

**NON-BREEDING SEASON ECOLOGY OF THE
CAPE SABLE SEASIDE SPARROW
(*Ammodramus maritimus mirabilis*)**

1997-1998 FIELD SEASON FINAL REPORT



**Tylan F. Dean and Joan L. Morrison, Ph.D.
Eagle Environmental, Inc.**

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Michael V. Dadd

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EXECUTIVE SUMMARY

To date, the majority of the research on the endangered Cape Sable seaside sparrow has been conducted during the breeding season, when sparrows are visible, vocal, and easy to locate. However, to effectively manage for this sparrow, it is essential to understand the sparrow's habitat needs and behaviors throughout all aspects of its life history. To document the movements and habitat use of sparrows during the non-breeding season when sparrows are secretive and difficult to consistently locate, we attached radio transmitters to 21 Cape Sable seaside sparrows between July and February.

We evaluated the effects of transmitters on sparrows to ensure that there were no severe detrimental effects to the birds. None of the four condition indicators we employed suggested that sparrows with transmitters declined in condition.

We radio-tracked 18 individuals for extended periods (1-7 months). These data suggest that sparrows are relatively sedentary, and maintain a non-breeding season home range that is larger than average breeding season territories. Individual sparrows were generally consistent in their scope and frequency of movements, and most birds moved approx. 160 meters between consecutive locations. Though many sparrows made longer movements away from home ranges at some point, most returned to their previous home ranges. However, three individuals did not return to previous home ranges, and settled 450, 6000, and 7000 meters from previous home ranges. These data indicate that sparrows are capable of moving long distances within the muhly prairies. No sparrows used habitats other than the open muhly- and sawgrass-dominated prairies.

At the landscape scale, sparrows generally occurred in the open prairies. They perched in sawgrass sways and small tree islands, but appeared to avoid large tree islands and tree-lines. Additionally, sparrows regularly occurred within old agricultural areas, but avoided old-grove agriculture areas that contain clumps of tall sawgrass and small trees or shrubs.

Micro-scale habitat selection models were not consistently able to distinguish between habitat characteristics at random points and at points used by sparrows. However, when we compared the use

of micro-habitats by sparrows under different hydrologic conditions, we found that selection of most habitat characteristics changed relative to the water depth at the site. Sparrows used muhly-dominated sites less frequently as water depths increased, and used sawgrass-dominated sites and sawgrass clumps more frequently as water depth increased. Use of other habitat characteristics also changed relative to water depth. Hydrologic condition of the prairies is one of the most variable environmental characteristics. Interpolated topographies of our two study sites indicated that there is as much as 20-30 cm of topographic variation within areas as small as 1 km². Water levels remained high throughout the non-breeding season, and one of our sites was still completely inundated in February.

Sparrow surveys in the muhly prairies provided supplementary evidence that sparrows do not drastically change distribution or habitat use between the seasons. Comparisons of point counts and rope-dragging transects also showed that transects were more effective for determining whether sparrows were present at a site.

We used a Kaplan-Meier survival estimator with a staggered entry design to determine survival probabilities for radio-marked sparrows. We documented 4 sparrow mortalities during our study period, and 5 radio-marked sparrows disappeared. The survival rate from these data for the 7-month monitoring period was 0.63. Other estimates of survival rates for Cape Sable seaside sparrows vary substantially, but there is no evidence to suggest that radio-marked sparrows suffer higher mortality rates than unmarked sparrows.

We heard sparrows singing as late as August 1997, and captured a recently fledged sparrow in August as well, which shows that sparrows do occasionally breed late into the season. We documented a decline in detections of unmarked sparrows beginning in late October and continuing through December as other authors have noted. However, we determined that this change merely represents a behavioral change, and sparrows do not change their movement patterns or habitat use. This behavioral change appeared to occur immediately after the completion of molt. Sparrows began singing again in early December, but did not show strong territoriality until February 1998.

INTRODUCTION

The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) is one of nine formally recognized subspecies of seaside sparrow in the United States. Initially considered a distinct species, the Cape Sable seaside sparrow was relegated to subspecific status in the early 1970's (Eisenmann 1973). The Cape Sable seaside sparrow is endemic to southern Florida, specifically the southern Everglades system and diverges ecologically from other races of the seaside sparrow by inhabiting freshwater marshes and seasonally inundated freshwater muhly (*Muhlenbergia filipes*) prairies (Kushlan and Bass 1983).

Over the last half-century, drainage and development have caused major changes in the vegetation and hydrology of the southern Everglades (Robertson and Frederick 1994). Currently, the Cape Sable seaside sparrow exists as six disjunct populations separated by areas of unsuitable habitat such as the deeper waters of Shark Valley Slough and Taylor Slough (Curnutt et al. 1998). Long-term monitoring has documented considerable changes in population size at some sites (>90% decline in the western population from 1992-1995). In addition, the overall population size declined by >50% between 1992 and 1995 (Curnutt et al. 1998).

Owing to the fragmented nature and small size of these populations, the Cape Sable seaside sparrow was listed by the USFWS as endangered in 1973, and is similarly listed by the Florida Game and Fresh Water Fish Commission. Current research on the Cape Sable seaside sparrow focuses on broadening knowledge of its breeding biology and demography, to assist in management planning for the subspecies and its habitat (Pimm et al 1997, Curnutt et al. 1998).

The ecology, behavior, and habitat associations of the Cape Sable seaside sparrow during the non-breeding season remain poorly understood. One reason for the lack of information on non-breeding season ecology is the sparrow's extreme secretive nature during parts of the year (Werner and Woolfenden 1983). This secretiveness makes it difficult or impossible to study the sparrow's behavior and ecology through direct observation.

To date, few data are available on non-breeding season habitat use. Kushlan et al. (1982) suggested that sparrows remained on or near their territories year-round, which implies little shift in habitat use among the seasons. Balent et al. (1997) also reported that sparrows did not appear to move into different habitat types during the non-breeding season but did seem to increase their use of large sawgrass sways and woody vegetation during parts of the non-breeding season. However, data on habitat use during this period may be biased by the detectability of sparrows in different habitats, and their secretive nature makes them almost impossible to locate consistently.

To effectively manage for the recovery of this endangered species, it is critical to understand all aspects of its life history, including its ecology during both the breeding and the non-breeding seasons. Our research focuses on elucidating the non-breeding season ecology of the Cape Sable seaside sparrow in Everglades National Park, particularly movements, habitat use, and survival. Because of the sparrow's secrecy during the non-breeding season, our primary methodology involves attaching radio transmitters to sparrows and subsequently tracking them throughout the non-breeding season. A primary assumption of this methodology is that data obtained from radio-marked sparrows reflect patterns characteristics of Cape Sable seaside sparrows in general. While this is a broad assumption, we have no way of testing its validity. Because of the sparrows' secrecy during the non-breeding season, there is no suitable method other than radio telemetry to obtain these data.

Objectives

This report covers results and findings from the first season of research. Major objectives of this first year were to:

- 1) Quantify the frequency and scope of Cape Sable seaside sparrow movements;

- 2) Evaluate potential affects of radio transmitters on sparrows;
- 3) Determine non-breeding season habitat associations of sparrows;
 - a) Determine landscape-level habitat associations;
 - b) Evaluate selection of micro-habitat characteristics;
 - c) Determine relationships between sparrows' habitat use and water levels;
- 4) Estimate survival probabilities for sparrows throughout the study period;
- 5) Assess distribution and relative abundance of sparrows throughout potential habitats.

STUDY AREAS

We established two study areas where we captured and radio-marked sparrows. Both areas are within the Ingraham population of sparrows (Population B, Curnutt et al. 1998), in an area of contiguous muhly prairie within Everglades National Park. Both sites are located north of Old Ingraham Highway and are approximately 2 km apart (Fig. 1). The Half Raccoon site (HR) is located immediately east of the Far East breeding season study plot, north of Old Ingraham Highway. The second site (End of Ingraham - EI) is northwest of the current end of Old Ingraham Highway, due west of the North Ingraham breeding season study plot and directly north of the Ingraham south breeding season study plot (Lockwood et al. 1997). Each site is approximately 1 km² in size. The extent of each study area was defined by the scope of movements of the radio-marked sparrows. Muhly and sawgrass (*Cladium jamaicense*) are dominant plant species at both sites, and both sites contain scattered tree islands and cypress domes.

We also conducted non-breeding season sparrow surveys at 12 sites within Everglades National Park. Eleven of the survey sites were within the area occupied by population B, with one site in Taylor Slough just north of Main Park Road. Figure 1 illustrates the approximate location of these sites.

METHODS

Trapping and Banding

To locate sparrows for capture, we searched within our study areas using both visual and aural cues. When we located sparrows, we attempted to capture individuals using mist nets. We place two to three nets in close proximity (within 50 m) to sparrows and worked to flush the birds into the net by encircling them. During periods when sparrows were secretive, we used weighted ropes to locate sparrows for capture and flush sparrows toward the nets. When we captured a bird, we measured basic morphological characteristics, including mass, wing chord, sex, age, molt progression, and fat scores for use in evaluating potential detrimental effects of the transmitter or harness. To allow individual identification, all captured sparrows at all of our sites received a purple plastic band over an aluminum U.S. Fish & Wildlife Service band on the right leg and a unique combination of two colored plastic bands on the left leg. We coordinated our color banding with Dr. Stuart Pimm to ensure that no sparrows were assigned duplicate color combinations.

Transmitter Attachment

If a captured sparrow weighed ≥ 17.0 g and appeared to be in good health, we attached a radio transmitter using a modified leg-loop harness (Rappole and Tipton 1991) constructed of 25-lb test braided nylon fishing line. We inserted a 0.5 cm length of cotton-polyester blend carpet thread into each harness to allow the transmitter to drop off the sparrow as the thread decomposed, in the event that we were unable to recapture sparrows to remove transmitters at the end of the study period. We fitted the harness to each individual and secured knots with a drop of super-glue. We also glued the transmitter to the harness material in the appropriate position to ensure that transmitters remained centered on the sparrow's back and did not slip down the side. After transmitter attachment, we briefly placed each sparrow into a test cage (52 x 40 x 20 cm) constructed of $\frac{1}{2}$ " hardware cloth and

lined with vinyl window screen and briefly monitored its activity to ensure that it was unhindered by the transmitter or harness. If the sparrow appeared to be behaving normally, we released it from the test cage. We closely monitored its activity for the following two days by recording its location twice a day and closely observing its flight behavior.

Transmitters weighed 1.0-1.2 g (Advanced Telemetry Systems, Inc., small bird transmitters) and had a battery life of 50-70 days. As batteries weakened, we recaptured individuals using the same technique described above and replaced transmitters. We again recorded each sparrow's mass, measurements, molt progression and fat scores. We also closely inspected the sparrow for indications of abrasion or other injuries. If the sparrow seemed healthy, we attached a new transmitter following the same attachment protocol. Transmitter replacement allowed us to obtain data on selected individuals for several months, in some cases through the entire non-breeding season. At the end of the study we removed transmitters from all radio-marked sparrows with active transmitters.

Assessing Potential Effects of Transmitters on Sparrows

The transmitter weight of approximately 1.1g is equivalent to 5.2% - 6.7% of sparrows' body weight. To evaluate potential detrimental effects, we first examined changes in mass and in fat scores for individual sparrows over time. Because of the lack of information on normal variation in individual weights, fat scores, and molt progression, it was difficult to evaluate condition relative to a control group. Consequently, simple inspection of condition indices across successive captures was used to determine whether sparrows' condition indices consistently declined, remained stable, or increased. We also tested whether sparrows with transmitters were within the ranges of condition indices for sparrows captured without transmitters, but the small sample of sparrows without transmitters during the non-breeding season made comparisons difficult.

To test the hypothesis that heavier transmitters relative to sparrows' body weights would have a greater effect on sparrows, we used linear regression to evaluate relationships between changes in

weight and fat scores relative to transmitter weight. We also used regression to test for declining trends in flight distances over time for sparrows with transmitters.

Radio telemetry

Individuals with transmitters were radio-tracked daily from the ground. We tracked the transmitter signals using a portable receiver and directional yagi antenna and closed in on the signal until the sparrow flushed. In this manner, we were usually able to determine the location from which the sparrow flushed to within 0.5 m. We then used a sighting compass to obtain bearings from the sparrow's flushing location to the two nearest reference posts (see below). Bearing data to each reference post were then used to calculate the exact UTM location for each sparrow via triangulation (White and Garrott 1990). For all sparrows we located, we recorded the sparrow's flight distance and direction. Flight distances were represented as the straight-line distance between the sparrow's flush location and the point where it alighted, and were recorded using calibrated Ranging 2000 rangefinders. If we could determine the location from which a sparrow flushed within 0.5 m, we conduct habitat measurements (see below). If we are unable to determine the exact location from which the sparrow flushed, we only recorded its approximate location, flight distance and direction.

Home range -- Home ranges were estimated using adaptive kernel home range estimators in the program Calhome (Kie et al. 1994). Adaptive kernel home range estimators are based on a weighted point probability distribution function, with weighting that emphasizes the centrality of the distribution (Worton 1989). We used a 90% probability contour to reduce the effects of outlying locations on the home range size. All home range contours were calculated using a zero smoothing parameter (Kie et al. 1994).

Movements -- Movement distances between consecutive locations were determined by calculating straight line distances between sparrow locations. We calculated the maximum distance moved by each sparrow and distances between consecutive locations.

Reference Posts

We placed 11 reference posts at EI and 16 at HR. Posts were spaced approximately 200 m apart throughout each site. These posts serve as reference locations that we used to determine sparrow locations through triangulation. They also served as reference sites where we regularly measured water levels. Posts were made of $\frac{3}{4}$ " white PVC pipe and were placed rigidly into the ground. Each post was marked at 0.5 cm increments at the base for recording water levels and was flagged with a unique color combination to facilitate identification and improve visibility. We recorded exact locations of each post using a Trimble Pathfinder Pro GPS system. To ensure accurate post locations, we averaged > 200 differentially corrected GPS positions. Tests of the GPS system suggested that post locations were accurate to within 2 meters.

Water Measurements

To address hydrologic patterns in the study areas, we measured water levels at reference posts throughout the HR and EI study sites. We recorded water depths at more than three posts every day, and we recorded depths at every post twice each week. A single control post near the entrance of each site served as a standard for each site where water depth was recorded daily.

Depths of different posts were not standardized in any way within the sites, and we were only able to record the change in water depth over time and any differences between the posts. In addition, most posts were placed in low points to record water depth even during dry periods. However, to provide an index of the water depth at each post, we calibrated each post by recording water depths one meter from the post in each cardinal direction and then averaged these measurements to determine the average ground level for each post.

We investigated the change in water levels over time at each site to describe the degree and timing of inundation. Water depths > 10 cm have been reported to preclude breeding activity (Nott et

al. 1998), but little has been reported on relationships between water depth and the sparrows' behavior, movements, and habitat use. Our primary purpose of monitoring water levels was to determine whether sparrows behaved differently or used different habitats during periods of different water conditions within their habitats.

To determine the availability of wet and dry sites across our study areas over time and to determine the spatial variation in water depth, we developed an elevational model for each site. We used a method similar to that used by Nott et al. (1998) to construct a pseudotopography for each study site based on the depth of inundation during wet periods. By subtracting the measured water level for each day at the standard post from water measurements taken at habitat measurement sites (see below), we determined the elevation at each habitat measurement site represented relative to the control post. For this analysis, we eliminated all points within dense sawgrass clumps or sways to avoid the effects of solution holes and other small depressions on the overall topography. We also eliminated all points recorded during dry periods (water at control points < 6 cm) to ensure that nearly all of the site was inundated when we conducted measurements.

We then interpolated a digital elevation model for each site within the IDRISI Version 2.0 GIS software (Clark Labs for Cartographic Technology and Geographic Analysis 1997) using distance-weighted averaging of elevation at points, with the reciprocal of the distance between adjacent points acting as the weighting factor.

Determining Habitat Associations of Sparrows

Habitat measurements -- We conducted habitat measurements at all accurate locations obtained for both radio-marked and unmarked Cape Sable seaside sparrows. To test for habitat selectivity by sparrows based on the measured characteristics and to facilitate comparisons between study sites, we also measured vegetation at random points across the landscape at both HR and EI study sites. Random points were selected relative to a series of parallel transects spaced 100m apart

that covered each entire study area. Stratified random numbers (0-50 m) determined the distance the observer traveled down the transect. A second random number determined whether the observer moved left or right off the transect, and a third random number (0-50 m) determined the distance the observer traveled perpendicular to the transect to the sample point. After completing measurements at each random point, the observer returned to the transect and started the process again, slowly progressing down the length of the transect.

We measured the following habitat variables within a 1 m radius circle centered on each sparrow location and each random point.

- 1) Water depth and soil depth at the center point and at points one meter from the center point in each cardinal direction. In analyses, we used these values to obtain average water and soil depths and variance in depth, as well as the depth at the center point.
- 2) Direction and distance from the center point to the nearest clump of sawgrass. We defined a sawgrass clump as a dense sawgrass stand (>70% sawgrass cover) that was taller than the surrounding vegetation and had a diameter > 1 m. Sawgrass clumps generally occurred in small solution holes.
- 3) Maximum and effective height of the vegetation within 0.5 m of the center point. Maximum height was the height of the tallest vegetation at the center point. Effective height was determined by placing a metal rod horizontally on top of the vegetation at the center point and measuring the distance from the soil surface to the bottom of the rod. Effective height is an index of the structural height of the vegetation at a site.
- 4) At each sample point, we described the dominant vegetation following Daubenmire (1959). We recorded percent canopy coverage of 6 vegetation variables - muhly, sawgrass, rush, litter, bare ground, and shrub - within a $1/8 \text{ m}^2$ rectangular quadrat centered on each sample point. "Rush" was composed of several structurally similar species that we assigned to this structural category - black-topped sedge (*Schoenus*

nigricans), beak rushes (*Rhynchospora katespii* and *R. inundata*), and spike rush (*Eleocharus sp.*). The litter category included litter of all species. Percent canopy coverage was determined by visually estimating the cover of each vegetation variable and assigning it to one of six broad cover categories. These categories were 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Daubenmire 1959). We did not estimate vegetation cover within cypress domes and tree islands.

Landscape-level habitat characteristics – There are many large-scale landscape features which the sparrows either associated with or avoided. For the purposes of this report, we described the movements of sparrows with respect to these landscape features. The landscape features we identified include tree islands, cypress domes, isolated trees, forested boundaries, old grove agricultural areas, and old-field areas. This is an analysis that we hope to develop further in the future.

Selection of micro-habitat characteristics – To analyze micro-site vegetation data, we first conducted descriptive analyses of sparrow and random locations and compared the occurrence of vegetation cover classes at the different study sites. Prior to advanced analyses, we tested for correlations among variables to meet assumptions of the analysis techniques. We determined a priori that we would consider variables with an R-value < 0.70 to be uncorrelated.

To evaluate selection of micro-habitat characteristics by sparrows, we employed a loosely defined use vs. availability design as outlined by Manly et al (1993). Sparrow locations were classified as the “used” resources and the random points across the study sites constituted the “available” resources. We used measured habitat variables and logistic regression analysis (Hosmer and Lemeshow 1989, Manly et al. 1993) to evaluate selection by sparrows. These procedures fit logistic regression models with dichotomous dependent (outcome) variables by the method of maximum likelihood (Menard 1995).

We used stepwise multiple logistic regression analysis to create parsimonious habitat selection models for each site as well as a single model combining both sites. Logistic regression models

describe the relationship between a dichotomous outcome variable and a series of independent (explanatory) variables (Hosmer and Lemeshow 1989). In our logistic regression models, we used whether a habitat measurement point was a sparrow locations or a random location as the dichotomous outcome variable and sought to determine which habitat variables were related to the two types of points. Because our vegetation cover classes represented categorical data, we created a series of dummy-coded variables for each vegetation type and retained the absence of a vegetation type at a point as the referent group for each set of dummy variables.

To eliminate the strong effects of cover categories with few occurrences in logistic regression models, we combined sparse vegetation cover categories with adjacent categories. We defined sparse categories as those with occurrence of a vegetation cover class within less than 10% of the points within each study area. In addition, if we recorded less than 10 occurrences (<1%) within a particular vegetation cover class, we eliminated all points containing those values to improve the interpretation and fit of models. At both sites, these rules eliminated the cover categories above 50% for muhly and sawgrass and categories over 75% for litter and open cover types. Rush cover categories over 25% were also eliminated.

We constructed parsimonious logistic regression models using a top-down modeling approach with both forward and backward steps, in which we removed variables that did not aid in predicting the outcome variable. We used the Wald statistic to identify potential variables for elimination but did not use this statistic alone because simulations have shown that the Wald statistic behaves erratically (Hosmer and Lemeshow 1989). After we removed a variable, we then tested whether the removal significantly reduced the predictive power of the model using likelihood ratio tests at an alpha-level of 0.05. If the removal of a variable resulted in a significant loss, we tested whether the addition of each previously removed variable increased the discrimination. With this approach, final models were those containing the fewest variables that did not differ from the saturated model (the model containing all habitat variables) in discriminatory power. In this manner, we produced parsimonious

models that distinguished between random and sparrow locations. We also tested final models against a constants-only model to determine whether addition of any habitat variables aided in discrimination.

Once we produced a model, we tested for goodness-of-fit using the Hosmer-Lemeshow goodness of fit chi square based on deciles of risk (Hosmer and Lemeshow 1989). In addition, we estimated the ability of the models to discriminate between sparrow and random locations, as expressed by the area under the ROC curve. The area under the ROC curve is obtained by plotting model sensitivity against specificity, and determining the area under the curve, which represents the likelihood of correctly classifying any one observation as a sparrow location or a random location.

Relationships between habitat use and water levels – To investigate relationships between habitat use and water depths, we disregarded random habitat measurement points and only used habitat measurements at sparrow locations at each site. To test the null hypothesis that sparrows did not use vegetation cover types differently under different depths of inundation, we used Kruskal-Wallis non-parametric ANOVA with Bonferroni-adjusted alpha levels.

There are two approaches to this analysis, and we investigated both. The first and more conservative approach is to compare sparrows' use of habitat cover types relative to the daily water depth at the control point for each site. The second approach involves comparing the vegetation cover at sparrow locations with the water depth at that point when sparrows used the site. The results were similar under both approaches, and we only present results from the second approach in this report. In all analyses, water depth was considered the dependent variable, and six ANOVAs were conducted for each site (one for each vegetation cover type and one for sawgrass clump use). The experiment-wise alpha level was maintained at 0.05 for each site. We used multiple comparison tests to determine which cover classes led to significant ANOVA results.

Survival Analysis

To estimate survival probabilities for radio-marked sparrows, we used the Kaplan-Meier procedure modified for staggered entry of animals (Pollock et al. 1989). This method produces a survival function, $S(t)$, which is the probability of an individual surviving t units of time from the beginning of the study. Animals are allowed to enter the study at different times and the time variable may be measured from the point where the first group of animals is tagged. Individuals whose fate is known (survived or died) and censored individuals (those that disappeared and whose fate is unknown) are included in developing the survival estimates (Pollock et al. 1989).

Survival estimates may be calculated for time periods of different lengths. However, because we were tracking few sparrows when we documented the first mortality in late July, survival estimates for the early time periods varied dramatically depending on the duration of the time periods used to calculate them. In addition, because the survival estimates are cumulative, erratic early estimates affected the overall survival rates. Therefore, to stabilize estimates, we calculated and present here survivorship of adult sparrows, using time periods of one month in length.

In calculating these survival estimates, we only used radio-marked birds, and we conducted three different analyses. For the first we considered individuals that disappeared within each time period as censored, making no assumptions about the fate of these birds. In this case, censored individuals were assumed to still be at risk until the instant after the time period in which they disappeared (Pollock et al. 1989). As a comparison, we calculated a worst-case survival estimate in which we assumed that all disappearances were actually mortalities in which transmitters were destroyed. Finally, in the best-case scenario, we assumed that all sparrows that disappeared represented transmitter failures only and did in fact survive to the end of the study period.

Assessing Relative Density of Sparrows in Potential Habitats

In addition to the radio telemetry, we conducted surveys for sparrows in other areas of known breeding activity and in areas without known breeding. Our main objective was to attempt to determine whether there were any large-scale changes in distribution or smaller changes in density of sparrows at different sites during the non-breeding season. We also compared two survey methods (rope-dragging transects and standardized point counts) to determine which was more effective for detecting sparrows. We established transects which we surveyed once monthly during November, December, and January, the period when sparrows were extremely secretive. Our 11 survey sites were within the area occupied by sparrow population B, as well as in Taylor Slough, all within Everglades National Park (see Figure 1). Each site contained two 800 x 25 meter belt transects approximately 300m apart and 6 count points, with the exception of the FS site, where we had only one transect and three points. We recorded birds on a total of 21 transects and at 63 count points.

The rope-dragging technique involves two people dragging a 25 m nylon rope between them along a transect. 1-m trailing ropes were tied to the main rope approximately every 1.8 m along the length of the rope, and two plastic bottles were tied to the trailing ends of these ropes to create noise and additional disturbance to the vegetation as the rope was dragged over the prairie. This technique was designed to create a large disturbance to the low vegetation to flush nearly all birds within the transect width without damaging the vegetation.

Point counts required one person to detect all birds within 100 m using visual and auditory cues, for ten minutes at each point. To allow the most direct comparisons between the techniques, census points were located along the centerline of each transect at points 200m, 400m, and 600m along its length. Point counts were conducted within 3 days of rope-dragging censuses at each site.

To test for differences in detection likelihood between the two techniques, we used McNemar's analysis of discordant pairs to compare the agreement in sparrow detection between each sampling method within each sample period (Rosner 1982, SAS 1990). We are currently unable to

compare breeding season and non-breeding season densities because we do not have comparable breeding season data.

RESULTS AND DISCUSSION

Trapping and Banding

Between 26 July 1997 and 28 February 1998, we performed 72 captures of Cape Sable seaside sparrows. We captured and banded 31 previously unbanded sparrows: 9 at the EI site, 4 at FS, and 18 at HR. (Appendix I). On 5 occasions, we recaptured sparrows (3 different individuals) originally banded during the breeding season by Stuart Pimm's field crew. We always successfully recaptured sparrows with functional transmitters and also recaptured sparrows without transmitters on several occasions. The number of recaptures of individual sparrows ranged from one to six during the field season.

Transmitter Attachment

We attached transmitters to 21 Cape Sable seaside sparrows (Table 1). Two transmitters fell off shortly after attachment, and we removed a third approximately 12 hours after attachment due to the individual's apparent difficulty with the attachment. No sparrow mortalities or injuries occurred during handling.

Effects of Transmitters and Harness on Sparrows

Sparrow weight and fat scores -- Transmitter weights were approximately 1.1g and ranged from 5.2% - 6.7% of sparrows' body weight. Because we were not able to consistently recapture sparrows without transmitters, we were unable to make direct comparisons of condition changes between marked and unmarked sparrows. However, comparisons of sparrows with and without

transmitters for the three months when we had sufficient samples of each show no differences in the groups. The range of weights and fat scores for sparrows with transmitters was similar to the range of sparrows we captured without transmitters within each time period considered, suggesting a lack of effect (Figs. 2-3).

Linear regression of individuals' weight change and changes in fat scores on relative transmitter weight did not reveal any significant relationships (Fig. 4). The slope of the regression of weight change on relative transmitter weight was marginally significantly different from zero however, suggesting that a relationship may exist. The relationship was in the positive direction, indicating that sparrows with heavier transmitters tended to gain weight more than sparrows with relatively lighter transmitters.

Although we detected substantial changes in both weight and fat scores of individual sparrows throughout the study period (Figs 5-6), we did not record any consistent changes over time that would indicate difficulty supporting the transmitter or difficulty with the harness. Both indices appeared to be affected by the initiation and completion of molt (Fig. 7). Sparrow body weight and fat deposition varied somewhat throughout the season, with the lowest average weight and fat scores occurring in September, near the peak of molt (Figs. 5 and 6). Weights increased after the completion of molt and seemed to stabilize from November through the end of the project.

Individuals' fat scores also varied over time (Fig. 6), and this was the most variable index we recorded. However, patterns among individuals were remarkably consistent, indicating that fat scores changed due to factors other than the presence of transmitters. Sub-dermal fat deposits were nearly absent during molt, rebounded after the completion of molt and then diminished as the breeding season approached. Again, sparrows with transmitters did not seem to differ from sparrows without transmitters with respect to fat scores.

Molt appeared to begin in late July, and sparrows had completed molt by November, with some individuals both initiating and completing molt earlier than others. Peak molt apparently occurs

in September-October (Fig. 7). We did observe some new feather growth after October, but in all cases only tail feathers or contour feathers were replaced, probably due to incidental feather loss. We did not observe any apparent molt retardation or difficulty replacing feathers in radio-marked sparrows.

Flushing distances -- Sparrows were generally consistent in the distances that they flew in response to flushing, though the average distance flown varied among individuals. Regression analyses of distance flown failed to exhibit significant trends, with the exception of two individuals whose slopes were significantly less than zero. Most individuals exhibited a negative though not significant slope (Table 1). It is difficult to interpret these changes over long time periods because changes in behavioral response to flushing might be expected considering that we flushed most individuals nearly once per day for six months. Dean and Vickery (1996) reported a similar result in radio-marked Florida grasshopper sparrows. This index was intended primarily to detect relatively short-term changes in flight distances that would indicate energy limitation or other extreme difficulty with the transmitter. Over longer periods, we are unable to distinguish between minor transmitter effects and habituation to flushing by observers. The fact that other condition indices failed to indicate difficulty with transmitters suggests that changes in behavioral response may have occurred.

Radio telemetry

Overall, we recorded 1881 locations of Cape Sable seaside sparrows from late July 1997 through mid-March 1998, 1712 of which were of radio-marked sparrows. The 169 locations of non-radio-marked sparrows were individuals that we encountered incidentally in the course of the project. These included several color-banded sparrows that we were able to identify. The majority of locations obtained on radio-marked sparrows were temporally separated by ≤ 30 hours, though we located individuals less frequently during periods of inclement weather.

Home range -- Sparrows at both study sites generally remained within discrete areas that we refer to as home ranges (Figs. 8-9). We did not observe territorial or defensive behaviors, however, and sparrows did not seem to be limited to these areas by the presence of other birds. We frequently observed several birds interacting (see below) without any indications of agonistic behaviors, and most of the home ranges within each study site overlapped considerably. Some individuals' home ranges were completely within the home ranges of other individuals, while other home ranges overlapped those of up to four other birds. Mean home range size for all birds at both study sites combined was $13.02 \text{ ha} \pm 1.30 \text{ (SE)}$ (range 6.5 to 29.4 ha, $n = 17$ birds), although sizes of individuals' home ranges varied substantially (Table 2). We did not detect differences in home range size or shape between the two study areas (Student's t -test, $t = -1.19$, $P = 0.25$). Average ($\pm$ SE) home range size at HR was $14.03 \pm 2.03 \text{ ha}$ ($n = 9$) and was $12.03 \pm 1.69 \text{ ha}$ at EI ($n = 8$). Because we did not begin work at the EI site until early September, differences in numbers of locations used to estimate home ranges and total monitoring time for each of the two sites might obscure any differences.

Movements -- Our results from radio-marked sparrows suggest that the sparrows' home ranges and scope of movements, in general during the non-breeding season, seem to be greater than during the breeding season. In addition, our non-breeding season observations of birds banded during the breeding season suggested that sparrows occasionally either move away from breeding sites or expand their scope of movements during the non-breeding season. Werner and Woolfenden (1983) recorded the size of 62 sparrow territories by marking observations of banded sparrows on field maps. They reported an average size of 1.4 ha, ranging from 0.3 ha to 6.8 ha. Curnutt and Pimm (1994) reported an average territory size of 2.43 ha, ranging from < 1 to 38 ha. The methods of territory delineation vary among these estimates making it difficult to make direct comparisons. However, territory size estimates are consistently smaller than the average non-breeding season home range.

Overall, results suggest that adult Cape Sable seaside sparrows are relatively sedentary during the non-breeding season. Distances between consecutive locations averaged 158.2 m ($\text{SE} = 5.2$, $n =$

1694) for all sparrows. The average rate of travel for the radio-marked sparrows (distances between consecutive locations/time between consecutive locations) was 6.4 m/hr, again suggesting that sparrows will generally not be far from their previous locations at the next check. Since these data only represent our sample of radio-marked individuals, at this time we can only assume that our results are representative of other Cape Sable seaside sparrows. However, because there is no other way to obtain these movement data, we believe that this is a reasonable assumption.

The great majority of each individual's movements were within the home range. However, we recorded many instances of relatively long movements of individuals away from their home ranges, and individuals exhibited some variation in the rate and scope of these longer movements.

The distribution of distances between movements is strongly leptokurtic, with the mode distance between locations within the 100-150 m category (Fig. 10). The distance traveled between consecutive locations by different individuals was generally consistent (Figure 11), indicating that the movements of most individual sparrows closely followed the overall movement distribution. The upper 10th percentile of the movements distribution includes all movements over 285 m, and the upper 5th percentile of movements includes those over 370 m. Of the 17 sparrows for which we recorded over 20 locations, all but two made movements > 370m, again suggesting that the scope of individuals' movements did not differ markedly. The maximum distance between consecutive locations for each individual was generally between 300 and 1000 m (Fig. 12).

Most sparrows returned to their previous home ranges after long-range movements outside of their established home ranges. However, three individuals (793, 581, and 544) moved long distances and subsequently failed to return to previous home ranges. The first two sparrows made a series of movements in a consistent direction over several consecutive days, then eventually established new home ranges far from their original home ranges and outside the study sites (Figure 13). Sparrow 544 moved outside of its original home range in HR but then established a new home range within the HR study area (Fig. 8).

Sparrow 793 was captured late in the season in the EI study area, after the completion of molt and after reproductive characteristics had disappeared on known adults. Consequently, we were unable to determine its age or sex, but we suspect that this sparrow was a juvenile due to an apparent incomplete molt. On 18 October, sparrow 793 began moving southeast from its normal home range. By 22 October, this sparrow was outside of the EI study area, continuing southeast. 793 moved long distances daily (700 – approx. 3000 m) from 18 October until 28 October. On 28 October, it remained near its location from the previous day and appeared to establish another home range, approximately 6 km south-southeast of its original home range at EI, in the area we refer to as Far South. 793 stayed in this area until 2 December, when we lost contact with its transmitter. We conducted one transmitter replacement while this sparrow was in the Far South area, and at that time, the sparrow seemed to be in good condition. Interestingly, the area in Far South where 793 settled contained other Cape Sable seaside sparrows. We incidentally captured and banded three other sparrows while pursuing 793 for transmitter replacement. We were never able to find sparrow 793 subsequent to 2 December and do not know whether it remained there.

The second sparrow that moved away from an established home range, 581, was also captured late in the season at our EI plot, and we were also uncertain of its age or sex. On 9 December, we lost contact with 581. That same day, we searched for it from the air and found it approximately 1.5 km northeast of its original home range. However, the next day we could not locate 581 on the ground. We searched for this sparrow again from the air on 16 December and found it approximately 7 km northeast of its original home range, due east of the Daniel Beard Research Center. Again, we observed other Cape Sable seaside sparrows near where it appeared to settle.

Sparrow 544, an unknown-age female, made a relatively long-range movement but remained within the HR study site. On 10 January, this sparrow moved from the southwest corner of HR, where it had established a home range, to the northwest corner of this site. This sparrow's new home range

was separated from its previous home range by approximately 450 m. It never returned to its previous home range before we removed its transmitter in late February.

These telemetry data, as well as non-breeding season observations that we made of sparrows initially banded during the breeding season suggest that movements in excess of 5 km may not be uncommon at a population level. So far, all movements that we recorded were within tracts of contiguous prairie. Both 793 and 581 moved until they nearly reached the end of the prairie vegetation. 793 stopped traveling approximately 0.75 km north of the mangrove belt at the southern edge of the muhly prairies. Water depths appeared to increase dramatically just south of Far South. 581 moved northward from the prairies along Old Ingraham Highway and traveled until it reached a pine-dominated forest at Long Pine Key. Its northernmost location was within 200m of the pine trees, and this bird could not have continued northward without traveling into the forest. It did make several short movements back to the south, away from the forest and settled nearly 800 m from the forest edge. The longest movement made by an individual sparrow between consecutive locations was made by sparrow 581 between 10 December and 16 December, with a period of 8 days in between when we were unable to locate it.

Band Resightings -- Incidental to our other activities, we also observed or recaptured several banded sparrows without transmitters. We were able to determine the complete color band combinations of sparrows on 24 occasions. However, many of these observations were of the same sparrows, and these resightings represent only 11 individuals. We recaptured three different banded individuals on a total of five occasions. Five of the banded sparrows that we observed were originally banded during the non-breeding season, and all were observed within the same plot where they were originally banded. Our observations of sparrows originally banded during the breeding season represent the only information available to date on movements of adult sparrows between the seasons.

The largest movement that we recorded through resightings was for a sparrow banded as an adult female on the Alligator Hammock plot along Main Park Road, approximately 1 km south of the

turnoff to Mahogany Hammock. On 8 September 1997, we observed this sparrow at our EI site, which represents a movement of over 4 km. If this individual survived through the non-breeding season but did not return to breed on the Alligator Hammock plot in 1998, it this would constitute a breeding dispersal. Other recaptures and resightings include observations of a sparrow within 500 m of its breeding territory and observations of a sparrow banded as a nestling within 1 km of its banding location.

Recaptures and resightings provide interesting information, but the difficulty of resighting banded birds multiple times over long periods makes it an impractical technique to document the relatively rare event of movements outside of regularly visited areas.

Water Levels

One of the most dramatic events in the prairies is the seasonal change in water levels. When summer rains begin, this environment is transformed from a grassland into a marsh, and this transformation likely plays a large role in the occurrence and distribution of organisms in the prairies. Throughout the study period, we recorded considerable changes in water depths at the reference posts at both study sites and considerable variation in depths at posts both within and between sites. The non-breeding season of 1997-1998 was wetter than normal (O. L. Bass, pers. comm.), particularly late in the season, before the initiation of breeding. One of our sites (EI) was still nearly completely inundated at the end of February.

Water depths at EI were consistently deeper than at the HR site throughout the season (Fig. 14), indicating a longer hydroperiod. On average, the water depth at the reference site at EI was 13.5 (SE = 0.16) cm deeper than at the HR site. The lowest water levels recorded at both sites occurred on 29 November, after a long, steady decline. The highest level recorded at HR occurred on 6 September, while EI's highest level was recorded on 5 December. Both sites showed minor peaks in water levels around 6 September, 20 September, 2 October, 5 December, and 4 January (Fig. 14).

Water levels fluctuated dramatically but relatively consistently between the study sites. However, the rate of change in water depth was slightly different between the two sites. Local effects of differences in rainfall seemed to affect water levels differently at the two sites. In addition, during drying periods, water levels at the HR site appeared to decline at a faster rate than they did at EI. The largest difference in rate of change between the sites was a measured increase of 3.9 cm in approximately 24 hours from 17-18 September at the EI site. During this same period, water levels at HR remained the same.

Development of the pseudotopography produced interesting results, the most dramatic of which was the degree of variation in the hydrologic conditions within the study areas. While these areas may appear relatively flat and level, they are not at all. Elevation at HR varied less than at EI but still varied by up to 20 cm (Fig. 15). At EI, the ground elevation varied by as much as 30 cm (Fig. 16). The consequences of this are that even during very wet periods, portions of the prairies may be only shallowly inundated. Though we did not observe apparent differential use by sparrows of wet or dry sites at this fine scale, we will continue to investigate such relationships. Variation in the depth of inundation may be more important to the sparrows when establishing home ranges than either the wetness or the dryness. The variation we observed may also become more important when considering whether prairies are dry enough for sparrows to initiate breeding, especially during wet periods.

At the wetter site, EI, we observed sparrows engaging in territorial behavior, including singing, as early as late January. According to Nott et al. (1998), sparrows do not initiate breeding activity or territoriality when water depths exceed 10 cm. The fine-scale variation in depth of inundation on our sites, and some small areas of higher elevation may have allowed sparrows to initiate territorial activities despite the fact that average water depths were in the range of 15-20 cm at the end of our study period in late February. The variation in local conditions may have also allowed sparrows to successfully fledge young as late as August at the HR site in 1997, when much of the area

was deeply inundated. Average water levels in excess of 10 cm at a site may not preclude nesting because some micro-sites may be considerably drier. Without knowledge of the scale of selection for nesting sites, it may be difficult to evaluate the likelihood of nesting when considering only coarse-scale data and ignoring the variation across the areas.

Determining habitat associations of sparrows

Landscape level habitat associations – In accordance with other studies, we affirmed that sparrows seem to be primarily dependent on the open expanses of muhly- and sawgrass-dominated habitats where they currently reside. Even within this relatively narrow definition of habitat, however, there are several other landscape features that are worthy of mention.

In addition to a mosaic of muhly- and sawgrass-dominated prairie patches, there are cypress domes, individual trees, tree islands of a variety of sizes, and tree-lines such as those along Ingraham Highway, or those that demarcate the pinelands and the prairies. Several areas with historical agricultural development are also evident on the plots and surrounding areas. We documented several trends in sparrow movements with respect to these landscape features.

We regularly observed sparrows within small tree islands, especially in the fall during the period when sparrows were molting. Sparrows did not seem to avoid areas containing few isolated trees or bushes, and occasionally perched in them. However, sparrows generally did not perch high in trees or bushes and rarely used or perched in very large tree islands, though they occasionally approached them and used dense sawgrass stands around the edges of the large tree islands. Sparrows rarely approached the linear forest features. Old Ingraham Highway delineates the southern edge of our HR plot, which is overgrown with woody vegetation. In the course of monitoring, we rarely recorded a sparrow within approximately 100 m of the road, despite the absence of any other apparent differences in the habitat nearer the road. We observed a similar response when sparrow 581 approached the pine forests of Long Pine Key.

Evaluation of sparrows' use of old agricultural land is complicated by the fact that it is difficult to delineate these areas on the ground. However, significant portions of the HR site had been farmed at some point, and remaining plowed rows are clearly visible from the air. The vegetation composition in these areas does not appear to differ strongly from the vegetation of the unfarmed prairies however. In general, old agricultural areas seem to be more homogeneous with respect to vegetation height and structural composition, but some of these areas still contain solution holes with sawgrass clumps.

In contrast to these areas are the old-grove agricultural areas. Here, dense clumps of sawgrass and small trees or shrubs occur at points evenly spaced throughout the area where trees probably had been planted. The areas between these clumps still appeared to be muhly-dominated, and the trees and shrubs are small and low. Sparrows apparently do not use these areas. The eastern edge of the HR plot follows the edge of one of these old groves, and sparrows have not gone farther than a few meters into these areas. They apparently did not avoid the edges of such features, however, and regularly perched in vegetation on the edges of these old groves.

Selection of micro-habitat characteristics -- We measured vegetation at 906 random points and 1469 sparrow locations within the two study sites. The majority of vegetation measurements were made at the HR site, where we had more sparrow locations and random points. These data indicate that the vegetation of the muhly prairies is composed primarily of four major components: muhly, sawgrass, "rushes," and graminoid litter. Shrubs and trees, including wax myrtle (*Myrica cerifera*), a variety of subtropical woody species, a variety of forbs, and emergent aquatic vegetation (primarily duck potato - *Sagittaria falcata*) represented minor components of the vegetation. The percent coverage of these 4 components varied greatly among both sparrow and random points, but there were some remarkable trends. The cover of live (green) muhly stems was less than 50% in more than 99% of all points, and live sawgrass cover was less than 50% in more than 96% of all points. Cover of graminoid litter generally ranged from 5 - 75%, and rush cover rarely exceeded 25%. Bare ground

cover generally ranged from 5 - 75%. There were significant differences in the occurrences of various vegetation cover classes between the two sites (Chi-square goodness of fit, Bonferroni-adjusted $\alpha = 0.01$), though the differences were not large (Table 3).

We constructed logistic regression models for HR and EI separately and also constructed a single overall model that included all points for both study sites (Table 4). Habitat measurements from all points were used to build the models. In all cases, addition of habitat and vegetation variables improved the models' ability to discriminate between sparrow and random locations compared to a constant-only model, suggesting that sparrows do select habitats during the non-breeding season with respect to the characteristics that we measured. In each of the three reduced models, we eliminated 7-9 of the 15 variables from the saturated model without a significant loss of discrimination (likelihood ratio test, df = difference in number of variables) (Table 4).

Overall, the discrimination produced by all three models was only marginal. The final models were only able to distinguish between sparrow and random points 66-70% of the time (Table 4). In addition, some of the results were difficult to interpret because of confounding relationships between sparrow locations and individual variables in the different models. While many of the same variables were important within each of the 3 models, there was a confounding result of the direction of association of some variables with sparrow locations. For example, at the HR site, increasing muhly cover was positively associated with sparrow locations, while at EI, increasing muhly cover was negatively associated with sparrow locations.

There are other considerations when interpreting logistic regression results. One potential limitation of this methodology is the assumption that each sparrow location represents an independent habitat selection event. This assumption may be violated in our analyses because sparrows did maintain home ranges and consequently did not utilize all potential habitat within the study areas. Using numerous points for the same individual within its home range may lead to biased results due to pseudoreplication. In future analyses, selectivity of habitat characteristics may be evaluated at the

home range scale by comparing characteristics at 'used' (sparrow locations) and 'available' (random points) locations for each individual within its home range (Manly et al 1993). We did not conduct these analyses during this study but may do so in the future. The fact that sparrow home ranges covered nearly the entire study area likely minimizes potential difficulties due to pseudoreplication.

A second major consideration involves the nature of logistic regression models and the design of our habitat sampling. Logistic regression assumes that each observation (each habitat measurement point) can be positively classified as a sparrow or random location. The difficulty arises from the use vs. availability design, in which the random points may also be sparrow locations. Additionally, we were not monitoring all individuals at a site and consequently did not include selections by all possible individuals. Overall, the effects from these would reduce the discriminatory power of the models. In light of this, discrimination of 66-70% may be a favorable outcome, because a portion of the random points that were misclassified by the model may in fact have been selected sparrow locations. While these limitations make it difficult to evaluate effectiveness of the models, they should not affect the associations between the variables that are expressed in the models.

Difficulties with discrimination and model interpretation suggest that we could not definitively identify inherent features of a site that were being selected by sparrows with respect to the features we measured and the time period in which we measured them. Assuming that this result is not due to the considerations noted above, or to an overall absence of selection by the sparrows, this result could occur under several different scenarios. First, sparrows may be selecting sites based on characteristics at a scale different from the scale at which we measured. Second, the suitability of any particular micro-site may change over time due to changing environmental conditions or temporal variations in sparrow selection criteria.

We are unable to test the first scenario because we only measured habitat characteristics at the scale of the micro-sites. A GIS-based habitat selection model may allow testing for selection at a variety of spatial scales, but it requires classified habitat data at a fine scale, which are currently not

available. We investigated the second scenario by comparing the sparrows' use of various habitat parameters under different environmental conditions.

Habitat and water levels. – Hydrological condition of the prairies is one of the most variable environmental characteristics, as well as one of the more readily measured ones. We tested for changes in sparrows' use of habitat characteristics that we measured under different water depths over time within each site using Kruskal-Wallis non-parametric ANOVA and multiple comparison tests. Results suggest that relationships exist between micro-habitats selected by sparrows and the depth of inundation at these sites (Table 5).

Muhly cover was the highest at sparrow locations when water levels were low (Fig. 17). Sparrows' use of muhly cover differed between the study sites as well. Average water depth decreased asymptotically with use of higher muhly cover. Sawgrass cover showed an opposite trend, with an asymptotic increase in sparrows' use of sawgrass cover as average water depth increased (Fig. 18). The sparrows' use of litter in response to changes in water levels was difficult to interpret. Sparrows tended to be associated with higher litter cover when water was deeper, while sparrows' use of micro-habitats containing low litter cover was associated with shallower water (Fig. 19). Sparrows tended to use micro-habitats with low rush cover when water levels were high, while use of sites containing more rush cover increased with lower average water depths (Fig. 20). Use of rush cover also differed between the two study sites. Use of open cover decreased as water depth increased (Fig. 21). Sparrows' associations with sawgrass clumps, maximum vegetation height, and effective vegetation height were all positively associated with increasing water depth based on regression analyses (Figs. 22, 23).

These results help explain the confounding results for sparrow micro-habitat selection obtained with the logistic regression models. Because selection of vegetation cover and type apparently changes relative to water depth, it is unlikely that logistic regression models would successfully distinguish between sparrow and random locations when the period of selection

encompassed both wet and dry periods. Classification of each sparrow location as occurring during a wet or dry period may improve the model's capabilities of distinguishing between sparrow and random locations.

These results may also explain the apparent difference in direction of association between sparrows and vegetation variables in the logistic regression models between our study sites. The EI site was substantially wetter than the HR site for the entire season, but both had similar levels of muhly cover. The negative association that the models produced between sparrow locations and muhly cover at EI may have been due to greater inundation at that site.

The univariate analyses of vegetation variables with water depth suggested the potential importance of vegetation structure as it relates to water levels. At sparrow locations, cover of muhly and rush, both relatively weak-stemmed and short-stature plants, were inversely related to water depth, while sawgrass cover and vegetation height variables were positively associated with water depth. During wet periods, sparrows are unable to walk on the ground or flit among the bases of grass clumps as they frequently do in areas of high muhly cover (T. Dean, pers. obs.). Sawgrass provides greater height and more complex structure at a level sufficiently above the water for the sparrows to use during periods of high water.

At this time, we conclude that there are some characteristics of any point within the study area that make it more or less likely to be used by a sparrow. However, the suitability of that point at any particular time may depend more on how wet the site is at that point in time. All these results suggest some importance of habitat structure as well as composition to the sparrows. Management objectives for this subspecies should consider not only the micro-habitat features but also the arrangement of these fine scale features, when considering the suitability of habitat for this relatively sedentary bird. Within the overall muhly prairie habitat, a sparrow's selection of a territory or home range may depend less on the presence of one particular habitat characteristic and more on a variety of habitat and

structural characteristics. Selection for variation in habitat structure may allow sparrows to have usable habitat under a wide variety of hydrologic and environmental conditions.

Survival Analyses

Known mortalities -- We documented 4 mortalities of radio-marked sparrows during the study. The first occurred within 48 hours after transmitter attachment, and the cause of death was not determined. We sent the specimen to Dr. Marilyn Spalding and Dr. Donald Forrester at the Department of Veterinary Medicine at the University of Florida, Gainesville for necropsy immediately after recovery. The necropsy failed to identify a cause of death but did document mild pulmonary edema. It is unclear what caused the pulmonary edema, but it was unlikely that it was related to the transmitter or harness (M. Spalding pers. comm.). The use of telemetry in this case may have allowed us to document a mortality related to handling that would have otherwise gone unnoticed. We did not document any other handling-related mortalities or injuries and can not confirm that this mortality was handling-related.

We documented three predations of radio-marked birds, and all appeared to have been taken by avian predators. We recovered the transmitter of one sparrow under an exposed branch of a small tree on 1 October 1997. We recovered few feathers but found some feathers stuck to the tree branch where we suspect the sparrow had been handled and eaten. The second predation was found on the ground within the sparrow's home range on 11 December. It had been plucked and mostly consumed. We recovered a portion of the leg of this sparrow, and a few feathers. The third predation event occurred in late February. We found the transmitter and a few feathers under a perch several hundred meters from this sparrow's home range, on the south side of Old Ingraham Highway, which was across the road from its normal range.

Kaplan-Meier survival estimates -- The overall survival estimate, from 26 July 1997 through 28 February 1998, calculated using a total of 19 sparrows, was 0.63. Though we were

unlikely to detect peaks in mortalities due to the small number of sparrows observed, mortalities seemed to occur throughout the season (Fig. 24). In determining this survival estimate, we used the 4 known mortalities and censored 5 individuals. Censures represent disappearances of 5 radio-marked sparrows, and we suspect that most or all were due to transmitter failure. Some of these disappearances may represent predation events in which transmitters were destroyed. However, we occasionally observed sparrows with non-functioning transmitters, so we think it unlikely that all disappearances were attributable to predation. Additionally, other studies that used these transmitters documented many radio failures (T. Dean, unpubl. data). It is often difficult to re-sight sparrows with failed transmitters after the end of the breeding season. We may incidentally encounter birds with transmitters but are only likely to do so if the birds do not move appreciably. Two of the disappearances were individuals that had moved considerable distances away from their original capture sites, and we were unlikely to encounter them.

We calculated worst-case and best-case survival estimates to demonstrate the range of possible variation that could occur under our observations. Under the worst-case scenario, we assumed that all disappearances (the 5 censored individuals) were actually mortality events in which transmitters were destroyed (e.g. during predation events). The resulting season-long survival estimate was 0.31. Under the best-case scenario, we assumed that the 5 censored individuals all survived to the end of the study and were merely not detected after transmitter failure. This scenario resulted in a season-long survival probability of 69%.

Few published estimates of annual survivorship for the Cape Sable seaside sparrow exist. These other estimates are not directly comparable to our estimates because methodologies and assumptions used in calculating survival probabilities differed and our estimates were calculated only using radio-marked birds. Also, our estimates were calculated only over a 7-month time period. S. Pimm's risk analysis model (Pimm 1997) estimated a 50% annual survival rate for this subspecies though it is not apparent how this number was determined. Werner and Woolfenden (1983) cited

12.5% and 7% annual losses of color-banded adults in Taylor Slough during 1974 and 1975. Kushlan et al. (1982) mentioned 90% adult survivorship and suggested that juvenile survivorship is likely 50-75%. Actual data on juvenile survivorship are non-existent. At this time, our survival estimates can only be interpreted as a possible range of survival probabilities that represents our sample of sparrows. This sample was composed primarily of adults, but some individuals marked late in the season may have been juveniles, and young birds are generally considered to have lower survival rates than adults (Ricklefs 1983). The widely disparate published estimates of survivorship that are currently available for this subspecies, including ours, should be viewed only as preliminary estimates at best. However, there do not appear to be indications that radio-marked sparrows suffered substantially higher mortality rates than unmarked or color-banded sparrows.

Relative abundance of sparrows in surveyed habitats

Overall, we detected 45 Cape Sable seaside sparrows during transect surveys and 17 sparrows on the point counts (Table 6). The two sites that were not known to be occupied by breeding sparrows did not appear to contain wintering sparrows. We detected sparrows on all breeding season and non-breeding season study plots with the exception of the Far South area. We do not know whether this site is occupied during the breeding season, but we have documented the presence of sparrows in the area during at least part of the non-breeding season, and we captured and banded three individuals there in December and January. We may have failed to detect sparrows at this site due to the reduced sampling effort compared to other sites (only 1 transect). Sparrow surveys did not yield evidence for changes in distribution or density between the breeding and non-breeding seasons at least on the 6 breeding season plots.

Comparisons of rope-dragging transects and point counts for detecting sparrows indicated that transects were both more efficient and more effective than point counts at detecting sparrows. A single transect required two observers and had a mean duration of 18 minutes, and a set of three point

counts (producing coverage similar to a transect) required only one person and lasted 38 minutes. Our analysis shows that sparrows are more likely to be detected using transects than point counts (McNemar's analysis of discordant pairs, $P < 0.05$). However, through the three survey repetitions, we failed to detect sparrows using point counts at only one site where we had found them using transect surveys. Transect surveys resulted in the detection of nearly three times as many sparrows as did point counts.

In addition to Cape Sable seaside sparrows, we documented the use of the prairies by many other birds, and in all, we counted 674 individual birds of 22 species (Table 7). In addition to Cape Sable seaside sparrows, the most abundant species we encountered included (in order of abundance): Palm Warbler, Common Yellowthroat, Sedge Wren, American Bittern, Red-winged Blackbird, and Eastern Meadowlark (see Table 7 for scientific names). Seaside sparrows were the fourth most abundant species using the prairie habitats from November through January.

Chronology and Other Observations

As other authors have reported, there are several distinct cyclical behavioral and environmental patterns and influences which we attempt to describe below. Figure 25 provides a graphical representation of these cyclical events for 1997-1998.

Late breeding -- We initiated our research almost two months after the first rains inundated the prairies in 1997. Consequently, we expected that the breeding season would have effectively ended before we arrived. However, our observations suggest that the sparrows' breeding season (potential and actual) may be longer than previously believed. During the first few weeks of our study in July, we regularly observed males singing and defending territories at the HR site. In addition, the sparrows that we captured during July and early August still appeared to be reproductively capable, with females having well-developed brood patches and males having substantial cloacal protuberances. On 9 August, we captured a young sparrow that had recently left the nest and was still

unable to fly. We suspect that this sparrow had fledged only 1-2 days prior to capture. On 19 September, we captured another sparrow that appeared to be quite young and still had a fleshy flange around its gape, suggesting that it too had recently fledged. It had not yet initiated molt at a time when all other sparrows we captured had replaced approximately half of their flight feathers and most contour feathers. While high water levels may preclude nesting in some areas, sparrows apparently do have the ability and do make attempts to nest quite late into the season.

Molt -- In seaside sparrows, the prebasic molt takes place just after the breeding season (Pyle et al. 1993), and the initiation of molt is probably a good indication of the end of the breeding season, though some degree of overlap may occur. The high energetic demands of molt likely make it difficult for adult sparrows to both replace feathers and raise young simultaneously. As mentioned earlier, we observed the initiation of molt in adult sparrows when we began this research in late July, and our data on captured individuals indicate that molt was essentially completed by the end of October. We also observed that while molting, early in the non-breeding season, sparrows were relatively gregarious and vocal. From the end of October through January and February, radio-marked sparrows remained relatively secretive but stayed within their home ranges. The radio-marked sparrows did not appear to change their movements or habitat use patterns in October, despite their secretive behavior. We occasionally observed several sparrows in close proximity to each other, but they were generally less vocal and perched lower in the vegetation than during molt.

Behavioral change -- Prior to our research, Balent et al. (1997) noted that sparrows were readily observable early in the non-breeding season and then became increasingly difficult to locate and observe beginning in October. We also recorded a change in the frequency of observations of unmarked sparrows (Fig. 26). This apparent "disappearance" of sparrows beginning in October and continuing through December has been attributed to ongoing molt in the sparrows (S. L. Pimm, pers. comm.). As noted above, however, our observations of molt timing are not consistent with this hypothesis. In addition, we failed to detect a change in movement patterns between times when

sparrows were readily observable and when they were secretive, indicating that the apparent change is only a change in behavior. We suspect that the increased detectability is a function of sparrows' frequency of vocalizations, which is the primary means of locating these small, secretive birds.

During the non-breeding season as a whole, Cape Sable seaside sparrows were generally solitary, but we recorded numerous instances where small aggregates of sparrows (2-3 individuals) were observed apparently occupying the same site. As well as being in close proximity to each other when located, these individuals frequently flew in the same direction when flushed, alighted within a few meters of one another and vocalized frequently. These small aggregates usually included several juveniles and 1-3 adult sparrows. Both male and female adults were observed within these small flocks. The frequency of these social interactions followed a trend similar to that observed for incidental sparrow detections (Fig. 26). Observations of aggregates began to decline in October, and thereafter, few social observations were made until early spring. Balent et al. (1997) also observed flocks of juveniles with one or more adults and suggested that these flocks consisted of family groups. Our observations of marked individuals do not support this hypothesis. Our observations suggest that membership in these small flocks changes over time, despite the fact that group sizes are generally similar over time. Werner and Woolfenden (1983) also reported changing membership in flocks of juveniles and adults in the fall.

We also noted that sparrow flocks frequently occupied thick shrubs, small tree islands and tall, dense sawgrass stands as did Balent et al (1997) and Werner and Woolfenden (1983). Solitary sparrows were less frequently associated with these features, and the use of these features seemed to decline after October when sparrows became less social.

We hypothesize that a likely explanation for observed changes in detection rates, social interactions, and use of dense cover by sparrows in the fall may be a means of predator avoidance. During the course of our project, three sparrows were predated, and all were apparently taken by avian predators. The period when sparrows are most social and vocal after the end of the breeding season

also roughly coincides with the fall migration of raptors, and we regularly observed red-shouldered hawks (*Buteo lineatus*), American kestrels (*Falco sparverius*), Peregrine falcons (*Falco peregrinus*), northern harriers (*Circus cyaneus*), and Accipiter hawks (*Accipiter* spp.) at our study sites during migration. During the breeding season, red-shouldered hawks are the only raptors that occurred on the study sites with any regularity, and swallow-tailed kites (*Elanoides forficatus*) were seen only occasionally. Increased vocalizations and some degree of flocking may be a means of avoiding or improving the detection of potential predators. In addition, the fact that sparrows are molting and may consequently be less able to flee from predators, may increase their tendency to employ other avoidance mechanisms such as flocking. We recorded a marked decrease in the frequency of observations of many avian predators in early November. From mid-November through January, we observed several predatory bird species over the prairies fairly regularly but less frequently than during migration. During this period, sparrows were generally secretive and solitary. This is only a working hypothesis, and should be considered tentative pending collection of additional data.

Early breeding season – We observed the first signs of territorial behavior in mid-January when we first heard males singing in our study areas. However, sparrows did not sing consistently until early to mid-February and at that time, we also observed the first song flights. From that point on, we regularly observed males singing, including many of our radio-marked sparrows. However, when we recaptured radio-marked sparrows for the last time at the end of February to remove transmitters, we still saw little evidence of reproductive capability. We did not observe brood patches on females, and males' cloacal protuberances were only mildly developed. Water levels were still relatively high during this period so they may have had some effect on the sparrows' breeding.

CONCLUSIONS

- 1) We captured and radio-marked 21 Cape Sable seaside sparrows and successfully recaptured most individuals several times to replace radio transmitters for long-term data collection.

- 2) Monitoring of several physiological condition indicators and breeding behaviors provided no evidence of detrimental effects of transmitters or the transmitter attachment technique on the sparrows.
- 3) Adult sparrows are relatively sedentary during the non-breeding season. Individuals maintained loosely defined home ranges. Some moved considerable distances but stayed overall within the study areas. Patterns of home range and movements of individuals did not differ substantially between genders or between the two study sites.
- 4) Sparrows apparently did not leave the prairies at any time during the non-breeding season.
- 5) Some sparrows did make relatively long distance movements (1-7 km) suggesting this capability at the population level. However, sparrows did not move beyond the extent of the prairie habitat.
- 6) Considerable variation existed between the study sites in terms of vegetation characteristics and water levels. Regular measurement of water levels indicated dramatically different hydrology at micro-sites both within and between study areas. Fine-scale variation in hydroperiod across our sites may allow some sparrows to breed late in the breeding season despite high average water levels.
- 7) Sparrows used different vegetation types in different proportions under different hydrologic conditions. They tended to use areas with higher sawgrass cover under wetter conditions and with higher muhly cover under dryer conditions.
- 8) Logistic regression modeling indicated selection by sparrows for some of the micro-habitat characteristics that we measured but the direction of selectivity toward certain variables was not consistent.
- 9) Sparrows appeared to be entirely dependent on the open prairie habitats. They apparently do not avoid woody vegetation but did appear to avoid large tree islands and treelines. Sparrows tended not to perch high in woody vegetation.

- 10) Survival estimates for our 7-month study period obtained for 21 radio-marked individuals was 0.63. We documented 4 mortalities of sparrows during our study. Three were due to predation, we suspected by aerial predators, and one was an unexplained mortality that may have been related to handling.
- 11) Surveys of potential sparrow habitats from November through January did not provide evidence of notable changes in either distribution or relative abundance of sparrows from the breeding season. Rope-dragging transects are more effective than point counts at detecting sparrows and resulted in the detection of three times as many sparrows as did point counts.
- 12) We documented marked behavioral change by sparrows in late October. From August through October, sparrows are relatively vocal and gregarious, improving their detectability. From November through January, sparrows are more solitary and secretive. We suggest that gregariousness in the early fall may be a predator avoidance mechanism to reduce predation while sparrows are molting and raptors are migrating through the area.
- 13) We observed territorial behaviors as early as mid-January, despite the fact that both study sites were still completely inundated. However, sparrows captured in the end of February lacked physiological evidence of reproductive activity.

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TABLE 1. Radio-marked sparrow summary. Shaded cells denote significant regression coefficient.

Bird ID	Site	Sex	Number of Locations	Flight distance regression coefficient	Transmitter attachment date	Final Status	End Date
742	HR	F	24	-0.426	07/26/97	Transmitter failure	08/14/97
545	HR	M	3	NA	07/26/97	Unknown death	07/27/97
893	HR	M	1	NA	07/27/97	Transmitter removed	07/27/97
494	HR	M	190	-0.092	07/27/97	Transmitter removed	02/27/98
442	HR	M	113	0.011	08/09/97	Predated	12/11/97
892	HR	M	174	-0.007	08/09/97	Transmitter removed	02/27/98
1092	HR	M	86	-0.069	08/10/97	Transmitter failure	11/10/97
843	HR	F	174	0.002	08/10/97	Transmitter removed	02/28/98
1042	HR	U	40	0.309	08/21/97	Predated	10/01/97
793	EI	U	61	-0.362	09/04/97	Transmitter failure	12/05/97
942	EI	U	154	-0.022	09/04/97	Transmitter removed	02/28/98
994	EI	F	154	-0.062	09/05/97	Transmitter removed	02/28/98
1143	EI	M	0	NA	09/05/97	Transmitter dropped	09/05/97
974	EI	M	137	-0.045	09/20/97	Transmitter removed	02/27/98
753	EI	U	29	-0.546	11/01/97	Transmitter failure	12/05/97
733	EI	F	96	0.058	11/01/97	Transmitter removed	02/28/98
544	HR	U	87	-0.008	11/11/97	Transmitter removed	02/27/98
1093	HR	M	2	NA	11/11/97	Transmitter dropped	11/13/97
581	EI	U	26	0.453	11/12/97	Transmitter failure	12/24/97
592	EI	M	85	0.060	11/12/97	Transmitter removed	02/27/98
1032	HR	U	76	0.098	11/20/97	Predated	02/22/98

TABLE 2. Home range characteristics of the 17 radio-marked sparrows for which we recorded ≥ 20 locations.

Bird ID	Site	Sex	Number of Locations	Home range size ¹
442	HR	U	113	9.36
494	HR	M	190	29.35
544	HR	F	87	18.13, 8.29
581	EI	U	26	8.26
592	EI	M	85	6.58
742	HR	F	24	10.90
733	EI	F	96	11.55
753	EI	U	29	6.60
793	EI	U	61	11.43
843	HR	F	174	13.74
892	HR	M	174	11.19
942	EI	F	154	17.81
974	EI	M	137	15.64
994	EI	F	154	18.40
1032	HR	U	76	10.05
1042	HR	U	40	13.53
1092	HR	U	86	13.61
			Average	13.02
			Standard Error	1.30

¹ Home ranges calculated using 90% adaptive kernel estimator

TABLE 3. Percent occurrence of vegetation cover classes within random points at HR and EI sites, Everglades National Park. P-values indicate significant differences in the percent occurrence of vegetation cover classes between the two sites (Chi-square goodness-of-fit test, Bonferroni-corrected $\alpha = 0.01$). Shaded cells denote the source of significant differences in occurrence within the vegetation cover type based on standardized residuals.

Cover Class (%)	Vegetation Cover Type and Site									
	Muhly		Sawgrass		Litter		Open		Rush	
	EI	HR	EI	HR	EI	HR	EI	HR	EI	HR
0	14.10	21.58	24.80	34.26	1.57	2.18	8.36	4.95	20.89	13.66
0-5	32.11	20.79	44.65	45.35	4.18	4.36	5.74	4.95	40.47	46.14
5-25	41.51	45.35	25.07	17.43	29.77	28.91	25.85	27.33	31.59	34.46
25-50	11.49	11.88	5.48	2.97	47.00	44.75	24.54	30.89	6.79	5.74
50-75	0.78	0.40	0	0	14.62	17.23	22.98	20.40	0.26	0.00
75-95	0	0	0	0	2.87	2.57	10.44	10.69	0	0
95-100	0	0	0	0	0	0	2.09	0.79	0	0
significance	P=0.000		P=0.000		P=0.492		P=0.003		P=0.000	

TABLE 4. Micro-habitat variables used in logistic regression analyses. Signs denote presence in model and direction and degree of association with sparrow locations. Empty cells signify that the variable was removed from the model and did not aid in distinguishing between sparrow and random locations.

Variable	Overall Model	HR Model	EI Model
Constant			
Effective vegetation height	+	+	+
Maximum vegetation height	+	+	
In sawgrass clump?	+++	+++	
Distance to nearest sawgrass clump	+		
Average site soil depth		+	-
Soil at center point			
SE of soil depths			+
Elevation index		-	
Elevation variance at site			
Elevation index at center point			
Muhly cover	++	+++	--
Sawgrass Cover			
Rush cover	--	--	+
Litter cover			
Percent open	++	-	++
Model Discrimination ¹	0.66	0.69	0.67

¹ Based on area under the ROC curve

TABLE 5. Sparrow use of vegetation cover types relative to water depth at the site: Kruskal-Wallis non-parametric analysis of variance results. Shaded cells denote significant tests using a Bonferroni-adjusted alpha level = 0.008.

Variable	Test statistic (Chi-square approximation)	Degrees of freedom	Site		Cover category	
			Chi-square	P-value	Chi-square	P-value
In clump?	Mann-Whitney U	1	4.326	0.038	489.790	0.000
Muhly	Kruskal-Wallis ANOVA	4	16.514	0.002	429.308	0.000
Sawgrass	Kruskal-Wallis ANOVA	4	6.430	0.169	269.596	0.000
Rush	Kruskal-Wallis ANOVA	4	23.981	0.000	390.346	0.000
Litter	Kruskal-Wallis ANOVA	5	9.822	0.080	101.930	0.000
Open	Kruskal-Wallis ANOVA	6	3.103	0.796	148.380	0.000

TABLE 6. Cape Sable seaside sparrows detected on surveys using rope-dragging transects and point counts at each site

Survey site	Rope-dragging transects			Point counts		
	November	December	January	November	December	January
Alligator Hammock	0	7	2	2	2	0
Dogleg	1	3	0	0	1	0
End-of-Ingraham	5	1	1	1	0	0
Far East	3	2	2	0	0	2
Far South	0	0	0	0	0	0
Half-Raccoon	4	0	1	1	0	1
Ingraham North	2	1	2	0	0	0
Ingraham South	1	2	4	0	0	1
Mahogany Hammock	0	0	0	0	0	0
North Mahogany	0	0	1	0	4	1
Taylor Slough	0	0	0	0	0	0
TOTAL	16	16	13	4	7	5

TABLE 7. Detections of bird species on transect and point count surveys in muhly prairies, Everglades National Park, November 1997 – January 1998

Species	Scientific name	Number on transects	Number on point counts	Total number
American Bittern	<i>Botaurus lentiginosus</i>	35	2	37
Boat-tailed Grackle	<i>Quiscalus major</i>	1	16	17
Seaside Sparrow	<i>Ammodramus maritimus</i>	45	17	62
Common Snipe	<i>Gallinago gallinago</i>	7	1	8
Common Yellowthroat	<i>Geothlypis trichas</i>	50	73	123
Eastern Meadowlark	<i>Sturnella magna</i>	7	12	19
Eastern Phoebe	<i>Sayornis phoebe</i>	0	2	2
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	3	0	3
Great Egret	<i>Casmerodius albus</i>	2	1	3
Great-blue Heron	<i>Ardea herodias</i>	1	2	3
King Rail	<i>Rallus elegans</i>	0	1	1
Least Bittern	<i>Ixobrychus exilis</i>	4	0	4
Palm Warbler	<i>Dendroica palmarum</i>	30	193	223
Red-shouldered Hawk	<i>Buteo lineatus</i>	0	4	4
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	4	53	57
Savannah Sparrow	<i>Passerculus sandwichensis</i>	2	1	3
Sedge Wren	<i>Cistothorus platensis</i>	39	41	80
Sora Rail	<i>Porzana carolina</i>	2	0	2
Swamp Sparrow	<i>Melospiza gerogiana</i>	2	1	3
Tri-colored Heron	<i>Egretta tricolor</i>	1	0	1
Tree Swallow	<i>Tachycineta bicolor</i>	0	10	10
White Ibis	<i>Eudocimus albus</i>	7	2	9
TOTAL		674	242	432

FIGURE 1. Study areas for the Cape Sable seaside sparrow non-breeding season telemetry project. Enlarged section is the southern tip of mainland peninsular Florida.

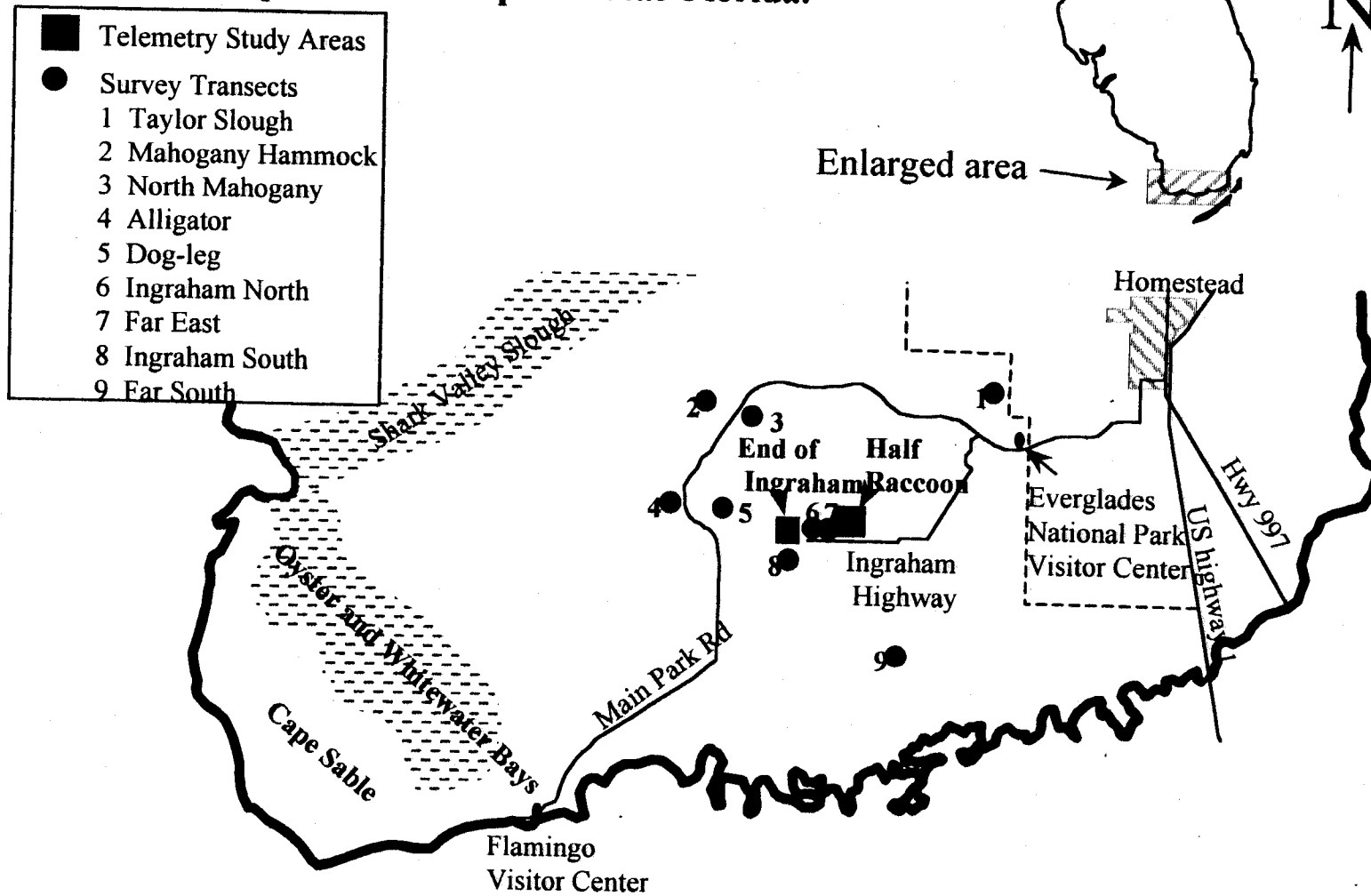


FIGURE 2. Weights of sparrows with and without transmitters

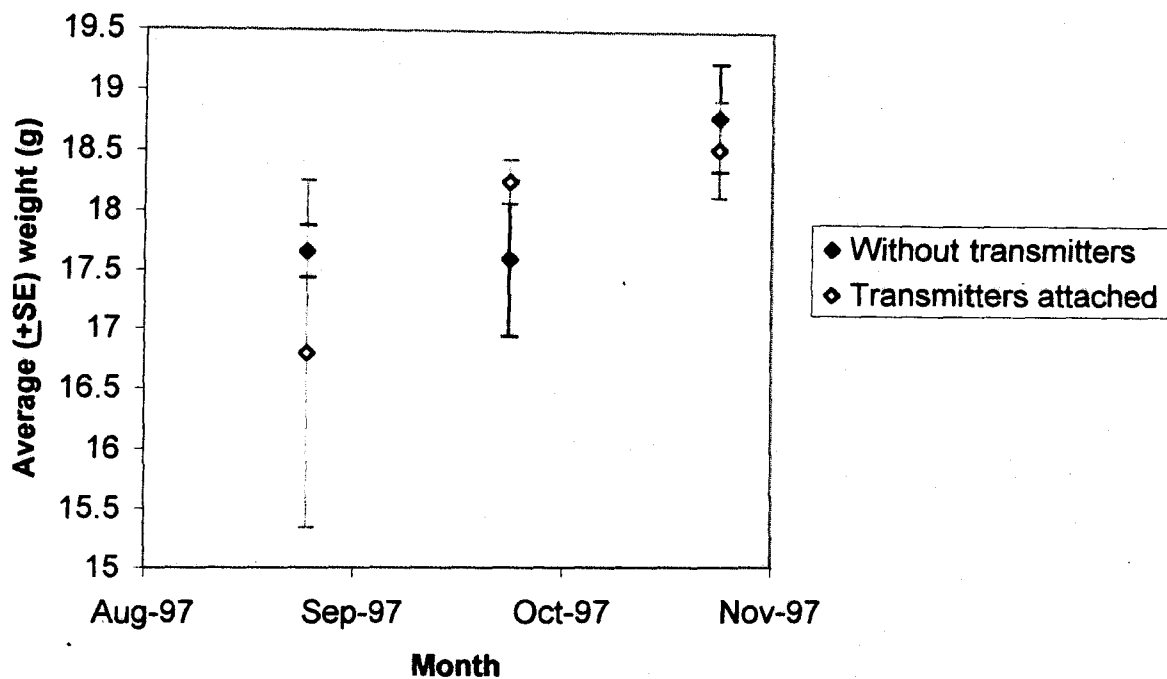


FIGURE 3. Fat scores of sparrows with and without transmitters

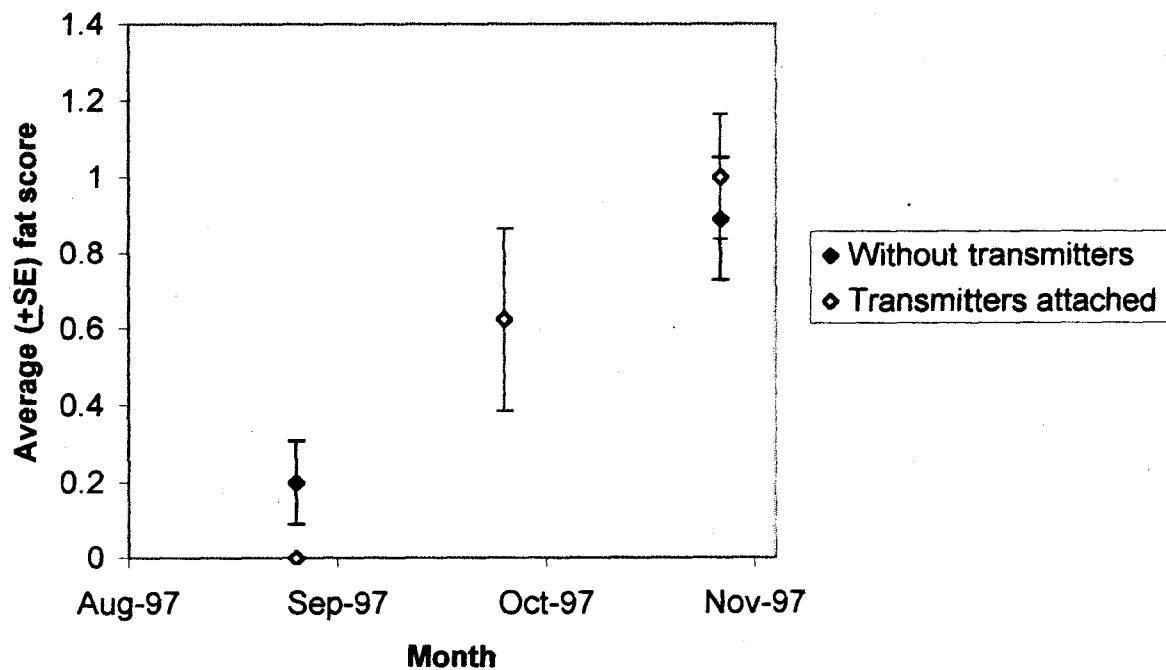


FIGURE 4. Change in weight and fat scores of radio-marked sparrows plotted against relative transmitter weight

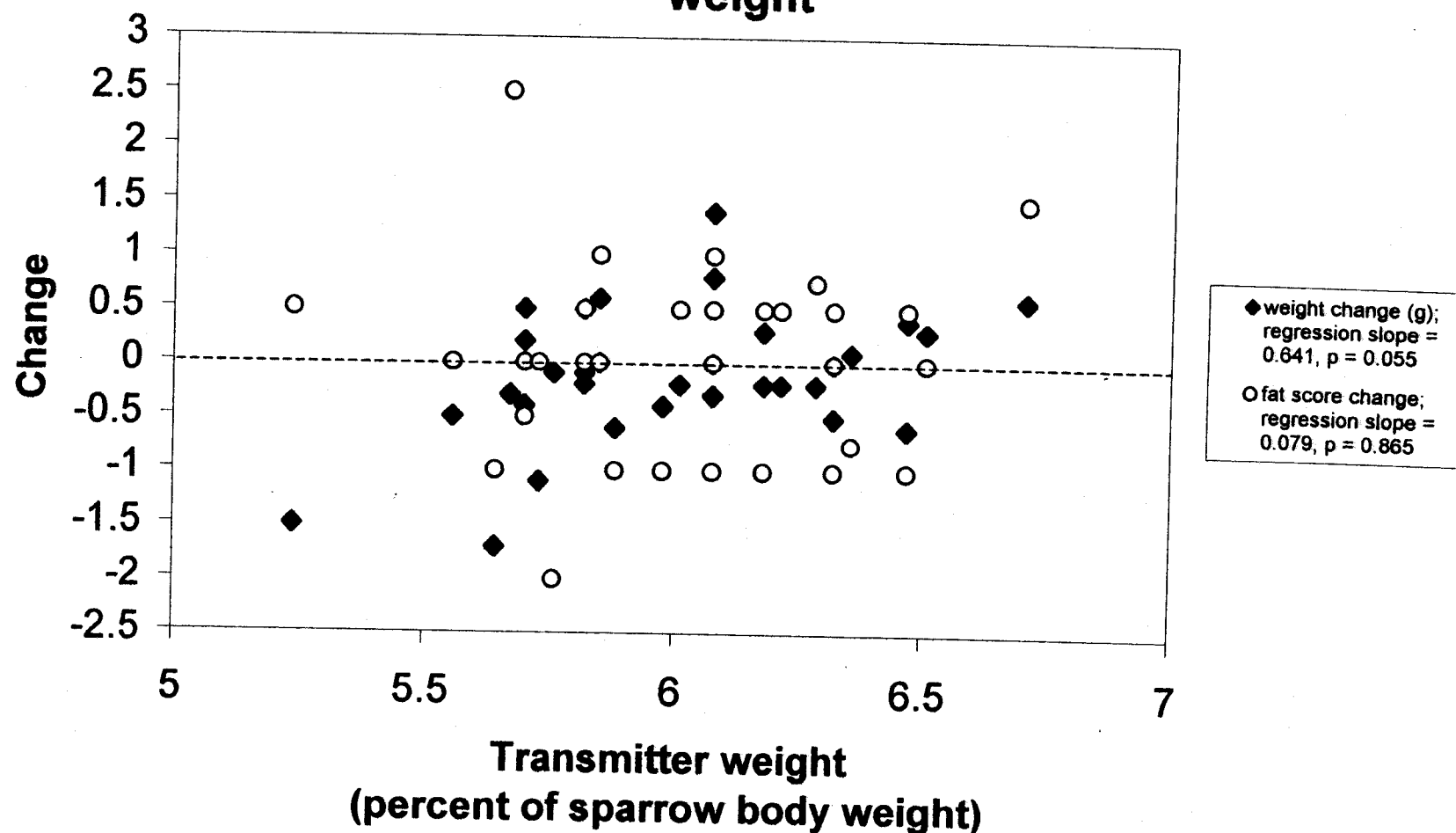


FIGURE 5. Mean ($\pm$ SE) weight of sparrows over time, 1997-1998

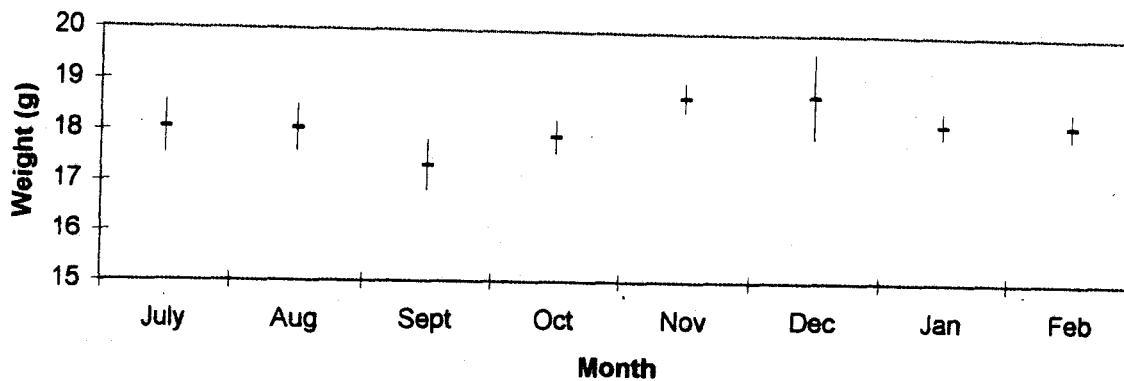


FIGURE 6. Mean ($\pm$ SE) fat score over time, 1997-1998

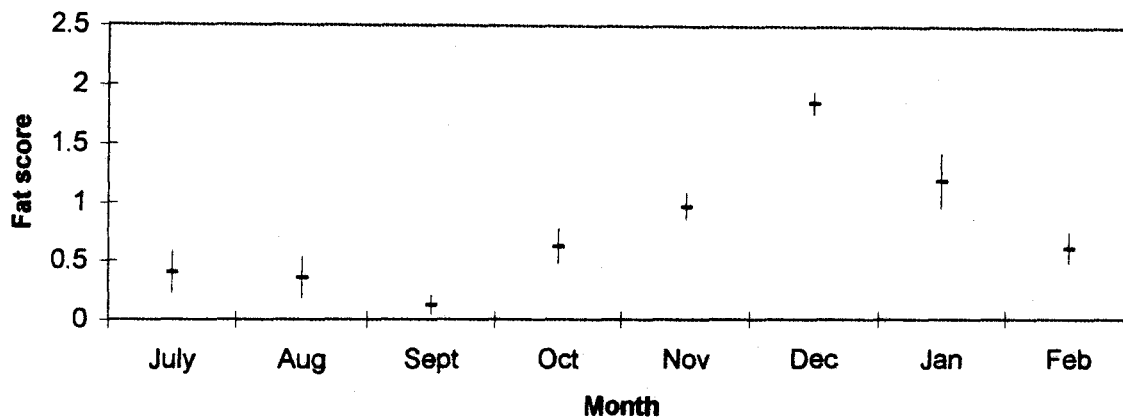


FIGURE 7. Mean ($\pm$ SE) number of molting (partial) flight feathers over time, 1997-1998

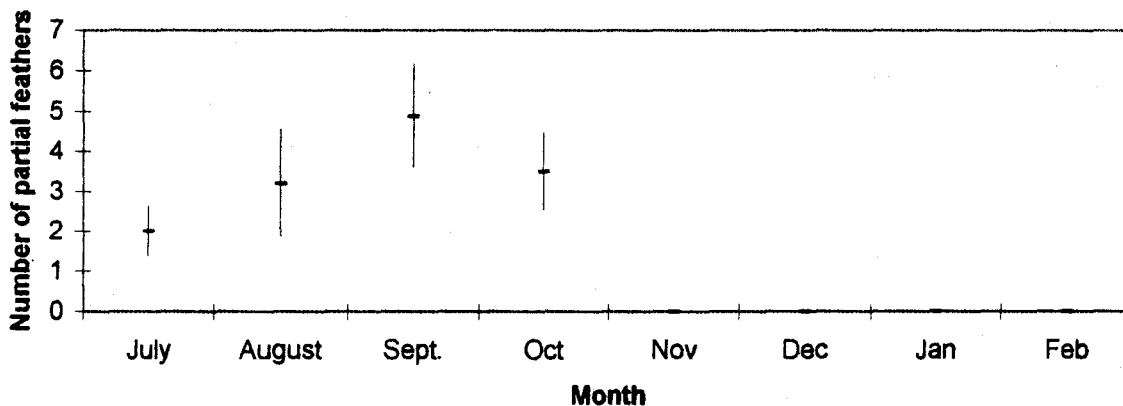


FIGURE 8. Sparrow home ranges at HR site, Everglades NP

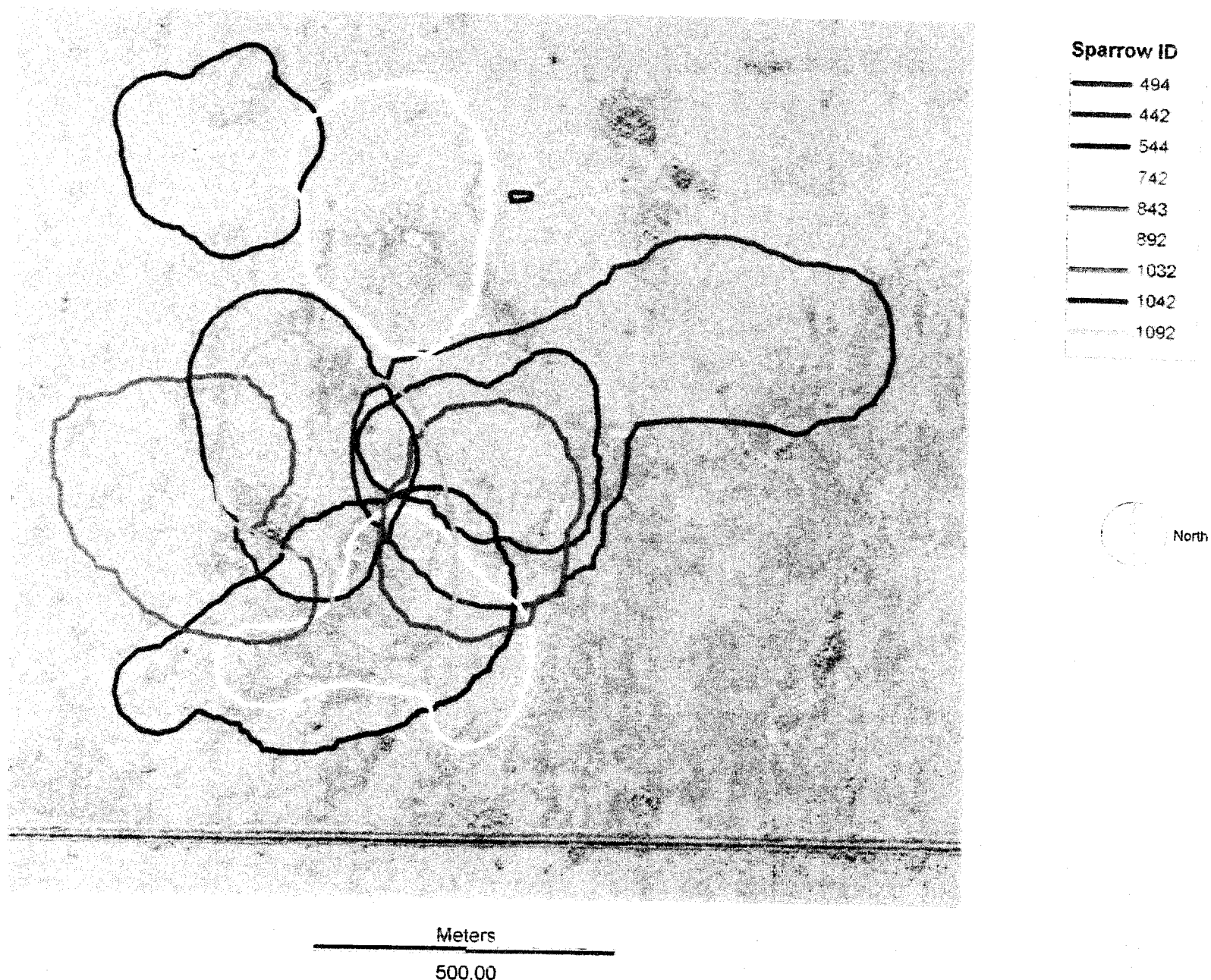


FIGURE 9. Sparrow home ranges at El site, Everglades NP

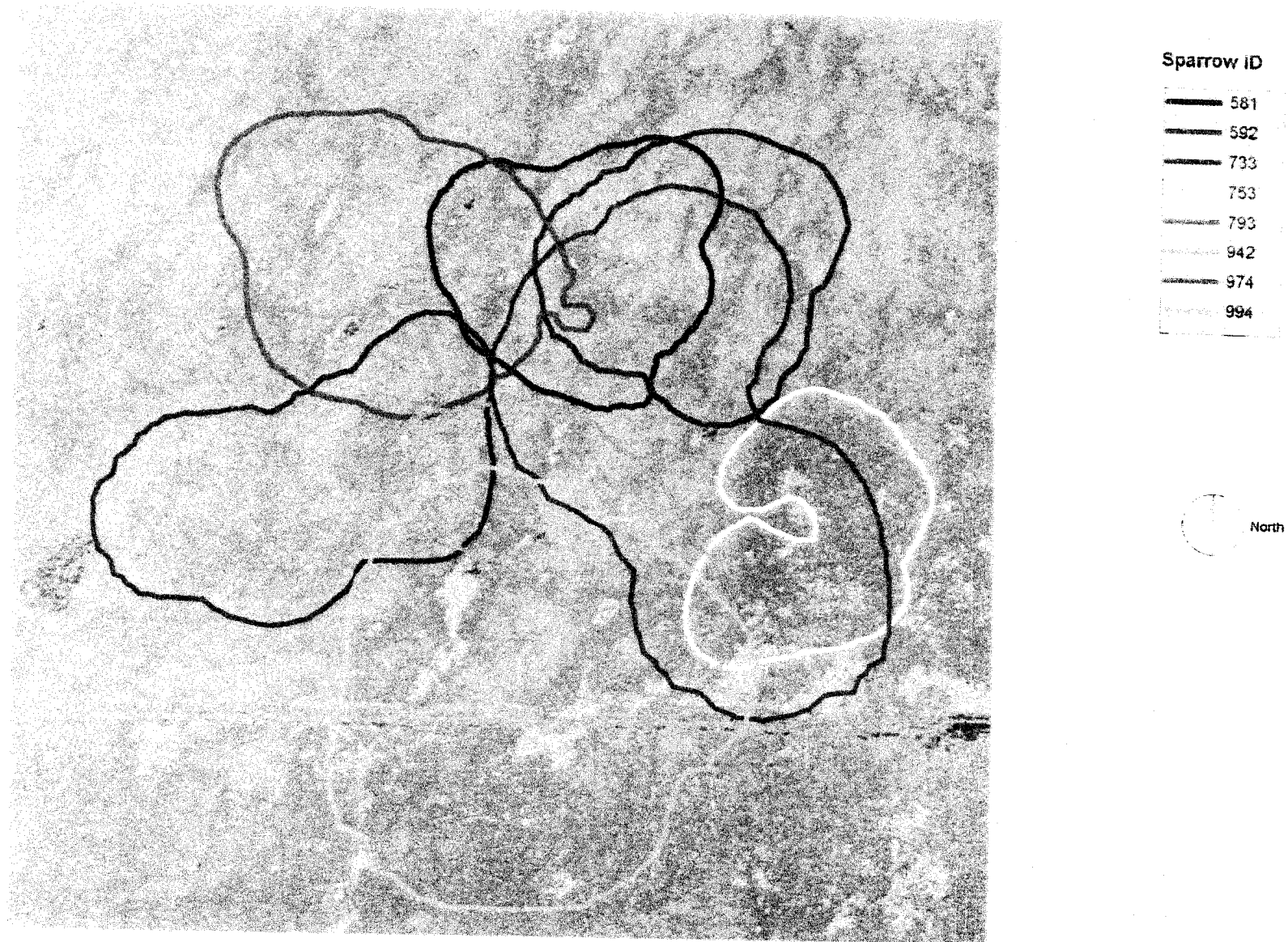


FIGURE 10. Distribution of distances between consecutive sparrow locations

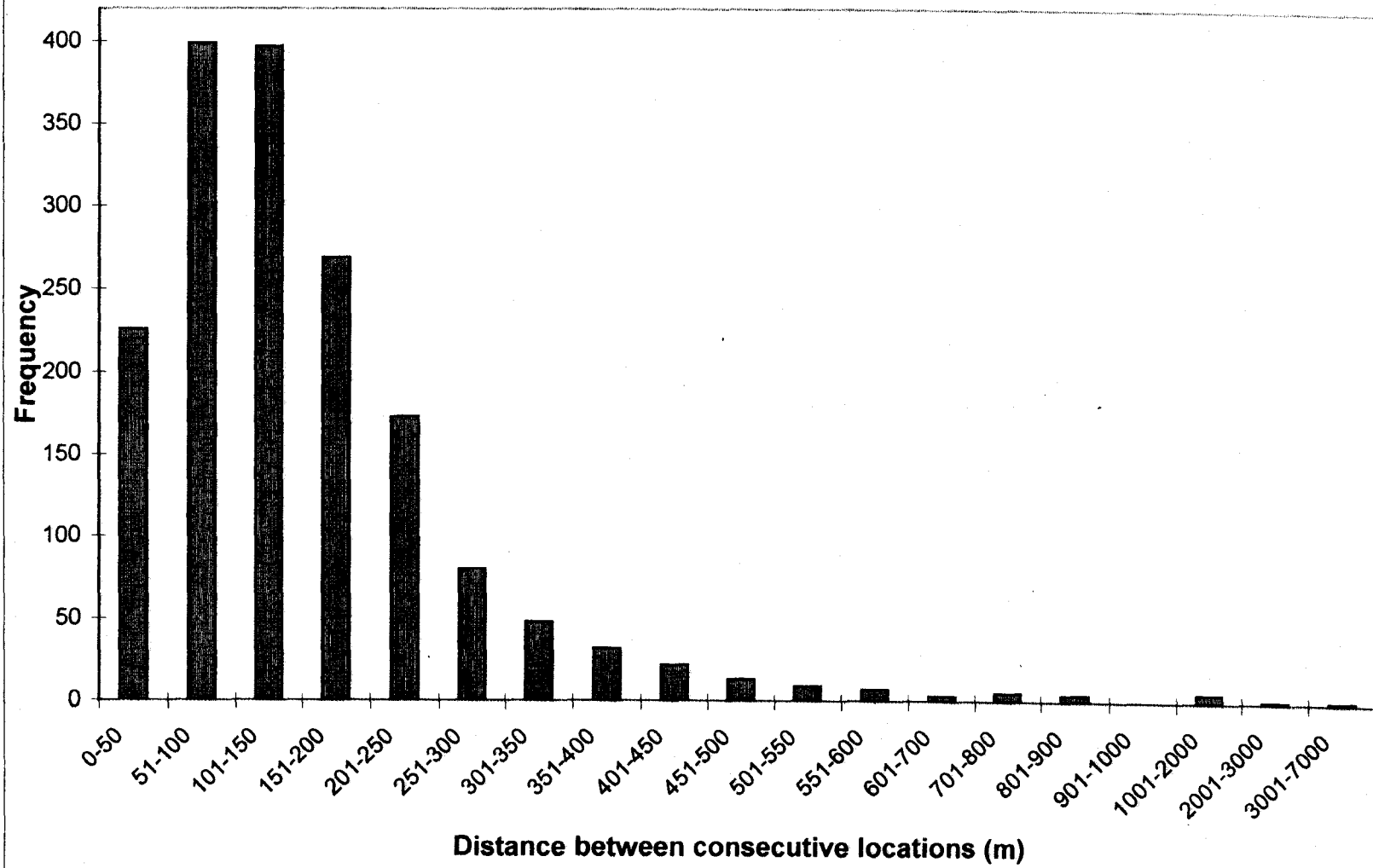


FIGURE 11. Average ($\pm$ SE) distance between consecutive locations for individual radio-marked sparrows

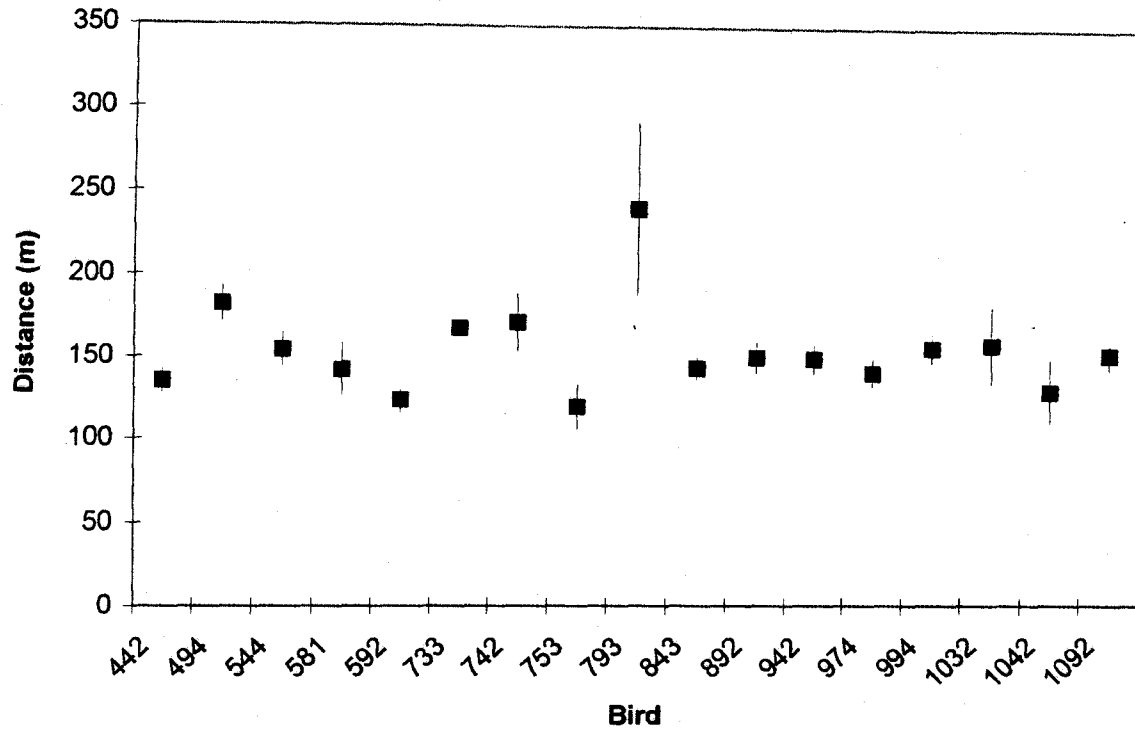


FIGURE 12. Maximum distance traveled by individual radio-marked sparrows

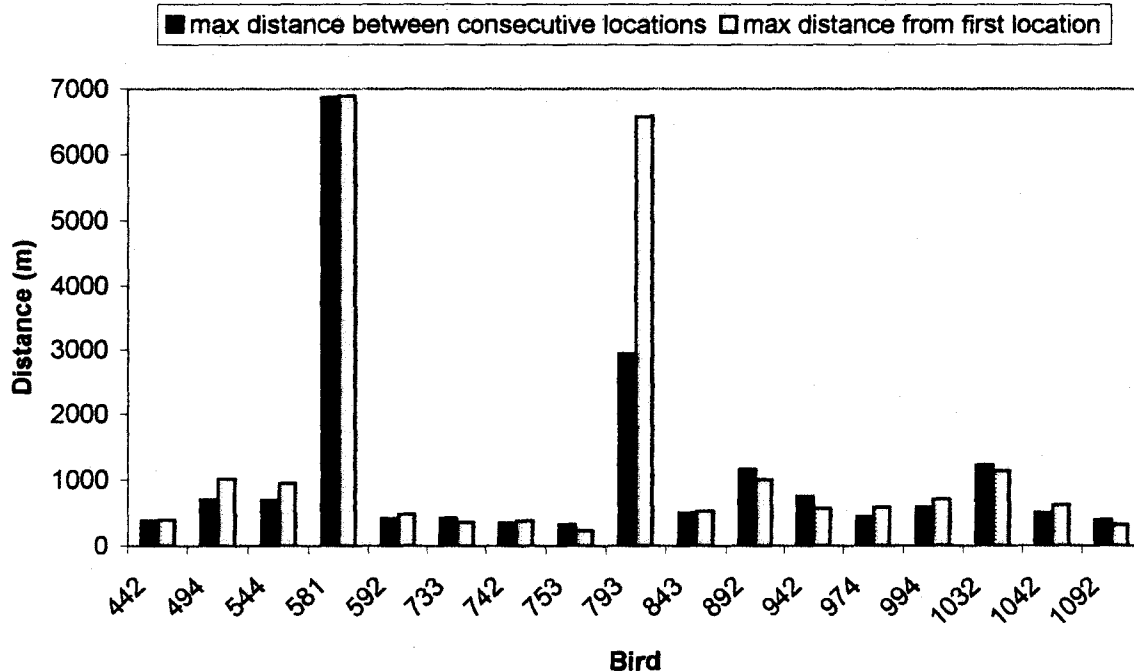


FIGURE 13. Long-distance movements away from study areas by sparrows 581 and 793

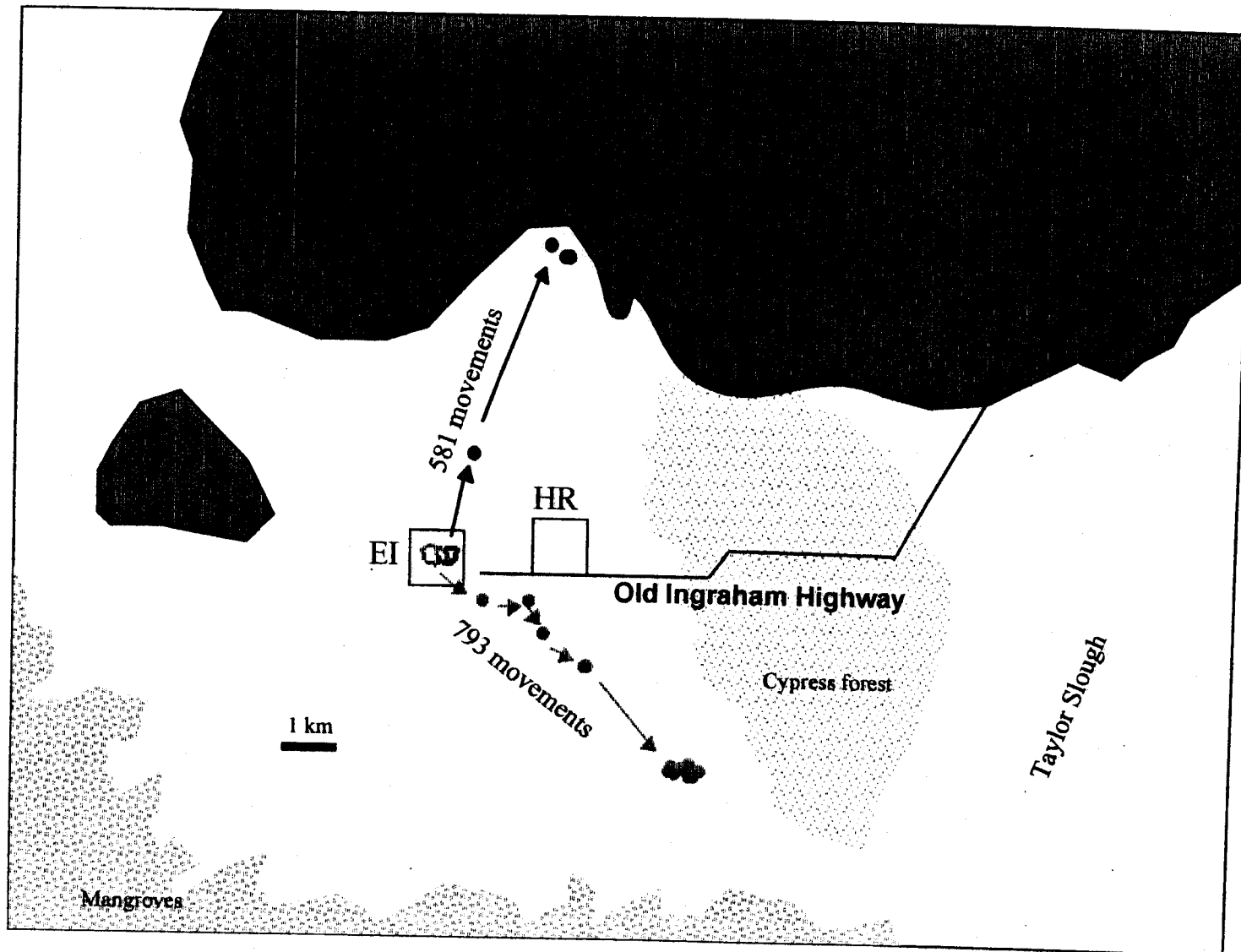


FIGURE 14. Water depths at HR and EI control points, Everglades National Park, July 1997 - February 1998

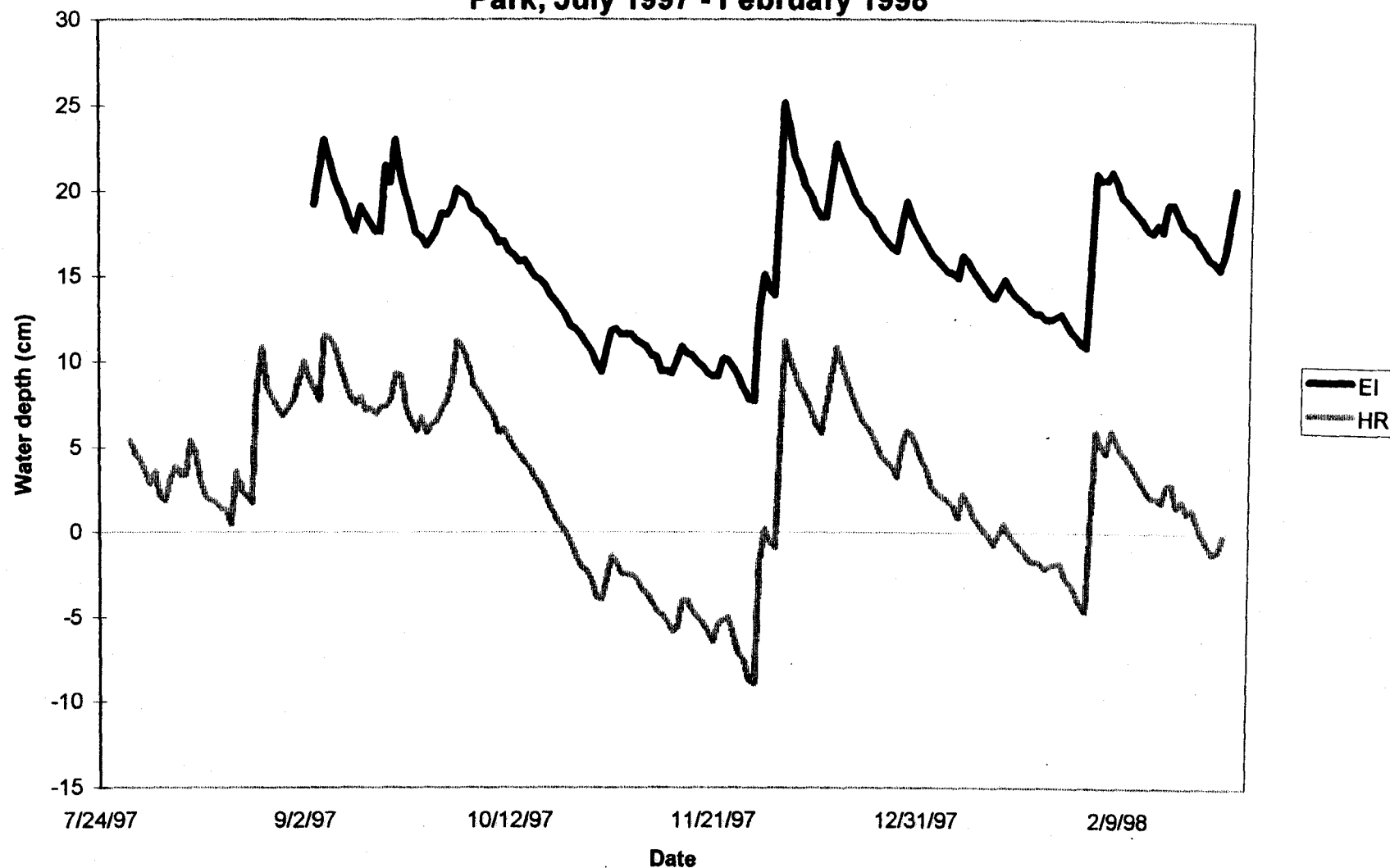


**FIGURE 15. Interpolated topography of the HR site.
Elevation relative to the control post**

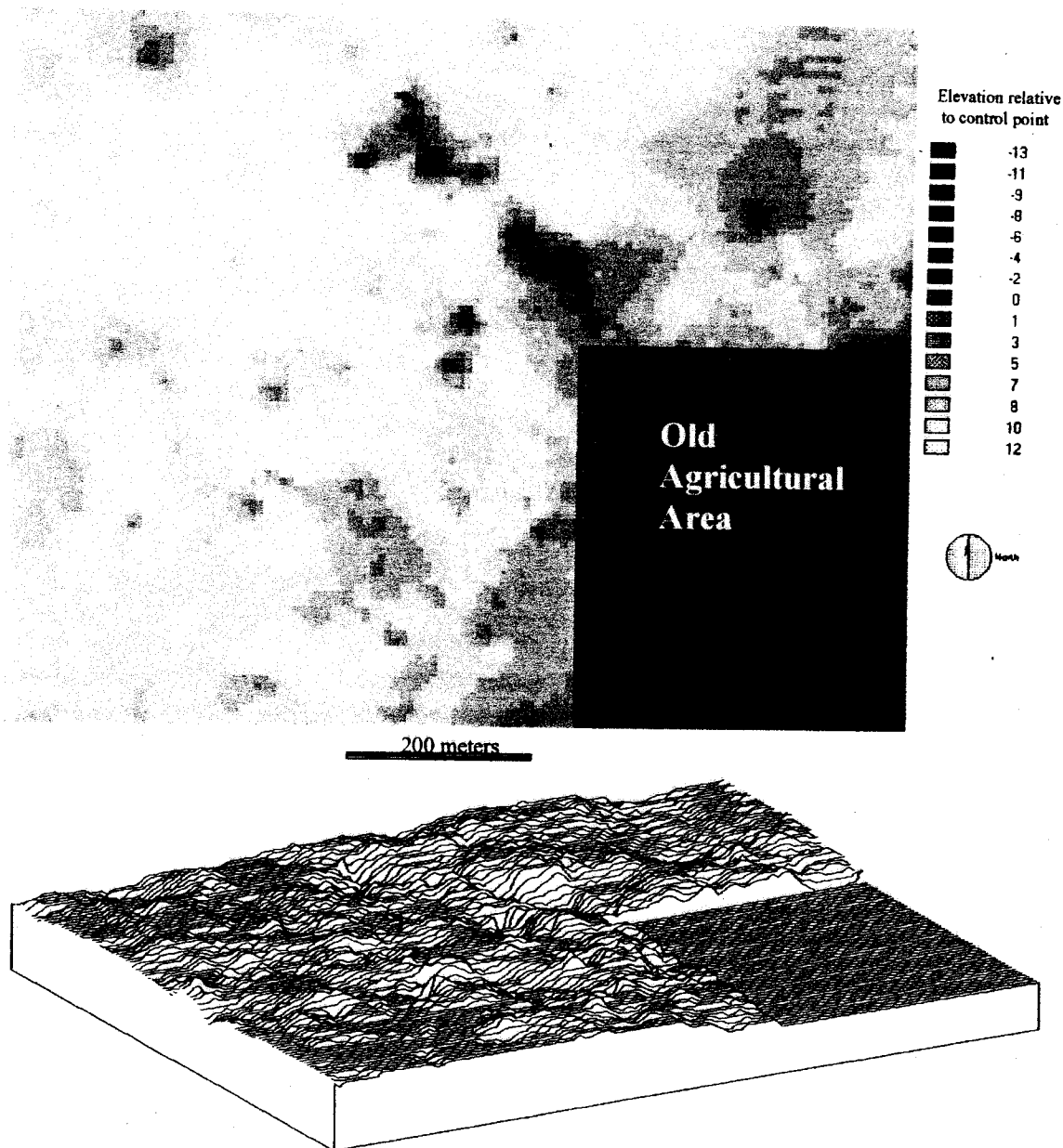
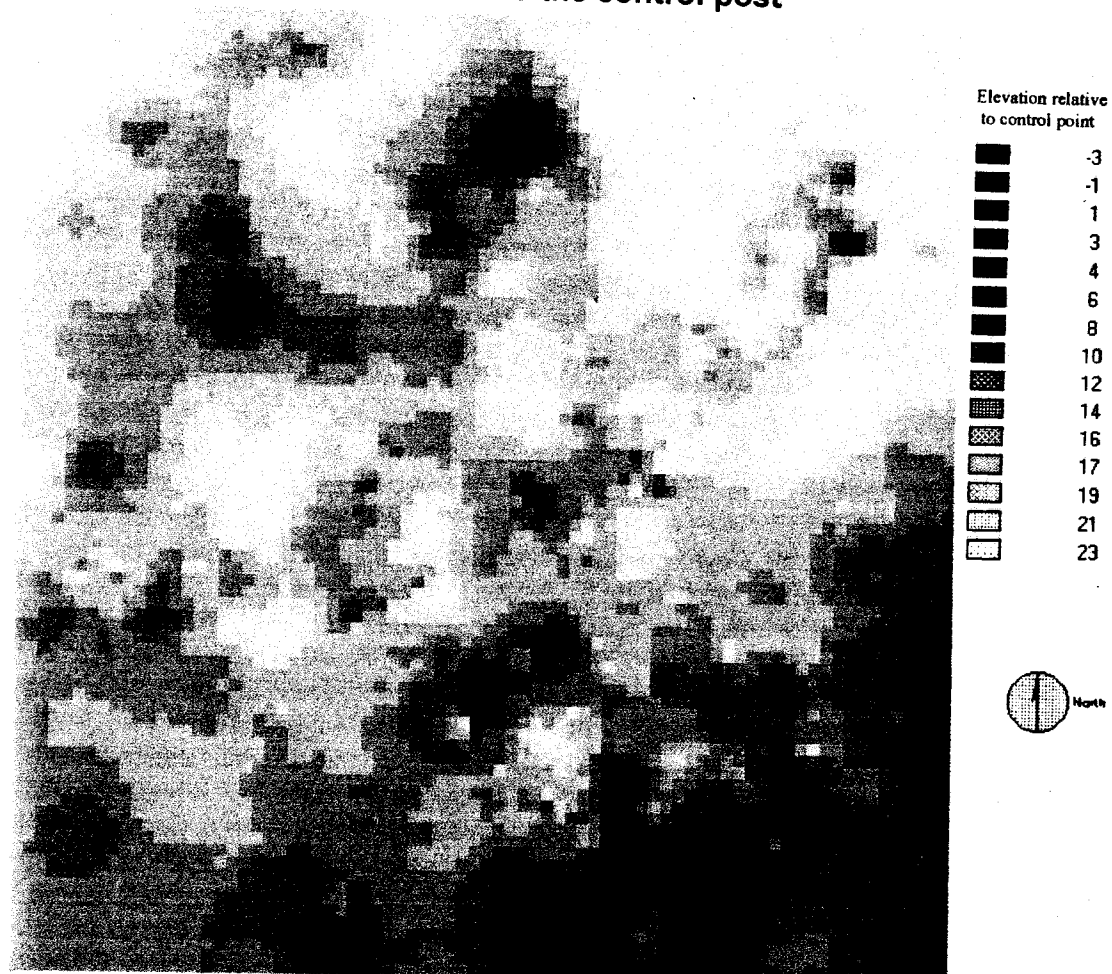


FIGURE 16. Interpolated topography of the EI site relative to the control post



200 meters

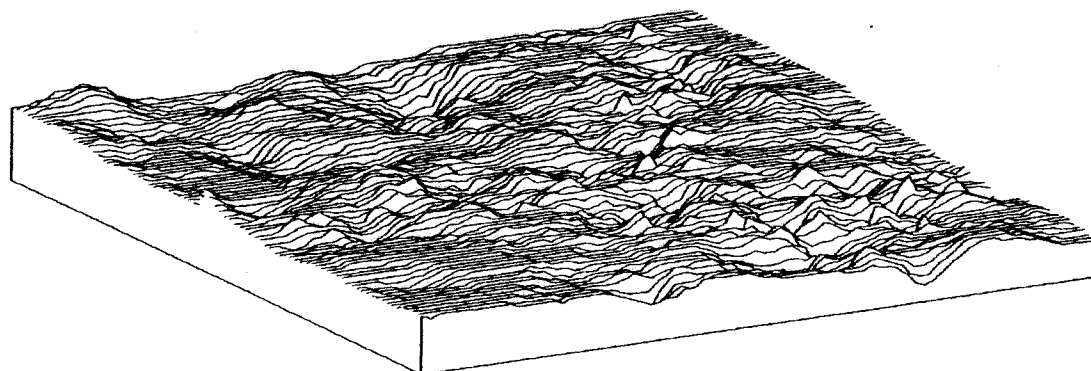


FIGURE 17. Sparrow use of muhly cover relative to water depth

(standard error bars not shown if they do not exceed bounds of marker)

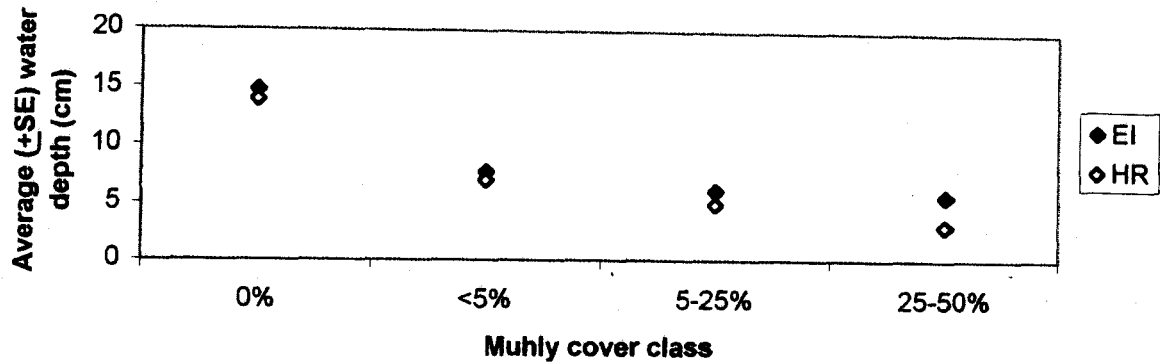


FIGURE 18. Sparrow use of sawgrass cover relative to water depth

(standard error bars not shown if they do not exceed bounds of marker)

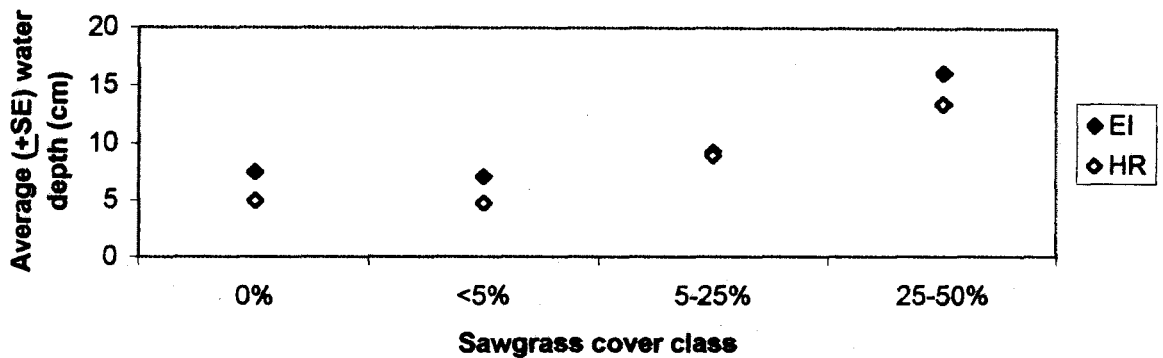


FIGURE 19. Sparrow use of litter cover relative to water depth

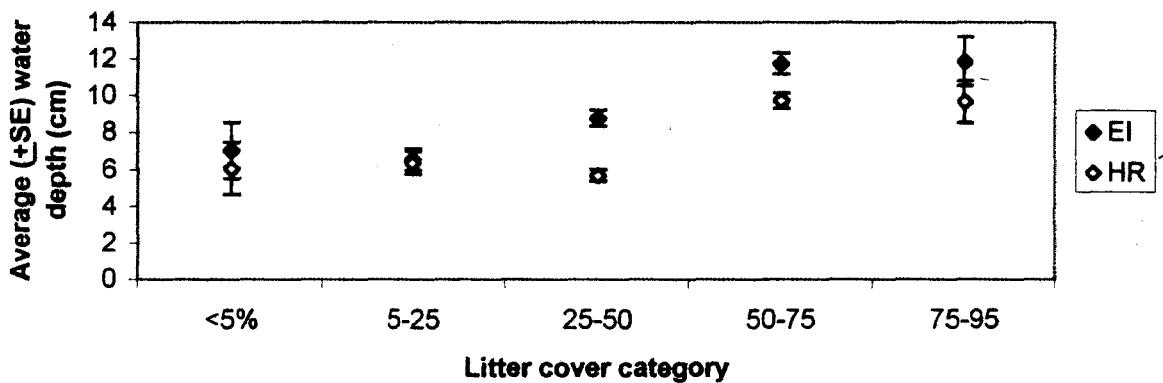


FIGURE 20. Sparrow use of open cover relative to water depth

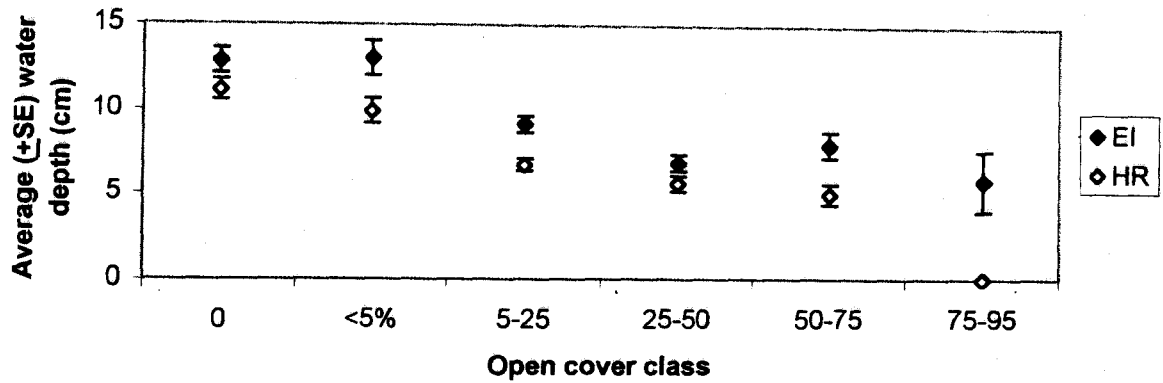


FIGURE 21. Sparrow use of rush cover relative to water depth

(standard error bars not shown if they do not exceed bounds of marker)

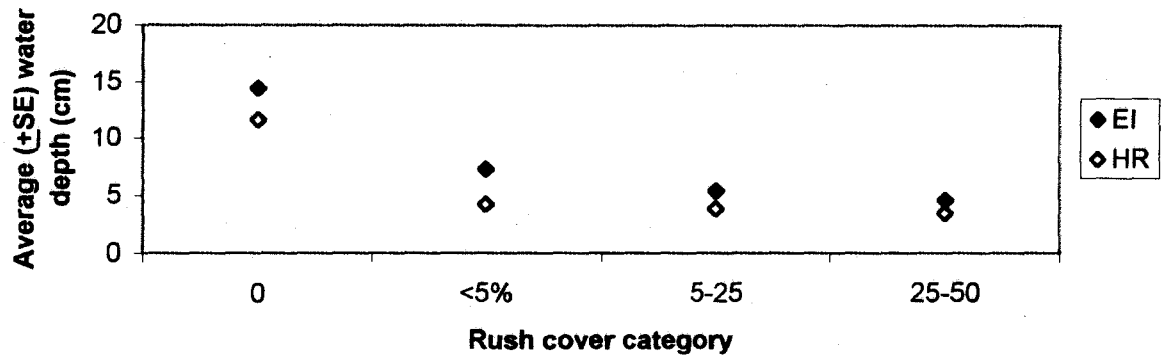


FIGURE 22. Sparrow use of sawgrass clumps relative to water depth

(standard error bars not shown if they do not exceed bounds of marker)

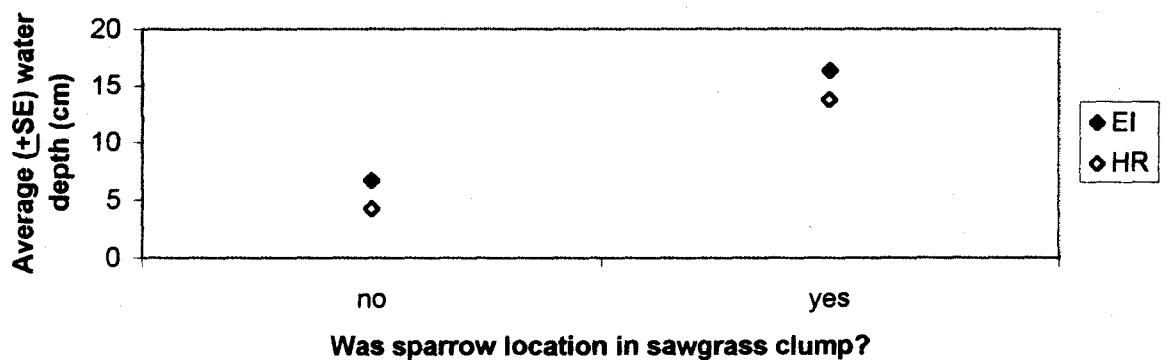


FIGURE 23. Effective height and maximum height at sparrow location relative to water depth

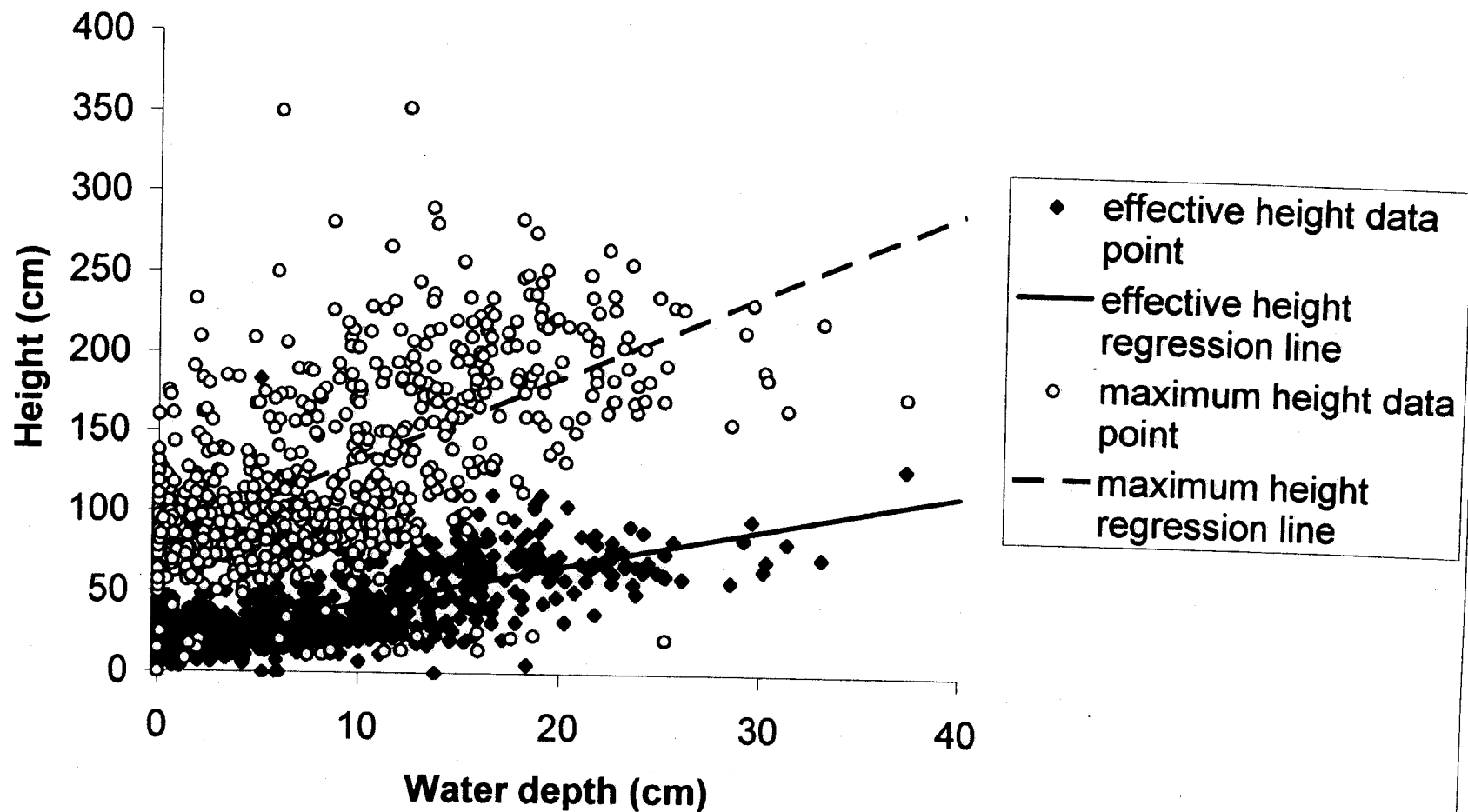


FIGURE 24. Kaplan-Meier survival probabilities (95% CI) for radio-marked Cape Sable seaside sparrows, Aug 1997 - Feb 1998

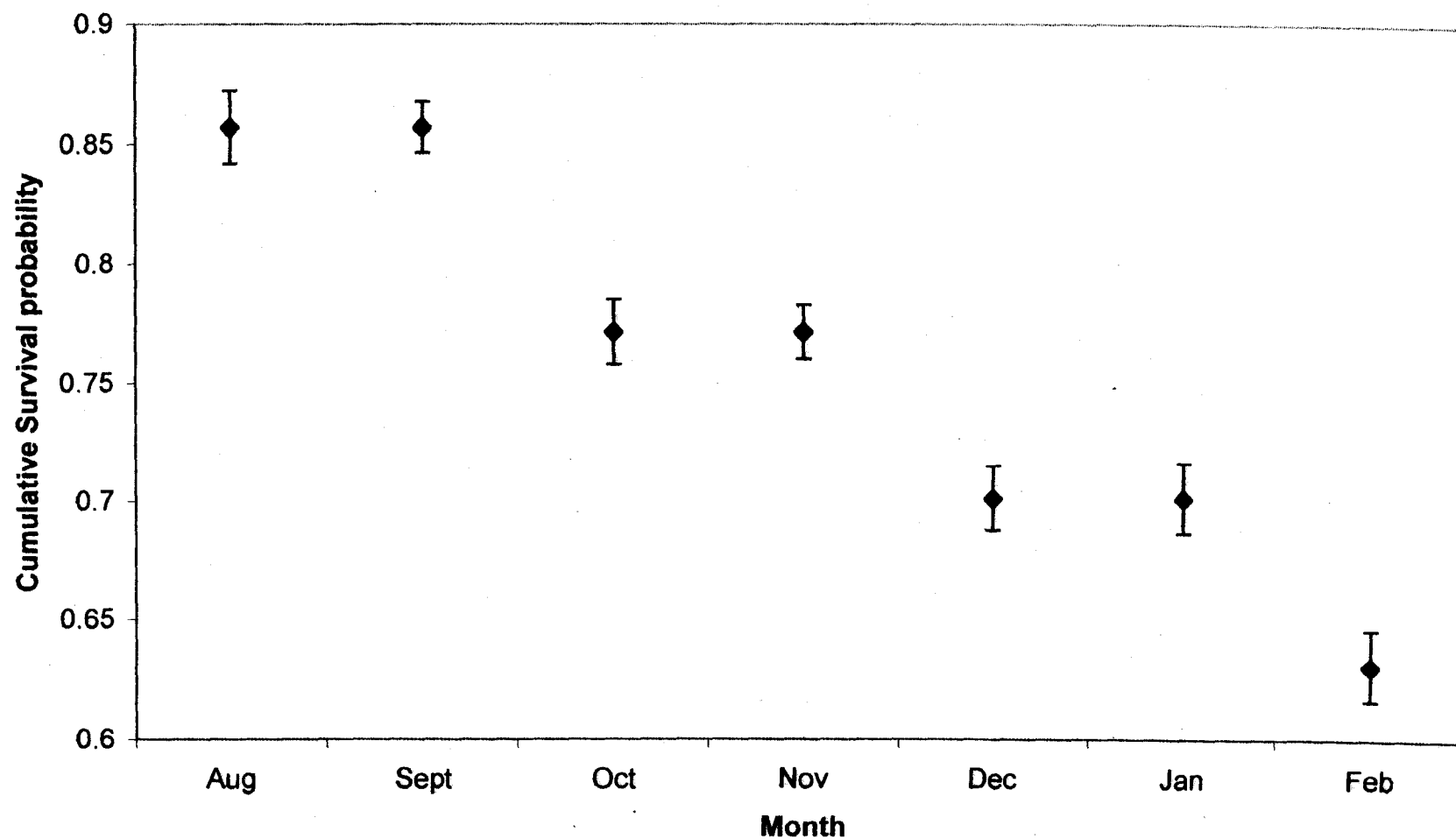
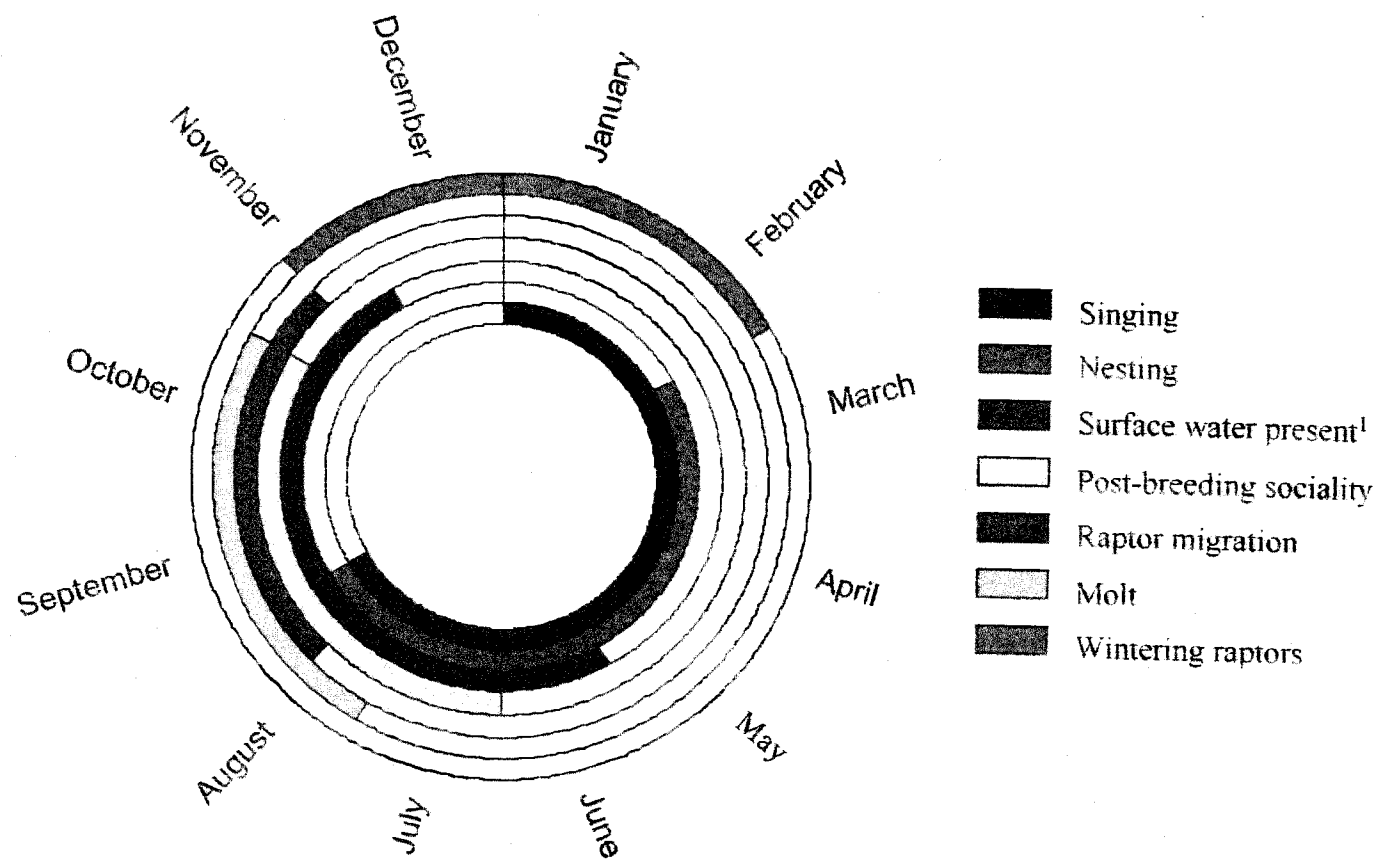
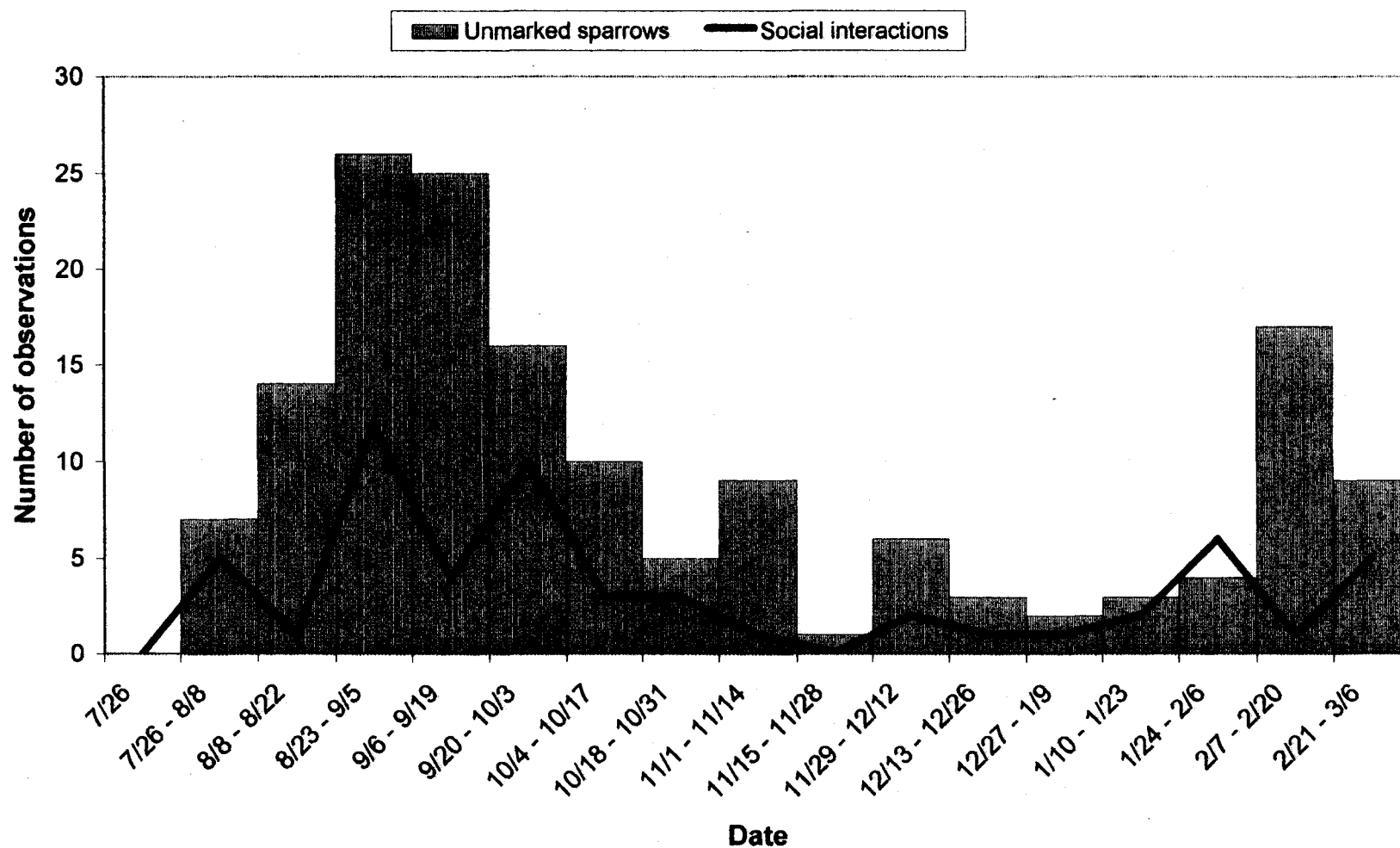


FIGURE 25. Annual chronology of Cape Sable seaside sparrow behaviors and environmental conditions. Beginning and ending dates of behaviors may vary among years, and we present here only the observations of dates from the 1997-1998 seasons.



¹ Average period of inundation based on 1966-1996 hydrological data from P-46 station, Everglades NP

FIGURE 26. Incidental observations of sparrows without transmitters and social interactions, July 1997 - March 1998



APPENDIX 1. Cape Sable seaside sparrows banded during the 1997-1998 field season. Site codes are: hr = half-raccoon, ei = end-of-Ingraham, and fs = far south. Age codes are: ahy = adult, hy = juvenile, u = unknown. Color band combinations are read from the left leg to the right leg, with the upper color band listed first on each leg. Each letter represents a single band. Color codes are: a = light blue (azure), b = dark blue, g = dark green, k = black, l = light green (lime), p = purple, r = red, s = silver (USFWS band), w = white, and y = yellow.

USFWS band number	Recapture?	Date	Time	Site	Age	Sex	Color Bands	Wing Chord	Weight	Fat	Radio-marked sparrow ID
148195801	no	7/26/97	7:20	hr	ahy	f	yyps	54	17	0.5	742
148195802	no	7/26/97	9:35	hr	ahy	f	yrps	56.5	16.8	0	545
148195803	no	7/27/97	8:20	hr	ahy	m	ykps	59.5	17.9	0	--
148195804	no	7/27/97	8:40	hr	hy	u	ywps	59.5	19.3	1	893
148195805	no	7/27/97	9:46	hr	ahy	m	ybps	58	19.3	0.5	494
148195806	no	8/1/97	9:40	hr	ahy	u	yaps	57	16.8	0	--
148195807	no	8/9/97	7:17	hr	ahy	f	ryps	56.5	16	0	--
148195808	no	8/9/97	7:54	hr	ahy	m	rrps	59	18.8	0	443
148195809	no	8/9/97	8:35	hr	hy	u	rkps	--	--	0	--
148195810	no	8/9/97	9:45	hr	ahy	m	rwps	61	19.3	1	892
148195811	no	8/10/97	7:36	hr	ahy	u	rgps	57	18.4	1	--
148195812	no	8/10/97	8:24	hr	ahy	u	raps	57.5	19.2	0.5	844
148195813	no	8/21/97	7:10	hr	ahy	u	raps	59.5	17.9	0	1042
148195814	no	9/4/97	9:23	ei	ahy	u	kyps	57.5	17.4	0	793
148195815	no	9/4/97	10:11	ei	ahy	u	krps	56.5	17.7	0.5	942
148195816	no	9/5/97	8:18	ei	u	u	kkps	57.5	17	0	994
148195817	no	9/5/97	8:30	ei	u	u	kwps	60	17.9	0	1143
148195818	no	9/19/97	9:09	hr	hy	u	kpbs	55.5	14	0	--
148195819	no	9/20/97	8:20	ei	u	u	kgps	60	18.3	0.5	974
148195820	no	10/5/97	8:42	hr	u	u	wyps	55	16	0	--
148195821	no	10/31/97	9:38	fs	u	u	kaps	61	19.2	1	--
148195822	no	10/31/97	10:28	fs	u	u	wrps	57.5	17.8	1	--

APPENDIX 1 continued

USFWS band number	Recapture?	Date	Time	Site	Age	Sex	Color Bands	Wing Chord	Weight	Fat	Radio-marked Sparrow ID
148195823	no	11/1/97	9:28	ei	u	u	wkps	56.5	17.8	1	754
148195824	no	11/1/97	10:08	ei	u	u	wwps	57	17.8	1	733
148195825	no	11/11/97	10:06	hr	u	u	wbps	57	18.1	1	545
148195826	no	11/11/97	10:47	hr	u	u	wgps	60	20.3	0.5	1093
148195827	no	11/12/97	9:15	ei	u	u	waps	56	17.6	0.5	581
148195828	no	11/12/97	9:15	ei	u	u	byps	60.5	18.9	0.5	593
148195829	no	11/20/97	11:23	hr	u	u	brps	61	21	2	1032
148195830	no	11/20/97	12:18	hr	u	u	bkps	58	20.1	1	--
148195832	no	1/16/98	11:12	fs	u	u	byps	58	17.5	0.5	--
152175795	yes	12/26/97	8:50	ei	u	u	rwys	59	21.5	2	--
152175833	yes	11/1/97	9:28	ei	u	u	kbys	59.5	18.7	1	--
152175833	yes	12/16/98	8:48	ei	u	u	kbys	59	20	2	--
152175880	yes	9/4/97	8:25	ei	ahy	u	wkys	56.5	17.5	0	--
152175880	yes	1/25/98	9:02	ei	u	u	wkys	58	16.9	0.5	--