estimate CSSS territory boundaries than in past years. Previously, territory points were collected relatively opportunistically while conducting nest searches and band resighting. In 2015, we instituted standardized protocols for territory mapping in an attempt to obtain data more systematically

with similar effort for all individuals being mapped. Our protocol called for visiting all male sparrows detected on study plots for a defined number of survey days (6-10 days spread out from Apr-Jun), and collecting at least 30 GPS points in total with fixed sampling periods (30 minutes minimum, or after at least 3-5 points were collected per survey). We believe that our sampling method provides a more precise estimate of CSSS territory sizes and standardizes sampling among subpopulations making plot density estimates more comparable.

Our modified survey methods in 2015 allowed for comparison of plot density estimates using two methods: (1) territory mapping, which we consider 'true' plot density, and (2) distance sampling, which may provide a method for estimating density over larger areas with reduced effort, and which provides an estimate of detection probability for Cape Sable seaside sparrows. The latter point is of great importance because presently detection probability is not being incorporated into population estimates using the ENP rangewide helicopter survey data; although distance sampling has recently been incorporated into the surveys.

4.4.1 Distance Sampling

The basic premise of distance sampling is that as distance from the observer increases, detectability of the animal of interest declines. Rather than relying on raw count data for density estimation, distance sampling allows for estimation of detection probability for the animal of interest when imperfect detection is expected, which is typically the case. Cape Sable seaside sparrows are difficult to detect in the tall grasses of Everglades marl prairies. Males are more easily detected than females since they often sing on exposed perches, however, detection is still imperfect. La Puma *et al.* (2010) estimated that detection probability was 0.60 in large CSSS subpopulations, and that this rate dropped to 0.40 in small subpopulations. The decline in detection probability may be due to reduced singing rates, perhaps caused in part by a lack of enough conspecific cues to induce singing at higher rates (Virzi *et al.* 2012), or simply due to lower encounter rates in small subpopulations as a result of the greater distances that single male sparrows are shown to travel in those areas (MacKenzie *et al.* 2005).

We collected distance sampling data during line transect surveys in a large CSSS subpopulation (B) and two small subpopulations (A and D) for comparison (**Figure 4.6**). We placed two line transects (1.5 km long) in our study plot in large subpopulation B, and four line transects (1.8 m long) in our study plots in small subpopulations A and D – more transects were needed to cover the larger study plots in these subpopulations. Observers walked transect lines recording all CSSS detections (male, female or unknown sex) made either visually or aurally within 100 m on either side of the line, and recorded the distance and bearing of birds from their location on the line. These data were later used to calculate the perpendicular distance of sparrows from the line, which is necessary for distance analysis. Surveys were replicated four times on each line transect between 01 Apr and 30 Jun, with at least 21 days between surveys.

We used Program Distance v. 6.2 for all analysis (Thomas *et al.* 2010; Buckland *et al.* 2001). We began our analysis by fitting two models with the following key functions: half-normal [HN] and hazard-rate [HR]. All models were first run with cosine [COS] and hermite [HM] series expansions to assess the need for truncating the data and to examine the detection function for signs of assumption violations. Models were named based on the combination of these factors (e.g., HN-COS = model with half-normal key function and cosine series expansion). Assumption violations may include evidence of evasive movement (e.g., few detections close to zero), a lack of a shoulder in the data distribution, or “heaping” of data at certain values indicating rounding errors in distance estimation. When making decisions about how much to truncate or whether to group the data, it's best to rely on a combination of goodness-of-fit test statistics and visually inspecting the fit of the data. We relied upon both the quantile-quantile plots and the Cramer Von Mises test with the cosine weighting function for assessing the fit of ungrouped data, as recommended by Buckland *et al.* (2001). Both are considerably more powerful than the Chi-squared test, which relies on grouping the data and is sensitive to the choice of cut points.

After deciding whether to truncate, we then fit a series of candidate models, consisting of the following key function/series expansions: half-normal/cosine [HN-COS], half-normal/hermit polynomial [HN-HERM], hazard-rate/simple Polynomial [HR-POLY], and uniform/cosine [U-COS]. We ranked competing models using Akaike's Information Criteria corrected for small

sample size (AICc). We judged models with ΔAICc values < 2.0 as having substantial support, ΔAICc values from $2.0 - 7.0$ having considerably less support, and ΔAICc values > 7.0 indicating essentially no support (Burnham & Anderson 2002). If more than one model received substantial support from the data (i.e., $\Delta\text{AICc} < 2.0$), we used the bootstrapping routine in Program Distance (with 999 iterations) to generate model-averaged estimates of density from the best-supported models. However, bootstrap models often had difficulty converging and generally produced density estimates higher than the selected models. Therefore, we simply chose to generate density estimates with the model with the lowest AICc value in instances where model convergence was an issue.

We initially ran models to estimate density and detection probability separately for males and females; however, we had too few female detections to run separate models. Thus, we decided to conduct our distance analysis only for males, which is the main sex of interest in this study because we wish to understand detection probability of males and want to compare density estimates to 'true' male density on our study plots based on territory mapping. We included covariates in our models for [PLOT] (i.e., subpopulation) and [DENSITY] (i.e., large vs. small sparrow subpopulation) to explore differences in detection probability among subpopulations with different sparrow densities. The minimum number of observations generally considered sufficient to produce reliable estimates of density is 60-80, although in some cases as few as 40 observations may be sufficient (Buckland *et al.* 2001). Models run to estimate subpopulation [PLOT] density were based on < 40 observations in small sparrow subpopulations (A and D), and thus results should be interpreted with caution. Models that included a [DENSITY] covariate essentially pooled data from the two small subpopulations (A and D) in order to increase sample size since there were so few detections in each of these study plots.

Cape Sable seaside sparrow density estimates represent the number of sparrows per hectare. Abundance estimates represent the total number of male sparrows on study plots based on density estimates and the total area of each plot; plots in small subpopulations A and D were twice the size of our plot in large subpopulation B. Results are presented with standard errors (SE), lower 95% confidence intervals (LCI) and upper 95% confidence intervals (UCI).

4.4.2 Results

There were five models that received substantial support ($\Delta\text{AICc} < 2.0$) in our distance analysis (**Table 4.6**). The top models include two models with a plot effect indicating some support for a difference in detection probability (p) between large and small subpopulations. However, the top models also included three models without a plot effect, which provides some evidence that there may not be a significant difference in p between large and small subpopulations. More data is needed to further investigate the effect of sparrow density on detection probability. However, it is worth noting that models including the [DENSITY] covariate (i.e., models pooling data from both small subpopulations A and D) also received some support (ΔAICc between 2.0 – 7.0) providing evidence that there may be a non-significant difference in p between large and small subpopulations, with detection probability being lower in small subpopulations.

Overall detection probability for male sparrows was high based on pooled data from three CSSS subpopulations collected over four replicate line transect surveys ($p = 0.811$, $\text{SE} = 0.088$) (**Table 4.7**). Sparrow density calculated using pooled data was very similar whether based on distance sampling results ($D_{ds} = 0.085$, $\text{SE} = 0.021$) or territory mapping ($D_{tm} = 0.093$). Abundance estimates were also very similar ($A_{ds} = 33$, $\text{SE} = 8.0$; $A_{tm} = 36$). Thus, our results show that using distance sampling along line transect surveys appear to be a reliable method to estimate CSSS density and abundance when there are enough sparrow detections for analyses.

Estimating density and abundance by CSSS subpopulation is more difficult due to small sample size issues. However, we were still able to model the detection function and estimate detection probability, density and abundance by subpopulation (**Table 4.8; Figure 4.7**). Total detections of male sparrows were low in our small subpopulation study plots, even with four replicate surveys ($n = 31$ in A; $n = 28$ in D). Even in large subpopulation B it was difficult to record many sparrow detections ($n = 43$). Despite limited data, density and abundance estimates were again similar whether based on distance analysis or territory mapping. Density was highest in large

subpopulation B ($D_{ds} = 0.201$, SE = 0.038), and substantially lower in both small subpopulations A ($D_{ds} = 0.079$, SE = 0.012) and D ($D_{ds} = 0.046$, SE = 0.014).

4.4.3 Discussion

We were able to derive a relatively precise estimate of detection probability for male Cape Sable seaside sparrows incorporating distance sampling on line transect surveys. Our estimate of detection probability ($p = 0.81$) is high compared to previous studies estimating detection probability for CSSS (0.60; La Puma *et al.* 2010), perhaps due to our survey methods and replicate surveys. Further, we found only moderate support that detection probability may be lower in small sparrow subpopulations with low densities of sparrows. Detection probability was lower in small subpopulation A ($p = 0.65$) compared to our estimate in large subpopulation B ($p = 0.83$); however, small subpopulation D had perfect detection ($p = 1.00$). Still, our results provide good evidence that there is imperfect detection in CSSS surveys that must be considered when attempting to use count data to estimate density or abundance.

Our results indicate that line transect surveys incorporating distance sampling are useful to estimate sparrow density on demographic study plots. If we wish to increase the size of our current demographic study plots, which is being considered to increase sample sizes, conducting line transect surveys may help reduce the field effort required to sample larger areas. Further research is needed to refine methods and to determine the amount of survey effort needed (e.g., number of transects and number of replicates) to obtain an adequate amount of data allowing precise density estimation using distance analysis. More data is also needed to better understand the effect of sparrow population density on detection probability so that sampling can be modified if necessary in small CSSS subpopulations.

Estimating detection probability directly for the ENP rangewide helicopter surveys is necessary in order to use these data to derive a precise population estimate. We cannot assume that detection probability will be the same as the rate reported here because we used a different survey method (line transects vs. point counts), and we conducted repeat surveys. It is likely that the detection rate will be similar if repeat surveys are conducted, but we suggest that it

should be estimated directly from the rangewide data to derive the most precise population estimate possible. Distance sampling, and possibly other methods such as time-to-detection sampling or removal models (Alldredge *et al.* 2007a and 2007b; Farnsworth *et al.* 2002), could be easily incorporated into current survey methods. Repeated surveys may also be needed to account for the zero-inflated nature of the ENP survey data and to obtain an adequate number of detections to model the detection function adequately, especially if individual population estimates are desired for each of the remaining six CSSS subpopulations, and this may require more advanced analysis techniques such as n-Mixture models (Cunningham & Lindenmayer 2005).

4.5 Conclusions

While we did not accomplish our original goal of developing a spatially-explicit population estimator for the CSSS, we did make great strides towards the development of this estimator in 2015. First, we created a geodatabase using 10 years of historic CSSS data from 2006-2015 that was then used to conduct exploratory analyses needed to inform the estimator. Next, we analyzed CSSS home range sizes and found that single male sparrows had significantly smaller territories than paired males. We also found that there was a much more highly male-biased sex ratio in small CSSS subpopulations, and therefore a greater number of single male floaters in these subpopulations. Thus, sparrow territory sizes in small subpopulations are significantly larger than in large subpopulations. Finally, we were able to successfully use line transect surveys incorporating distance sampling to provide estimates of CSSS density and detection probability. Detection probability appears to be lower in small subpopulations; however, more data is needed to confirm this finding. Still, the low detection probabilities observed, even with replicate surveys, indicate that methods to estimate detection probability must be incorporated in surveys to enable accurate population estimation using count data. All of these results provide invaluable information that can inform continued development of a spatially-explicit population estimator and provide insight into ways to improve the ENP rangewide helicopter surveys to better estimate population size. We suggest that in 2016 additional data be collected to fill information gaps needed to complete development of the population estimator, and that

new survey methods (e.g., time-of-detection sampling) be tested in the field in a continued attempt to improve the ENP rangewide helicopter surveys as suggested by the AOU review conducted by Walters *et al.* (2000).

4.6 Tables and Figures

Table 4.1: Comparison of mean home range sizes (HR_{95}) for male Cape Sable seaside sparrows in all subpopulations monitored (2006-2015). Data separated by breeding status (paired or single), and summarized by subpopulation size (large vs. small).

| | All Male Territories | | | Paired Males | | | Single Males | | |
|-----------|----------------------|-----------|------|--------------|-----------|------|--------------|-----------|------|
| Pop | <i>n</i> | HR_{95} | SE | <i>n</i> | HR_{95} | SE | <i>n</i> | HR_{95} | SE |
| A | 81 | 44.1 | 9.5 | 52 | 20.9 | 3.6 | 29 | 85.7 | 24.0 |
| B | 55 | 7.1 | 0.8 | 45 | 6.9 | 0.8 | 10 | 7.6 | 2.2 |
| C | 29 | 56.1 | 11.5 | 20 | 50.0 | 15.0 | 9 | 69.5 | 15.6 |
| D | 50 | 32.4 | 7.3 | 16 | 25.2 | 8.5 | 34 | 35.8 | 9.8 |
| E | 153 | 7.3 | 0.6 | 130 | 7.1 | 0.5 | 23 | 8.2 | 2.2 |
| F | 5 | 25.7 | 5.1 | 3 | 30.7 | 5.4 | 2 | 18.2 | 7.2 |
| Pooled | 373 | 22.7 | 2.6 | 266 | 14.4 | 1.6 | 107 | 43.3 | 7.9 |
| Large Pop | 208 | 7.2 | 0.5 | 175 | 7.1 | 0.4 | 33 | 8.0 | 1.4 |
| Small Pop | 165 | 42.1 | 5.6 | 91 | 28.4 | 4.3 | 74 | 59.0 | 11.0 |

HR_{95} = mean area (ha) of home range based on 95% isopleth contours derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset.

Table 4.2: Comparison of mean ‘core’ home range sizes (HR_{50}) for male Cape Sable seaside sparrows in all subpopulations monitored (2006-2015). Data separated by breeding status (paired or single), and summarized by subpopulation size (large vs. small).

| | All Male Territories | | | Paired Males | | | Single Males | | |
|-----------|----------------------|-----------|-----|--------------|-----------|-----|--------------|-----------|-----|
| Pop | <i>n</i> | HR_{50} | SE | <i>n</i> | HR_{50} | SE | <i>n</i> | HR_{50} | SE |
| A | 81 | 11.2 | 2.8 | 52 | 4.9 | 0.8 | 29 | 22.3 | 7.1 |
| B | 55 | 1.7 | 0.2 | 45 | 1.6 | 0.2 | 10 | 2.0 | 0.6 |
| C | 29 | 13.1 | 2.7 | 20 | 12.0 | 2.7 | 9 | 15.5 | 3.5 |
| D | 50 | 7.7 | 1.8 | 16 | 6.0 | 2.1 | 34 | 8.4 | 2.4 |
| E | 153 | 1.7 | 0.1 | 130 | 1.7 | 0.1 | 23 | 1.9 | 0.4 |
| F | 5 | 6.0 | 1.4 | 3 | 7.2 | 1.8 | 2 | 4.2 | 1.5 |
| Pooled | 373 | 5.5 | 0.7 | 266 | 3.4 | 0.4 | 107 | 10.7 | 2.2 |
| Large Pop | 208 | 1.7 | 0.1 | 175 | 1.7 | 0.1 | 33 | 1.9 | 0.3 |
| Small Pop | 165 | 10.3 | 1.5 | 91 | 6.7 | 1.0 | 74 | 14.6 | 3.1 |

HR_{50} = mean area (ha) of ‘core’ home range based on 50% isopleth contours derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset.

Table 4.3: Mean sex ratios (Ω) in Cape Sable seaside sparrow subpopulations (2006-2015). Dashes indicate years where sex ratios were not estimated because: (1) there was no demographic study plot that year, or (2) there were insufficient data to estimate Ω .

| Pop | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-----|-------|-------|-------|-------|-------|-------|----------------------|-------|-------|-------|
| A | - | - | 0.609 | 0.533 | 0.655 | 0.727 | 0.773 | 0.667 | 0.571 | 0.571 |
| B | - | - | - | - | - | - | 0.643 ⁽¹⁾ | 0.593 | 0.567 | 0.529 |
| C | 0.593 | 0.643 | 0.692 | 0.750 | - | - | - | - | - | - |
| D | 0.667 | 0.667 | 1.000 | 0.667 | 0.778 | 0.857 | 0.750 | 0.600 | 0.786 | 0.917 |
| E | 0.521 | 0.595 | 0.543 | 0.557 | - | - | - | - | - | - |
| F | 0.667 | 1.000 | - | - | - | - | - | - | - | - |

Ω = Sex ratio [number of males / total population].

⁽¹⁾Data for subpopulation B in 2012 excluded from further analyses since reduced survey effort this year likely led to a sex ratio that was biased high.

Table 4.4: Comparison of mean sex ratios (Ω) observed in Cape Sable seaside sparrow subpopulations (2006-2015) based on a single factor analysis of variance (ANOVA). Results of the ANOVA indicate rejection of the null hypothesis (H_0 = means are equal).

SUMMARY

| <i>Subpopulation</i> | <i>Count</i> | <i>Sum</i> | <i>Mean Ω</i> | <i>Variance</i> |
|----------------------|--------------|------------|---------------------------------|-----------------|
| A | 8 | 5.107 | 0.638 | 0.007 |
| B | 3 | 1.674 | 0.558 | 0.002 |
| C | 4 | 2.678 | 0.669 | 0.005 |
| D | 10 | 7.687 | 0.769 | 0.016 |
| E | 4 | 2.215 | 0.554 | 0.001 |
| F | 2 | 1.667 | 0.833 | 0.056 |

ANOVA

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F-critical</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|-------------------|
| Between Groups | 0.248 | 5 | 0.050 | 4.655 | 0.004 | 2.603 |
| Within Groups | 0.267 | 25 | 0.011 | | | |
| Total | 0.515 | 30 | | | | |

Ω = Sex ratio [number of males / total population].

Table 4.5: Comparison of mean sex ratios (Ω) observed in large and small Cape Sable seaside sparrow subpopulations (2006-2015) based on a Student's *t*-Test (assuming unequal variances). Results indicate there is a significant difference between Ω in large and small CSSS subpopulations.

| t-Test | <i>Large</i> | <i>Small</i> |
|------------------------------|---------------------|---------------------|
| Mean Ω | 0.556 | 0.714 |
| Variance | 0.001 | 0.016 |
| Observations | 7 | 24 |
| Hypothesized Mean Difference | 0 | |
| df | 29 | |
| t Stat | -5.536 | |
| P(T<=t) one-tail | 0.000 | |
| t Critical one-tail | 1.699 | |
| P(T<=t) two-tail | 0.000 | |
| t Critical two-tail | 2.045 | |

Ω = Sex ratio [number of males / total population].

Table 4.6: Final model selection results for distance analysis of male Cape Sable seaside sparrow detections made in three subpopulations (A, B and D) in 2015. Data was pooled for analysis to maximize sample size and increase precision of parameter estimates.

| Model | <i>K</i> | <i>AIC_c</i> | ΔAIC_c | <i>ESW</i> |
|-----------------|-----------------|-------------------------------|----------------------------------|-------------------|
| U+COS | 1 | 928.04 | 0.00 | 77.02 |
| HN+COS+PLOT | 3 | 928.24 | 0.20 | na |
| HN+HERM+PLOT | 3 | 928.24 | 0.20 | na |
| HN+COS | 1 | 928.46 | 0.42 | 80.14 |
| HN+HERM | 1 | 928.46 | 0.42 | 80.14 |
| HR+POLY | 2 | 930.07 | 2.03 | 76.03 |
| HN+COS+DENSITY | 2 | 930.44 | 2.40 | na |
| HN+HERM+DENSITY | 2 | 930.44 | 2.40 | na |
| HR+POLY+PLOT | 6 | 932.85 | 4.81 | na |
| HR+POLY+DENSITY | 4 | 934.07 | 6.03 | na |

K = Number of parameters.

AIC_c = Akaike's Information Criteria corrected for small sample size.

ΔAIC_c = Difference in *AIC_c* value from top model (strong support for models with $\Delta AIC_c < 2.0$).

ESW = Effective strip width (pooled data).

Table 4.7: Distance sampling results based on pooled data ($n = 102$) collected from three Cape Sable seaside sparrow subpopulations (A, B and D) in 2015. Results include density (D) and abundance (N) estimates based on distance sampling analysis (ds) and territory mapping (tm) – grey shaded area. Data was pooled for analysis to maximize sample size and increase precision of parameter estimates.

| Parameter | Pooled | SE | LCI | UCI | UCI |
|-----------|--------|-------|-------|-------|-------|
| n | 102 | | | | |
| p | 0.811 | 0.088 | 0.654 | 1.000 | 1.000 |
| D_{ds} | 0.085 | 0.021 | 0.051 | 0.142 | 0.086 |
| N_{ds} | 33 | 8.0 | 20 | 55 | 14 |
| D_{tm} | 0.093 | | | | |
| N_{tm} | 36 | | | | |

n = Number of observations.

p = Detection probability.

D_{ds} = Density based on distance sampling analysis.

N_{ds} = Abundance based on distance sampling analysis.

D_{tm} = Density based on territory mapping.

N_{tm} = Abundance based on territory mapping.

Table 4.8: Distance sampling results based on analysis by Cape Sable seaside sparrow (CSSS) subpopulation (i.e., models including PLOT covariate). Data was collected from one large CSSS subpopulation (B) and two small CSSS subpopulations (A and D) in 2015. Results include density (D) and abundance (N) estimates based on distance sampling analysis (ds) and territory mapping (tm) – grey shaded area.

| Parameter | A | SE | LCI | UCI | B | SE | LCI | UCI | D | SE | LCI | UCI |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| n | 31 | | | | 43 | | | | 28 | | | |
| p | 0.645 | 0.090 | 0.489 | 0.862 | 0.829 | 0.126 | 0.611 | 1.000 | 1.000 | 0.213 | 0.650 | 1.000 |
| D_{ds} | 0.079 | 0.012 | 0.058 | 0.107 | 0.201 | 0.038 | 0.128 | 0.315 | 0.046 | 0.014 | 0.025 | 0.086 |
| N_{ds} | 13 | 2.0 | 9 | 17 | 14 | 2.7 | 9 | 21 | 7 | 2.1 | 4 | 14 |
| D_{tm} | 0.050 | | | | 0.250 | | | | 0.069 | | | |
| N_{tm} | 8 | | | | 17 | | | | 11 | | | |

n = Number of observations.

p = Detection probability.

D_{ds} = Density based on distance sampling analysis.

N_{ds} = Abundance based on distance sampling analysis.

D_{tm} = Density based on territory mapping.

N_{tm} = Abundance based on territory mapping.

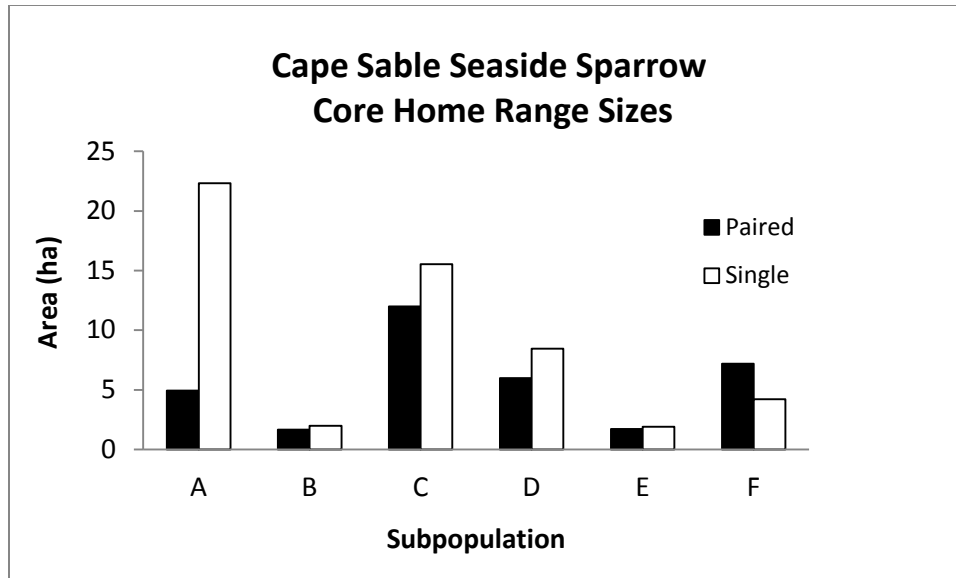


FIGURE 4.1: Comparison of mean core home range sizes of paired (black bars) and single (white bars) male Cape Sable seaside sparrows by subpopulation (2006-2015). Core home range size represents area (ha) of 50% isopleth contours derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset. Core ranges were larger in all small sparrow subpopulations, and single males generally reported larger core ranges than paired males with the difference also more noticeable in small subpopulations.

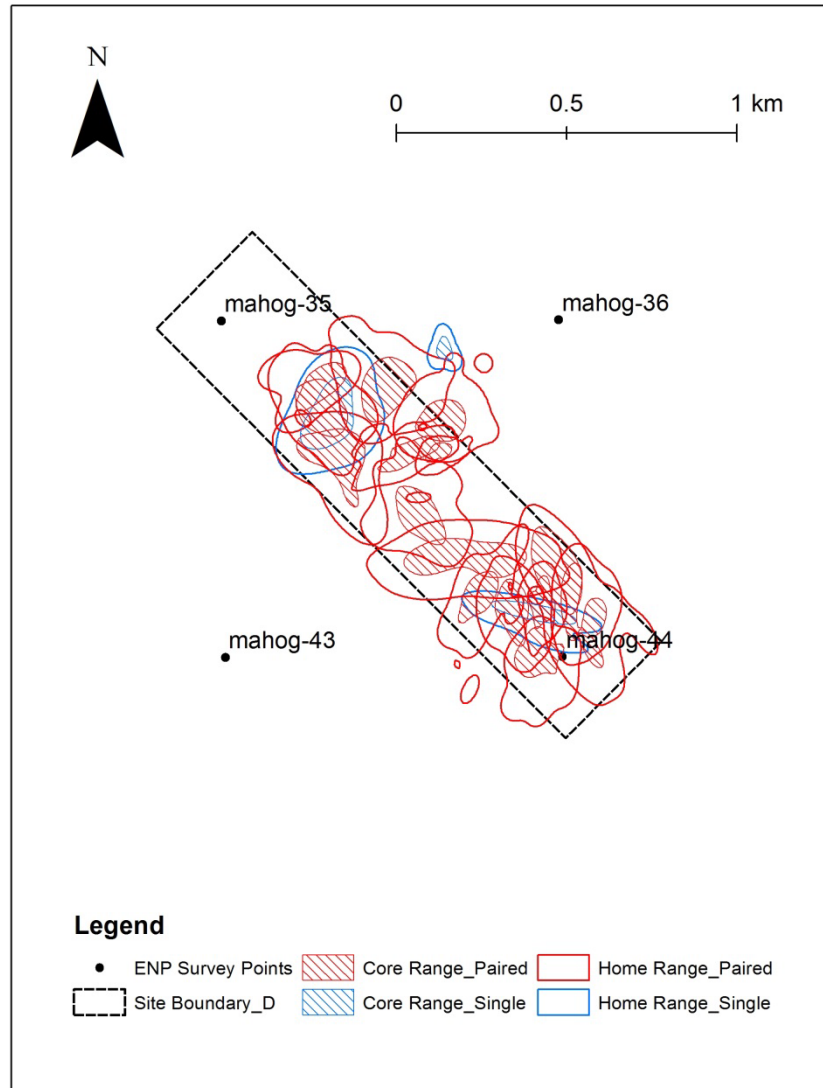


FIGURE 4.2: Example map of Cape Sable seaside sparrow home ranges for paired (red lines) and single (blue lines) males in large subpopulation B (2015). Core ranges (hatched areas) represent area (ha) of 50% isopleth derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset. Note the tightly packed territories with some overlap in core ranges and substantial overlap in home ranges.

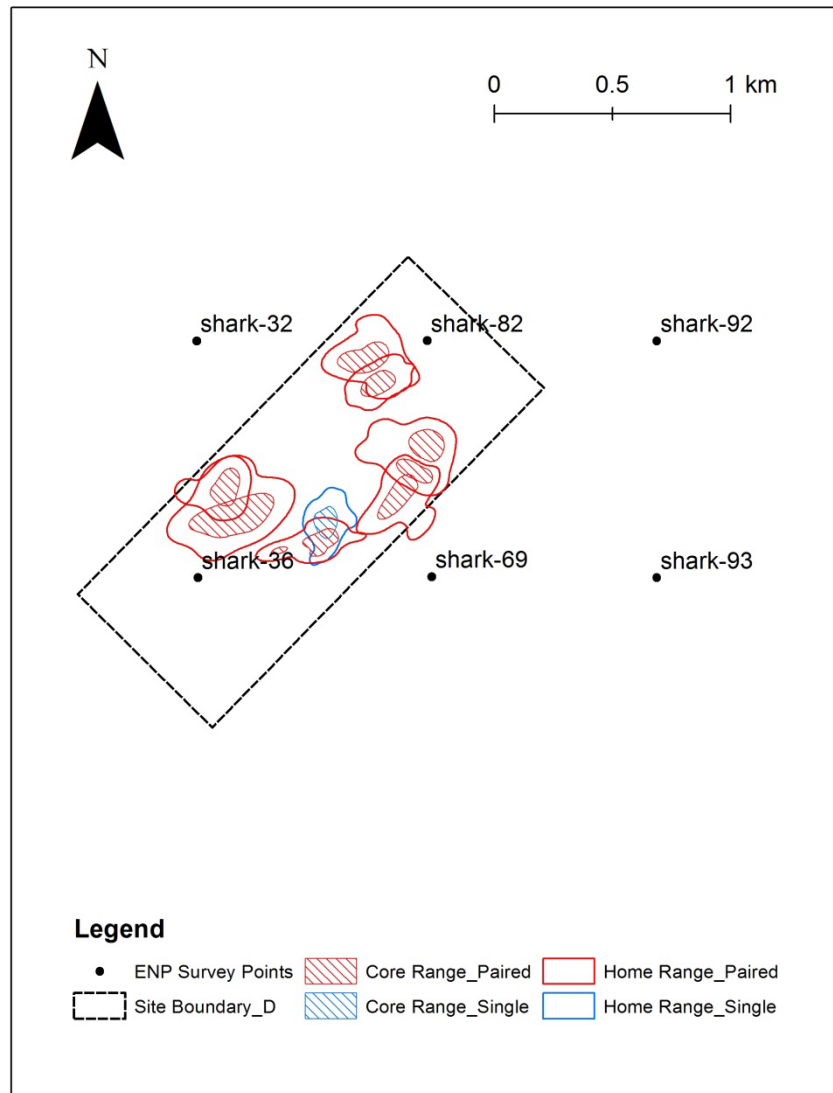


FIGURE 4.3: Example map of Cape Sable seaside sparrow home ranges for paired (red lines) and single (blue lines) males in small subpopulation A (2015). Core ranges (hatched areas) represent area (ha) of 50% isopleth contours derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset. Note the lower density of territories compared to large subpopulation B and minimal overlap in core ranges.

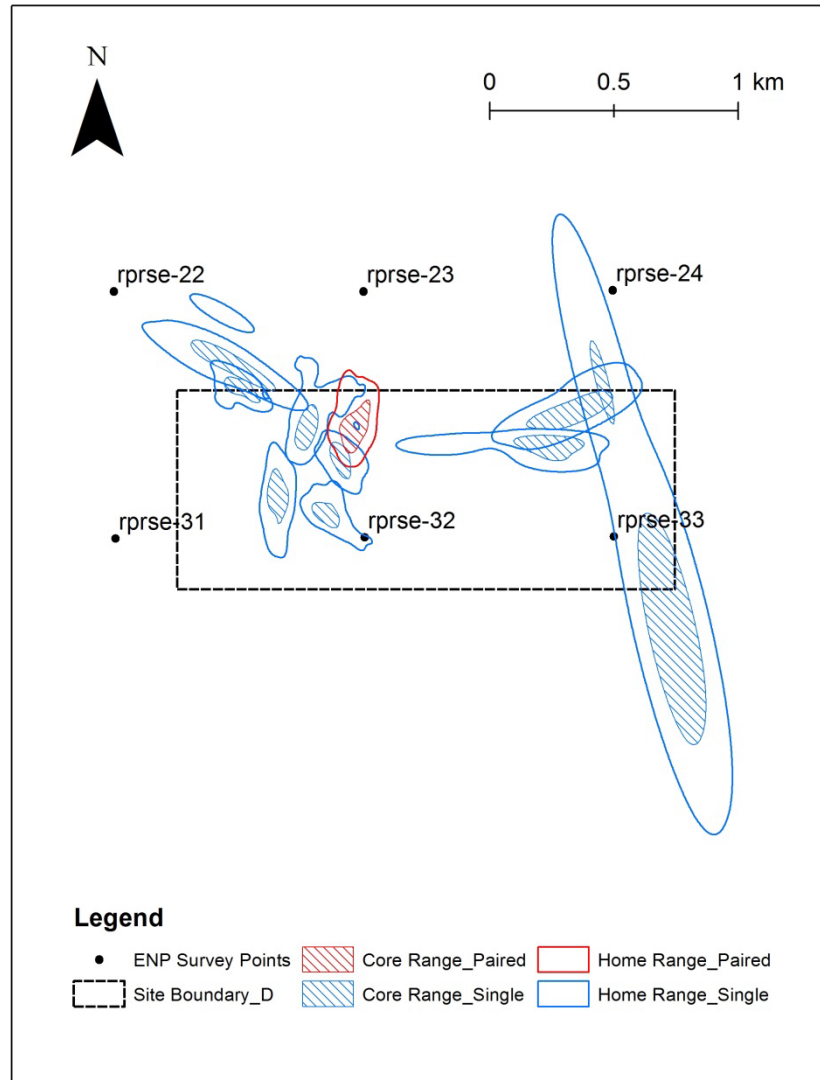


FIGURE 4.4: Example map of Cape Sable seaside sparrow home ranges for paired (red lines) and single (blue lines) males in small subpopulation D (2015). Core ranges (hatched areas) represent area (ha) of 50% isopleth contours derived by kernel density estimation analysis conducted in ArcGIS 10.2.2 using the Geospatial Modelling Environment plug-in toolset. Note the similar density and overlap in core ranges as compared to small subpopulation A; however, also note the larger home ranges for single male sparrows.

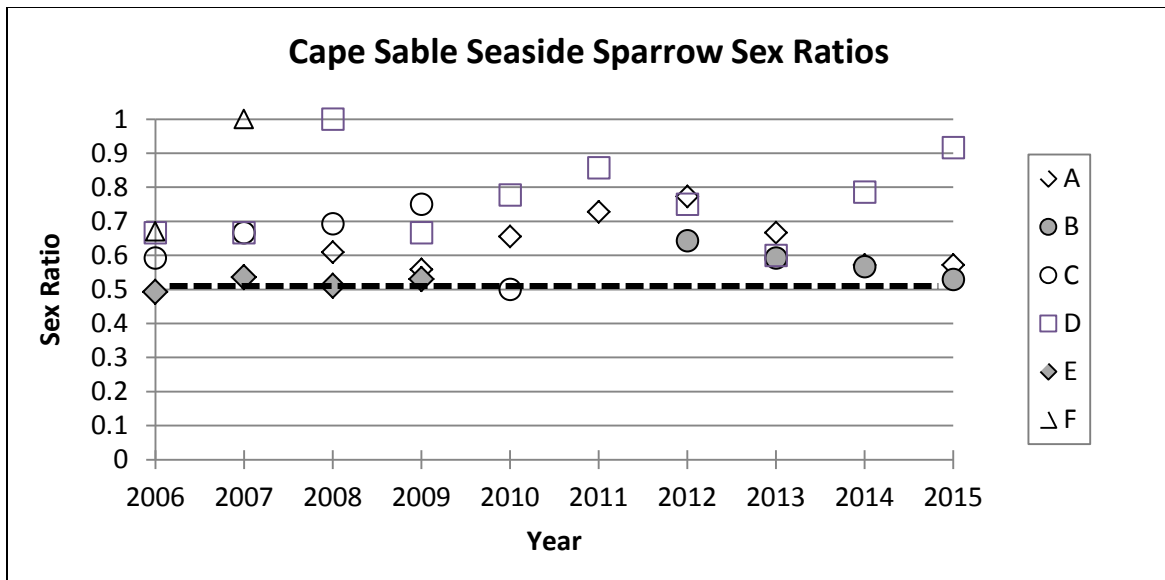


FIGURE 4.5: Cape Sable seaside sparrow (CSSS) sex ratios observed in all subpopulations monitored from 2006-2015. Sex ratio equals the number of male sparrows divided by the total population size; a ratio > 0.50 indicates a male-biased sex ratio (black dashed line). Large subpopulations (B and E) indicated by grey symbols; small subpopulations (A, C, D and F) indicated by hollow symbols. Sex ratios were more male-biased in small CSSS subpopulations in all years where comparisons could be made.

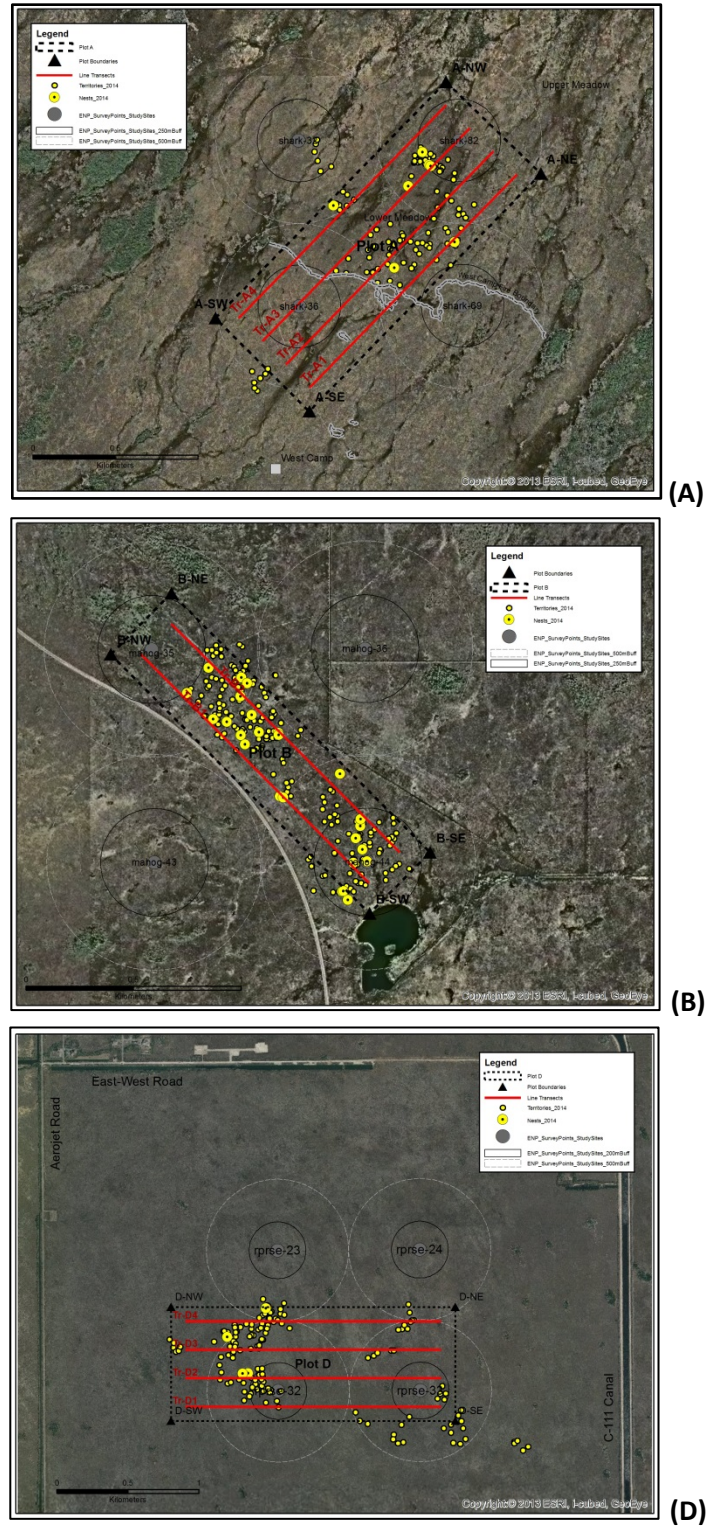


FIGURE 4.6: Maps showing location of line transect surveys conducted in Cape Sable seaside sparrow subpopulations A, B and D in 2015.

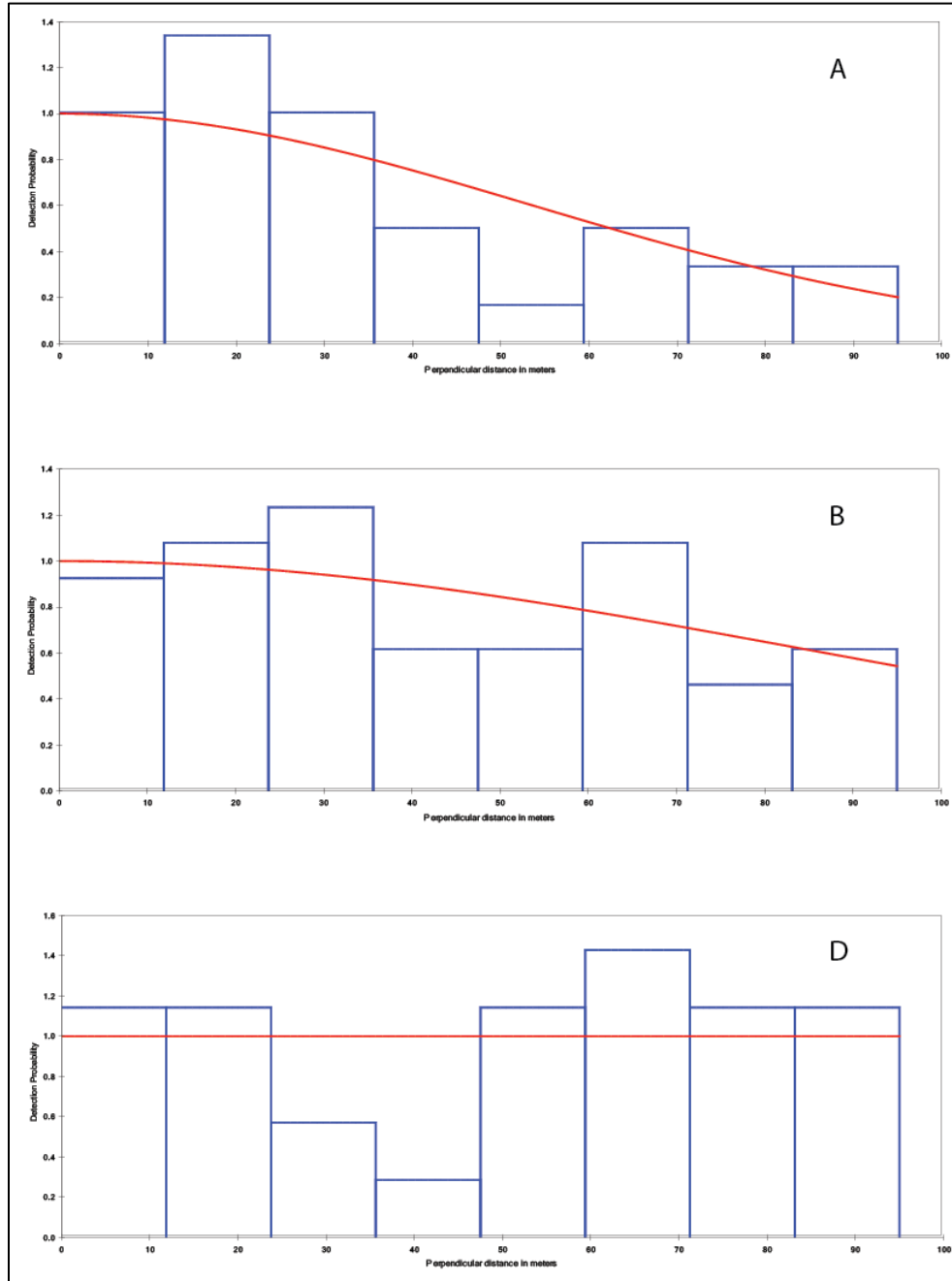


Figure 4.7: Histograms of Cape Sable seaside sparrow detections by subpopulation showing detection probability plots based on distance analysis.

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