National Park Service
U.S. Department of the Interior

South Florida Natural Resources Center
Everglades National Park

RESOURCE EVALUATION REPORT

SFNRC Technical Series
2017:1

Behavioral Observations of the Cape Sable Seaside Sparrow from an Acoustic Array

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Homestead, Florida

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EXECUTIVE SUMMARY

The Cape Sable seaside sparrow is an endangered subspecies endemic to critical habitats of the Florida Everglades and there is concern that environmental change has potential to reduce suitable habitat. Difficulties observing the sparrow limit data informing the sparrows range, population, and importantly its response to environmental conditions. We present analysis of a 5 month monitoring effort using passive acoustics to observe sparrow behavior finding that sparrows avoid treelines while engaged in territory maintenance, continue to vocalize while habitat is inundated, do not vocalize on a day-to-day basis, that individuals can be uniquely identified from acoustic spectral signatures, and quantify the hourly distribution of song. This study demonstrates that the ability to remotely localize animals in both space and time is a significant advantage of array-based monitoring over single microphone recordings, and, the passive nature of the sensing poses no threat of injury to the animals. Application of this technology is well-suited to address questions of animal habitat usage and behavioral responses.

Restoration or expansion of suitable habitat through ecological management has been identified as a viable tactic for survival of the subspecies. These results indicate that removal of artificially introduced woody vegetation to expand suitable habitat may provide such a transition.

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FOREWORD

Everglades National Park is internationally recognized for its unique biological diversity and beauty, classified both as an International Biosphere Reserve and UNESCO World Heritage Site. Roughly 86 percent of the park is designated as wilderness, housing thirty-six federally protected animal species. One species in danger of extinction is the Cape Sable seaside sparrow whose range is restricted to Everglades National Park and Big Cypress National Preserve. The lifecycle of the sparrow is intimately tied to marl-prairie grasslands and the hydrologic cycle, where they thrive at the interface of seasonal inundations and the lower reaches of waist-high sedges and grasses.

The natural hydrologic cycle within the park has been significantly impacted by 20th century water control infrastructure, with continuing tension between goals prescribed in the Comprehensive Everglades Restoration Plan (CERP) and the expected regional hydrologic cycles in some sparrow subpopulations. The ability of the sparrow to colonize new habitats may hold a key to species survival.

This report documents an innovative technical synthesis of acoustic remote sensing and signal processing enabling tracking of male sparrows without the presence of human observers. The primary question posed for this research was whether or not male sparrows avoid artificially introduced woody vegetation, with results supportive of the hypothesis. This has immediate consequence for ecological management since the results suggest that removal of the artificially introduced woody vegetation has potential to expand viable sparrow habitat. Aside from this primary finding, it was also discovered that the birds have individual voices, and can be reliably identified from the spectral features of their song. The report also quantifies daily vocalization behavior and statistics over an entire breeding season providing valuable information for the design and improvement of sparrow monitoring and survey efforts.

Research such as presented here demonstrates the transference of science into actionable ecological management for an endangered species, work that must continue in earnest to afford the best chance of survival for our endangered cousins.

Robert Johnson
Director
South Florida Natural Resources Center
Everglades National Park

November 2016

1 Introduction

Globally, extinction risks appear to be accelerated by climate change and industrialization with concern for up to one sixth of species (*Urban*, 2005; *Bellar et al.*, 2012; *Li et al.*, 2016). Subsequent landscape changes can influence species-specific habitat usage through complex interactions that need to be understood in order to facilitate meaningful assessments of extinction risk (*Keith*, 2008). The Florida Everglades encompasses several such habitats and species including the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) a non–migratory endangered subspecies endemic to open wetlands (*Howell*, 1919; *Nicholson*, 1928; *USFWS*, 1967). Sparrow habitat is classified as critical (*USDOI*, 2007) with concern that environmental change is leading to a reduction in suitable habitat (*Nott et al.*, 1998; *Dean and Morrison*, 2001; *SEI*, 2007).

The sparrow is found predominantly in marl prairies characterized by clumped grasses consisting of muhly grass (*Muhlenbergia filipes*) and short sawgrass (*Cladium jamaicense*). These freshwater plant communities are sustained by hydroperiods that are not too wet, such as those found in freshwater sloughs which may be perennially inundated favoring floating aquatic vegetation, or conditions that are too dry allowing establishment of woody vegetation (*USFWS*, 1999, 2016). Sustenance of these habitats is directly influenced by interannual variations in hydroperiod and water depth such that long-period hydrologic conditions and their associated landscape responses are determinants of sparrow habitat suitability. As such, efforts to influence regional hydrology currently form the basis of ecological management strategies aimed at species preservation (*USFWS*, 2016).

The sparrow is thought to have once proliferated near the Cape Sable region along the southwestern extremity of the Florida peninsula (*Howell*, 1919; *Nicholson*, 1928). However, in response to rising sea level and episodic extreme saltwater inundation from storm surge, this region has changed from freshwater prairie to salt–tolerant floral communities. Contemporary ranges encompass marl prairies between the northern boundaries of Everglades National Park and coastal wetlands. These modern settlements are part of the greater Everglades ecosystem, a system that is modified through control and redistribution of water resources feeding the park as well as by interior landscape features introduced before park establishment. The remarkably flat and uniform topography of the Everglades coupled with subtropical hydrologic cycles imposes a narrow range of habitat suitability such that relatively small changes in hydrologic conditions or topography can allow the emergence and dominance of different ecological communities. One such example is the introduction of treelines along abandoned agricultural drainage ditches. Although elevation differences between ditch excavation spoil banks and the surrounding marsh are less than a meter, it is sufficient to allow woody vegetation to establish and sustain treelines along these ditches. Observations of sparrow behavior suggest that they avoid areas with woody vegetation, perhaps as a mechanism to avoid areas where predators can easily establish (*Lockwood et al.*, 1997; *Dean and Morrison*, 2001) such that these artificially introduced treelines may be reducing suitable sparrow habitat.

Observing the sparrow is difficult. The bird is small, its habitat remote and often difficult to access, only males sing, and only during the breeding season. These difficulties limit data

informing the sparrows' range, population, and importantly their response to environmental conditions. For example, although interannual hydrologic conditions control habitat suitability, relationships between bird abundance and hydrologic variables on daily or weekly time scales are less clear with an apparent insensitivity to hydroperiod (*Beerens and Romañach*, 2016) but preference for drier conditions (*Beerens et al.*, 2016). It has also been suggested that sparrows are behaviorally impacted by inundation (*Dean and Morrison*, 2001; *Beerens and Romañach*, 2016), do not sing when their territory is flooded (*Nott et al.*, 1998) or when water depth exceeds 10 cm (*Lockwood et al.*, 1997). On interannual time scales survival rates are not associated with water levels (*Boulton et al.*, 2009), but within intraannual periods wetter conditions preceding the breeding season favor earlier breeding and larger clutch sizes, presumably from abundant food sources, while nest survival is negatively associated with high average rainfall late in the breeding season (*Baiser et al.*, 2008; *Boulton et al.*, 2011).

The song of a male sparrow provides important conspecific information to other individuals as he establishes a breeding territory early in the season and continues to defend boundaries of his territory throughout the season broadcasting song from grass perches around the territory (*USFWS*, 1999; *Virzi et al.*, 2012). It is also a primary auditory cue for human observers engaged in demographic and census studies. The vocal nature of the male lends itself to remote sensing based on passive acoustics (*Virzi and Davis*, 2012), as well as to experiments using conspecific acoustic cues to influence behavior (*Virzi et al.*, 2012). *Virzi and Davis* (2012) developed a general sparrow song recognizer with an automated spectral classifier capable of detecting the presence of sparrows with a 95% success rate and false-negative (failure to correctly classify a sparrow song) rate of 14%. Based on manual observations and acoustic studies it is thought that males vocalize primarily in the early morning, while little is known about the day-to-day repeatability of an individual's efforts to maintain its territory through vocalization and how such variations are related to specific behaviors.

Data informing questions of sparrow behavior such as song frequency and timing, influences of water levels, as well as questions of habitat suitability have traditionally been answered with human observers conducting field-studies requiring visual, aural, or capture techniques. Here, we augment these observations with long-term observations from a passive acoustic monitor. The monitoring system provides an automated, daily monitoring presence with the ability to localize sparrow songs, allowing us to characterize spatially-explicit sparrow behavior while engaged in territory defense and maintenance. Restoration of suitable habitat through ecological management may be a viable tactic for the survival of the species. These results indicate that removal of artificially introduced woody vegetation to expand suitable habitat may provide the desired restorative effect.

2 Methods

A passive acoustic monitoring system was deployed within Everglades National Park from March 23 through September 2, 2016 in sparrow subpopulation B, coinciding with the sparrow breeding season (March through August) and annual wet-season. The system consisted of a 4-microphone array deployed at 25.33754° N, 80.79918° W in an equilateral triangular arrangement with one microphone at each vertex, and one in the center as shown in Figure

1. Nominal sensor spacing was 1.1 m between the central and peripheral microphones, 2 m between vertex sensors. Sensor coordinates are listed in Table 1. The microphones were model SMM-A1 manufactured by Wildlife Acoustics (*Wildlife Acoustics*, 2016), two automated digital recorders, model SM3BAT, recorded two microphone channels per recorder. Audio recordings were synchronized with GPS timing signals to a 1 millisecond accuracy. Details on the acoustic performance of this system are described in *Park and Kotun* (2017).

Figure 1. Acoustic array on July 8, 2016 consisting of (4) SMM-A1 microphones denoted S1, S2, S3 and S4, (2) SM3BAT digital recorders, and (2) SM3 GPS antenna. The S1 - S2 arm is aligned east - west. Sensor S1 is located at 25.33754° N, 80.79918° W.

Table 1. Sensor coordinates in local reference frame with origin at sensor S1. Sensor S1 is geolocated at 25.33754° N 80.79918° W.

Sensor	East (m)	North (m)
S1	0.000	0.000
S2	-1.103	1.058
S3	-1.630	-1.042
S4	-1.815	0.952

2.1 Recording Schedule

Audio recordings were made 14 times each day in 10 minute blocks. The first five recordings followed a 10-minute-on, 10-minute-off format with the first recording starting 10 minutes before sunrise. The next five recordings were made at 09:00, 10:00, 13:00, 17:00 and 18:00 local time. The final four recordings followed the 10-minute-on, 10-minute-off format with the last recording ending 10 minutes after local sunset.

2.2 Song Identification and Source Localization

Recorded sparrow songs were manually identified with Wildlife Acoustics Songscope software and locations estimated with an automated 3-step processing algorithm. The first step is verification of coherent energy across the acoustic array with cross-spectral coherence computed over 0.5 s windows. If the coherence across the frequency band of 2.5 to 5 kHz at all sensor pairs exceeds a threshold, typically 0.4, then the signals are passed to step 2. The second step is determination of relative sound arrival times at each microphone by cross-correlation, subjected to limits imposed by the known sensor separations. Lastly, an algebraic solution to the GPS navigation equations from the inter-sensor time delays provides a source location estimate (*Wilson et al.*, 2014).

2.3 Water Depth

Water depth is estimated from data observed at the Everglades National Park hydrologic monitoring station NP46 located 2 km south of the acoustic monitoring location. The estimate is derived from the water depth difference between the observed data at NP46 and water depth estimated at the acoustic monitor by the Everglades Depth Estimation Network (EDEN) (*Telis et al.*, 2015). The difference is 3.0 cm so that reported depths are the observed depth at NP46 gauge minus 3.0 cm.

2.4 Territory Mapping

Cape Sable seaside sparrow territory boundaries were mapped in ArcMap 10.2.2 using the Geospatial Modeling Environment spatial analysis tools for home range estimation. Territory data were collected on a 68 ha demographic study plot located southwest of the acoustic array. Four replicated line transect surveys were conducted on the study plot between April 5 and June 27, 2016 to detect breeding sparrows. The study plot was subsequently revisited to collect perching points for all male sparrows detected on the surveys. Points were collected using a handheld GPS device and later entered into ArcMap for analysis. The first step in the analysis used the kernel density estimation (KDE) tool to provide an estimate for a probability density function of perching points. Model parameters were applied consistently among KDE estimates for all individuals: bandwidth = SCV; cell size = 10 m; extent = study plot boundary. Once the KDE estimate for each individual was calculated, the isopleth analysis tool was used to calculate the 95% home range isopleth for each territory.

3 Results

A total of 3373 songs were recorded over the period March 23 through September 2, 2016 of which 1417 were localized, although no songs were detected after July 24, 2016. A song of exceptional clarity recorded at close range on May 23, 2016 exemplifies the sparrow song as shown in the spectrogram of Figure 2. Previous recordings allow one to distinguish a two-note preamble followed by a shrill trill. Here we find a three-note preamble followed

by the trill, with the interesting observation that the three-note sequence follows a musical major scale harmonic sequence of octave - fifth - root. Features above 5 kHz are normally not present in sparrow recordings at larger distances from the microphone as these components are relatively weak in amplitude, but here we observe high-frequency components of the initial note and trill between 5 and 6 kHz.

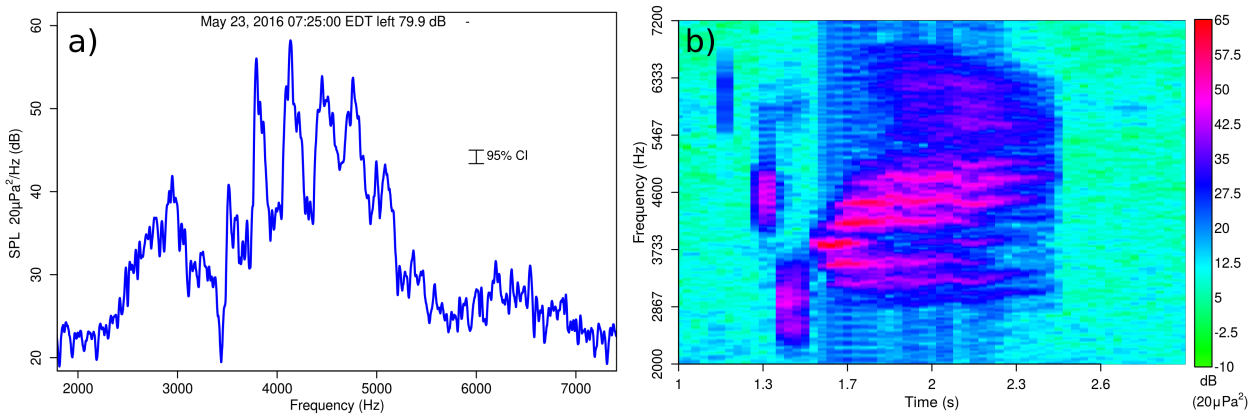

Figure 2. a) Power spectral density of a song recorded at close range on May 23, 2016 at 07:25:00 EDT. b) Spectrogram of the song.

3.1 Source Level

The traditional method to assess sparrow abundance consists of transporting an observer to a study plot either on foot or by helicopter where the observer listens for songs or visually sights birds over a period of 7 to 10 minutes with specific plots visited once per season. More detailed demographic studies establish plots that are visited daily throughout the breeding season, again relying on aural or visual detections. Population estimates derived from these point or line-transect surveys require an estimate of the maximum detection range (*Buckland*, 2006), and in the auditory case this estimate can be analytically determined if the animal radiated acoustic power, or source strength, is known along with detection parameters such as the noise level and observer auditory acuity. We were able to estimate the source strength of the May 23 song from power spectral densities at the 4 microphones exemplified in Figure 2 where we note the bulk of acoustic power is located in the frequency band from 3.5 to 5 kHz. Integration of the spectral sound pressure levels and addition of a transmission loss estimate from the source location to the microphones results in an estimated sound pressure level of 85 ± 3 dB//20μPa. This compares well to the mean maximum broadcast amplitude of 82 dB//20μPa determined by *Rindy et al.* (2008) for the song sparrow (*Melospiza melodia*).

3.2 Spectral Uniqueness

Virzi and Davis (2012) developed a general song recognizer based on an ensemble of individual songs. Here we find that individual birds present a unique spectral signature. Figure 3 shows a spectrogram of three individuals denoted A, B and C, competing simultaneously

on June 10, 2016. Sparrow C consistently vocalizes with emphasis in the upper frequency range from 4 to 5 kHz with a distinctive frequency modulation of the trill near 4.7 kHz. Bird A had perhaps the most robust vocal presentation with emphasis on the preamble note near 2.8 kHz. Bird B emphasizes the 3.7 kHz note at the beginning of the trill, often produced a preamble note near 5 kHz, and exhibited a declining frequency modulation during the trill. These unique spectral signatures were first noticed on June 10, 2016 and last recognized on July 22, 2016 indicating that individual spectral signatures are stable over a period of at least six weeks and that spectrographic identification can be a viable complement to capture and banding techniques.

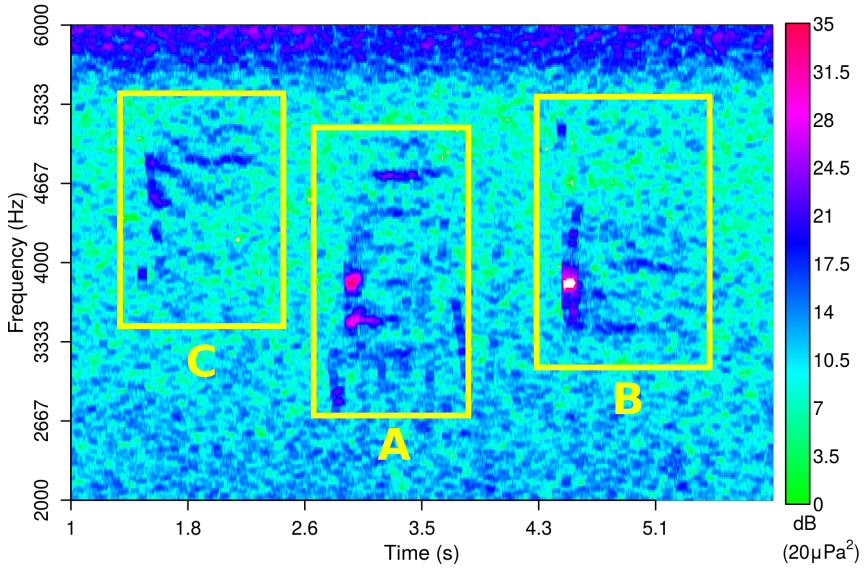

Figure 3. Spectrogram of three individuals denoted C, A and B respectively from left-to-right recorded June 10, 2016 at 06:44:49 EDT.

3.3 Behavioral Observations

3.3.1 Territory Defense

On June 10, 2016 between 06:43 and 06:52 there was an intense vocal exchange between sparrows A, B and C. Initially at 06:43, C was the sole sparrow observed vocalizing from a bearing of 268 ±12°. At 06:43:42, A was detected at a bearing of 280 ±7°, wherein C and A subsequently engaged in counter-singing. At 06:44:37 B was first detected at a bearing of 273 ±9°, and all three continued counter singing until 06:45:08, after which C was not detected. At 06:45:29 A moved to a bearing of 253 ±18°, remaining there until 06:46:45. From 06:50:15 until 06:50:57 B moved to a bearing 250 ±10°, followed by repositioning of A to a bearing of 199 ±5° from 06:51:07 until 06:51:57. At 06:51:08, B moved to a bearing of 200 ±6°, both A and B continued counter-singing until 06:52 after which no songs were recorded. We interpret these movements as evidence that bird A or B maintains a territory to the west or southwest of the array, and that this encounter could represent the efforts of B to defend his range. These observations are consistent with independently conducted

demographic surveys (below) identifying nest locations to the west (265°) and southwest (230°).

3.3.2 Helicopter

Current survey methods assume that the birds are indifferent to the presence of a helicopter such that the arrival and departure of the machine produces no change in behavior. Survey periods from helicopter observers are typically 7 or 10 minutes. On May 25, 2016 a helicopter was recorded in close proximity from 07:04 to 07:09. Prior to aural evidence of the helicopter sparrows were singing until 07:06 when the helicopter noise reached peak intensity at which time all sparrow songs ceased. The helicopter moved away after 07:08, with the last detectable sounds arriving at 07:09. Sparrow songs resumed approximately two minutes after the helicopter was inaudible, indicating that the birds ceased singing for approximately 5 minutes in response to the helicopter incursion.

3.3.3 Red-shouldered Hawk

On May 4, 2016 from 07:36:00 to 07:36:14, and from 07:42:26 to 07:43:08, a red-shouldered hawk was recorded near the monitor. Sparrow songs were also recorded during these intervals allowing us to examine their relationship. During the first interval the hawk approached from the southwest traveling to the northwest. During the second interval the hawk continued to the northeast, then flew back around to the southwest and west. Examination of the first interval found continuous sparrow songs at approximately 5 second intervals before, during, and continuing after the hawk calls for a period of 2 minutes 15 seconds. The second period (07:42:26–07:43:08) was more challenging to aurally detect and classify sparrow songs as their amplitudes were weaker and background noise levels had increased, however, the hawk calls are much clearer. A sparrow vocalization was evident 1.5 seconds before the hawk call initiates, however, it is not clear if they continue during the hawk calls. Sparrow songs were found again 1 minute 15 seconds after the hawk calls end. We interpret these data as suggestive that male sparrows engaged in territory defense are indifferent to the presence of a red-shouldered hawk.

3.3.4 Daily Song Distribution

Sparrow population surveys based on aural detection are dependent upon the time of day which the birds are most likely to sing. The continuous presence of the monitoring system allowed us to assess the hourly distribution of song detection with results presented in Figure 4. Although the recording schedule did not record equal intervals throughout the day, there is evidence of a bi-modal song distribution with the majority of songs between 6 AM and 8 AM local time, and another less-intense period from 6 PM to 9 PM local time.

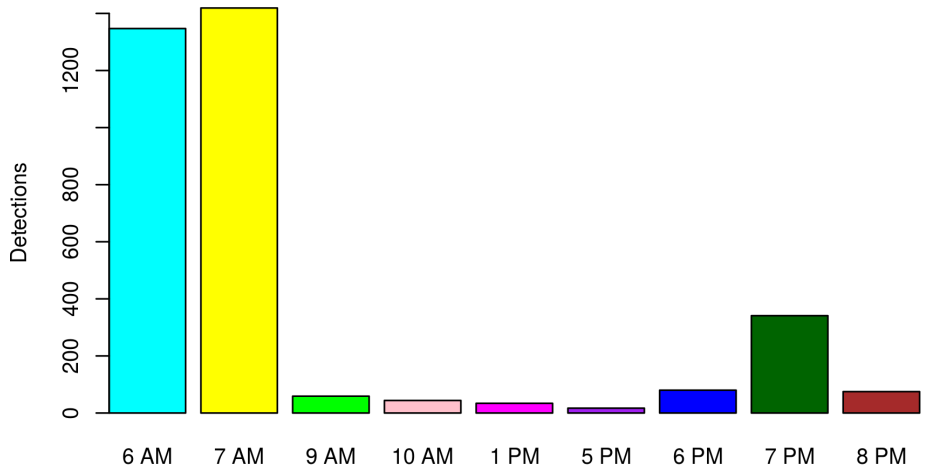

Figure 4. Hourly distribution of song detections. Note that data were not recorded every hour of the day. The recording schedule is detailed in the methods section.

3.3.5 Water Levels

As discussed above, long-term hydrologic conditions dominate habitat suitability for the sparrow, while behavioral responses to short-term conditions are less-clear. In Figure 5 we compare the number of songs recorded each day with water level. The water table was generally below ground until May 18th, when a large rain event (9.1 cm) abruptly inundated the marsh with the area remaining submerged for the remainder of the study. 3025 (90%) of the songs were recorded with inundated habitat, and 635 (19%) when the water depth exceeded 10 cm indicating that sparrows continue to engage in song and territory maintenance during inundated conditions. There does not appear to be an obvious relationship between number of songs recorded per day and water depth.

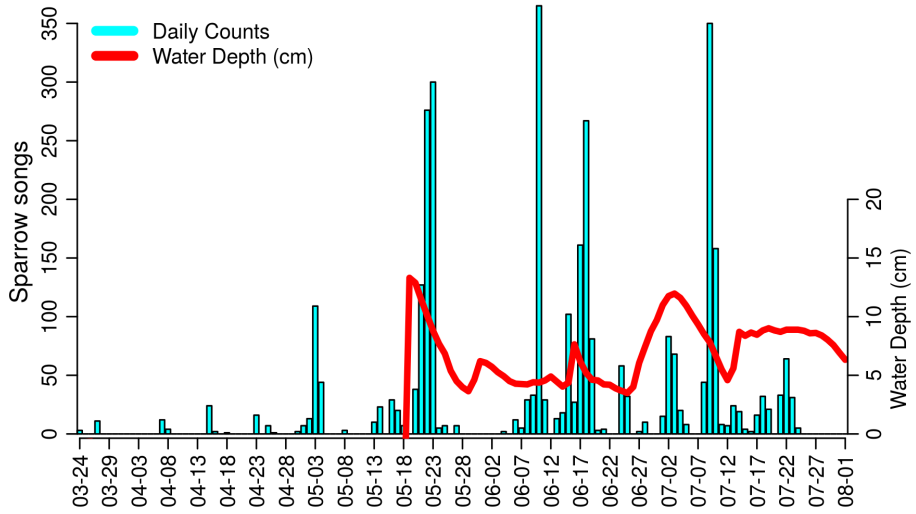

Figure 5. Total daily number of songs and water depth.

3.3.6 Daily Song Clustering

To our knowledge the counts shown in Figure 5 are the longest continuous, autonomous observations of sparrow songs and reveal that song activity tends to occur in clusters. Days of peak activity are often preceded by days with an increasing number of songs, and these clusters are separated by days with no songs. It may be that the observed clustering is related to initiation of multiple clutches, as sparrows are known to engage 1 to 3 nesting attempts per season (*Boulton et al.*, 2011). The episodic nature of these observations should be considered when conducting aural surveys.

3.3.7 Treeline Avoidance

A particular strength of the monitoring system is the ability to localize songs with the resultant probability density of azimuthal bearings from all detections shown in Figure 6. Also shown are 95th percentile isopleths of territories and two nest locations determined from independent line-transect surveys of demographic study plots. Territories west and southwest of the array are consistently localized by the array, with evidence of an additional territory northwest of the array outside of the line-transect survey boundary (green line). The azimuthal distribution of songs indicates that males avoided the treeline with 88% of songs localized to bearings outside of the sector from 20° to 160° and 94% outside the sector from 40° to 140°.

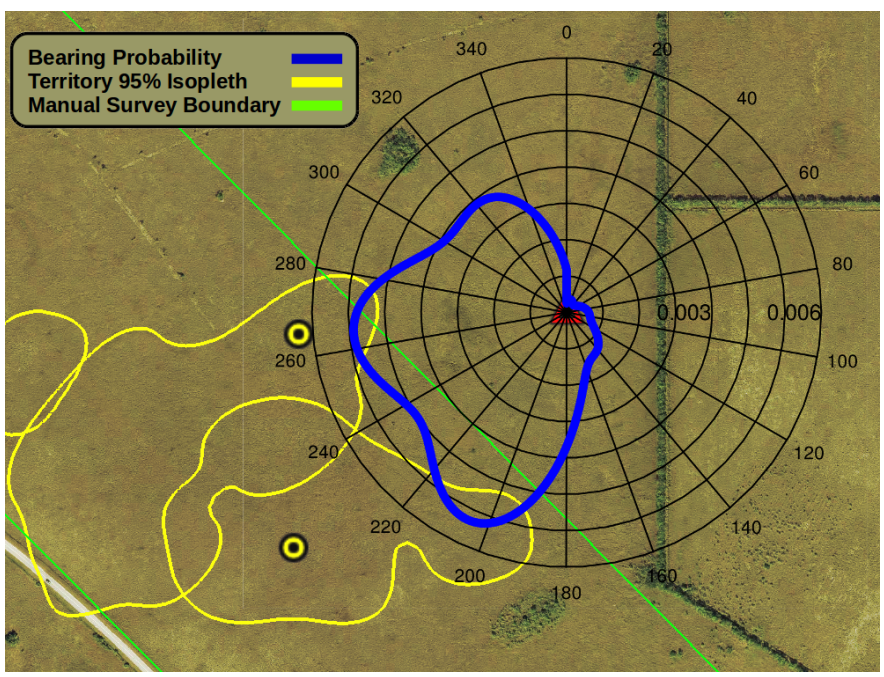

Figure 6. Aerial photograph of deployment location (25.33754° N 80.79918° W) with polar plot of detected bearing probability (blue). Polar grid radial azimuths are aligned to bearings with respect to north. The linear landscape features east of the deployment are treelines introduced by abandoned agricultural drainage canals. Each circle of the polar grid corresponds to a radial interval of probability density 0.1% and linear dimension of 36 m. Black and yellow circles mark nest locations, yellow contours are 95th percentile isopleths of territories derived from territory mapping on demographic study plots, diagonal green lines indicate survey boundaries.

4 Discussion

Observation of the Cape Sable seaside sparrow traditionally relies on manual field surveys to visually sight, aurally identify, or capture the bird for demographic and behavioral studies. *Virzi and Davis* (2012) first applied passive acoustic remote sensing to sparrow monitoring, and here we extend their work with the addition of a multi-element acoustic array capable of localizing sparrow songs. The array autonomously records a preprogrammed sequence of time blocks based on local sunrise and sunset times, is continuously present, and once deployed provides minimal habitat disruption.

The acoustic nature of the sparrow song has been clarified with a high-resolution spectral analysis revealing a descending three-note preamble followed by the trill. We were also able to estimate the radiated acoustic source strength of a sparrow song as 85 ± 3 dB//20μPa. The source level is required to estimate maximum aurally observable distances, a necessary component of distance-sampling techniques for population estimates. The data also suggest that male vocalization generally follows a bimodal daily distribution with most activity between 6-8 AM, and a secondary peak between 6-9 PM. Inspection of song spectral properties suggests that individual males can be uniquely identified and that these unique signatures are stable over a period of at least six weeks. Combining spectral uniqueness with temporal changes in song location provides a method to passively record behavioral dynamics without direct, real time manual observation.

The known range of the sparrow is within the Florida Everglades, a landscape that is ecologically driven by hydrologic conditions governing the spatiotemporal extent of suitable habitats. Specifically, interannual hydrologic conditions control the development and sustenance of open grasslands favored by the sparrow, and the birds have adapted their breeding cycle to precede and coincide with the annual wet season. Intraannual variations in water level can have positive or negative impacts on nesting success depending on the timing of hydrologic conditions, while short-term water levels have not been clearly associated with sparrow song behavior. Our data find that male sparrows continue to vocalize when their territory is inundated, with no obvious dependence on water depths between 3 and 13 cm.

Examination of the number of daily songs over the deployment period finds that song activity was recorded in clusters with days of peak activity preceded by days with increasing numbers of songs. We also note that these clusters are separated by days where no songs were recorded. Identification of environmental covariates with these clusters may reveal useful information regarding sparrow vocalization behavior. It further suggests that abundance surveys should visit survey sites more than one day per season.

The ability to localize songs both in space and time represents a significant advantage of an array-based monitoring station over single microphone recordings with the resultant spatial distribution of songs indicating a territory exists to the north of the array. This area was not manually surveyed in the demographic study suggesting that acoustic source localization deployments early in the breeding season may inform subsequent manual field-observations. Along with identification of an apparent indifference to water levels and a red-shouldered hawk when male sparrows are engaged in vocalization, perhaps the most ecologically pertinent finding is that male sparrows avoided an artificially introduced treeline suggesting that ecological management aimed a species preservation should investigate remediation methods to return these habitats to their natural condition.

5 Conclusion

Owing to its small population size, limited distribution, and concerns over habitat sustainability, the Cape Sable seaside sparrow was one of the first species listed under the Endangered Species Preservation Act of 1967, a status that remains in place today. Expansion of suitable habitat is recognized as an important strategy for preservation of the subspecies (*SEI*, 2007) and we find that male sparrows overwhelmingly avoid treelines composed of woody vegetation when vocalizing in defense of their breeding territories. Since there have been past successes in ecological restoration by the removal of invasive woody vegetation (*Ewel*, 2013; *NRC*, 2007), this work suggests that the removal of woody vegetation and treelines introduced by remnant agricultural features may provide opportunities for habitat expansion.

This work also demonstrates the utility of passive acoustic source localization to monitor animal behavior over an entire season. Relevant findings are that sparrows do not sing every day during the breeding season, an important factor in the design and conduct of manual demographic and population surveys, and, that acoustic arrays have potential to detect sparrow territories that were not captured by manual surveys. Further, it is shown that individuals can be uniquely identified by the spectral signature of their song, that vocalizations do not exhibit a clear dependence on water depth, that there is an approximately 2-5 minute refactory period of vocalization in response to a helicopter, and, an apparent indifference of male sparrow vocalization to the aerial presence of a red-shouldered hawk.

REFERENCES

Baiser, B., Boulton R.L., and Lockwood J.L. 2008. Influence of water depth on nest success of the endangered Cape Sable seaside sparrow in the Florida Everglades. Animal Conservation 11: 190-197.

Bellar, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. 2012. Impacts of climate change on the future of biodiversity. Ecology Letters, 15 (4): 365377. DOI:10.1111/j.1461-0248.2011.01736.x

Beerens. J. M. and Romañach S. S. 2016. Using Cape Sable Seaside Sparrow Distribution Data for Water Management Decision Support. Submitted to U.S. Fish & Wildlife Service in contribution to the Cape Sable Seaside Sparrow Biological Opinion, U.S. Geological Survey, Wetland and Aquatic Research Center, 3 March 2016, 20 p., pubs.er.usgs.gov/publication/70170126

Beerens, J.M., Romañach, S.S., and M. McKelvy. 2016. Evaluating water management scenarios to support habitat management for the Cape Sable seaside sparrow: U.S. Geological Survey Open-File Report 2016-1107, 62 p., http://dx.doi.org/10.3133/ofr20161107.

Boulton R.L, Lockwood J.L., Davis M.J., Pedziwilk A., Boadway K.A., Boadway J.J.T., Okines D., and S.L. Pimm. 2009. Endangered Cape Sable Seaside Sparrow Survival. Journal of Wildlife Management, 73 (4): 530-537, DOI: 10.2193/2007-467.

Boulton, R.L., B. Baiser, M.J. Davis, T. Virzi, and J.L. Lockwood 2011. Variation in laying date and clutch size: the Everglades environment and the endangered Cape Sable seaside sparrow. The Auk 128: 374-381.

Buckland, S.T. 2006. Point transect surveys for song-birds: robust methodologies, The Auk 123: 345357.

Dean, T. F. and J. L. Morrison. 2001. Non-breeding season ecology of the Cape Sable seaside sparrow. Final report to the U.S. Fish and Wildlife Service, Vero Beach, Florida.

Ewel, J. 2013. Case Study: Hole-in-the-Donut, Everglades. Novel Ecosystems: Intervening in the New Ecological World Order, 9-15. doi:10.1002/9781118354186.

Howell, A. H. 1919. Description of a new seaside sparrow from Florida. Auk 37: 86-87.

Keith, D.A., H. R. Akakaya, W. Thuiller, G.F. Midgley, R.G. Pearson, S.J. Phillips, H.M. Regan, M.B. Arajo, T.G. Rebelo. 2008. Predicting extinction risks under climate change: coupling stochastic population models with dynamic bioclimatic habitat models. Biology Letters 4 (5): 560-563. doi:10.1098/rsbl.2008.0049.

Li H., Xiang-Yu J., Dai G., Gu Z., Ming C., Yang Z., Ryder O.A., Li W., Fu Y., and Zhang Y. 2016. Large numbers of vertebrates began rapid population decline in the late 19th century. PNAS 113 (49): 14079-14084, doi:10.1073/pnas.1616804113.

Lockwood, J. L., K. H. Fenn, J. L. Curnutt, D. Rosenthal, K. L. Balent and A. L. Mayer. 1997. Life history of the endangered Cape Sable Seaside Sparrow. Wilson Bulletin 109: 720-731.

National Research Council (2007). Progress Toward Restoring the Everglades: The First Biennial Review, 2006. Washington, DC: The National Academies Press. https://doi.org/10.17226/11754

Nicholson, D. J. 1928. Nesting habits of seaside sparrows in Florida. Wilson Bulletin 40: 234-237.

Nott M. P., Bass O. L., Fleming D. M., Killeffer S. E., Fraley N., Manne L., Curnutt J. L., Brooks T. M., Powell R. and Pimm S. L. 1998. Water levels, rapid vegetational changes, and the endangered Cape Sable seaside-sparrow, Animal Conservation 1: 23-32.

Park J. and Kotun K. 2017. Spectral coherence and hyperbolic solutions applied to time difference of arrival localisation, Applied Acoustics, doi:10.1016/j.apacoust.2017.08.026. https://doi.org/10.1016/j.apacoust.2017.08.026

Rindy C., Anderson R., Searcy W., Peters S. and Nowicki S. 2008. Soft Song in Song Sparrows: Acoustic Structure and Implications for Signal Function, Ethology 114: 66267.

Sustainable Ecosystems Institute (SEI). 2007. Everglades Multi-Species Avian Ecology and Restoration Review. Final Report submitted to United States Fish and Wildlife Service. www.fws.gov/verobeach/CERPPDFs/Everglades2007FinalReport.pdf

Telis, P.A., Xie, Zhixiao, Liu, Zhongwei, Li, Yingru, and Conrads, P.A. 2015. The Everglades Depth Estimation Network (EDEN) Surface-Water Model, Version 2: U.S. Geological Survey Scientific Investigations Report 2014-5209, 42 p., doi 10.3133/sir20145209. sofia.usgs.gov/eden/

Urban, M.C. 2005. Accelerating extinction risk from climate change. Science 348 (6234): 571-573. DOI: 10.1126/science.aaa4984.

U. S. Fish and Wildlife Service (USFWS) 1967. Endangered Species. Federal Register, Vol. 32, No. 48, 4001.

U. S. Fish and Wildlife Service (USFWS). 1999. South Florida multi-species recovery plan, Cape Sable seaside sparrow. Fish & Wildlife Service Reference Service, 5430 Grosvenor Lane, Suite 110, Bethesda, MD 20814, pp. 4-345 : 4-369. www.fws.gov/verobeach/MSRPPDFs/CapeSableSeasideSparrow.pdf

U. S. Fish and Wildlife Service (USFWS). 2016. Biological Opinion for the Everglades Restoration Plan - 2016. South Florida Ecological Services Office, Vero Beach, FL.

United States Department of the Interior (USDOI) 2007. Endangered and Threatened Wildlife and Plants; Critical Habitat Revised Designation for the Cape Sable Seaside Sparrow; Final Rule. Federal Register, Vol. 72, No. 214, 62736-62766. www.gpo.gov/fdsys/pkg/FR-2007-11-06/pdf/07-5460.pdf

Virzi, T., Boulton, R., Davis, M., Gilroy, J., and Lockwood, J. 2012. Effectiveness of Artificial Song Playback on Influencing the Settlement Decisions of an Endangered Resident Grassland Passerine. The Condor 114 (4): 846-855. doi:10.1525/cond.2012.100197

Virzi, T. and Davis M.J. 2012. C-111 Project and Cape Sable seaside sparrow subpopulation D annual report - 2012. Report to the South Florida Water Management District, November 2012, 56 p.

Wildlife Acoustics 2016. Song Meter SM3. www.wildlifeacoustics.com/products/song-meter-sm3

Wilson, D. R., Battiston M., Brzustowski J. and Mennill, D. J. 2014. Sound Finder: a new software approach for localizing animals recorded with a microphone array, Bioacoustics 23 (2): 1-14.

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