

The role of fire in sustaining populations of Cape Sable seaside sparrows within the southern Everglades.

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Introduction

Between 1948 and 1992 the wetland areas of Everglades National Park experienced 752 fires for an average of 17 fires per year (Gunderson and Snyder 1994). The plants and animals of this region are adapted to these frequent burns (Robertson 1953, Egler 1952). Fire is a necessary component of the Everglades. It maintains a habitat mosaic and prevents hardwood shrubs from invading the characteristically open Everglades marshes (Taylor 1983). The Cape Sable seaside sparrow (*Ammodramus miratimus mirabilis*), an endangered subspecies endemic to the southern Everglades, relies on a specific type of Everglades marsh (Werner 1975). The sparrow places its nest near the ground, imbedded in the base of graminoid plants such as muhly grass (*Muhlenbergia fillipes*), black-top sedge (*Schoenus nigra*), and sawgrass (*Cladium jamicense*) (Lockwood et al. 1997, Werner 1975). This vegetation association is restricted to seasonally dry marshes imbedded in marl, inorganic soils (Gunderson 1994). As it has proved difficult to delineate the extent of these marl prairies, the role of fire in their maintenance is largely unknown. However, sparrow biologists have long believed that fire was critical for maintaining suitable breeding habitat (Werner 1975, Taylor 1983, Kushlan and Bass 1983, Curnutt et al. 1998). We first review this work, making explicit the proposed mechanistic links between fire, sparrow occupancy, vegetation, and soil depth. We then test aspects of this mechanism by combining two long-term data sets, one on sparrow density and the other on the spatial extent of fire within the southern Everglades.

The History of Sparrows and Fire

The first accounts of the effects of fire on sparrows portrayed burning as a threat (Stimson

1956, 1968). Stimson (1956, 1968) recorded the loss of pockets of sparrows due to the effects of recent fires. When fire moves through the open marshes of the Everglades, grass serves as the primary fuel (Gunderson and Snyder 1994). Given that sparrows place their nests near the ground and well within the grass layer, a fire that burns during the breeding season (the driest time of the year) will almost certainly cause the destruction of most active nests. It is not as clear whether fire causes the death of adults since they are highly vagile and there are no obvious impediments to their escaping fire through flight.

Beginning with the observations of H. Werner in the 1970s (Werner 1975, Werner and Woolfenden 1983), fire began to emerge as an important component to sparrow management. Werner deduced, based mostly on incidental observations within and around his study site near the Taylor Slough bridge, that sparrows were capable of recolonizing a burned site after one year post-fire. He also observed a decline in sparrow density within sites that burned three and four years earlier. This led Werner to the conclusion that fire was a necessary component to the maintenance of sparrow populations. Werner and others believed fire prevented shrub invasion and decreased the amount of dead vegetation that builds in post-fire years (Werner and Woolfenden 1982, Kushlan and Bass 1982, Taylor 1982). They concluded that too much of either will transform marl prairies into an unsuitable state for sparrows.

D. Taylor conducted a follow-up study in 1981 using the same study population as Werner. Taylor recognized that the rate at which vegetation regenerates post-fire is the principle determinant of how quickly sparrows will return to a site (Taylor 1983). Taylor

showed that vegetation grows quickly over deep soils and thus will return to pre-burn biomass levels two or three years faster than vegetation over shallow soils. Based on this, Taylor suggested that sparrows would respond to previously burned sites differently based on soil depth. Taylor did not attempt to quantify the 'four-year rule' of Werner.

Together these two biologists outlined a mechanistic relationship between fire, vegetation growth, soil depth, and sparrow density. Figure 1 illustrates how this mechanism operates under normal conditions. Sites that burn immediately become ill-suited for sparrow occupancy. Burned sites lack any vegetation cover. Some cover is required for the placement of nests and the concealment of adults and recently fledged young from predators (Werner 1975, Dean and Morrison 1998, section V).

Sites that have deep soils will begin to re-sprout vegetation almost immediately.

Sawgrass, the principle graminoid of Everglades marshes, can reach heights of 20cm to 40cm within two weeks post-fire as it's growing bud lies underneath the soil and does not burn (Kushlan 1990). The rapid re-growth of sawgrass, and supposedly other marl prairie vegetation, produces enough cover for sparrow use often by the next breeding season (Taylor 1983, Werner 1975). The same can not be said of vegetation overlying shallow soils. Re-growth here is much slower. Thus, it takes far longer for the burned area to accumulate enough cover such that it once again becomes attractive to sparrows.

The second component of the Werner-Taylor mechanism, is the rate at which habitat becomes unsuitable after fire (Figure 1). Burned sites will continue to accumulate

biomass, some live and some dead. The ratio of live to dead is initially weighted heavily toward live growth, but as time passes, the ratio tends in the other direction. It is the accumulation of dead vegetation that is proposed to render a site unsuitable for sparrow occupation. Dead vegetation tends to lie horizontal to the soil surface creating impenetrable mats (Werner 1975). The presence of these mats may prohibit sparrow movement on the ground, a characteristic behavior of this subspecies that allows it to enter the nest undetected, forage, and hide from predators (Werner 1975, Lockwood et al. 1997).

Although not often made explicit, the Werner–Taylor mechanism predicts that over deep soils this transition will occur much sooner than over shallow soils. Thus, sparrows may occupy a burned site sooner if the soil is deeper. However, they will soon find themselves in sub-optimal habitat. Burned sites that have shallow soils will not support sparrows until several years after the effects of the fire have been ameliorated, however sparrows that occupy these sites will enjoy prime conditions for longer periods of time.

This mechanism allows us to make several predictions about the relationship between fire, soil depth, vegetation and sparrow density. First, the rate that vegetation increases after a fire should be faster over deep soils than over shallow soils. Second, sparrow density should increase as vegetation cover increases. If these two predictions are correct, we can make a second set that includes sparrow density. First, increases in sparrow density post-fire (i.e. the slopes of lines in Figure 1) should be distinctly different among sites with deep soils versus those with shallow soils. Second, the lag time

between a fire and sparrow re-occupation should be longer among sites with shallow soils than among those with deep soils. Finally, maximum sparrow density should be attained earlier in deep soil sites than in shallow soil sites. We test each of these predictions below.

Data sets

Beginning in 1981, and then continuing from 1992 to present, ENP personnel have conducted a range-wide survey of the Cape Sable seaside sparrow. Points are laid out along a 1km grid that encompasses all known locations of the sparrow. These count locations are visited once every breeding season (April and May) via helicopter. Each point is referenced with a latitude/longitude coordinate generated from a Global Positioning System (GPS). At these points, once the helicopter has flown off, the observer records the number of birds seen, or heard singing. Other information is also recorded such as water depth, plant association, and percent cover of vegetation. For a more detailed account of the methods and assumptions of these counts see Curnutt et al. (1998) and Kushlan and Bass (1983).

Through aerial surveys, ENP fire managers have mapped the spatial extent of all fires occurring within park boundaries since 1982. This coverage includes the entire range of the Cape Sable seaside sparrow. We overlay these fire maps onto the results of the point count surveys in order to test each of the above predictions. Thus, unlike most studies of the effects of fire on vertebrate populations (Whelan 1995), we have the luxury of using two long-term data sets that encompass all of the sparrow's range.

As part of an overall review of sparrow biology, Curnutt et al. (1998) combined these same two datasets to understand the effects of fire. After instituting a series of rules that excluded point count locations that were likely influenced by factors other than fire (e.g., excessive water, and shrub invasion), Curnutt et al. (1998) found two significant relationships. The first contradicts the 'four year rule' of Werner. The mean number of sparrows recorded was positively related to time since fire and no evidence of a drop in density occurred up to the limit of their records (10 years post-fire). Second, sparrow numbers were highest in areas that burned once or twice within a 10 year period. Very frequent fires (one fire every one or two years) appeared to preclude sparrow occupancy.

As we use the same datasets, updated with information to 1999, we consider our results an extension of Curnutt et al. (1998) and do not re-evaluate their conclusions. However, we do institute a slightly different set of rules that are designed to more efficiently filter non-fire effects. Some of these are related to sampling and some to the physical condition of the point count sites.

Data Processing

The first modification to the methods of Curnutt et al. (1998) is to recognize the imprecision of the point count locations. Although not accurately known, we estimate an 200m error associated with the yearly location of the actual spot in which point counts are made. It is not always possible to land the helicopter in an exact location due to wind conditions and because the GPS units used to locate point counts have an inherent error

of between 20 and 200m. Given that the detectability radius around each observer is assumed to be another 200m (Kushlan and Bass 1983), we delineated a 400m circle around the lat/long coordinate of each point count location. It is within this circle that we are certain the birds counted actually reside.

Second, we assumed there is a similar error in recording the edges of fires. In the 1980s fire maps were created using photointerpretation. Beginning in the early 1990s, fires were mapped using GPS either by walking or flying around the perimeter of the burn (K. Thatcher pers. com.). The error surrounding the generation of these maps is also unknown. However, through limited comparisons of aerial to GPS interpretation of fire perimeter we determined that the delineation of fire edges has a maximum error of 200m. Thus, we consider any point count location 'burned' if 50% or more of the area encompassed within 400m around that point are mapped as 'burned'.

The remaining modifications relate to the physical conditions of the survey sites. As in Curnutt et al. (1998), we exclude all point count locations in which sparrows have not been recorded during the period of record. These sites may not hold sparrows for reasons other than fire but for which we have no measure (e.g., shrub invasion). We also exclude sparrow populations west of Shark River Slough as they are known to have been influenced by extensive flooding since 1992 (Nott et al. 1998).

Curnutt et al. (1998) further exclude all point counts in which water depths of over 1cm were recorded at survey time. We do not incorporate the same filter here. Our data

shows a negative correlation between water depth and number of sparrows counted (linear regression, $P = 0.0044$, $df = 1$), however the explanatory value of water depth is very low ($R^2 = 0.006$). The maximum water depth recorded during any survey was 16cm. The vast majority of sites (98%) held less than 5cm of water at the time of survey. Based on detailed demographic studies we believe these water levels will not influence the presence, or detection rate, of sparrows (JLL pers. obs. and section IV). Thus, we did not exclude any point count locations based on water depth. These filters left 139 point count locations and 1606 density estimates.

All mapped fires and survey results were converted into ArcView format. Associated information, such as date of fire ignition, was also included. We delineated a grid of 400m radius circles that represent the point counts. As we were only interested in fires that effect these circles, this left XX fires in the record. Using ArcInfo, we attached the date of last fire to each count of sparrows for every year counts were made. Thus, for every sparrow count and for every year of the survey, we have an associated time since last fire. For some analyses, records are separated into year classes (e.g., one year since fire) with every 'year' starting after the completion of the range-wide survey (no later than June 1).

In the 2000 range-wide sparrow survey, the observers recorded the soil depth at each point count location by sinking a meter stick into the soil until it hit bedrock. This was done six times at every location to account for extreme microtopographic differences in soil depth. We used the median of these six measurements as a guide to the soil depth

within each 400m point count zone. Although very hot fires can burn organic peat soils, and thus lower soil depths in other Everglades marshes, the inorganic marl soils associated with sparrow habitat do not burn (Kushlan 1990). Soil accretion rates are largely unknown in the southern Everglades, but soil deposition is believed to operate at the of scale centuries (Gunderson 1994). Thus, the soil depths recorded in the 2000 sparrow point count very likely reflect predominate conditions over the entirety of our records.

Soil depth ranged from 0 to 65cm, with the median at 12cm. We excluded sights with no measurable soil depths recorded (e.g., observer was standing on pinnacle rock outcropping) and two sites with extreme soil depths (i.e. over 50cm). We divided the point count locations into two groups, shallow or deep soils, based on the median soil depth calculated with these extreme points excluded (12.17). As the distribution of soil depths is approximately normal, it is possible to divide the soil depths into more categories thus better reflecting this distribution. However, when points were divided into four groups rather than two, those groups above and below the median plotted as parallel lines in all subsequent analyses. Thus, we continued to use only two soil depth groups.

Statistical analyses

We began by looking for relationships between soil depth and vegetation. Cape Sable seaside sparrows can exist within a range of vegetation compositions as long as these compositions provide the necessary structure needed for nest placement and feeding

(Werner 1975, Lockwood et al. 1997). Individuals whom conducted point counts identified the dominate plants, and percent cover of vegetation, within approximately 10m of their location. Percentage cover is divided into four ordinal groups starting with zero to 25% cover. Percentage cover can not exceed 100%. Observers typically identified two or three of the dominate plants to the taxonomic level of species. We have grouped these dominate plants into three associations; muhly mix, muhly+sawgrass, and sawgrass mix. The first association includes all sites where muhly grass was considered dominate, or was co-dominate with other sedges besides sawgrass. The muhly+sawgrass association includes sites where muhly and sawgrass co-dominate. The sawgrass association includes sites where sawgrass dominates, or co-dominates with sedges and grasses besides muhly. Only sites where the dominate vegetation was identified to the species level and only grasses and sedge identifications were included in these associations. We looked for a non-random occurrence of these plant associations within the two soil groups using a contingency test.

We then tested the first set predictions stated above. First, we expect that vegetation biomass (here measured as percentage cover) will increase more rapidly after fire at deep soil sites than at shallow soil sites. For each soil depth group, we performed an ordinal logistic regression of vegetation cover against days since last fire. We compared the slopes and elevation of these two lines using log-likelihood estimators with soil depth and time since fire as crossed factors (Zar 1984).

The second, often untested, assumption made by Taylor and Werner is that sparrows

respond positively to vegetation cover. Thus, in our next analysis we looked for differences in mean sparrows counted according to percent vegetation cover using ANOVA.

Next, we tested our second set of predictions concerning the effects time since fire on sparrow density. We expect that sparrows will respond to time since fire in the same way as vegetation cover. Thus, for each soil depth group, we performed a simple linear regression of sparrows density against days since last fire. We compared the slopes and elevation of these two lines using an ANCOVA (Zar 1984). Second, for sites that burned during the period of record (1992-1999), we computed the time to sparrow re-occupation after the last fire. We then regressed these recovery times against the soil depth at these sites. Finally, we calculated the number of years before, and after, maximum sparrow density was obtained post-fire. We compared these counts for deep and shallow soil sites using a Fisher's Exact Test. If the Werner-Taylor mechanism is correct, we expect the number of years before maximum densities are obtained to be significantly fewer in deep soil sites than in shallow sites.

Results

Figure 2 is a graph of sparrow density according to number of years since last fire. Two things are apparent from this figure. First, sparrows regularly colonize sites one year post fire. Second, the relationship between time since fire and sparrow density is humped such that sites that have not burned in 10 years or more have fewer sparrows. Maximum sparrow density is reached at eight years post fire (mean = 1.262, standard deviation =

1.610, $n = 107$). The lowest density is reached after 15 years post-fire (mean = 0.378, standard deviation = 0.143).

This relationship becomes much more complex when we add soil depth to Figure 2. Shaded circles represent shallow soil sites. Black squares represent deep soil sites. Using this shading scheme, it is apparent that the tails of this distribution are a by-product of site specific soil profiles.

When we look for differences in dominate vegetation between soil groups, there is a significant tendency for shallow soil sites to support muhly mix plant associations and deep soil sites to support sawgrass mix associations ($\chi^2 = 51.71$, $df = 2$, $P < 0.0001$). These two associations, however, are not exclusive to each soil group (i.e. it is still possible to observe muhly mix association within the deep soil sites). Muhly-sawgrass associations are equally divided between the two groups.

According to the work of Taylor (1983), shallow soil sites will recover to pre-burn biomass levels at a slower rate than deep soil sites and vegetation cover will positively influence sparrow density. We found vegetation cover to be positively correlated to time since fire (Wald $\chi^2 = 45.09$, $df = 1$, $P < 0.0001$). Cover increases at a faster pace in deep soils than in shallow soils (Wald $\chi^2 = 4.74$, $df = 1$, $P = 0.029$). Vegetation cover reaches higher mean values in deeper soils than in shallow soils (Wald $\chi^2 = 8.54$, $df = 1$, $P = 0.004$).

Further, mean sparrow densities between the vegetation cover categories were significantly different ($F = 5.45$, $df = 3$, $P = 0.001$). Mean sparrow density reached maximum levels at 50 to 75% cover (1.28) and minimum levels at zero to 25% cover (0.64) and over 75% cover (0.98). Thus, the first part of the Taylor-Werner mechanism is supported by our data. Sparrows do respond to vegetation cover and cover does increase rapidly over deep soils when compared to increases over shallow soils.

We then expect that measures of how sparrow's respond to time since fire will show similar patterns. Figure 2 also illustrates how soil depth influences the rate at which sparrow density increases according to time since last fire. Among shallow soil locations, there is a positive correlation between mean sparrow density and time since last fire (Figure 2, broken line, $P = 0.007$). However, among deep soil locations there is no correlation (Figure 2, solid line, $P = 0.667$). The slopes of these lines are significantly different ($F = 5.71$, $df = 1$, $P = 0.017$), however mean sparrow density was the same between deep and shallow soil sites ($F = 0.582$, $df = 1$, $P = 0.446$).

When we looked at how soil depth influences the time lag between a burn and sparrow re-occupation, we found 23 survey locations that had experienced one or more fires between 1992 and 1999. Most sites experienced one fire, however four sites experienced two fires and were excluded from consideration. At six sites soil depths were not taken leaving a total of 12 sites for the regression. The number of lag years between when a site burned and when sparrows were again detected was significantly and positively

correlated to soil depth (Figure 3) ($R^2 = 0.427$, $P = 0.0211$).

Finally, we expect that maximum sparrow densities will be obtained sooner after fire in shallow soil sites than deep soil sites. When we include only sites with shallow soils, maximum sparrow density is reached eight years post-fire (mean = 1.474, standard deviation = 1.606, $n = 38$). Minimum mean sparrow density was observed at one year post-fire (mean = 0.286, standard deviation = 0.810, $n = 28$). Among sites with deep soils, maximum sparrow density was attained four years sooner than among sites with shallow soils (mean at four years post-fire = 1.347, standard deviation = 1.466, $n = 49$). Minimum mean sparrow density was obtained after 14 years post-fire (mean = 0.333, standard deviation = 1.047, $n = 15$). This yields a ratio of number of years before maximum density to after of 7:3 for shallow soils as compared to a ratio of 1:12 for deep soils. These ratios are significantly different ($\chi^2 = 7.726$, $df = 1$, Fishers Exact $P = 0.0104$) and are weighted in the direction predicted by the Werner-Taylor mechanism.

Discussion

Our results confirm several predictions that emerge from the combined work of Werner (1975) and Taylor (1983). At first glance our results suggest that burning marl prairie every eight or more years should serve to maintain populations of Cape Sable seaside sparrows within eastern ENP. Further, failure to burn after ten or more years appears to drive sparrow densities to very low levels. However, we find ample evidence that there are spatial differences in how marl prairie vegetation, and consequently sparrows, respond to time since fire. This suggests extreme caution when interpreting the above burn

interval recommendations. Specifically, it suggests there are considerable spatial differences in how fire should be managed across the southern Everglades if sparrow populations are to be maintained or restored. At a minimum these spatial differences are driven by variations in soil depth and may include corresponding differences in dominant vegetation.

This spatial difference in response of sparrows to fire has immediate conservation implications. Burning shallow soil sites keeps local sparrow populations at low densities for extended periods exposing them to the vagaries of demography and the environment. If too many shallow soil sites are burned in one year, even if the timing interval is correct, the Cape Sable seaside sparrow may be driven to extinction. Thus, the spatial pattern of fire management within marl prairies is of equal importance as the temporal pattern.

A burn interval of eight to ten years is at least twice as long as that put forth by Werner (1975) but consistent with the recommendations of Taylor (1983). Werner's study site was situated over what we consider (and Taylor considers) deep soils (14 to 20cm).

When Werner's conclusion is viewed as limited in application to only to deep soil sites, it becomes consistent with our results. Among the subset of survey locations with deep soils, we also observed that maximum sparrow density was obtained four years post fire.

Unlike Werner, we did not observe a significant drop in density after four years post-fire. Instead we found no relationship between time since fire and sparrow density among deep soil sites. Given the consistency of all other evidence supporting the Werner-Taylor

mechanism, we suggest that the lack of correlation between time since fire and sparrow density in deep soil sites is in part a by-product of the very quick sparrow re-occupation times in these sites. We were simply unable to detect low sparrow density in burned sites because our records are calculated at too coarse a time interval.

It remains unclear why these sites did not quickly become unsuitable for sparrow occupation as predicted by Figure 1. It is the lack of such a response that provides the right-hand tail of the distribution seen in Figure 2. Thus, we see a 'hump' instead of an increasing relationship between sparrow density and time since fire.

Discerning what habitat changes drive sparrows from previously suitable habitat is perhaps the most neglected portion of the Werner-Taylor mechanism, and of sparrow biology in general. Given the differences in dominant vegetation between the two soil depth groups, it is possible that sawgrass and muhly accumulate and deposit biomass in very different ways and this in turn drives sparrow occupancy patterns post-fire.

Although we have some understanding of how sawgrass recovers from fire and flood (Herndon et al. 1991), the same is not true for muhly grass. Muhly grass simply may not grow as quickly as sawgrass and thus sites that are dominated by muhly may not deposit as much litter annually. As this litter layer often serves as the support for nests and cover for juvenile sparrows (section V, Lockwood et al. 1999c, Werner 1975), this difference could easily translate into a lack of suitability for sparrow occupancy.

Since the effects of fire are mediated through soil depths (and possibly vegetation

dominance), it may be possible to test more specific predictions of the Werner-Taylor mechanism that have thus far been beyond reach. Instituting controlled burns within occupied habitat of an endangered species is risky. Further, existing fire patterns are homogenous within intensively studied and accessible sparrow habitat within ENP. Soil depth, however, varies considerably and on a much smaller scale than fire. This should make possible the testing of relationships such as how different rates of accumulation of dead vegetation effects sparrow occupancy. Further, our results are restricted to the drier portions of the sparrow's range. Changes in Everglades hydrology have already driven subpopulations of the Cape Sable seaside sparrow to near extinction (Nott et al. 1998). Understanding how hydrology enters into Figure 1 remains of prime importance.

Literature Cited

blah, blah, blah

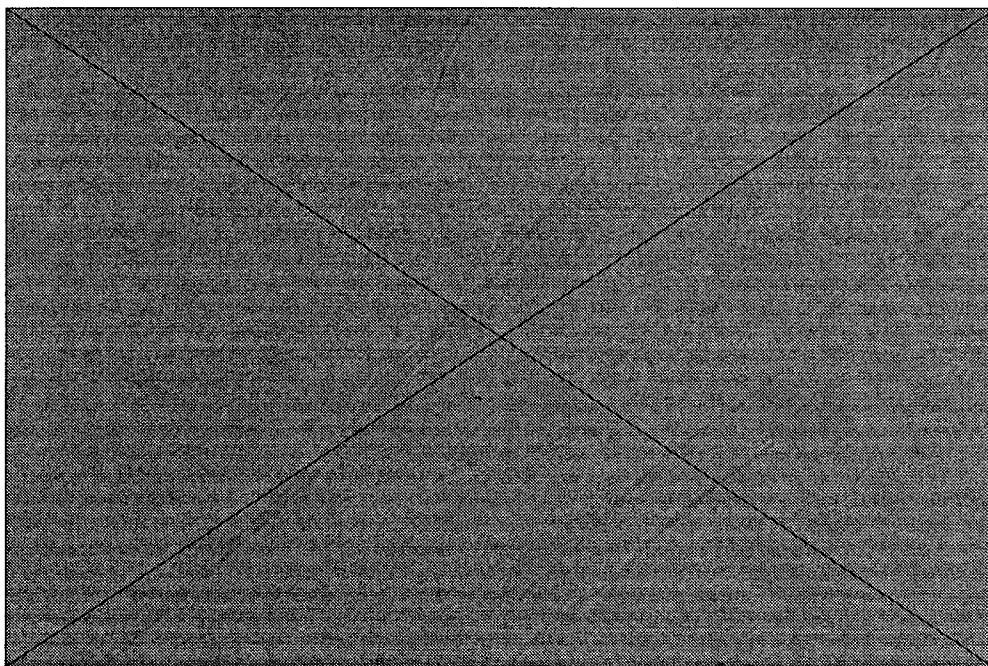


Figure 1. Relationship between soil depth, vegetation cover, sparrow density and years since fire as developed by Werner (1975) and Taylor (1983).

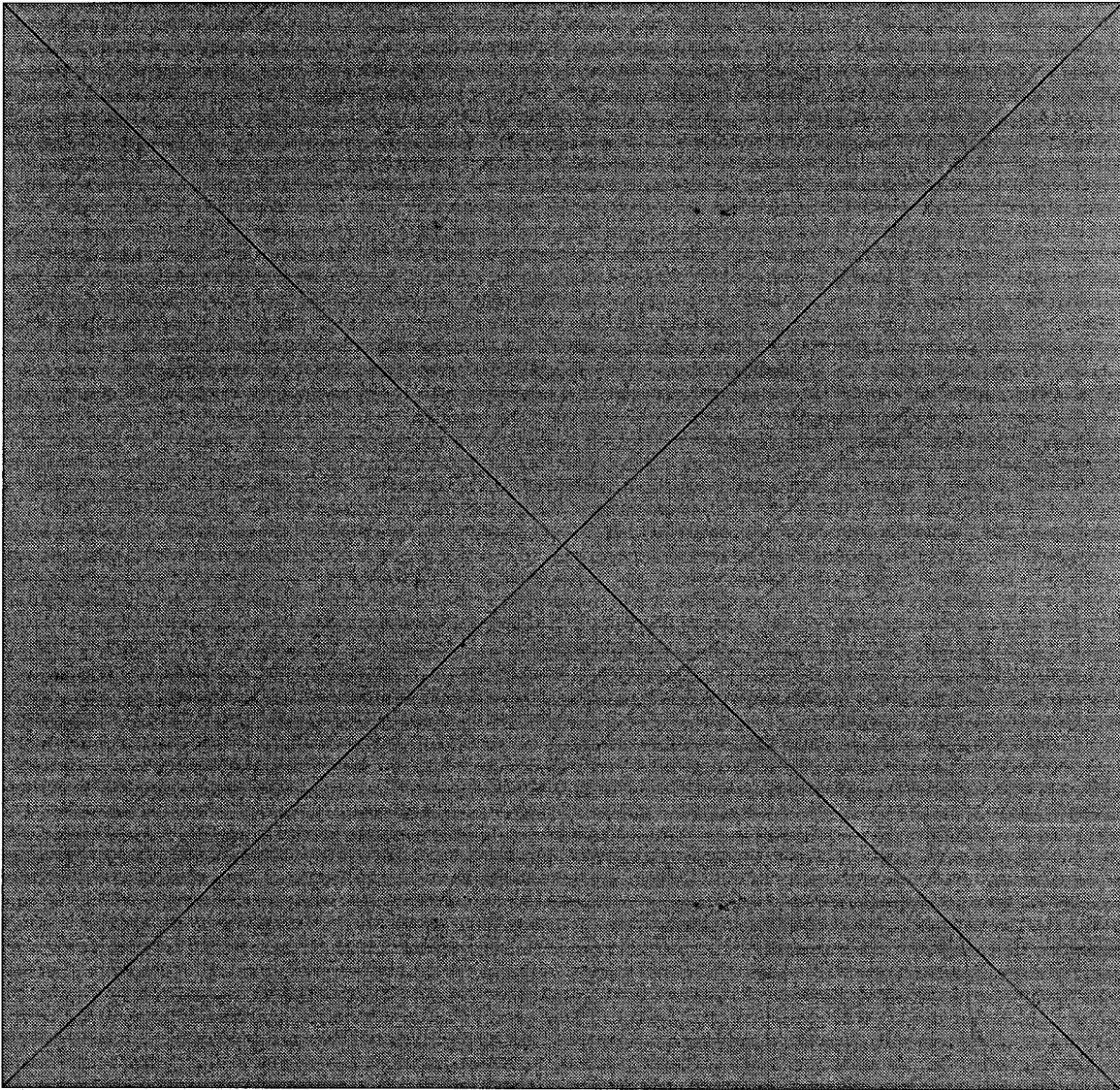


Figure 2. Number of Cape Sable seaside sparrows recorded according to days since count location last burned. Solid line is a simple linear regression using only deep soil sites. Broken line is a simple linear regression using only shallow soil sites.

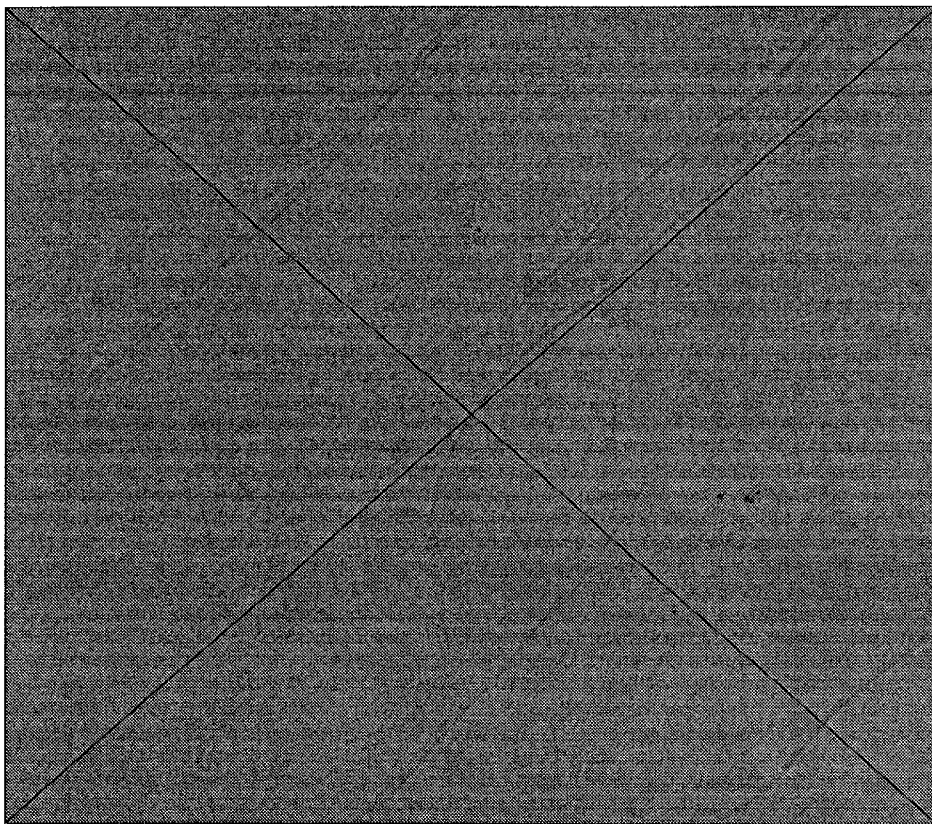


Figure 3. Number of years until sparrows re-occupy burned sites as a function of soil depth.

Date: 9/1/00 8:25 AM
Sender: Julie L Lockwood <lockwood@cats.ucsc.edu>
To: john_curnutt@usgs.gov
cc: Sonny Bass
Priority: Normal
Subject: Fire paper

Hi guys,

This is a long and detailed one. You might want to just print it out.

I have been working on the fire paper per our discussion awhile back.
I'll refresh your memory a bit and then tell you where I'm at.
The main point from the meeting (from my perspective) was the division of the soil depth data. I had divided at the median. John suggested I divide the data into a few more groups so that it better reflected its nearly normal distribution. It was suggested that I look at the vegetation recorded at each point and see if I couldn't divide the soil depth data such that each group held a 'random' smattering of veg types. After this re-distribution of soil depth groups, I should 1) see if veg cover increases faster after fire in deep soils as compared to shallow soils, 2) see if % veg cover is related to bird density 3) see if bird density increased faster after fire in deep soils as compared to shallow soils.

So, here is the update:

The vegetation codes in the extensive survey needed some serious interpolation since there are 18 codes which can be combined in any possible permutation. I decided to remove all 'landscape' codes, which included all tree designations and hammock codes. This left only grass and sedge species codes. I'm assuming that these were taken where the person landed and reflect what was around within about 10 to 20m from the observer. In other words, I don't think people were dropped in a hammock and the grass codes reflect the predominate nature of the area. I'm not sure what to do with hammock presence, or tree presence in the general area. That to me was more of a landscape thing and wouldn't fit neatly into what we were trying to do.

I then combined the remaining permutations into three groups, Muhly mixes, Muhly-Sawgrass mixes, and Sawgrass mixes. Muhly mixes did not

contain
sawgrass (apparently); sawgrass mixes did not include Muhly; and
Muhly-Sawgrass contained both, at least. I did not include
'mixed
prairie' or 'other sedges' in the analysis at all as they were
too vague.

Ok, when I compare this to the soil depths, it is clear that
shallow soils
contain far more Muhly mixes than Sawgrass mixes, and vice
versa.
Muhly-Sawgrass mixes are randomly associated with soil depth.
In other
words, I can see NO way to divide the soil depth data such that
it
contains a random smattering of vegetation types. Not
surprisingly,
vegetation is correlated to soil depth.

As for simply dividing the data into three or four soil depth
groups to
better represent the normal dist. of the soil depth data:

When I divide into smaller groups and re-do the steps from
above, I end up
with a clear break in trends at about the median. In other
words, when I
divide 'shallow' soil sites into two groups instead of one, and
then plot
veg cover against time since fire, the two lines are almost
perfectly
parallel. The same happens when I divide 'deep' into two
groups.
HOWEVER, the two groups of lines are quite different. I know
this is hard
to visualize with words. But, the bottom line to me is that
there is no
reason to divide the soil depth into more than two groups.
Whatever is
happening at about the median is biologically relevant.

The relevance may be due to the tendency for sawgrass to
dominate (perhaps
to the point of excluding Muhly) over deep soils. Shallow soils
seem to
support only muhly. We have a clear vegetation signal in these
soil
groups that we can't get rid of and very likely is driving some
of this
difference in response to fire.

When I continue with the steps per above
with two soil depth groups (divided at the median) the answers
are: 1.
yes, veg cover increases faster after fire in deeper soils AND
it reaches
higher mean cover values, 2) yes, bird density does increase
with
vegetation cover, and 3) no, bird density increases through time
after a
fire in shallow soils and there is no change (or a slightly

negative one)
in bird density after fire in deep soils.

This veg typ X soil depth thing is an interesting wrinkle. I'm
curious
as to what
you guys think, if
you can decipher this message at all.

Julie

Received: from cats.ucsc.edu ([128.114.129.45]) by
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From: Julie L Lockwood <lockwood@cats.ucsc.edu>
X-Sender: lockwood@teach.ic.ucsc.edu
To: john_curnutt@usgs.gov
cc: Sonny_Bass@nps.gov
Subject: Fire paper
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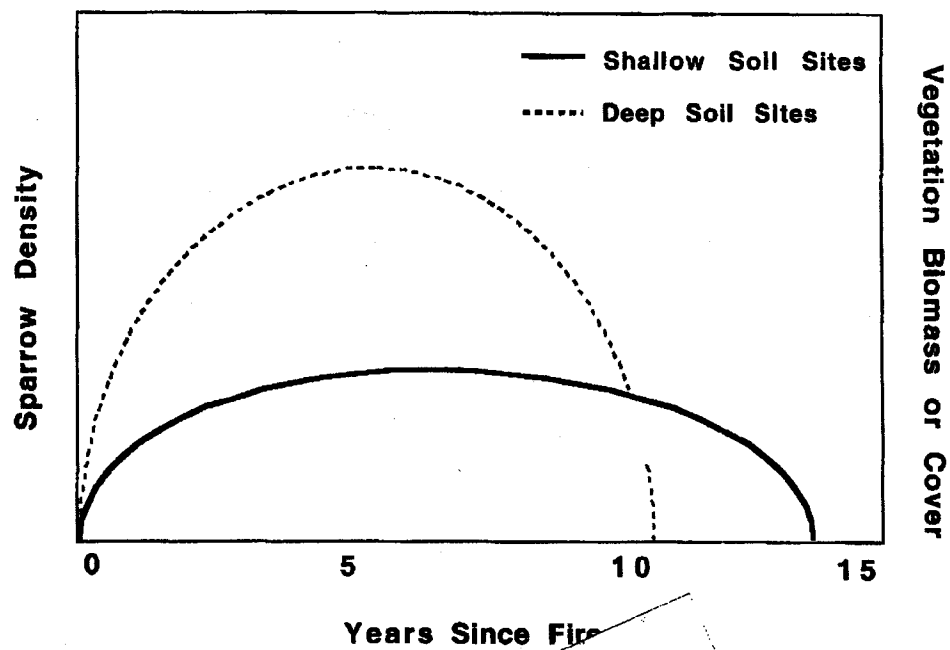


Figure 1. Relationship between soil Sparrow density and years since fire as developed by W.

305.242-7836

831

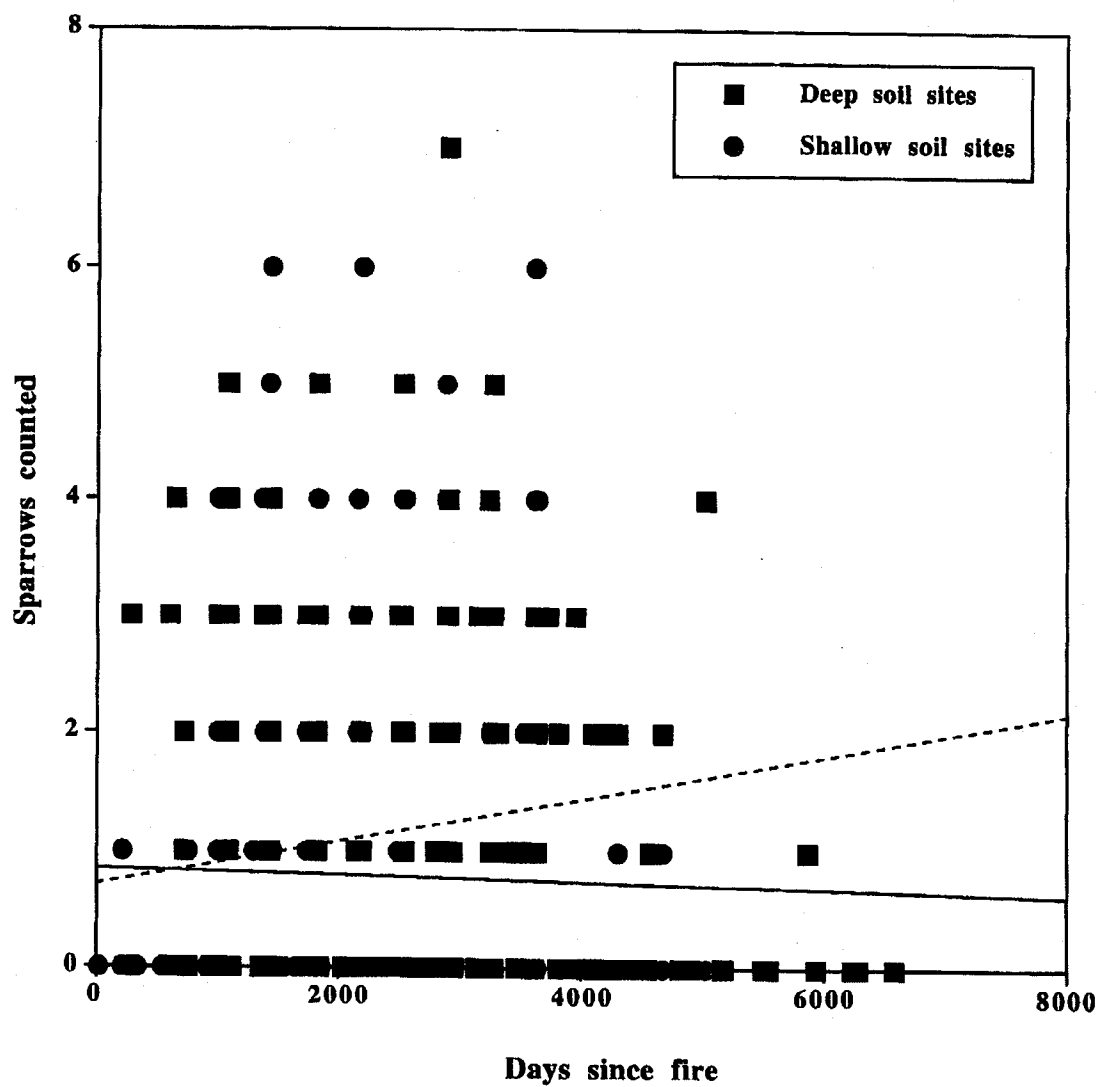


Figure 2. Number of Cape Sable seaside sparrows recorded according to days since count location last burned. Solid line is a simple linear regression using only deep soil sites. Broken line is a simple linear regression using only shallow soil sites.

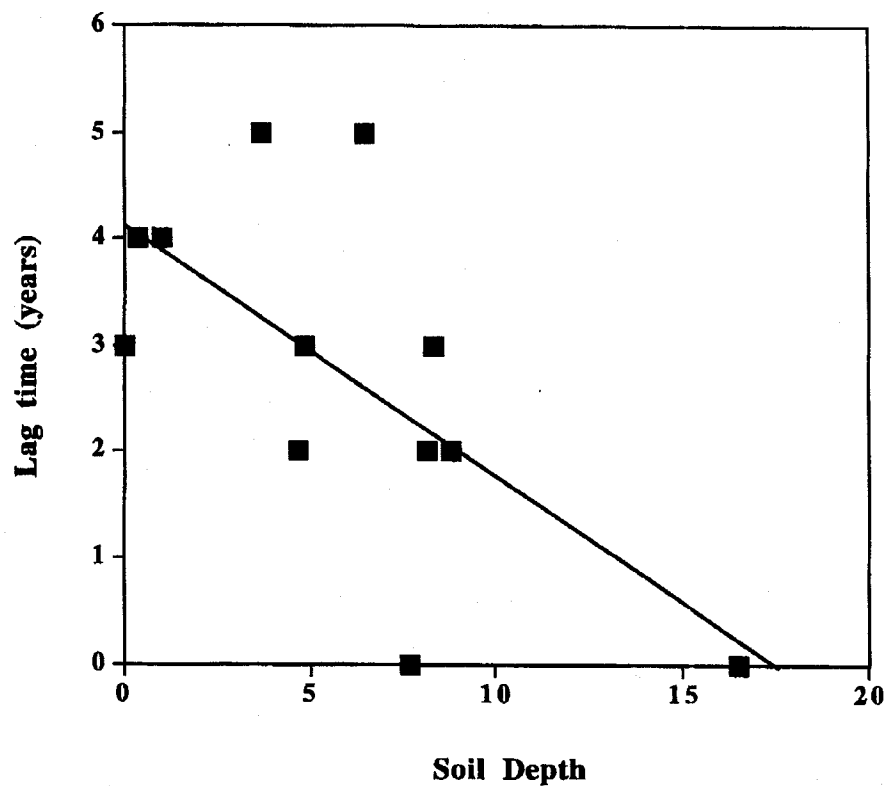


Figure 3. Number of years until sparrows re-occupy burned sites as a function of soil depth.