

Identifying Cape Sable Seaside-Sparrow (*Ammodramus maritimus mirabilis*) habitat from satellite images.

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Abstract

The Endangered Cape Sable Seaside-Sparrow (*Ammodramus maritimus mirabilis*) inhabits the freshwater marl prairies in the interior of Everglades National Park. Since 1850, hydrologic projects have affected the vegetation of South Florida, including the Cape Sable sparrow's habitat. Sparrow numbers have declined by over 50% in the past five years, when high water levels flooded one of the two core populations. Using nest locations, we produced a conservative classification scheme, and determined how much suitable habitat was available to the sparrow from 1992 to 1996. We then used vegetation data from ground surveys to identify specific vegetation characteristics that were correlated with our satellite classification. These characteristics may indicate satellite-visible habitat features. We measured the total area of suitable habitat available to sparrows in each year, and discuss implications of our study for conservation of the species.

Introduction

The Endangered Cape Sable Seaside-Sparrow (*Ammodramus maritimus mirabilis*) inhabits the freshwater marl prairies in the interior of Everglades National Park. Early researchers observed these sparrows in *Spartina* sp. marshes (Howell 1919, Semple 1936, Dietrich 1938, Nicholson 1938, Anderson 1942, Stimson 1944, 1948, 1956), although Ogden (1972) and Werner (1975) found them in *Muhlenbergia filipes* prairies beginning in the early 1970's. Since 1972, most of the Cape Sable sparrow population has utilized *Muhlenbergia* prairie, although this habitat type is believed to be a recent invader (Werner and Woolfenden 1983, Olmsted et al. 1980). *Spartina* habitat has disappeared from most of its current distribution in South Florida (Olmsted et al. 1980). Except for the extinct Dusky Seaside-Sparrow (*A. m. nigrescens*), which inhabited freshwater *Spartina* marshes as well, all other subspecies use brackish or tidal saltwater marshes along the Atlantic and Gulf coasts (Post and Greenlaw 1994).

The Swamplands Act of 1850 began the US Army Corps of Engineers' campaign to drain the Everglades for agriculture and flood control for the eastern urban area (U.S. Department of the Interior 1994). Over 2200km of canals, gates, and levees divert freshwater from Lake Okeechobee into the Atlantic Ocean, or into the western half of Everglades National Park. These structures have altered the natural hydrology and fire regimes, and consequently changed the distribution of many habitats (Loveless et al. 1970, Alexander and Crook 1973, Olmsted et al. 1980, Olmsted and Armentano 1997). Studies in Cape Sable sparrow habitat have documented vegetational changes resulting from altered hydrological and fire regimes (Werner and Woolfenden 1983, Kushlan and Bass 1983, and Curnutt et al. 1998, Nott et al. 1998). In flooded areas, *Cladium jamaicense* can form tall dense stands, which sparrows avoid. In areas that are too dry shrub invasion occurs, and sparrows abandon these areas as well.

To determine the effectiveness of management decisions on the Cape Sable sparrow population, we need to know the distribution of the sparrows, population trends, and changes in the distribution and occupancy of their habitat. In 1981, and 1992 through the present, Kushlan and Bass (1983) and Curnutt et al. (1998) conducted an extensive helicopter survey to map sparrow populations, suitable habitat and potential habitat. Observers stopped every kilometer, and recorded the number of singing sparrows heard, as well as cursory vegetation and water data. Werner and Woolfenden (1983) used aerial photography to identify potential sparrow habitat, which included clumped *Spartina*, unclumped *Spartina*, sparse *Cladium*, and *Muhlenbergia*. In areas they identified as potential habitat, subsequent ground visits determined the accuracy of their classification. Satellite imagery and Geographic Information Systems are increasingly useful for habitat mapping, especially for threatened and endangered species (Palmeirim 1988, Breininger et al. 1991, Franklin and Steadman 1991, Pereira and Itami 1991, Rickers et al. 1995, Sperduto and Congalton 1996). Paired with vegetation and life history data from the ground, satellite images become a powerful conservation tool. Here, we use this technology to map all potential Cape Sable sparrow habitat in Everglades National Park, and determine specific vegetation characteristics common to this habitat.

Study Area and Methods

Much of the Cape Sable Seaside-Sparrow's population inhabits areas that are accessible only by helicopter. We therefore collected most of our nest and vegetation data within areas on the eastern side of Everglades National Park (Figure 1). We first discuss our methods for analyzing satellite images, and then discuss our plant data collected from ground surveys.

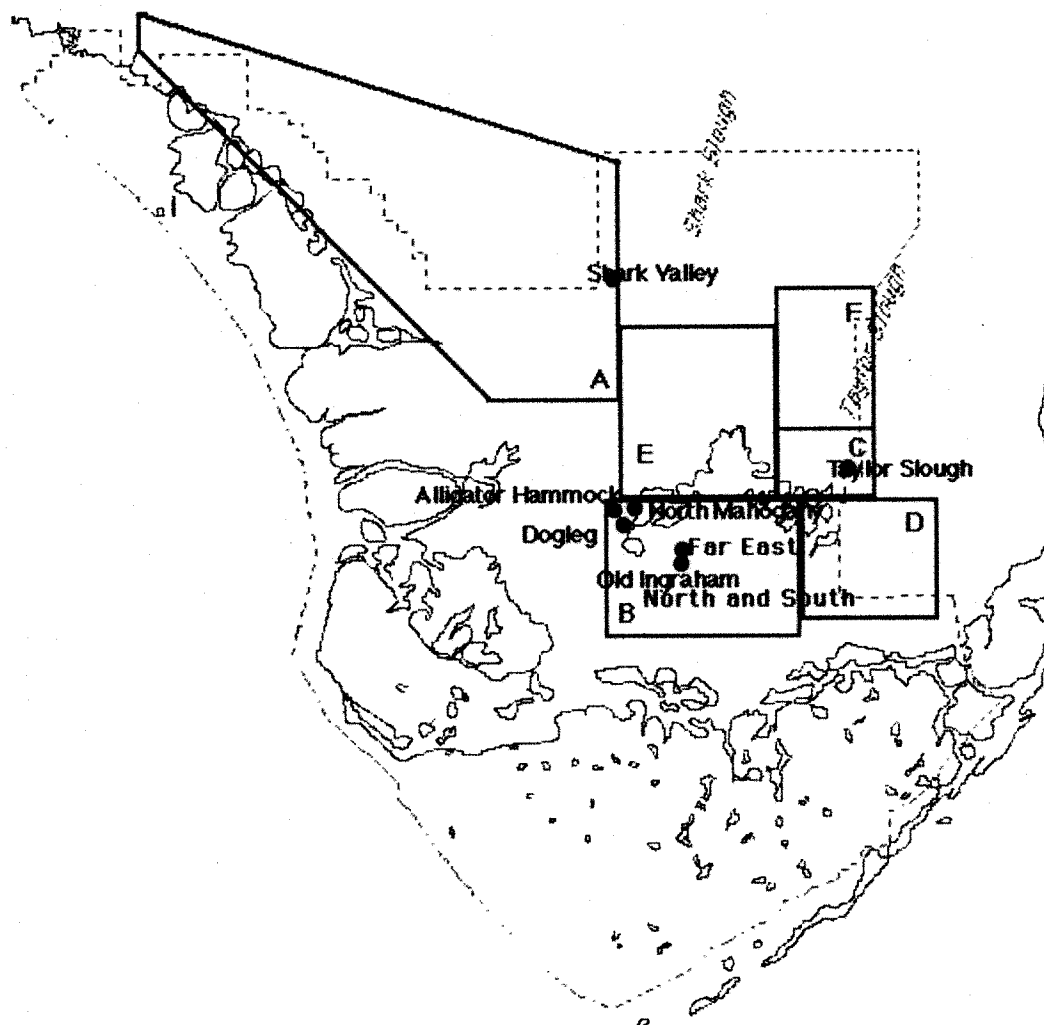


Figure 1. Map of Everglades National Park and study areas.

Satellite data

We conducted our satellite image analysis in three stages: image preparation, classification and image analysis.

Image Preparation

We classified five Landsat Thematic Mapper (TM) images to identify sparrow habitat. These TM images had a resolution of 28.5m². Table 1 gives the pertinent information on the images used.

Year	Acquisition Date	Entity ID
92	13 May	LT501504209213410
93	14 Apr	LT501504209310410
94	1 Apr	LT501504209409110
95	6 May	LT501504209512610
96	21 Mar	LT501504209608110

Although we attempted to limit our window for images from April to May, clouds obscured all available 1996 images during this period. In 1997, no image was sufficiently clear of clouds from March through June, and we were unable to make any analyses for that year.

We used nest location data from 1996 through 1998 in our classifications, concentrated in five of our study areas (Figure 1). In 1997 and 1998, we used a Trimble Pathfinder Pro Global Positioning System (GPS) receiver, and took two hundred UTM readings at each nest. We applied differential corrections later that day at the research station. With this method, our calibration runs demonstrated an receiver RMS error of slightly greater than one meter. Our UTM locations for our 1996 nest sites are less accurate, within 5-15 meters, since we used the Coast Guard beacon for real time differential correction.

We first calculated the covariance matrix for the seven layers. Bands 3 and 4 (red and near infra-red) contained the majority of the information, and band 6 (thermal infra-red) added no information to the analysis. However, retaining all seven available bands did not restrict our analysis capabilities, so we kept all of them and gained a marginal increase in generality. Since each image was over 360 megabyte, we used only a 7 megabyte subset of each image that contained our study areas. We rectified our 1996 image with 17 ground control points from 7.5 minute quadrangle maps and UTM coordinates of recognizable features on both the image and the maps. The RMS error of the rectification was a little more than one meter. We rectified the rest of the images by pixel matching with the 96 image. For this rectification, the RMS error of the pixel matches was approximately one centimeter. To determine whether this accuracy was sufficient, we randomly generated 50 test cases, each consisting of a source image, a target image and a set of coordinates. We had an 87.5 percent

probability of identifying the exact pixel of a known coordinate. We georeferenced our nest locations to the same projection as the TM imagery, and produced an ARC/INFO vector coverage of nests. We overlaid these coverages on the satellite images to identify the corresponding pixels.

Classification Techniques

An image analysis *classification* refers to an identification of a region or regions of an image with certain attributes. In our case, we wished to identify the areas of the Everglades National Park and its surrounds containing suitable nesting habitat for the Cape Sable Seaside-Sparrow. A classification is performed by finding a *signature* for the region of interest in terms of its spectral response. Each pixel of the image is then compared to the signature through a *decision rule* to decide whether to include the pixel in the classification (Jensen 1997). We performed unsupervised and supervised classifications using the ERDAS Imagine image processing software on an IBM RS/6000 workstation (Jensen, 1996; ERDAS, Inc, 1997). Our unsupervised classifications gave us an overview of the system as a whole and the degree of variation within and among our study sites. Unsupervised classifications seek a requested number of clusters in the data. This method classifies pixels according to the cluster they are "nearest" to, spectrally speaking. We used the ISODATA method to acquire 5, 10 and 20 classes in our classification (Jensen 1997). In all cases, iterations continued until less than one percent of the pixels in the scene changed class, which took less than 25 iterations.

We then developed a supervised classification technique to identify sparrow habitat. We first used the rectified 1996 image, then applied this technique to all other images. Training samples "grown" from the nest locations generated habitat signatures. We used one nest to pick a seed pixel, then examined all pixels within a physical radius of 20 pixels. The training sample included all pixels within a Euclidean spectral distance of 30 from the seed pixel. This technique produced training samples of about 1,000 pixels.

A series of trials used nest site capture as the measure of merit to establish our parameters. We grew a training sample for a given physical limit and spectral distance, with spectral distance as a parameter of particular interest. We scored the samples by comparing the number of nests captured in the training sample with the total number of nests in a square of a side equal to twice the radius constraint. The results were insensitive to the value of the physical radius on the region growing process. We found that a value of 20 pixels gave a sample size that generated sufficient margins of errors.

Every pixel on every band had a brightness value (BV) scaled to the range of an unsigned eight-bit integer (0-255). The seven-dimensional Euclidean distance gives us the spectral distance d between two pixels A and B:

$$d = \left(\sum_{i=1}^7 (BV_{Ai} - BV_{Bi})^2 \right)^{\frac{1}{2}}$$

As the spectral distance increases, so does the variability of the sample. A useful spectral distance should produce a training sample with a variability roughly equal to the variability in nest sites. If the spectral distance is too small, the training sample will not reach a plateau and the sample size will be too small. The proportion of nest sites captured will also be small. As the spectral distance goes up, the samples increase until the plateau is reached, and the proportion of nest sites captured also increases. Beyond this point, the sample size remains constant but the spectral variability of the included pixels continues to increase, as does the proportion of nests captured continues. At large spectral distances, the sample encompasses the whole spectrum and every pixel (and every nest) within the physical radius. The number of nests captured increased linearly with spectral distance until a plateau near 29-31BV. Above this "knee" in the curve, the range of the signature increases disproportionately for every nest captured. A spectral distance of 30 consistently produced nest captures in the range of 90-95 percent.

Since we had very accurate nest locations in 1997 and 1998, but only had usable imagery from 1996 through 1995, we compared many supervised signatures. In the next section, we discuss our method for identifying sparrow habitat, that could be applied to all images.

Image Analysis

The most stable and productive sparrow communities are in our Ingraham North (IN) and Far East (FE) study areas (Pimm et al. 1998). We have extensive data from these sites from 1995 through 1998, and hoped the signatures produced in these sites would be applicable to the entire Park. These areas are fairly insulated from the effects of water management decisions outside the park, and have a history of modest burn frequency (REFS). The work proceeded in three phases. First, we produced unsupervised classifications of all our study areas, from the Main Park Road and Sweetbay Pond, and ranging eastward along the Old Ingraham Highway. We knew from ground surveys that these areas supported different vegetation communities, and wanted to test the ability of the satellite imagery to differentiate between them as well. This work established the essential homogeneity of the area.

Second, we produced many signatures based in IN and FE in a wide variety of ways. We tested the ability of the signatures to capture nest sites across all the study areas, and concluded that we could reliably identify sparrow habitat based on the characteristics of the core areas. Finally, we extended the methodology and made identifications of suitable sparrow nesting habitat throughout the park for all years for which we had imagery. We compared these identifications to data previously gathered

through helicopter surveys taken in previous years, as part of the National Park Service Systematic Reconnaissance Flights project.

Analyses of Unsupervised Classifications

As noted above, we produced three unsupervised classifications on the 96 image. Using field data and a set of 1:10,000 scale color-infrared aerial photos (National Aerial Photo Project, 1994), we assigned interpretations to each of the classes. The classification with only five classes proved to be too coarse, as only two classes could be related to grasslands. A ten-category classification produced five categories that could be related to grasslands, four in the prairie area and one on the periphery which we assigned to wet prairie. This classification method proved to be the most useful. The twenty-category classification produced 12 grassland categories, three or four each in four major groups differentiated by appearance: bright grass, prairie grass, dark grass, and wet grass. Although this classification was too detailed to be useful for analyses without extensive ground truthing, it did lead to a deeper understanding of the structure of the grassland community in the study areas. Briefly, the groups can be described as follows:

Bright grass areas were stands of relatively sparse vegetation cover and higher exposure of periphyton and limestone. The latter reflect energy very well, leading to higher BVs and a brighter appearance in the image. This group had the biodensity (biomass per unit area).

Prairie grass signatures correspond to areas of moderate density and height, mainly mixtures of sawgrass (*Cladium jamaicense*) and other graminoids, particularly *Muhlenbergia filipes*. These grasses do not completely obstruct the underlying periphyton and limestone. We estimated the biodensity to be considerably higher in prairie grass areas than in bright grasses, but less than in dark grass areas.

Dark grass areas were tall dense stands of sawgrass and other dense monocots. Sawgrass inflorescences were often over six feet high. Most of the other graminoids were absent. In the denser areas, other sedges and rushes such as needlerush and even cattails were abundant. The vegetation covers all of the ground, eliminating any exposure of the periphyton or the limestone. Biodensity was much higher than in any of the other areas.

Wet grass areas were common to the periphery of the region as the elevation decreases toward sea level. In these areas, there was usually a certain amount of standing water, which shifted the signature to the darker end of the range. Sawgrass, swamp lily (*Crinum americanum*), and other hydrophilic species dominated these areas, while other prairie graminoids decreased. Biodensity in these areas is highly variable, but never as high as in the dark grass areas.

In general, the wet grass areas are highly variable and occur in strips to the west and south of the core areas. The wet grass classes may comprise a more or less continuous change from the prairie grass communities to the very wet areas in Shark Slough to the north, and the mangrove swamps that dominate the lower areas of the Everglades. The amount of water in the area seems to be the dominating variable of this group.

The other three groups, however appear to exist on another continuum characterized by variation in structure. At one end is the bright grass group with smaller clumps of grass and much exposed ground. At the other end is the dark grass group consisting of heavy vegetation with little or no ground visible. The prairie grass group is intermediate to these, and is moderately dense stands of taller grasses with moderate ground visibility. The sparrow may prefer this habitat because it frequently travels along the ground to and from its nest. The sparrow also need sufficient grass structure to support its nests. The presence of *Muhlenbergia*, long associated with sparrow nesting areas, is an indicator of correct proportions of critical habitat characteristics. *Muhlenbergia*, then, would seem to be a sufficient condition for sparrow breeding, though not a necessary one.

We performed several tests on the ten-category classification. First we counted up the number of pixels corresponding to each of the categories in each of the study areas. We then ran a chi-square test to see if the distribution of categories was independent of the study area. Our analysis overwhelmingly rejected this hypothesis ($\chi^2=2195$, $P=.05$, $df=56$). This supported our qualitative conclusion that IN and FE were much more uniformly dominated by prairie grasses, while the Ingraham South (IS), Sweet Bay (SB) and Alligator Hammock (AH) study areas possess a larger proportion of the other grass classes.

We performed similar tests for the distribution of nests over the classes. We found nests in four to seven classes, depending on the year. Chi square tests showed that for any given year structure was present in these distributions ($\chi^2=22.2$, $P=.05$, $df=12$). Preference was shown for three of the prairie grasses classes; however, a significant number of nests were found in one of the dark grass classes. These nests were on the periphery of prairie grass regions which hosted vigorous nesting communities. Another chi square test demonstrated that the distribution of nests in each class did not differ significantly from one year to the next ($\chi^2=4.46$, $P > 0.05$, $df=8$). We therefore concluded that nest locations of later years could be used as seed pixels for classifications on images from earlier years.

The greater variability of the grassland signatures, compared to the other elements of the image, limited the utility of the twenty-category classification. Features such as water, hardwood hammocks, and bayheads, had well defined signatures. When generating more classes, the ISODATA algorithm subdivided the more highly variable grass classes into narrower classifications before splitting tighter

classes. This gave an unrealistic picture of the overall homogeneity of the grasses. The supervised classifications gave a much different view.

Analyses and Results of the Supervised Classifications

We obtained many signatures using nest sites in IN and FE as seed pixels. These signatures classified almost the whole of the IN and FE study areas as suitable habitat, except for those areas that were obviously unsuitable (hammocks, open water, bayheads, road edge shrubbery, etc.). This opposed the results of the unsupervised classifications, which indicated great heterogeneity in the grassland communities. Our statistics tests demonstrated the following:

The signatures generated in IN and FE were applicable generally over all the prairie study areas. When we used the signatures to classify the other study areas, the percentage of nests captured were about the same as in the areas where the signatures were generated (90-95 percent).

A chi square test on the distribution on captured nests over the study areas for ten randomly generated signatures failed to detect any structure ($\chi^2=32.88$, $P=0.05$, 54 DOF). Thus, there was no significant difference between the signatures in their ability to capture nests in the seven study areas.

We lumped all nest captures from all the areas and tested the signatures for significant differences in nest capture. A t-test showed that none was evident even at well below the 0.10 level ($t=.033$, $P=.05$, $df=9$).

We found no significant differences on 1996 images among signatures based on nest data from 1996, 1997 or 1998 ($t=.231$, $P>.2$, $df=8$).

To test whether we could identify habitat by eye based on interpretive skill alone, we generated five signatures each from nests. From the IN/FE area, we chose the pixels, and generated a stratified random sample of pixels (we eliminated obvious non-habitat). For each signature, we counted the the number of nests captured in all seven of the applicable areas. An analysis of variance showed no significant difference. ($F_{.05}(2,df=12) = 3.88$).

We concluded that sparrows use a broader pattern of habitat characteristics than the unsupervised classifications had led us to believe. Quite simply, the sparrows are less choosy than the ISODATA algorithm. Furthermore, we can use almost any part of the core area to generate a signature for sparrow habitat, and no signature so generated differs significantly from any other.

Identifying Sparrow Habitat

We then used the signatures generated in the core areas to identify sparrow habitat across space and time. We applied the signature to 70 megabyte images that included all of the Everglades National Park and the southern portion of Big Cypress National Preserve. We used a parallelepiped decision

rule leaving all unclassified pixels unclassified (in lieu of specifying some kind of tie-breaker, Jensen 1997). This gave a monochrome image consisting of just those pixels that complied with the signature. We overlaid this image on the 96 image of the park. The overlay identified 13-15 percent of the park area as suitable for sparrows. We identified all the known major sparrow populations.

To standardize the identification, we used the intersection of three signatures generated from the locations of random nests in IN and FE. This method provides a conservative estimate of sparrow habitat, and showed that intersecting the third signature caused a change of one percent or less of the number of pixels identified. For example, on the 1996 image, the intersection of first two signatures classified 12 percent of the park. The addition of the third signature did not result in any decrease in the number of pixels included in the classification. When we increased the overlay to four signatures, the pixels lost in the intersection were almost all located on the periphery of the identified regions. Geographically marginal areas are also spectrally marginal. Mathematically, there is no reason why this should be so, but we suspect that it makes sense ecologically. Unfortunately, such an exploration was not possible under the present limitations of time and funding.

With the goal of gauging the accuracy of the identification, we compared these classifications with the 1996 helicopter survey (REF). The survey covered the major sparrow breeding areas on a 1 km grid, and observers recored all sparrows seen and heard for ten minutes. In 1996, sparrows were recorded at 76 points. Identified sparrow habitat occurred within 500m of 69 of these points, which gives our classification about a 91 percent accuracy.

However, this accuracy may be decreased with a decrease in helicopter navigation precision. Also, the survey results were plotted on an unrectified image. The rectification error is about 250 m in areas where we have made accurate measurements. The navigation accuracy of the helicopter survey is certainly no better than this. Because of the uniformity of vast areas of the Everglades and the lack of precise landmarks discernable on the satellite images, rectification of the whole of the park area is a challenging task that is still in progress. Nevertheless, these errors must to a certain extent be offsetting. In summary, while we cannot quantify the error, we can only be encouraged by such good agreement between the helicopter data and the habitat classification.

We extended sparrow habitat identification to the rest of the images by applying the same technique. It was not always possible to find a signature that is valid from one year to the next, and we had to generate new signatures for each image. This may at first seem to contradict our previous conclusion that it is possible to use the locations of nests from one year to predict habitat in another, but the relationship is not really reflexive. The birds do return to the same areas year after year, the

vegetation components do remain very much the same (at least on the Ingraham prairies), but the spectral response of those components may well be different due to seasonal variation, weather changes, water levels and instrument drift (Peplies, 1998).

We made a preliminary investigation in the changes in the histograms of the images. The shape of the distribution is similar from one year to the next, but the distribution is shifted up or down the scale. Further work might elicit a transformation to normalize seasonal and other variations, and provide a useful baseline for finer analyses. Such a project would require many more images than in our possession.

We then calculated the amount of area classified as "suitable" habitat in all of Everglades National Park in the 1992 through 1996 satellite images (Table 2).

Table 2. Amount of Everglades National Park classified as sparrow habitat from satellite images.	
1992	760,528ha
1993	290,119ha
1994	653,763ha
1995	196,509ha
1996	433,469ha

Figure 2 shows a composite of our habitat identifications for 1992-96.

Plant data

From March to May 1997, we performed 20 transects in five of our study sites; four in subpopulation B, and one in subpopulation C. We used a stratified random sampling technique to place these 50m-strip transects, and took vegetation measurements from 10 1m² quadrats, one every 5 meters of the transect. All transects have associated UTM coordinates. In each 1 m² quadrat we collected floristic and structural data. Floristic data included:

- Species composition – We took presence/absence data and cover estimates (see scale below) for every species in each quadrat. Here, we only report the cover data for the four dominant graminoids in the areas we surveyed: *Cladium jamaicense*, *Muhlenbergia filipes*, *Rhynchospora* sp., and *Schizachyrium rhizomatum*.

Structural data included:

- Cover – We used a Braun-Blanquet method (from 1 (0 to 1.0%) to 6 (75-100%) Phillips 1959, Mueller-Dombois and Ellenberg 1974), and estimated total live plant cover, dead matter cover, and periphyton cover. To assure that our estimates were consistent, we compared our cover estimate to actual stem densities for one quadrat of each transect (chosen at random).

- Stem density – For each plant species, we counted the number of stems per quadrat. Using data from our plant removal study in 1995 and 1996, we found a direct relationship between stem density and standing biomass (adjusted for species composition and abundance). We used this relationship in this year's data to indirectly measure biomass in each quadrat.
- Maximum vegetation height (cm)
- Effective height (cm, Wiens 1969) – Using a field notebook, we recorded the maximum height at which 90% of the side of the notebook is obscured by vegetation. Werner (1975) used a similar measurement, which he called "vertical obscurity profile". While this is a crude measurement, it allows us to quantify an aspect of the habitat that may be important to the sparrow for nest locations, predator evasion and thermal regulation.

We used a nonparametric Mann-Whitney U test to compare vegetation characteristics between transects in suitable versus unsuitable pixels, and used an alpha level of .05 to determine significance. We also used this test and parameters for comparing transects burned in the last 10 years, with those that have not burned. We conducted all tests using SPSS 8.0 for Windows (SPSS Inc.).

Results

We detected significant trends in most of our structural measurements and two of our floristic measurements when classified into suitable and unsuitable pixel groups (Table 1, Figure 2). Maximum vegetation height and dead matter cover were lower in suitable pixels, whereas effective height, periphyton cover, biomass, percent cover of *Muhlenbergia filipes* and *Rhynchospora* sp. were higher in suitable pixels.

Table 1. Mann-Whitney U comparison of vegetation transect data in pixels classified as suitable or unsuitable from satellite imagery (bolded characteristics are significant).

<u>Vegetation characteristic</u>	<u>Mean unsuitable pixels</u>	<u>Mean suitable pixels</u>	<u>Mann-Whitney U sig. (2-tailed)</u>
Total live plant cover	1.96	1.86	.244
Maximum vegetation height (cm)	103.64	93.52	.002
Effective height (cm)	1.77	2.93	.006
Dead matter cover	2.00	1.73	.002
Periphyton cover	4.39	4.69	.003
Species Richness	7.80	8.02	.543
Biomass (dry grams)	1711.49	2014.00	.004
% cover <i>Cladium</i>	2.00	1.92	.583
% cover <i>Muhlenbergia</i>	1.03	1.37	.007
%cover <i>Rhynchospora</i>	.86	1.20	.022
%cover <i>Schizachyrium</i>	1.06	1.23	.125

We suspected that the dominant graminoids create some of the structural characteristics we observed in the habitat. Although we cannot say for certain that these species do create the structure, we can at least determine whether or not particular species are correlated with particular structural features. We used Kendall's tau-b nonparametric correlation test with an alpha level of .05 or lower. Percent cover of *Cladium jamaicense* was positively correlated with maximum vegetation height and biomass (correlation coefficient = .393 and .367 respectively, $p = .000$ for both), but negatively correlated with effective height (coefficient = -.169, $p = .014$). Effective height and percent cover of *Muhlenbergia* were positively correlated (coefficient = .356, $p = .000$), while the percent cover of *Muhlenbergia* and *Cladium* were negatively correlated (coefficient = -.216, $p = .002$). Percent cover of both *Rhynchospora* and *Schizachyrium* were negatively correlated with maximum vegetation height (coefficient = -.252 and -.180, $p = .000$ and .008 respectively). *Rhynchospora* was also positively correlated with effective height (coefficient = .256, $p = .000$). Our observations in the field agree with these results. *Cladium* is by far the tallest growing graminoid in these prairies, and its thick, wide leaves may also account for a significant portion of the biomass in areas where it dominates. *Muhlenbergia*, and to some extent *Rhynchospora* (especially *R. tracyi*), typically grow in small bunches, and never grow taller than .7cm (pers. obs.).

Fire

Plant cover and effective height were higher in areas that have burned once the past 10 years, while periphyton cover and percent cover of *Rhynchospora* sp. were lower in these areas. An analysis of vegetation characteristics and years post fire is in progress.

Table 3. Mann-Whitney U comparison of vegetation transect data in areas burned once since 1987, and those not burned (bolded characteristics are significant).

<u>Vegetation characteristic</u>	<u>Burned once</u>	<u>Not burned</u>	<u>Mann-Whitney U sig. (2-tailed)</u>
Total live plant cover	1.73	2.03	.001
Maximum vegetation height (cm)	94.87	98.65	.270
Effective height (cm)	2.08	2.90	.048
Dead matter cover	1.74	1.88	.660
Periphyton cover	4.69	4.51	.016
Species Richness	7.82	8.11	.839
Biomass (dry grams)	1867.45	1947.75	.247
% cover <i>Cladium</i>	1.99	1.91	.518
% cover <i>Muhlenbergia</i>	1.21	1.28	.558
%cover <i>Rhynchospora</i>	1.36	.88	.003
%cover <i>Schizachyrium</i>	.90	1.37	.000

Discussion

The variation in the amount of available habitat agrees with the results of the helicopter surveys for the applicable years. Figure 4 shows a composite of helicopter survey points that found sparrows with identified habitat. Table X.X-X summarizes the agreement. This is the principal independent confirmation of the ability of signatures generated in the core areas to predict habitat over the rest of the park.

In addition, the effect of water discharges over the S-12 gates as reported elsewhere (Curnutt *et al.*, 1998; Nott *et al.*, 1998) is clearly seen in the fluctuation of the amount of available habitat in the Rattlesnake Ridge area (just south of 40-Mile Bend on the Tamiami trail, roughly between gauging stations NP-205 and P-34). Note the large reduction in identified habitat in 1993 and the almost complete disappearance of habitat in 1995 due to inundation. Note, too, that the available habitat in 1996 is much less than that of 1992 or 1994. Water level records for the period (Curnutt, *et al.*, 1998) indicate that the area was no wetter at the time the image was taken in 1996 than the corresponding time for the 1994 image. The significant loss in habitat in 1996 is consistent with a conclusion of damage to the vegetation system on which the sparrow critically depends. Presumably, the habitat is recovering, but we will have to wait for the 98 imagery before we can make any definite statements.

Finally, we have included a composite (Figure 3) with overlaid fire data for each year from 19XX to 19XX. Figure X.X-X gives a cumulative picture of the fire frequency. Each pixel is colored to show how many times the pixel has burned in the past 18 years. The area east of Shark Slough and north of the Main Park Road has been burned much more frequently than other parts of the park. Curnutt *et al.* (1998) and Nott *et al.* (1998) discuss the ecological effect of burn frequency, and the contribution of water management decisions. The elevated rate of burning in this area is a principal contributor to the decline in what was once a thriving population of sparrows.

The technique for identifying sparrow habitat finds correlations in the type and structure of the vegetation preferred by the sparrow. However, this method also has immediate value as a tool for evaluating management policy, especially related to water delivery and the protection of productive sparrow breeding areas. Above all, it gives a vivid picture of the vulnerability of the Cape Sable sparrow. The west side population is directly affected by the amount of water entering the park. The east side population has been severely reduced by overburning. The Ingraham prairie population appears to be healthy and resilient, but one only has to look at the great Ingraham fire of 1989 to see the risk to that population as well. If the sparrow habitat were reduced to just the Ingraham area, extirpation by some catastrophe would be only a matter of time.

Maximum vegetation height is lower in "suitable" pixels. Sparrows may require a high perch above their nest for territory defense, but the effectiveness of this perch is decreased if a majority of the

surrounding vegetation is also high (such as in dense stands of *Cladium*). Effective height and the percent cover of two plant species that may provide it (*Muhlenbergia filipes* and *Rhynchospora* sp.), were higher in pixels of suitable habitat. Transects in suitable pixels had lower dead matter cover and higher periphyton cover and biomass. On transects that burned in the past ten years, fire may have decreased the plant cover and effective height, but favored *Rhynchospora* and periphyton growth. Our analysis of years since fire and effect on habitat characteristics is still in progress.

Most of these results agree with previous findings by Lockwood et al. (in prep) and Mayer et al. (in prep). Maximum vegetation height decreased in transects further from sparrow territories, but was highest in the 1m area immediately surrounding the nest. These studies also found effective height to be highest in suitable habitat and around nests. Sparrows may require these clumps for nest sites. Dead vegetation may also provide this structure. Lockwood et al. (in prep) found higher dead vegetation cover at nest sites than in areas further away (but still within a territory), and Mayer et al. (in prep) found dead cover to be highest in transects closest to sparrow territories. We found periphyton cover to be higher in suitable habitat pixels, while Mayer et al. (in prep) found periphyton cover to increase with distance from a sparrow territory.

Muhlenbergia filipes cover was considerably higher in suitable pixels, which is what we expected. The majority of the Cape Sable sparrow population now exists in one habitat type; *Muhlenbergia* prairies. In areas, such as Taylor Slough, where the hydroperiod has become longer and the area wetter, *Cladium jamaicense* can replace *Muhlenbergia* (Olmsted et al. 1980, Kushlan and Bass 1983, Nott et al. 1998, Mayer et al in prep). Since the percent cover of *Cladium* was highly correlated with maximum vegetation height, we would expect that as *Cladium* increases and *Muhlenbergia* decreases in an area, the area would support fewer sparrows. These changes can be picked up by satellite images, and can be tracked spatially and over time.

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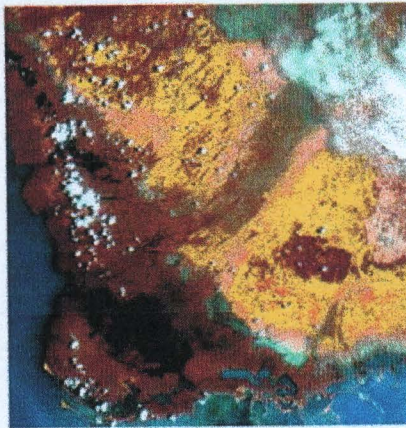
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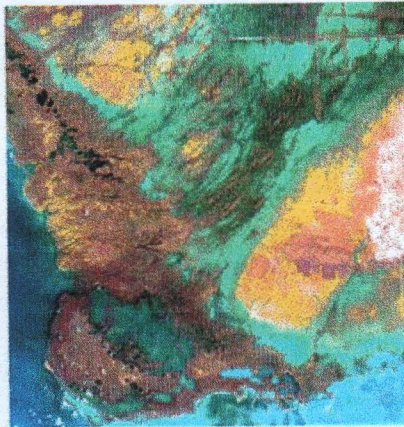
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Cape Sable Seaside Sparrow Habitat

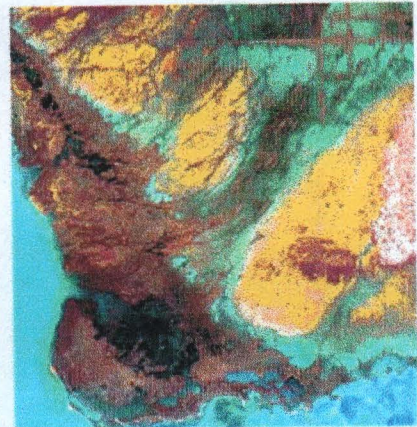
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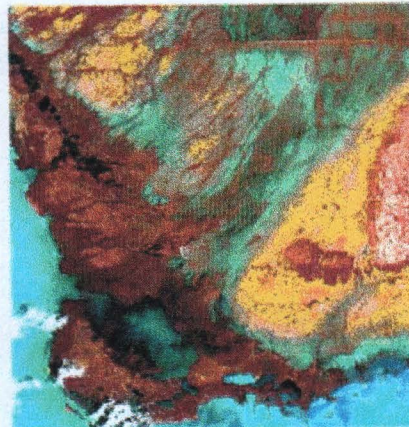
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6 May 1995



21 March 1996

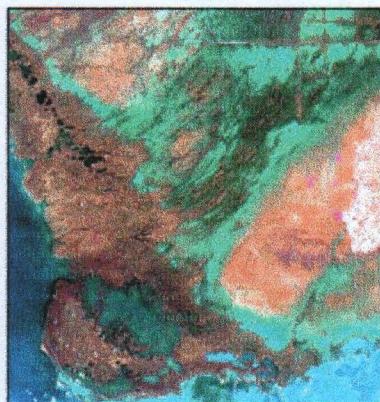


Fire History of Everglades National Park

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1993



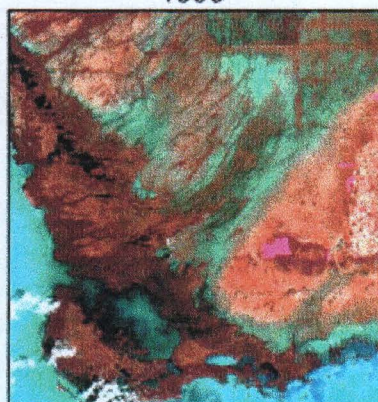
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1995

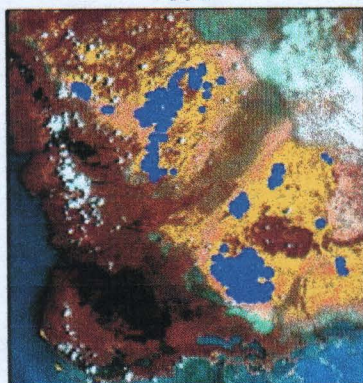


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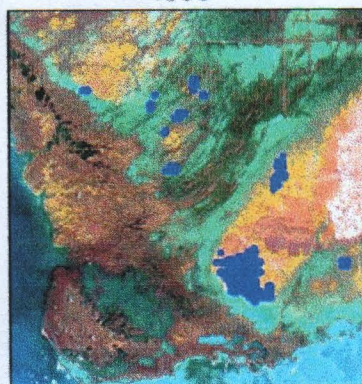


Helicopter Survey Results (1992-1996)

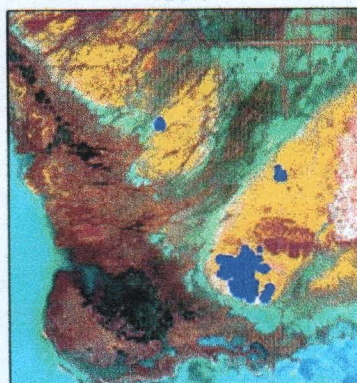
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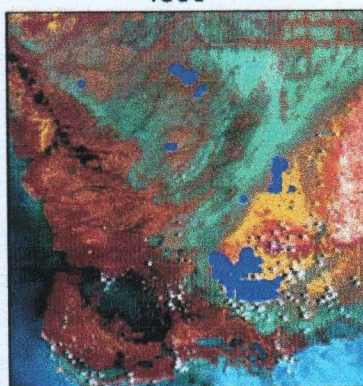
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