Effects Of Fire On The Cape Sable Seaside Sparrow
2006 Annual Report

Julie L. Lockwood, David A. La Puma, Phillip Cassey, Michelle J. Davis, and Katherine H. Fenn

Ecology, Evolution and Natural Resources
14 College Farm Road
Rutgers University
New Brunswick, NJ 08901
lockwood@aesop.rutgers.edu

A report to the United States National Park Service, Everglades National Park, Homestead, Florida.

How To Read This Report

This report comes in three sections and reflects two substantive research efforts conducted under this grant. The first section provides a comprehensive assessment of the effects of a fire that burned through Cape Sable seaside sparrow habitat within subpopulation E in 2001. We have been following the demography of sparrows in this area since well before this fire occurred, and thus we had the unique opportunity to fully explore the effects of fire on sparrow population persistence. The first section is a manuscript that was recently submitted to *Biological Conservation*, which details demographic changes in the sparrow population due to fire. This section will continue to undergo changes as it makes its way through the peer-review process.

The second and third sections describe our efforts to evaluate changes in sparrow population numbers across its range using information generated by the range-wide helicopter survey. The second section of this report is a draft manuscript detailing the results of our efforts to document changes in sparrow occupancy through time. This manuscript will also continue to evolve as it is further refined and makes its way through the peer review process. The third and final section provides a series of issues that should be considered if the extensive survey is to be re-designed. Our recommendations stem from the work in this report and from related adaptive surveys carried out in subpopulations C, D and F detailed in Lockwood et al. (2006).

This report is the product of considerable work on the part of its co-authors and several generations of field technicians. We especially wish to thank Ben Baiser, Rebecca Boulton, Blake Mathys, Orion Welden and Amanda Holmgren for the long days they spent in the field and for their endurance of rain, mosquitoes and heat at East Camp.

We also wish to acknowledge all those that collected the range-wide sparrow survey data over the years including Sonny Bass, Stuart Pimm, John Curnutt, Tom Brooks, Lisa Manne, Lori Oberhofer, Jason Osborne and Mario Alvarado among others. We owe a special thanks the crew at Everglades Fire Cache and Aviation Safety, including our helicopter pilots and especially Gary Carnall, for ensuring our safe travel and for sling loading all of our equipment and supplies in and out of camp every season. Finally, we would like to thank David and Bob Lockwood for helping rebuild our camps after they were destroyed (twice) by hurricanes.

Section 3

Recommendations For Modifications To Range-Wide Cape Sable Seaside Sparrow Survey

Julie L. Lockwood and Phillip Cassey

Background

The history of the Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) is one of mysterious disappearances, presumed extinction, and re-discovery (Pimm et al. 2002). Up until the early 1970s the species was considered nearly extinct, if not already so, and thus it was one of the original species listed as endangered under the US Endangered Species Act of 1973 (Pimm et al. 2002). In response to this listing Everglades National Park (ENP) biologists began intensive efforts to define the range and estimate the population size of the Cape Sable seaside sparrow in the mid- and late-1970s. From these surveys ENP biologists discovered that the sparrow occupied extensive areas of freshwater marl prairie within the Everglades ecosystem, and that the sparrow was present in fairly high numbers (estimated population size of over 6000). This desirable situation did not last long, as changes in ecosystem management precipitated large declines in sparrow numbers between 1993 and 1996 (Pimm et al. 2002 and Section 2). Overall numbers of sparrows have not increased in the ensuing 10 years (see Section 2) and biologists are struggling to determine the best way to recover lost population numbers (Pimm et al. 2002, Pimm 2005). The population decline that

occurred in the 1990s sparked controversy as it was attributed to State of Florida and US Federal water management decisions that resulted in heavy flooding over a good portion of the sparrow's range (Curnutt et al. 1998, Nott et al. 1998, Walters et al. 2000, Lockwood et al. 2001). These results led to required changes in water management practices that remain controversial to this day (Walters et al. 2000, Jenkins et al. 2003).

There are several lines of biological evidence that water management practices in the early 1990s lead to serious declines in Cape Sable seaside sparrow numbers (e.g., Lockwood et al. 2001, Jenkins et al. 2003). However, one of the principle sources of evidence comes from the annual range-wide survey of the sparrow that is conducted by ENP biologists (e.g., Nott et al. 1998, Curnutt et al. 1998). The results from this survey have been questioned on statistical grounds that we review below (see also Walters et al. 2000).

The range-wide Cape Sable seaside sparrow survey reflects a common situation when rare or threatened populations are monitored for management purposes. The existing monitoring scheme was put into place well over 10 years prior to controversial changes in ecosystem management. Mangers would like to use the results from this monitoring scheme to understand the impact these changes might have had on the sparrow and to evaluate the success of recent restoration actions, but this is made difficult for at least three statistical reasons (Walters et al. 2000). First, and like many other surveys of rare species, in any given year there are no Cape Sable seaside sparrows detected in most of the range-wide survey locations. This preponderance of 'zeroes' in the survey leaves inferences concerning population change through time or across space tricky as sampling variance is high (MacKenzie et al. 2005, Cunningham and

Lindenmayer 2005). Second, it is very tough to determine if these zero-counts were because the sparrow is truly absent from the location where sampling occurred, or because the observer simply failed to count individual sparrows that were there (MacKenzie 2005). This situation makes it very hard to determine habitat preferences or other spatial factors that determine site occupancy (Tyre et al. 2005). Third, there is uncertainty in how to convert survey sparrow counts into estimates of true density as it is not clear how the detectability of sparrows changes as population size changes or as habitat conditions change across space or through time (Walters et al. 2000).

In Section 2 we treated the extensive survey results as measures of occupancy and in so doing managed to statistically confirm prior conclusions concerning population declines and highlight more nuanced management issues that arise from a careful examination of the survey data. Here we answer the following questions related to the design of the extensive survey;

(1) Using small-scale point counts that mimic the procedures for the range-wide survey, what does the spatial detection function look like for a relatively large sparrow subpopulation?

(2) What does this detection function suggest in terms of the validity of using currently accepted methodologies to estimate true density?

(3) How do the extensive survey results compare to detailed on-the-ground territory mapping of sparrows in the small sparrow subpopulations C, D and F?

(4) How many times must a site be surveyed to be certain that sparrows are truly not present?

(5) What is the power of the survey to detect observed trends in occupancy within subpopulations?

(6) What are the options for modifying the survey so that it better meets the current needs of managers without losing the ability to compare results across all survey years?

The Current Status Of The Range-Wide Survey

Following the 'discovery' of Cape Sable seaside sparrows in inland freshwater marshes of the Everglades ecosystem by Ogden (1972), biologists with Everglades National Park endeavored to document the full extent of the sparrow's range (Kushlan and Bass 1983, Pimm et al. 2002). These biologists began this effort by placing 1km^2 grids over sampling units defined by US Geological Survey 7.5 minute orthophoto quadrangles (hereafter called quads) across the 1,000km^2 interior of the Everglades ecosystem (Pimm et al. 2002). At every grid intersection (i.e. every 1km) a survey site was established. Kushlan and Bass (1983) eliminated any survey sites where the habitat was clearly unsuitable for sparrows, such as within cypress domes or prairies with near-monocultures of sawgrass. The final result was a sampling grid with 864 survey locations (Figure 1). Curnutt et al. (1998) later divided these sites into six subpopulations (A to F) based on the physical arrangement of the survey locations and the presence of barriers to sparrow dispersal between them (e.g. sloughs or pine islands)(Figure 1).

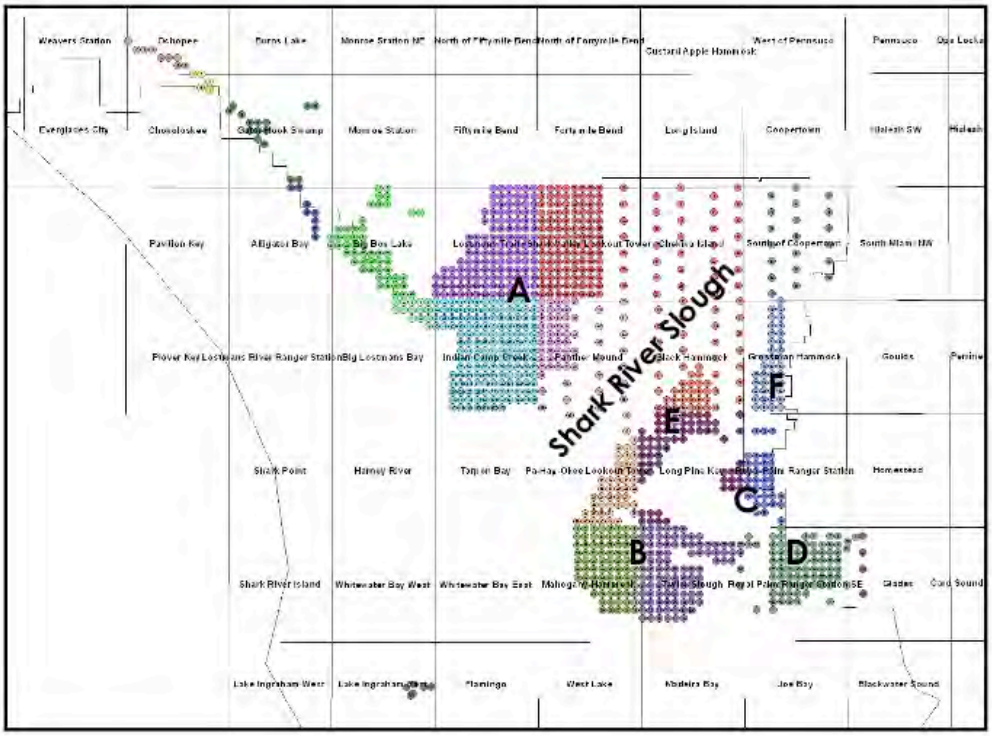

Figure 1. Range-wide Cape Sable seaside sparrow survey grid with USGS 7.5 minute quads shown. Most survey sites are 1km apart from one another. This figure shows all survey sites originally considered by Kushlan and Bass (1983). In Section 2 we provide equivalent maps that show the number of times each of these survey sites was visited between 1992 and 2005 (map produced by Mario Alvarado courtesy of ENP).

Kushlan and Bass (1983) visited each of these sites in 1981 using a Bell C-47 helicopter. The helicopter was turned off upon landing at each survey site, and after the helicopter noise ceased, the observer began counting all sparrows seen or heard over the next 7 minutes. The observer then moved on to the next survey site via helicopter and the whole process was repeated. Later surveys used larger helicopters that allowed more observers to participate and the method for progressing through survey points was changed accordingly (Pimm et al. 2002). Although seemingly an odd way to survey a small passerine, the use of helicopters to reach the survey sites has proven quite reliable

(the sparrows do not flee the approaching helicopter, pers. obs.), and the only way to logistically visit all survey sites within a time span that encompasses the height of sparrow breeding season (April and May). Most survey locations originally established by Kushlan and Bass (1983) were resurveyed in 1992 and every year since then (see Section 2 for more details on frequency of site visits). Thus, this monitoring scheme has resulted in a range-wide survey of the Cape Sable seaside sparrow that spans 25 years, with annual censuses conducted over past 14 years. The current cost of conducting the range-wide survey stands at about $100,000 per year and the survey requires three observers working daily two full months to complete (O.L. Bass Jr. pers. com.).

It is hard to dispute the fact that this survey is one of the most spatially extensive and longest records for an endangered species ever collected. The question is how best to statistically approach the information it provides. Originally, population size (or true density) was inferred using a straight-forward correction factor that itself was derived from on-the-ground field observations. Kushlan and Bass (1983) estimated the maximum distance over which a sparrow could be detected as 200m. Thus, the survey they constructed is best thought of as fixed-radius circular point count of 200m radius. To convert these counts into population estimates Kushlan and Bass (1983) applied a correction factor of 15.87, rounded up to 16. This correction factor was derived by noting that each observer was counting sparrows within a 12.6ha area (i.e. the total area within a 200m radius circle) and thus the total number of birds within a $1km^2$ area could be estimated by first multiplying the count by 8; simply because 12.6 * 8 = 100.8ha = $1km^2$. The resultant number of birds estimated within each $1km^2$ block is then doubled

(bringing the correction factor to 16) to account for females; only male sparrows sing and it was assumed that all singing sparrows were mated.

There are several assumptions that accompany the use of this method of estimating true density beyond assuming all singing males are mated. First, the correction factor assumes that observers detect sparrows across the entire 200m radius survey area with a probability equal to 1. In other words, sparrows that have territories far from the observer (but still within 200m) are assumed to have an equal probability of being detected as sparrows whose territories are beside the observer. Second, it is assumed that the spatial distribution of sparrows within the $1km^2$ block is uniform normal, meaning that sparrows are equally likely to be found at any location within the block. Third, the use of the same correction factor across the entire range of the sparrow assumes that observers are equally likely to detect sparrows no matter the underlying true density of sparrows (e.g., sparrows may be much harder to detect when there are only a few of them around) or habitat conditions (e.g., sparrows may be more difficult to detect when water levels are high).

These are clearly strong assumptions and they have been criticized as such (Walters et al. 2000). Given these statistical issues associated with using the 16-multiplier to estimate true density, the information from sparrow surveys is best thought of as a population index (Greenwood 1996). A population index is assumed to reflect true density as follows; $\frac{I}{N} = K$ where I is the population index, N is true density, and K is a constant called the index ratio. In this case the population estimate produced using the method of Kushlan and Bass (1983) is I, which itself is related to N by an unknown but assumed annually and spatially constant index ratio, K. The population index values

produced to date for the Cape Sable seaside sparrow can be, and have been, used to identify population declines and increases with some success (Walters et al. 2000, Pimm et al. 2002). This index is not nearly as precise a tool for detecting population change as we would like given the various statistical issues we reviewed above and in Section 2. Thus, the primary goal of the below analyses is to assess various statistical aspects of the sparrow survey with an eye toward improving the inferences we can draw from it, or any sparrow monitoring scheme, for management.

Can We Estimate Detection Probability And Calculate True Density?

Detection probability can be estimated using a variety of methods, however, we will use Program DISTANCE from Buckland et al. (2002). This program formally chooses between competing statistical models of how the probability of detecting an object of interest decreases as the distance between the object and the observer increases. The key observation here is that as distance increases, detection probability decreases. The question is how fast does detection probability decrease and what shape does the probability function take. DISTANCE employs information-theoretic procedures to choose between competing models of the detection function.

Past surveys for Cape Sable seaside sparrows did not demand that observers record the precise distance between themselves and any sparrows detected and thus we cannot use DISTANCE to calculate the detection function for the survey itself or over large areas of sparrow habitat. However, the small-scale point counts conducted in our fire-effects study plot described in Section 1 did require observers to record some distance information, and thus we can derive a rough approximation of the detection function within a relatively densely occupied area. In these point count surveys,

observers recorded if sparrows were seen within 50m, between 50m and 200m, and beyond 200m of their location. Although this distance information is not ideal (the preferable situation is to have distance information on all sparrows detected), we can place these sparrow detections into distance 'bins' and, using DISTANCE, settle on the most likely detection function for this study population.

Figure 2 shows the detection function selected when all point count surveys were pooled across years (2002 to 2005) from this study plot (note that the results do not change appreciably when information from each year is considered separately). The 'best fit' detection function is the hazard-rate, and from Figure 2 it is clear that the ability of an observer to detect a sparrow when present drops off dramatically as the distance between the sparrow and the observer increases. This result is very typical for small passerines, and especially for grassland birds that are secretive and spend much time near the ground and thus out of sight of observers (e.g., Difenbach et al. 2003). Although we consider this detection function as an approximation because we do not have exact distance information for all sparrows detected, this result does suggest that the underlying inherent assumption in the 16-multiplier that detection probability = 1 across the entire 200m radius point count area is invalid.

Once the detection function is determined, an estimate of true density ($\hat{D}$) can be derived that includes indices of variability. Using the information on the detection function shown in Figure 2, $\frac{n}{K}$ the detection rate, can be estimated for this study population, where n is the number of sparrows detected and K is the number of survey sites. These variables can then be used to determine the probability that a sparrow will be

detected at a survey given that a sparrows are present (i.e. detectability) and to make inferences about changes in sparrow density in the area of interest.

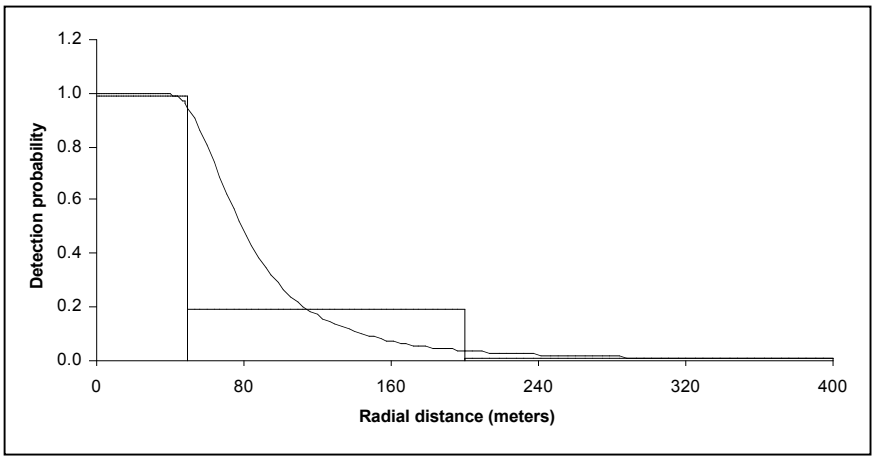

Figure 2. Detection function for Cape Sable seaside sparrows derived from point counts conducted in the fire-effects plot within subpopulation E (see Section 1). This detection function uses information pooled across all years (2001 to 2005). Observers binned the distances and these were used to create the detection function. Thus this function should be considered a rough estimation of how probability of detection decreases as the distance between a sparrows location and the observer increases.

In the fire-effects study plot described in Section 1, detectability did not statistically change through the years (Figure 3 top panel), however, detection rate and estimates of true density did change (Figure 3 bottom panel). The drop in density in 2004 may reflect the poor reproductive performance of sparrows in this plot during the 2002 and 2003 breeding season and the drop in fecundity that followed the 2001 fire event that burned nearly half the plot (see Section 1). Notably this study population rebounded in 2005 as we may have expected given the relatively high reproductive success rates observed in 2004 and 2005 and the increase in fecundity on the plot following vegetation recovery after the fire (Section 1).

Ideally we would calculate detection functions across all sparrow subpopulations as we did for this study plot. Furthermore, these functions would be based on estimates

of distances between all sparrows counted and the observer instead of placing detections into distance bins *a priori* as was done above. With the caveat that this is not possible, it is still valuable to judge how our estimates of true density using DISTANCE compare to other methods used previously to estimate true density.

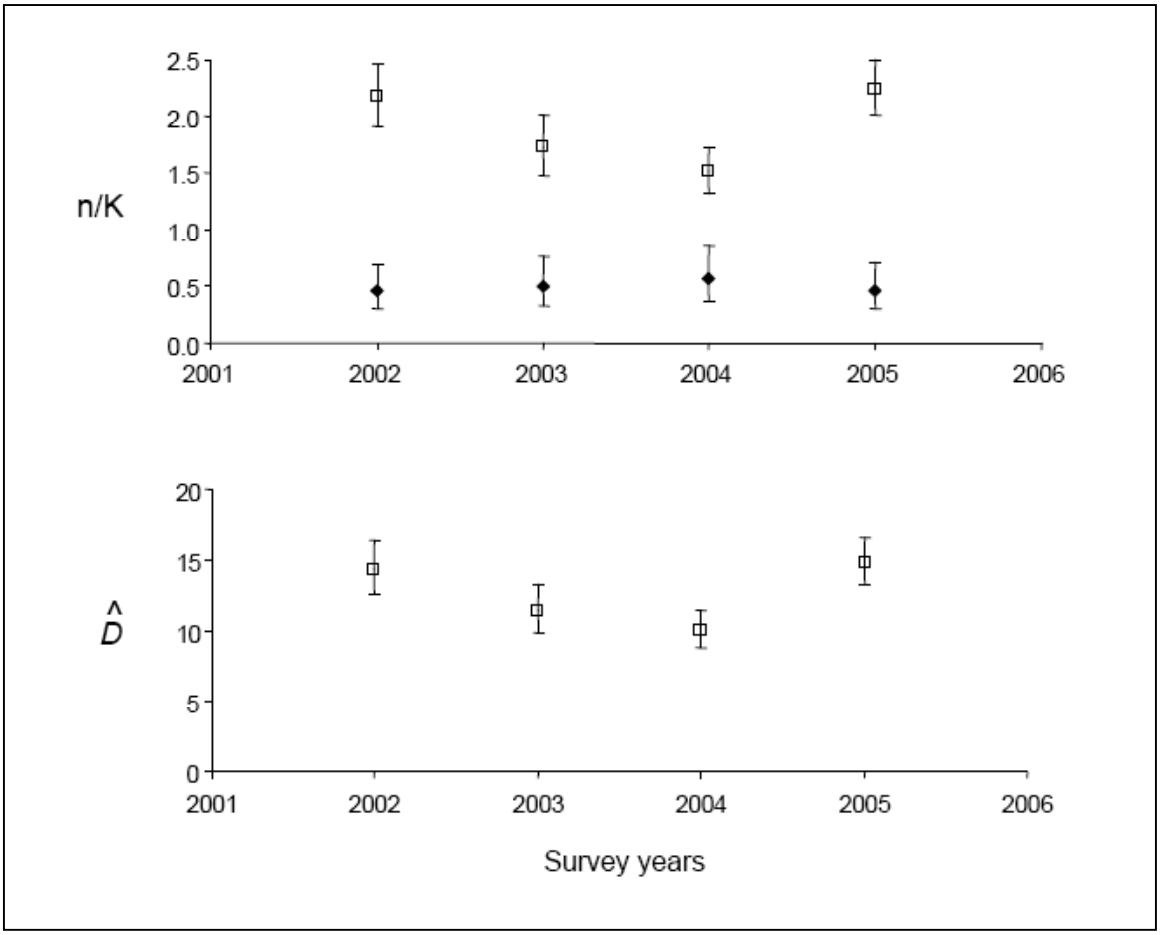

Figure 3. Top Panel: Detectability of sparrows (closed diamonds) and detection rate (open diamonds) across all years of the point count surveys in the fire-effects plot described in Section 1. Although detection rates varied between years of the survey, detectability did not. Bottom Panel: Estimates of true density for sparrows within the fire-effects plot (see Section 1) through time.

Thus, we next broadly compare three different methods of estimating true density/km^2 within areas that hold relatively large numbers of sparrows; (1) using DISTANCE (results from above), (2) using the Kushlan and Bass (1983) correction

factor of 16, and (3) from detailed territory mapping results given in Pimm et al. (2002). If we pool the estimates of sparrow density across all years for the fire-effects plot, density $\hat{D}$ = 64.13/km^2, with the 95% confidence intervals spanning 54.73 to 75.14 sparrows per km^2. The maximum number of sparrows detected in the range-wide point counts hovers around 4-5. Applying the correction factor of 16 to these numbers of detected sparrows yields an estimate of 64 – 80 sparrows/km^2. Finally, Pimm et al. (2001) mapped breeding territories within 0.25km^2 and 0.6km^2 study plots in the largest sparrow subpopulation (B) and found territory density to be around 22 sparrows per 25ha, which produces a density estimate of about 88 sparrows/km^2. These estimates of density per km^2 are close to one another, which indicate that in the absence of more sophisticated ways to estimate true density, the 16-multiplier of Kushlan and Bass (1983) provides a reasonable approximation to true density when sparrow abundance is high.

Despite this encouraging result, there are two major drawbacks to relying on the 16-multiplier to make detailed management decisions. First, there is no clear way to place indices of variability around the density estimates it produces. This means that we lose the ability to perform robust statistical analyses on changes in sparrow density through time. We return to this point in our recommendations for modifications to the range-wide survey below, and we refer readers to the results from Section 2 for a more detailed look at this issue. Second, and perhaps more importantly when evaluating the conservation status of the sparrow, we do not understand how well the 16-multiplier performs when estimating density in areas with relatively few sparrows present. From results from Section 2, however, we do have evidence that detectability drops off as occupancy decreases. Thus, sparrows appear to become more difficult to detect (given

that they are there) when there are only a few of them around. This is key to our understanding of how sparrow population size varies across space and time because the majority of range-wide survey points visited hold fewer than 2 sparrows. We are thus confronted with the possibility that the 16-multiplier over-estimates sparrow abundance in areas that often hold very few sparrows. This realization is worrisome as it suggests that using the 16-multiplier to estimate population size within very small populations leads us with to overly optimistic view of how 'safe' the Cape Sable seaside sparrow is from extinction. We more thoroughly evaluate this possibility in the following section.

How Good Are Current Estimates Of Density in Small Sparrow Subpopulations?

In the 2006 sparrow breeding season Lockwood et al. (2006) located and banded several sparrows within subpopulations C, D and F. Having sparrows banded allowed them to track the movements of these individuals, estimate their territory size, and follow the fate of their nesting attempts. The results suggested that sparrows are very rare in these subpopulations, maintain unusually large territories (relative to sparrows in larger subpopulations), and disperse between subpopulations more often than previously thought (Lockwood et al. 2006). Although searching and banding efforts were extensive, only ~30 sparrows were tracked in subpopulation C, 15 in subpopulation F, and 3 in subpopulation D. With a series of years devoted to banding, resighting and recapturing sparrows in these areas, this information can be converted into estimates of true density (a topic we will return to below). For now we can think of these as minimum estimates of sparrows in these subpopulations as there is always a chance that we did not find sparrows that were resident in these areas. However, given the number of times we

walked these sites searching for sparrows (see Lockwood et al. 2006), we feel that these are the best estimates of true density currently available.

If we compare these field-based estimates of density to the estimates produced by the range-wide survey for 2006 we see that that 16-multiplier tended to grossly over-estimate the number of sparrows in these small subpopulations, provided that the survey detected any sparrows at all. The range-wide survey estimated the number of sparrows in subpopulations C, D and F as 160, 0, and 32 respectively. Thus, in subpopulation C the extensive survey estimate of population size is 5-times our estimates and in subpopulation F the survey estimate is 2-times our estimate. There were no sparrows detected by the range-wide survey in subpopulation D, and our estimate was also quite low at about 3 sparrows.

The ground-based efforts of Lockwood et al. (2006) also revealed that two singing males, one from subpopulation D and one from F, dispersed into subpopulation C during the time frame of the range-wide survey. Furthermore, each of these males was unmated for all or most of the 2006 breeding season. This suggests that we cannot assume that male sparrows heard singing in small populations are mated, nor that they will remain in these small subpopulations throughout the breeding season. It is not clear to what extent such behaviors effect estimates of density in these small subpopulations as we do not know if these males were counted in the range-wide survey, or how many times they were counted. However it does suggest that we should be cautious of inferring too much about the health of these populations from the range-wide survey results alone. We discuss options for estimating true density of sparrows in these small populations below.

How Many Times Must A Survey Site Be Visited To Be Reasonably Sure Sparrows Are Not There?

In Section 2 we provided a way to calculate the probability that sparrows have become extirpated from survey sites. We found that 14% of regularly visited sites (i.e. those surveyed 10 years or more since 1992) had a greater than 50% probability of having had sparrows extirpated and that the majority of these sites were located within subpopulations A and D. This analysis reinforces the need to carefully manage these populations, however its implications are ambiguous in terms of the need to continue to survey these sites. If these sites are impacted sections of sparrow habitat that may recover through time, they should be re-visited. If these sites can be shown to have profoundly changed such that sparrows are unlikely to re-colonize them, the sites should be dropped. If there is uncertainty about the chances that the sites will be re-colonized, the cautionary approach is to continue to survey these sites into the future. There is likely room for more formal analyses of habitat changes coincident with site extinction probabilities, and this may inform any decisions as to which survey sites can be dropped due to local sparrow extirpation. However, there will always be need to apply best-judgment when deciding when to exclude a site from further surveys.

A related question is how many times must a survey site be visited *within a single breeding season* to be reasonably sure that there are in fact no sparrows occupying that site. If we can assess the visitation rates necessary to determine year-to-year non-occupancy we can derive more meaningful statistical interpretations of occupancy trends than provided in Section 2. For example, by using occupancy information corrected for

false-negative errors (see Section 2 for a definition) we can accurately estimate site extinction/recolonization rates and the contraction or expansion of occupied habitat (MacKenzie et al. 2005). If we assume that survey visits within a season are comparable and independent (e.g., we are not likely to count recently fledged juveniles in later visits, Pimm et al. 2002), we can calculate the probability (F) of not seeing a sparrow after N visits given a detection probability (p), as $F = (1-p)^N$ (Reed 1996, Pellet and Schmidt 2005).

In Table 1 we use the range of estimates of detection probability calculated in Section 2 (the $\hat{q}$'s) to calculate the visitation rate necessary to establish that a sparrow is truly not using a survey site with a probability of around 0.10 (i.e. we *a priori* set a 10% chance of Type I error or failing to declare a site as unoccupied when it really was unoccupied). Thus, given a set probability of detection, we increased N sequentially until $F = 0.10$ or came very close. We then incrementally changed the probability of detection and repeated the process. As might be expected given the underlying equation for calculating F, the number of within-season site visits necessary to confirm non-occupancy increases in an exponential manner as detection probability linearly declines. The highest detection probability we estimated in Section 2 (0.64) was for subpopulations B, and encouragingly it would only take two site visits within the same breeding season to confirm that a sparrow truly did not occupy a survey site in this subpopulation. The lowest estimated detection probabilities was near 0.14 and may be lower on occasion. This detection probability is typical of small sparrow subpopulations such as A, D and F. In these areas, we estimated that at least 8 visits are necessary to conclude that sparrows are truly not occupying a survey site. This result echoes the difficulties of estimating true

density in these small sparrow subpopulations and suggests that in areas (or years) where sparrows are very rare it is difficult (and expensive) to be certain that a site is truly unoccupied in a given season. Note that managers could change the degree of certainty they require for management decisions by varying *F*. This will correspondingly reduce the number of visits necessary to conclude that a site is unoccupied although clearly this efficiency comes at the cost of gaining certainty in this declaration.

Table 1. Range of visitation rates (within a breeding season) necessary to conclude with 90% certainty that a sparrow survey site truly is not occupied by Cape Sable seaside sparrows. Estimates of detection probability, *p*, come from Section 2 (ZIB model), *N* is the number of site visits, and *F* is the probability that a site is truly not occupied (set *a priori* = 0.10). Relatively large sparrow subpopulations (e.g., B and E) have detection probabilities around 0.5 to 0.64, whereas small sparrow subpopulations have probabilities below 0.24.

p	***1-p***	***N***	***F***
0.64	0.36	2	0.129
0.54	0.46	3	0.097
0.44	0.56	4	0.098
0.34	0.66	6	0.083
0.24	0.76	8	0.111
0.14	0.86	15	0.104
0.04	0.96	55	0.105

How Much Power Does The Range-Wide Survey Have To Detect Observed Changes in Occupancy?

In Section 2 we used a binomial mixed model regression to detect trends in occupancy across years. Here we ask whether we could have detected these same significant trends in occupancy if we had instead conducted the survey every 2 years, every 3 years, or every 4 years (Figure 5). An important assumption in this analysis is that the survey record always begins with the year 1992, which was a year of relatively high sparrow occupancy especially in subpopulation A. Because we detected significant trends only

within subpopulations A, C and D when examining the full dataset (see Section 2), we present the results from only these three subpopulations in the top panel of Figure 5.

If the survey was conducted every other year we would still have detected significant trends in occupancy for each subpopulation where we detected such trends using survey information from all years (A, C and D). Within subpopulation A, declines were so dramatic that we would have detected them even if the survey had happened every 4 years. In contrast, we lose the ability to detect observed trends (positive or negative) in subpopulations C and D by dropping back on surveying effort to every 3 or 4 years. Thus, our results suggest that to detect moderately sized increases or decreases in sparrow occupancy the survey must be conducted at least every other year.

	Population 'A' {-14%}		Population 'C' {+15%}		Population 'D' {-14%}	
	Estimate	t-statistic	Estimate	t-statistic	Estimate	t-statistic
2 Years	**-0.20 ± 0.03**	**-6.52*****	**0.15 ± 0.06**	**2.30***	**-0.18 ± 0.07**	**-2.52***
3 Years	**-0.27 ± 0.04**	**-7.01*****	0.14 ± 0.07	1.93+	-0.15 ± 0.08	-1.86+
4 Years	**-0.19 ± 0.03**	**-5.62*****	**0.16 ± 0.08**	**2.07***	-0.14 ± 0.08	-1.83+

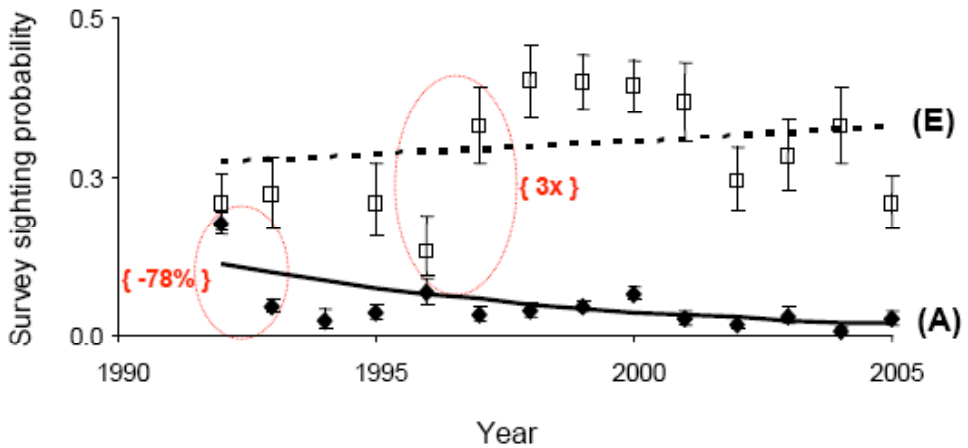

Figure 5. Top Panel: Assessment of the power of the range-wide survey to detect observed changes in Cape Sable seaside sparrow occupancy through time. Trends are evaluated using binomial mixed model regression (see Section 2), and the scenarios evaluated are; surveys conducted every 2 years, every 3 years, or every 4 years. Only the subpopulations where significant trends were observed using the full data set are evaluated. + indicates observing significant trends at the 0.10 level, * indicates significance at the 0.05 level and *** at the 0.0001 level. Bottom Panel: Changes in occupancy through time for subpopulations A and E. Circled areas and parenthetical numbers indicate very large increases or decreases in occupancy across one-year intervals and their associated values respectively.

Having said this, the bottom panel of Figure 5 illustrates the benefits of surveying every year. Annual surveys are capable of picking up large one-year changes in occupancy such as the observed 3-fold increase in occupancy seen in subpopulation E between 1996 and 1997, and the 78% decrease in occupancy seen in subpopulation A between 1992 and 1993. Thus, although we do not lose much statistical power to detect

observed trends by surveying every other year, we do miss the opportunity to detect large single-year changes in occupancy that are likely of management interest.

How Should The Range-Wide Survey Be Modified To Meet Present Management Goals?

To answer this question in any detail we must have a fairly narrow set of monitoring goals specified. The range-wide survey was designed 25 years ago to meet specific objectives that included defining the range limits and primary habitat of the sparrow and estimating total population size. Since the range-wide survey was reinstated (1992), the survey information has been used as a way to monitor changes in abundance at the spatial scale of subpopulations and above (e.g., Pimm et al. 2002). The range-wide survey has also been used as a yard-stick by which the accuracy of sparrow individual-based models and GIS models are evaluated (P. Nott pers. com., Jenkins et al. 2003). These uses may, or may not, be the uses to which the survey will be (or should be) used in the future.

In addition, managers must determine the degree of certainty they require about changes in sparrow density, occupancy and so forth before they are willing to act. The scientific standard is accepting a Type I error rate of 5%, however this is an arbitrary cutoff and relaxing that value is often considered warranted when evaluating biological harm as such harm is usually irreversible (Mapstone 1995, Taylor and Gerrodette 1993). Determining the threshold of certainty necessary for initiating a management response will greatly clarify final recommendations for sparrow survey protocols. A good example of this comes from our look at how many times a survey site must be visited within a season to confirm that the site is truly unoccupied. The less certainty required,

the fewer visits that are necessary to gain that level of confidence that a survey site is truly unoccupied. There is an inherent tradeoff between survey efficiency and the power to detect trends in any state variable monitored and, in the case of the Cape Sable seaside sparrow, this tradeoff deserves serious consideration (e.g., Field et al. 2004). Thus, our first recommendation is to convene a meeting of interested biologists and managers to discuss what the monitoring goals of the range-wide survey should be over the coming years, and what degree of statistical certainty agencies require before they are willing to implement management actions. This discussion should be inclusive but should have the clear intention of defining a relatively narrow set of goals for the survey to meet in the near future.

Given that final recommendations for survey modifications cannot be made until this discussion occurs, below we provide three statistical 'rules of thumb' that might serve to guide these discussions.

Estimates of True Density Require Modifications to Survey Protocols

Although there have been several attempts to estimate probability of detection for Cape Sable seaside sparrows (see Pimm et al. 2002 and Section 2), all of them fall short for one reason or another. From a broad range of published studies, it is increasingly clear that probability of detection of wildlife species changes according to year, habitat conditions, or both (Kissling and Garton 2006). There are a variety of statistical techniques for estimating probability of detection and any of these could be adopted by the survey participants and used to measure detectability across the sparrow's range and for all years

of the survey in the future. Not all of these are practical given the logistics and cost of the sparrow range-wide survey, however.

Although we could conduct a formal analysis of survey efficiency given various options for estimating probability of detection, an educated-guess on our part is that the most efficient method is to adopt distance methods. Distance information can then be used to produce unbiased estimates of true density at a variety of spatial scales (e.g., from USGS quads up to the entire population). We view this method as the most efficient way to estimate true density of Cape Sable seaside sparrows since distance protocols do not require repeat visits to survey sites to estimate detectability, which in this case is very expensive and time consuming. The only required modification to the existing survey protocol is to have survey participants estimate distance to all visually detected sparrows using laser range-finders or the equivalent. Thus, adopting distance methods should add minimal extra time to the survey protocol at each site while allowing probability of detection and true density to be estimated.

Collecting such information has several benefits besides the ability to estimate detectability and true density. First, it allows for an unbiased estimate of the underlying detection function for each year and across subpopulations (or quads). We may find that the detection function does not vary through time or space, however, if we find otherwise we can explicitly account for these differences in our estimates of true density. Second, the use of distance protocols allows for the measurement of variance in true-density estimates, such as the calculation of confidence intervals. This allows for a much more robust method of estimating population trends though time (or across space) than has been previously possible. Third, the use of distance protocols increases the power of the

survey to detect changes. Thus, a change of certain magnitude (whatever is deemed of management concern) can be detected in fewer years of survey effort than if the survey only yielded information on occupancy or a population index (Kissling and Garton 2006). Fourth, the statistical package that is required to do all of the above can be downloaded for free and is supported with detailed books published by Oxford University Press (e.g., Buckland et al. 2002, 2004) and by professional courses regularly scheduled in the US by the Center For Research in Ecological and Environmental Modeling (UK).

Estimates of Occupancy Requires Repeat Visits to Survey Sites Within a Season

Although we had success in using presence/absence information from the range-wide survey to detect changes in occupancy through time in Section 2, we could not directly compute unbiased false-negative error rates. Survey participants will often fail to detect sparrows at a survey site even if sparrows are using that site, which is to say that they often make false-negative errors. This is an unavoidable problem in sampling and it plagues all efforts to understand the extent of suitable habitat for any species (including sessile organisms; MacKenzie et al. 2002). We attempted to evaluate the incidence of false-negatives for the range-wide survey in Section 2, however we could not compute unbiased estimates of such errors because sparrow survey sites have never been visited more than twice in a single breeding season. Indeed it was a real logistical feat, and an expensive one, to conduct the entire survey twice in one season (Pimm et al. 2002, O.L. Bass Jr. pers. com.).

Occupancy statistics have matured over the past 5 to 10 years and there are several ways to derive unbiased estimates of habitat extent, extinction/recolonization

rates, and abundance using presence/absence information (Vojta 2005). Nevertheless, if occupancy is to be used to provide unbiased estimates of the extent of sparrow habitat (MacKenzie et al. 2005), to understand how habitat extent changes through time (MacKenzie and Kendall 2002), or to estimate abundance (Royle and Nichols 2003), several visits to each site must be performed within a single season. Repeated visits to the same site within one season allows for the direct estimation of false-negative error rates, including how these change through time or across space. It also allows for the calculation of the probability true absence using the *F*-formula we described above (Pellet and Schmidt 2005).

The advantage to using occupancy as a state-variable of interest (rather than density) is that it decreases the amount of time that observers need to be at any given survey site since they only need record the presence of a sparrow and not the number of sparrows heard or seen (Joseph et al. 2006). The drawback is the expense of visiting survey sites more than once in a season. Even though observers can stay at one site for less time than when conducting counts, the travel costs to get to these sites is the same. For the range-wide survey, these costs are not trivial. Thus, we suggest that occupancy measures may be profitably used to make management decisions about Cape Sable seaside sparrows, however, the area surveyed must be carefully chosen (and probably circumscribed) so that costs of making repeated visits are not made exorbitant.

Neither occupancy nor count information will do an adequate job of monitoring changes within small sparrow subpopulations

Based on the above comparisons between ground-based banding and tracking estimates of sparrow numbers and the range-wide survey estimates, we do not think any incarnation of the range-wide survey will provide enough power or accuracy to adequately track changes in true density or occupancy in small sparrow subpopulations. This conclusion does not negate earlier findings that sparrow numbers have declined precipitously within these subpopulations in the past. These changes were large and have now been statistically validated using at least two independent methods (Section 2 and Pimm et al. 2002), and despite statistical drawbacks, these declines are of real biological importance (Walters et al. 2000).

We believe the main issues lie in our desires to demonstrate further population growth or decline in these areas as a result of current or planned management activities. Increases in density or occupancy are sure to be gradual and of much less magnitude than the declines observed in the early 1990s if for no other reason than because the life history of sparrows dictates a slower population recovery rate as compared to population decline (Lockwood et al. 2001). Furthermore, the Comprehensive Everglades Restoration Plan relies heavily on monitoring of affected species so that adaptive management actions can be implemented. Because these sparrow populations are already very small, they cannot long endure bad ecosystem management. We will thus need a much more precise and accurate way to estimate density and occupancy in these areas in the coming years so that managers can react appropriately and quickly to any inadvertent harm caused.

We have explored options in terms of on-the-ground surveys that could replace the range-wide survey for estimating true density in very small subpopulations, however

even a design specifically geared for estimating density in rare or elusive species does not work well for Cape Sable seaside sparrows (Lockwood et al. 2006). We therefore suggest that there is no better way to estimate sparrow numbers than through mark-resight-recapture methods (Borchers et al. 2002). These methods require extensive field time finding sparrows, banding them, and then resighting or recapturing them. The advantages to using mark-recapture estimates of abundance lie in the robustness of the associated statistics and the availability of free statistical packages to run the statistics, such as Program MARK (White and Burnham 1999). There are substantial side benefits to this approach of density estimation as we also have the ability to gather information on territory size and location, survivorship, dispersal, and breeding success of sparrows in low-density subpopulations. All of this information is of use for modeling the persistence of sparrows in general, for understanding habitat relationships, and for our understanding why these populations may be continuing to decline, or are beginning to increase. The disadvantage to this approach is the cost, as such detailed information is expensive to obtain and gathering such information across all of the small sparrow subpopulations (A, C, D and F) is logistically difficult.

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