SECRETIVE MARSH BIRD RESPONSE TO PRESCRIBED FIRE IN MID-ATLANTIC TIDAL MARSHES

by

Rebecca A. Kern

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Approved: ____
W. Gregory Shriver, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____
Douglas W. Tallamy, Ph.D.
Chair of the Department of Entomology and Wildlife Ecology

Approved: ____
Robin W. Morgan, Ph.D.
Dean of the College of Agriculture and Natural Resources

Approved: ____
Debra Hess Norris, M.S.
Vice Provost for Graduate and Professional Education

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ABSTRACT

In North American tidal marshes, prescribed burning has been employed to manage waterfowl, furbearers, invasive plants, and fuels since at least the 1930's. Prescribed burning may also affect non-target species, such as marsh birds, but few studies have examined these potential impacts, particularly in the mid-Atlantic region. To address this informational need, I studied breeding secretive marsh birds on the Chesapeake Bay in Dorchester County, Maryland, where prescribed marsh burning has been conducted for at least 70 years. I examined the effect of time since fire on density, nest success, productivity and occupancy.

Seaside Sparrows (*Ammodramus maritimus maritimus*) were the most abundant species in the study area. Seaside Sparrow density was greatest on 2 - 4 months post-fire marshes, and densities decreased as time since fire increased. Seaside Sparrow nest survival rates were lowest on 5 or more years post-fire marshes, and highest on 3 - 4 years post-fire marshes. Nest survival was also dependent on landscape context and annual weather variation.

Least Bittern (*Ixobrychus exilis*) and Virginia Rail (*Rallus limicola*) occupancy was positively influenced by fire. Saltmarsh Sparrows (*Ammodramus caudacutus*) appear to have a delayed response to winter prescribed burns, as occupancy was negatively impacted by burning over the short-term (3 years), but positively impacted over the long-term (24 years). Coastal Plain Swamp Sparrows (*Melospiza georgiana nigrescens*) occupied only ecotonal habitat, and did not respond strongly to prescribed burns.

I found that prescribed marsh burning had a positive effect on Least Bittern, Virginia Rail, and Saltmarsh Sparrow occupancy, and that Seaside Sparrows were abundant in burned areas. However, there was some evidence that predation may increase immediately following a burn, which may have negatively impacted Seaside Sparrow nest success and productivity on marshes burned 2 - 4 months ago. The natural fire frequency of the study area has been estimated to be 4 - 6 years, indicating that marsh birds may have adapted to occasional fire events. For these reasons, I recommend burning once every 3 - 4 years to maintain habitat quality for breeding secretive marsh birds.

Chapter 1

SEASIDE SPARROW REPRODUCTIVE SUCCESS IN RELATION TO PRESCRIBED FIRE

INTRODUCTION

Prescribed burning has been used as a land management tool since prehistoric times (Whelan 1995). Presently, prescribed fire is applied in ecosystems throughout the United States to achieve a variety of management objectives, such as reduction of fuel loads and conservation of fire-adapted species (Brawn et al. 2001). Prescribed burning of tidal marshes occurs throughout the Gulf and Atlantic coasts, but few studies have evaluated whether marsh burning fulfills its objectives or how it impacts non-target species (Mitchell et al. 2006).

Tidal marshes are stressful habitats, dominated by herbaceous vegetation, that experience extremes in salinity and tidal inundation (Greenberg et al. 2006). Located in the intertidal zone of temperate estuaries, tidal marshes are highly productive systems due to influx of nutrients and high levels of photosynthesis (Mitsch and Gosselink 2000). A high proportion of their vertebrate and vegetation communities are endemic species (Greenberg et al. 2006). Worldwide, tidal marshes cover only 45,000 km^2, an area twice the size of New Jersey and less than 1% of the size of tropical rainforests (Greenberg 2006). Between the 1950's and 1970's, over 50% of all coastal marshes in the continental U.S. were lost through draining/filling for agriculture, channelization and pollution (Tiner 1984, Dahl 1990). Despite conservation efforts, intertidal wetlands declined by 0.5% from 1998 – 2004 and they continue to be threatened by development, pollution and sea level rise (Dahl 2006).

The natural fire regime of tidal marshes along eastern North America is difficult to quantify, but appears to vary regionally. The pre-European fire frequency of marshes on the mid-Atlantic coast, including the southern Delmarva Peninsula, is estimated to be 4 – 6 years (Frost 1998, Baily et al. 2007). Historically, fires were thought to have occurred more frequently on southeast Atlantic and Gulf coast marshes (1 – 3 years) (Frost 1998, Brown 2000). The causes of these fires include lightning strikes and Native American activities. Since at least the 1930's, managers throughout the Atlantic and Gulf coasts have used prescribed burning to improve waterfowl and furbearer habitat, facilitate invasive species removal, and reduce wildfire risk (Griffith 1940, Hoffpauir 1961, Givens 1962, Hackney and de la Cruz 1981, Nyman and Chabreck 1995).

Little is known about the impacts of prescribed burns on passerine marsh birds, many of which are of conservation concern (Mitchell et al. 2006). Seaside Sparrows (*Ammodramus maritimus*), tidal marsh specialists that range from Maine to Texas, are included on the Bird Conservation Region (BCR) 30 list of priority species and the National Audubon Society's WatchList (Post and Greenlaw 1994, National Audubon Society 2007, Atlantic Coast Joint Venture 2008). Studies have evaluated the effects of fire on 2 Gulf Coast subspecies (*A. m. fisheri* and *A. m. mirabilis*), but the response of the northern race (*A. m. maritimus*) to fire is not well-understood (Taylor 1983, Gabrey et al. 2001, La Puma et al. 2007). To determine the effects of prescribed burning on Seaside Sparrows, I studied a population of breeding sparrows in Chesapeake Bay tidal marsh habitat. Winter prescribed burning (January – March) has occurred in this region for over 70 years and understanding the impacts of this practice on marsh birds has become a management priority (Flores 2003). The objectives of this research were to determine the impact of prescribed burning on 1) tidal marsh vegetation and 2) Seaside Sparrow reproductive success, density, and nest-site selection. During this study, annual weather conditions and sampling periods varied greatly, so I also examined the effects of sampling year on vegetation and Seaside Sparrow nest survival.

METHODS

Study Area

I studied breeding Seaside Sparrows at Blackwater National Wildlife Refuge (NWR) (38° 24′ N, 76° 0′ W) and Fishing Bay Wildlife Management Area (WMA) (38° 23′ N, 76° 59′ W) in Dorchester County, Maryland (Figure 1). Fishing Bay WMA, which contained 25,000 acres of tidal marsh, abutted the eastern border of Blackwater NWR, which contained 9,700 acres of tidal marsh (U.S. Fish and Wildlife Service 2006, G. Schenck, Maryland DNR, personal communication). The primary marsh type was brackish high, which is characterized by intermediate salinity levels (0.5-30 ppt) and a relatively diverse vegetation community, including eastern baccharis (*Baccharis halimifolia*), spikegrass (*Distichlis spicata*), Jesuit's bark (*Iva frutescens*), needlerush (*Juncus roemerianus*), chairmaker's bulrush (*Schoenoplectus* *americanus*), smooth cordgrass (*Spartina alterniflora*), big cordgrass (*Spartina cynosuroides*), meadow cordgrass (*Spartina patens*), and switch grass (*Panicum virgatum*) (Frost 1995, U.S. Fish and Wildlife Service 2006). Some areas in Fishing Bay WMA contained predominantly saltmarsh vegetation communities (spikegrass and meadow cordgrass) and had higher salinities than Blackwater NWR (Flores 2003).

The study area included 5 fire management units (Table 1). These units were established by Blackwater NWR staff to facilitate research on the effects of prescribed burning on the tidal marsh ecosystem. The units ranged in size from 89 ha – 231 ha and differed in their landscape context (Table 1). Unit 2, which borders Blackwater Lake, had a very great proportion (93%) of its perimeter adjacent to channel (water). Units 4 and 7 were closest to the marsh edge and about 1/3 of their perimeter bordered upland (forest) or road.

Each unit was divided into 4 burn treatments and I established one study plot within each burn treatment within each unit, for a total of 20 plots. Plots ranged in size from 3 – 4 ha and were delineated in a 25 m^2 grid pattern with red wire stake flags. Whenever possible, I standardized plot shapes to be as rectangular as possible, but channels or large subsiding areas often forced me to create unusual shapes to take advantage of contiguous, intact marsh. All plots were separated by at least 100 m except for 2 pairs (7C and 3C; 3B and 3C), which had to be placed in closer proximity (75 m and 40 m, respectively) due to logistic constraints (Figures 2 and 3). I placed each study plot in 1 of 4 burn classes: 0 years since burn (the plots had been burned 2 – 4 months before sampling), 1 – 2 years since burn, 3 – 4 years since burn and 5+

years since burn (time since burn ranged from 5 – 12 years) (Table 1). Total area sampled for each burn class ranged from 38 – 53 ha (Table 2).

Prescribed burns were conducted on a predetermined schedule, conditions permitting, by the Blackwater NWR Fire Program. Prescribed burning occurred during the non-growing season (January – March) when several centimeters of water were present over the marsh surface, creating a cover burn. Cover burns remove dead standing vegetation, but do not damage roots or peat, allowing the vegetation to rapidly regrow in the subsequent growing season (Lynch 1941, Nyman and Chabreck 1995). Specifically, prescribed burns on Blackwater NWR and Fishing Bay WMA were intended to remove 70% of the above-ground biomass and leave 5 – 10 cm of stubble (U.S. Fish and Wildlife Service 2010).

Vegetation Sampling

During each season, I sampled vegetation within 1-m^2 quadrats at 10 random points per plot and around each nest site. Random vegetation sampling occurred in June and July, 2007 – 2009, and nest-site vegetation was sampled immediately following nest termination. At each vegetation sampling location, I took 6 measurements of thatch depth, recorded the height and species of the tallest vegetation stem, and used a Robel pole to take one visual obstruction reading (VOR) in decimeters in each cardinal direction (Robel et al. 1970). I also used the line-intercept method to measure (cm) all live vegetation along 4 evenly-spaced, parallel transects within the 1-m^2 quadrat (Krebs 1999, Shriver et al. 2007). Vegetation species included spikegrass, Jesuit's bark, chairmaker's bulrush, smooth cordgrass, big cordgrass, meadow cordgrass, sweetscent (*Pluchea odorata*) and sturdy bullrush (*Schoenoplectus robustus*). The portion of transects not covered by live vegetation was assumed to be either dead vegetation, bare ground and/or open water. At nest sites, I also measured the height (cm) from the nest to the ground.

Seaside Sparrow Density and Reproductive Success

I used multiple techniques to estimate Seaside Sparrow territory density, nest density and reproductive success during the breeding seasons (mid-May to mid-August, 2007 – 2009). Seaside Sparrows form socially monogamous breeding pairs where the males defend territories, which can be mapped by standard spot-mapping techniques (International Bird Census Committee 1969, Post and Greenlaw 1994). I spot-mapped each plot 10 – 15 times per year using the established 25 m grid system as a reference for locating sparrows. Visits occurred between 0545 and 1230 and were completed in one hour or less (International Bird Census Committee 1969, Verner and Milne 1990). In order to reduce observer bias, other observers were trained to identify birds by sight and sound. I also searched for nests on each plot, standardizing effort (search hours) and minimizing disturbance. I located nests using behavioral cues of nesting females or by incidental discovery. Upon locating a nest, I marked it with a white wire stake flag approximately 1 m away, recorded its location on a Global Positioning System (GPS) and noted the number of eggs/chicks present. All nests were re-visited every 2 – 5 days until termination (failure or success) and the nest contents were recorded on each visit (Martin and Geupel 1993). I defined a successful nest as one that fledged at least one young.

Data Analyses

I compared the means of 7 vegetation covariates (thatch depth, VOR and percent cover of spikegrass, chairmaker's bulrush, smooth cordgrass, meadow cordgrass and bare ground/open water/dead vegetation) using a univariate generalized linear model with burn class, unit, and year as the main effects, and the interaction of burn and unit (Zar 1999). I included only plant species that had an average percent cover of > 1%. If there was a significant main effect, I used Tukey's post-hoc contrasts to investigate differences (Zar 1999). To evaluate nest-site selection by burn class, I used two-way ANOVA with vegetation covariate and point type (nest-site or random point) as main effects (Zar 1999).

I used an information-theoretic approach (Burnham and Anderson 2002) to model the effects of 11 explanatory variables (burn class, unit, year, thatch depth, VOR, nest height and percent cover of spikegrass, chairmaker's bulrush, smooth cordgrass and meadow cordgrass) on Seaside Sparrow nest survival. I modeled the effects of all variables individually and then grouped them to test 4 hypotheses. I hypothesized that fire management affected nest survival and evaluated this hypothesis in 7 models that incorporated all combinations of burn and the 7 vegetation variables. I hypothesized that landscape context affected nest survival and tested this hypothesis in 7 models that included all combinations of unit and the 7 vegetation variables. To evaluate the hypothesis that the effect of fire management depended on landscape context, I created 16 models that included all combinations of burn, unit, burn*unit interaction and the 7 vegetation variables. I observed significant variation in weather conditions and sampling times between study years, so I hypothesized that year affected nest survival. I tested this hypothesis in 3 models that combined year with burn, unit and burn*unit.

I fit the aforementioned candidate models, as well as a constant survival model, using the logistic-exposure method in R (version 2.10.1; Shaffer 2004). Logistic-exposure is based on logistic regression (a generalized linear model with a binomial response distribution) and uses the logit-link function ($\log_e[p/1\text{-}p]$, where *p* is the probability of a success). It allows daily nest survival rates (the probability that an active nest survives a given day) to be estimated when exposure periods vary and requires no assumptions about when nest losses occur. It can also model nest survival in terms of categorical, continuous, or time-dependent explanatory variables (Shaffer 2004).

I selected the best-supported model using Akaike's Information Criterion (AIC; Burnham and Anderson 2002, Shaffer 2004). Using the best model, I estimated daily nest survival rates and associated confidence intervals across burn classes, units, and years (Shaffer and Thompson 2007, Gonzalo-Turpin et al. 2008). I also estimated period nest survival (the probability that a nest survives the 26 day nesting period), which is often more intuitive for presentation (Shaffer and Thompson 2007). Lastly, I calculated odds ratios and associated confidence intervals for model parameter estimates (Burnham and Anderson 2002, Shaffer and Thompson 2007, Gonzalo-Turpin et al. 2008). Odds ratios, a measure the size of a parameter's effect, allow for straightforward interpretation of parameter estimates by controlling for other variables in the model (Davies et al. 1998, Allison 1999).

Measures of nest survival are not always correlated with reproductive productivity and therefore should not be the only basis for management or conservation strategies (Jones et al. 2005). To further elucidate the effect of fire on population-level processes, such as reproductive output, I examined Seaside Sparrow productivity and density. I compared the mean number of eggs produced per ha (by both failed and successful nests) between burn classes using one-way ANOVA and Tukey's post-hoc test (Zar 1999). I also compared the mean number of fledglings produced per ha (chicks successfully fledged from nests) between burn classes using one-way ANOVA and Tukey's post-hoc test (Zar 1999). I made comparisons between burn classes of territory density per ha and nest density per ha using one-way ANOVA and Tukey's post-hoc test (Zar 1999). Nests used for density calculations were only those found on the plots or within 25 m of the perimeter.

RESULTS

Vegetation by Burn Class, Unit and Year

Vegetation cover differed among the burn classes (Table 3). The 0 years since burn (YSB) class had 1.4 – 2.1 times less thatch ($F_{3, 996} = 48.14$, $P < 0.001$), and 2.6 – 4.9 times more spikegrass cover than all other burn classes ($F_{3, 996} = 30.03$, $P < 0.001$). The 0 YSB class also had 1.4 times more meadow cordgrass cover than the 3 – 4 YSB ($F_{3, 996} = 3.66$, $P = 0.01$), and 1.1 times less bare ground/dead vegetation/open water cover than all other burn classes ($F_{3, 996} = 5.66$, $P = 0.001$).

Smooth cordgrass cover was 1.4 times lower on the 1 – 2 YSB class than the 0 YSB and the 3 – 4 YSB classes ($F_{3, 996}$ = 3.81, *P* = 0.01).

Vegetation cover also differed among the units (Table 4). Units 2 and 4 exhibited several distinctive vegetation characteristics. Average VOR on Unit 2 was 1.3 – 1.6 times greater than all other units ($F_{4, 995}$ = 26.44, *P* < 0.001). Unit 2 also had 3.4 – 8.7 times more chairmaker's bulrush cover ($F_{4, 996}$ = 42.71, *P* < 0.001) and 1.7 – 2.7 times less meadow cordgrass cover than all other units ($F_{4, 996}$ = 11.41, *P* < 0.001). Unit 4 had 1.8 – 3.2 times more spikegrass cover than all other units ($F_{4, 996}$ = 13.32, *P* < 0.001). Units 2 and 4 also had 1.6 – 4.0 times less smooth cordgrass cover than all other units ($F_{4, 996}$ = 18.89, *P* < 0.001).

Vegetation sampled in 2009 was distinctive from the previous years in several ways (Table 5). There was approximately 40% more thatch in 2009 than in 2007 or 2008 ($F_{2, 996}$ = 25.54, *P* < 0.001). The vegetation was also about 1.1 times more dense ($F_{2, 995}$ = 4.37, *P* = 0.01).

Seaside Sparrow Territory and Nest Density

Within the units and burn classes, I located and monitored 353 Seaside Sparrow nests from 2007 – 2009. I detected 41% of all nests on the 0 YSB class (Table 6). Territory density was 1.5 times greater ($F_{3,48}$ = 2.56, *P* = 0.07) and nest density was 2.4 times greater ($F_{3,48}$ = 2.83, *P* = 0.05) on the 0 YSB class than on the 5 + YSB class (Table 7). Territories on Unit 4 were about 2 times less dense than on Units 3 and 7 ($F_{4,47}$ = 5.78, $P \leq 0.001$; Table 8). Nest density on Unit 4 was 3.5 times lower than Units 3 and 7 ($F_{4,47}$ = 4.29, $P \leq 0.005$; Table 8). The 0 YSB class produced about 2.5 times more eggs and fledglings per ha than the 5+ YSB class ($F_{3,48}$ = 4.74, P = 0.006; $F_{3,48}$ = 3.39, P = 0.03; Table 7).

Seaside Sparrow Nest Survival

Of the 353 Seaside Sparrow nests, I excluded 30 nests from the survival analysis because their fate could not be determined (n = 323). Nest success was best explained by the model that included burn class, unit, year and the interaction of burn class and unit (Table 9). The variables burn class, unit and burn*unit interaction appeared together in 6 of the top 10 models, a strong indication that they were important in explaining nest survival. The best model included the interaction of burn class and unit, supporting the hypothesis that the impact of burning depended on landscape context. However, within the best model, only year had a strong, detectable impact on survival, as indicated by the significance of the parameter estimates (2008: z = -3.20, $P \leq 0.001$; 2009: z = -4.57, $P \leq 0.000$; Table 10). Time since burn had a complex effect on nest survival. Nest survival rates were greatest in the 3 – 4 burn class and lowest in the 5+ burn class (Table 6). Period nest survival was 71% greater on the 3 – 4 YSB class than on the 5+ YSB class. The 0 YSB class had the second-greatest nest survival, which was 22% lower than the 3 – 4 YSB class (Table 6). The location of nests on the landscape also influenced nest survival. Nest survival differed most between Units 2 and 4, with a 53% greater nest survival rate on Unit 4 than on Unit 2 (Table 11). However, the precision of the nest survival estimate for Unit 4 may have been affected by a relatively small sample of nests. Nest survival was strongly influenced by weather and declined across study years (Table 12). Between 2007 and 2009, period nest survival declined by 92% and odds of survival by 75% (Table 12).

Nest-site Selection

In all burn classes, nest-sites had about 2 times more smooth cordgrass cover than random points ($P \leq 0.001$). I detected significant burn class x point type (nest-site or random point) interactions for meadow cordgrass and bare ground/dead vegetation/open water cover ($P \leq 0.02$). Meadow cordgrass cover at nest-sites was 1.6 – 1.9 times greater than random points in the 0 YSB and 1 – 2 YSB classes ($F_{1,309} = 17.18$, $P \leq 0.000$; $F_{1,215} = 8.88$, $P \leq 0.003$). Nest-sites had about 1.2 times less bare ground/dead vegetation/open water cover than random points in the 0 YSB and 1 – 2 YSB classes ($F_{1,309} = 16.19$, $P \leq 0.000$; $F_{1,215} = 11.24$, $P \leq 0.000$).

DISCUSSION

Prescribed burning reduced dead standing vegetation, increased live vegetation cover and altered the relative abundance of spikegrass, chairmaker's bulrush, smooth cordgrass and meadow cordgrass. Flores and Bounds (2001), also working on study areas at Blackwater NWR and Fishing Bay WMA, reported that burning increased spikegrass, chairmaker's bulrush, and meadow cordgrass biomass about 9 months post-fire. I found that spikegrass cover was greatest in the 0 YSB treatment (2 – 4 months post-fire), but that chairmaker's bulrush cover did not differ between the 0 YSB, 1 – 2 YSB and 3 – 4 YSB treatments. One objective of prescribed marsh burning is to increase sedge cover (such as chairmaker's bulrush), preferred foraging substrates of wintering waterfowl. However, the effect of burning on chairmaker's bulrush cover is not clear. Stevenson et al. (2001) reported that chairmaker's bulrush cover was higher 1 year post-fire than 2 – 3 years post-fire, while Gabrey et al. (2001) found that burning did not increase its cover. Gabrey et al. (2001) also found that, in a Louisiana tidal marsh, vegetation needed 2 – 3 years to recover to pre-fire conditions (VOR and total percentage vegetation cover). Vegetation in my study plots appeared to recover in a similar time span, as I found few differences between the 3 – 4 YSB and 5+ YSB classes.

I observed the greatest Seaside Sparrow nest and territory densities immediately following fire, and did not observe a drop in density in the first breeding season post-burn, unlike other studies (Werner 1975, Gabrey and Afton 2000, La Puma et al. 2007). Patterns of Seaside Sparrow response to fire frequency are equivocal. In the first breeding season post-fire, some studies have reported that Louisiana and Cape Sable Seaside Sparrows left burned areas (Werner 1975, Gabrey and Afton 2000, La Puma et al. 2007), whereas another detected no decrease in density (Curnutt et al. 1998). Re-colonization after fire is closely tied to the patchiness of the burn and the rate of vegetation recovery. Researchers often did not describe the patchiness of fire, with the exception of: La Puma et al. (2007; nearly all the vegetation was consumed and Seaside Sparrows left the site) and Curnett et al. (1998; the burn was patchy and Seaside Sparrows remained on the site). Prescribed fires at Blackwater NWR and Fishing Bay WMA were intended to remove only 70% of above-ground vegetation, leaving an unburned vegetation mosaic that may have provided cover for birds. Vegetation in the study area also recovered rapidly, as the 0

YSB class reached the same density as the other burn classes within the first growing season.

On the Chesapeake Bay, I detected a general trend of decreasing Seaside Sparrow density with increasing time since fire. Several studies have reported that Louisiana and Cape Sable Seaside Sparrows decreased in abundance 4 – 10 years after fire, when dead vegetation presumably reached a density threshold (Werner 1975, Taylor 1983, Gabrey 1999, Gabrey and Afton 2000). Other studies found no decrease in Cape Sable Seaside density up to 10 years after a burn, and suggested that burning more than every 4 – 5 years may be detrimental (Taylor 1983, Curnutt et al. 1998). In my study area, it appears that burning every 3 – 4 years creates more favorable conditions for Seaside Sparrow reproduction. The natural fire frequency of mid-Atlantic marshes has been estimated to be 4 – 6 years (Frost 1998). My findings seem to indicate that the northern Seaside Sparrow subspecies has adapted to a fire frequency of approximately 5 years, lending support to fire history estimates.

Few studies have estimated the effect of fire on Seaside Sparrow nest survival. Period nest survival for Cape Sable Seaside Sparrows varied, ranging from 0.27 – 0.41 in burned areas and 0.14 – 0.46 in unburned areas (La Puma et al. 2007). Estimates of nest survival on Blackwater NWR and Fishing Bay WMA fell within the low end of this range. Differences in nest survival can be partially attributed to vegetation. Predation may have significantly impacted reproductive output on the 0 YSB class, as nests were more visible due to lack of dead vegetation cover. Other studies have also suggested burning increases depredation rates (Gabrey et al. 2002, Almario et al. 2009). I detected twice as many nests on 0 YSB than the other burn classes, yet the overall reproductive output (fledglings/ha) was equal to the 1 – 2 YSB and 3 – 4 YSB classes, indicating that perhaps the greater nest density was compromised by higher predation rates in the 0 YSB treatment. Interestingly, the burn classes with the lowest nest survival (1 – 2 YSB and 5+ YSB) had the greatest dead vegetation depth, possibly indicating that too much thatch also negatively impacts nest survival.

The effects of prescribed burning on Seaside Sparrows in my study area were confounded by management unit. Extreme outliers found in certain burn class x unit combinations can be attributed to small sample sizes. This likely occurred on the 1 – 2 YSB class of Unit 5 (nest survival = 1.00, n = 3) and on the 5+ YSB class of Unit 4 (nest survival = 0.00, n = 5). In general, nest survival estimates for Units 4 and 5 were affected by small sample size. No more than 14 nests were found on any burn class in Unit 4 and no more than 8 nests were found on any burn class in Unit 5 except 0 YSB. Unit 2 had the lowest nest survival and $\geq$ 10 nests on each burn class, indicating that vegetation or other landscape factors may have negatively impacted survival. Parameter estimates and odds ratios indicated that year strongly influenced survival, but there was insufficient evidence to detect an impact from burn class or unit. The odds ratio confidence intervals for burn class and unit were wide, indicating that their impact on survival was varied. A biologically-significant effect may be present, but not at a level that I was able to detect.

Nest survival was very low in 2009, as demonstrated by the 1 – 2 YSB on Unit 7. This burn class x unit combination was only sampled during 2009 and had low survival (0.786) despite having an adequate sample of nests (n = 22). Sampling years differed in the time-frame of data collection and in weather conditions. My nest-monitoring period in 2007 began a month later than in 2008 or 2009 (June 10 versus mid-May). Not sampling early-season nests in 2007 may have inflated the nest survival estimate, as Seaside Sparrows experience the highest rate of nest failure early in the season, during flooding from spring tides (Marshall and Reinert 1990). However, excluding nests found before 10 June 2008 and 2009 had little impact on the survival estimates for those years (0.945 and 0.891, respectively). Thus, annual variation in nest survival can be primarily attributed to weather.

In May and June 2009, 34 cm of precipitation fell in Salisbury, MD (about 80 km from the study sites; National Climatic Data Center 2009a, National Climatic Data Center 2009b). This was a notable increase from May and June 2007 and 2008, when 8.4 cm and 23.9 cm of precipitation were recorded, respectively (National Climatic Data Center 2007, National Climatic Data Center 2008). Mean tide levels in Cambridge, MD from 20 May to 20 June were higher in 2009 than in 2007 or 2008 (1.23 m above station datum versus 1.17 m and 1.14 m respectively; NOAA 2009). Thus, low nest survival in 2009 was likely the result of increased nest flooding. Of nests whose cause of failure could be determined, a greater percentage flooded in 2009 than in 2007 or 2008 (55% versus 20% and 16%, respectively). The leading cause of nest failure in 2007 and 2008 was predation (80% and 76%, respectively).

Worldwide, sea levels are expected to rise by 0.18 – 0.59 m in the next 80 – 90 years (IPCC 2007). Sea levels within the Chesapeake Bay are rising at nearly twice the average global rate and Dorchester County, MD is predicted to be especially impacted (Kearney 1996, Wilson et al. 2007). Global climate change is likely to increase heavy precipitation events, as well as the frequency and intensity of tropical storms and hurricanes (IPCC 2007). Thus, Seaside Sparrows in Blackwater NWR and Fishing Bay WMA are likely to experience more breeding seasons like 2009, with frequent flooding and heavy precipitation events, in the coming centuries.

Unit 2 provided an example of how rising sea levels may affect the Seaside Sparrow population in Dorchester County. Nest survival rates from Unit 2 were the lowest of any unit. A high proportion of its perimeter was channel and it abutted Blackwater Lake, an area that was created by high rates of marsh subsidence and sea level rise over the last 70 years (U.S. Fish and Wildlife Service 2006). Interestingly, Unit 4, which had the highest nest survival rate, was the only unit to border a forested upland edge. The contrast between nest survival in Units 2 and 4 may demonstrate the positive impact of distance from the advancing sea level front.

Management Implications

Determining the best prescribed burn management at Blackwater NWR and Fishing Bay WMA is complicated by the impact of unit and yearly variability in survival. However, based on Seaside density and nest survival, as well as fire history estimates, I recommend burning on a 3 – 4 year rotation in the mid-Atlantic region. I recommend continuing to burn only 70% of above-ground vegetation in order to provide cover for sparrows. The importance of unburned refugia has been noted by other authors (ie. Gabrey and Afton 2000, La Puma et al. 2007), so I recommend that managers maintain a mosaic of marsh of varying post-burn ages. Nest survival estimates from Blackwater NWR and Fishing Bay WMA are lower than most published values, with several exceptions: Gulf Hammock, FL: 0.03; Everglades, FL: 0.14; South Dartmouth, Massachusetts: 0.22 (Post et al. 1983, Marshall and Reinert 1990, La Puma et al. 2007). Management decisions should take the apparent vulnerability of this population into account, especially given the anticipated impacts of rising sea levels.

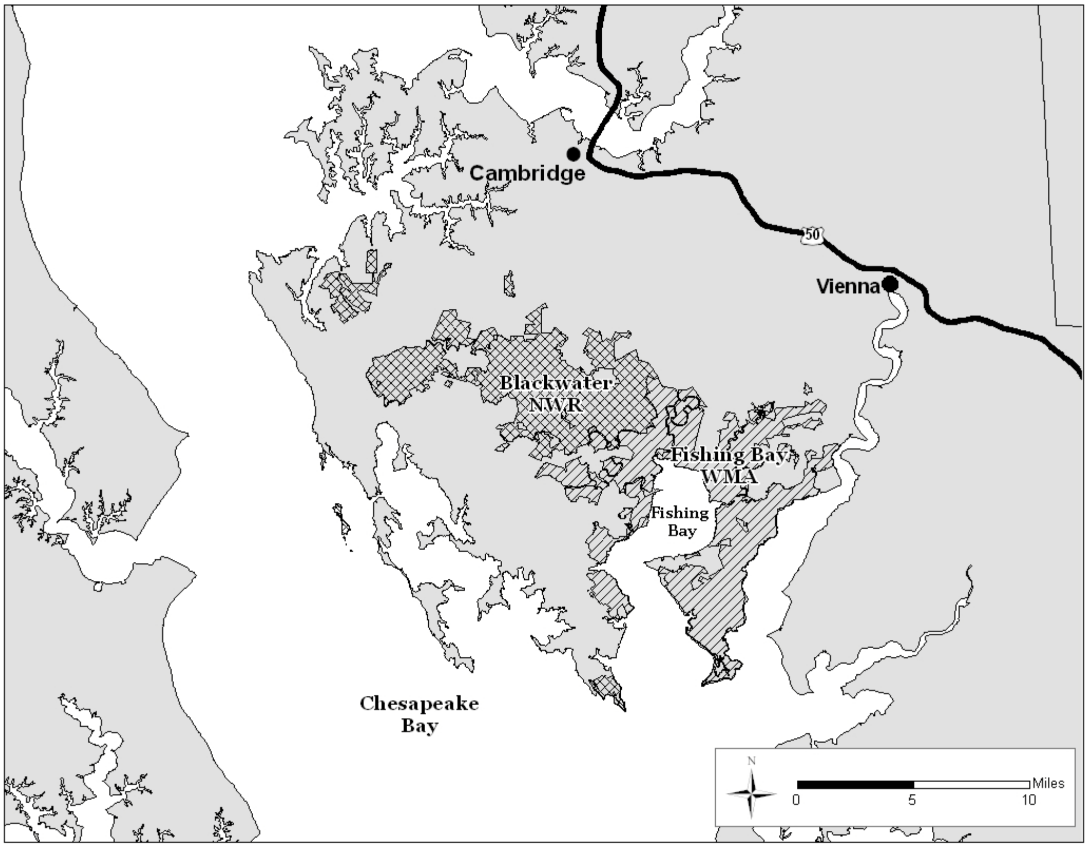

Figure 1. Map of Blackwater National Wildlife Refuge (NWR) and Fishing Bay Wildlife Management Area (WMA), Dorchester County, MD.

Table 1. Fire management units at Blackwater NWR and Fishing Bay WMA, MD, from 2007 - 2009. Plots were placed in one of four burn classes in each year of the study (0 = 0 years since burn; 1 = 1 - 2 years since burn; 3 = 3 - 4 years since burn; 5 = 5+ years since burn). Units 4 and 5 were added to the study in 2008.

Plot Location	Unit	% Perimeter Adjacent to: Marsh	Upland/Road	Channel	Plot ID	Plot Area (ha)	Lat.	Long.	2007 Burn Class	2008 Burn Class	2009 Burn Class
Blackwater NWR	2	7.4	0.0	92.6	2A	2.88	38.4130	76.0803	0	0	0
					2B	2.94	38.4080	76.0685	1	0	1
					2C	3.13	38.4139	76.0697	1	3	3
					2D	3.66	38.4062	76.0821	3	3	5
	3	37.0	0.0	63.0	3A	2.99	38.3860	76.0779	0	0	0
					3B	2.98	38.3908	76.0744	1	0	1
					3C	3.14	38.3945	76.0731	1	3	3
					3D	4.33	38.3909	76.0813	5	5	5
	7	27.2	29.4	43.4	7A	3.26	38.3898	76.0719	0	0	1
					7B	4.23	38.3958	76.0723	3	0	1
					7C	3.14	38.3983	76.0814	3	3	5
					7D	4.27	38.4008	76.0676	5	5	5
Fishing Bay WMA	4	41.7	33.8	24.5	4A	3.74	38.4112	75.9931	-	0	0
					4B	3.11	38.4078	76.0028	-	1	1
					4C	3.27	38.4114	76.0096	-	5	5
					4D	3.28	38.4121	76.0116	-	5	5
	5	58.0	0.0	42.0	5A	3.27	38.3781	76.0111	-	0	0
					5B	3.33	38.3813	76.0109	-	1	1
					5C	3.33	38.3802	76.0016	-	3	5
					5D	4.27	38.3896	75.9978	-	3	5

Figure 2. Study plots (in yellow) within Units 2, 3 and 7 at Blackwater NWR (Dorchester County, MD), 2007 - 2009.

Figure 3. **Study plots (in yellow) in Units 4 and 5 at Fishing Bay WMA (Dorchester County, MD), 2008 - 2009.**

Table 2. **Area of each burn class sampled at Blackwater NWR and Fishing Bay WMA, MD, 2007 - 2009.**

	Area Sampled (ha)			
Burn Class	2007	2008	2009	Total
0 yrs since burn	9.13	26.29	12.88	48.30
1 - 2 yrs since burn	12.19	6.44	19.85	38.48
3 - 4 yrs since burn	11.03	20.67	6.27	37.97
5+ yrs since burn	8.60	15.15	29.55	53.3

Table 3. **Dominant vegetation cover (mean ± SE) within each burn class at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009.**

	Time Since Burn			
Vegetation Covariate	0 years	1 - 2 years	3 - 4 years	5+ years
Thatch depth (cm)	$8.24 \pm 0.55_{a}$	$17.58 \pm 0.74_{c}$	$11.37 \pm 0.73_{b}$	$17.30 \pm 0.88_{c}$
Visual obstruction reading	$3.25 \pm 0.08_{a}$	$3.32 \pm 0.12_{a}$	$3.06 \pm 0.14_{a}$	$3.03 \pm 0.13_{a}$
Percent cover of *Distichlis spicata*	$1.97 \pm 0.24_{a}$	$0.40 \pm 0.07_{b}$	$0.47 \pm 0.10_{b}$	$0.76 \pm 0.12_{b}$
Percent cover of *Schoenoplectus americanus*	$2.39 \pm 0.25_{a,b}$	$2.74 \pm 0.26_{a}$	$2.41 \pm 0.30_{a,b}$	$1.64 \pm 0.20_{b}$
Percent cover of *Spartina alterniflora*	$6.28 \pm 0.35_{a}$	$4.48 \pm 0.36_{b}$	$6.20 \pm 0.49_{a}$	$5.55 \pm 0.39_{a,b}$
Percent cover of *Spartina patens*	$16.66 \pm 0.86_{a}$	$15.28 \pm 1.65_{a,b}$	$11.92 \pm 1.07_{b}$	$13.78 \pm 1.15_{a,b}$
Other (dead vegetation, bare ground, open water)	$71.56 \pm 0.91_{a}$	$76.64 \pm 1.59_{b}$	$77.72 \pm 1.04_{b}$	$77.39 \pm 1.07_{b}$

(Burn classes with same letter do not differ, $P > 0.05$)

Table 4. Dominant vegetation cover (mean ± SE) within fire management units at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009.

Vegetation Covariate	Unit 2	Unit 3	Unit 4	Unit 5	Unit 7
Thatch depth (cm)	$14.80 \pm 0.89_{a}$	$14.23 \pm 0.75_{a}$	$14.79 \pm 1.32_{a}$	$11.92 \pm 0.87_{a,b}$	$10.68 \pm 0.61_{b}$
Visual obstruction reading	$4.07 \pm 0.13_{c}$	$3.18 \pm 0.11_{a}$	$2.91 \pm 0.16_{a,b}$	$3.09 \pm 0.17_{a}$	$2.56 \pm 0.07_{b}$
Percent cover of *Distichlis spicata*	$1.22 \pm 0.24_{a}$	$0.74 \pm 0.13_{a}$	$2.23 \pm 0.46_{b}$	$0.87 \pm 0.17_{a}$	$0.70 \pm 0.11_{a}$
Percent cover of *Schoenoplectus americanus*	$5.64 \pm 0.37_{a}$	$1.57 \pm 0.19_{b}$	$1.65 \pm 0.29_{b}$	$0.65 \pm 0.15_{b}$	$1.35 \pm 0.17_{b}$
Percent cover of *Spartina alterniflora*	$3.91 \pm 0.39_{a}$	$7.34 \pm 0.37_{b}$	$1.83 \pm 0.38_{c}$	$7.03 \pm 0.55_{b}$	$6.39 \pm 0.39_{b}$
Percent cover of *Spartina patens*	$8.36 \pm 0.85_{a}$	$14.81 \pm 1.00_{b}$	$22.65 \pm 3.04_{c}$	$18.88 \pm 1.58_{b,c}$	$14.35 \pm 0.99_{b}$
Other (dead vegetation, bare ground, open water)	$80.23 \pm 0.91_{a}$	$74.36 \pm 1.09_{b,c}$	$70.15 \pm 2.88_{b}$	$70.64 \pm 1.46_{b}$	$76.97 \pm 0.99_{a,c}$

(Units with the same letter do not differ, $P > 0.05$)

Table 5. **Dominant vegetation cover (mean ± SE) within each sampling year at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD). 2007 includes only data from units 2, 3 and 7 (at Blackwater NWR).**

	Year		
Vegetation Covariate	2007	2008	2009
Thatch depth (cm)	$10.43 \pm 0.62_{a}$	$10.59 \pm 0.53_{a}$	$17.45 \pm 0.69_{b}$
Visual obstruction reading	$3.09 \pm 0.11_{a}$	$3.01 \pm 0.08_{a}$	$3.40 \pm 0.10_{b}$
Percent cover of *Distichlis spicata*	$1.50 \pm 0.26_{a}$	$1.00 \pm 0.13_{b}$	$0.72 \pm 0.10_{b}$
Percent cover of *Schoenoplectus americanus*	$2.55 \pm 0.28_{a}$	$1.96 \pm 0.19_{a}$	$2.47 \pm 0.21_{a}$
Percent cover of *Spartina alterniflora*	$5.14 \pm 0.36_{a}$	$5.38 \pm 0.31_{a,b}$	$6.31 \pm 0.35_{b}$
Percent cover of *Spartina patens*	$14.72 \pm 1.10_{a}$	$14.99 \pm 1.09_{a}$	$14.39 \pm 0.88_{a}$
Other (dead vegetation, bare ground, open water)	$75.07 \pm 1.12_{a}$	$76.01 \pm 1.05_{a}$	$74.90 \pm 0.89_{a}$

(Years with the same letter do not differ, $P > 0.05$)

Table. 6. **Seaside Sparrow daily nest survival (± 95 % CI's) and period nest survival for burn classes at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. Nests indicate the total number monitored throughout the burn class.**

	Time Since Burn			
	0 years	1 - 2 years	3 - 4 years	5+ years
Nests	131	69	60	63
Daily Nest Survival	0.937	0.923	0.946	0.902
95% CI	0.923 - 0.951	0.899 - 0.947	0.927 - 0.965	0.872 - 0.932
Period Nest Survival	0.185	0.123	0.237	0.069

Table 7. Seaside Sparrow nest, territory, egg and fledgling densities (mean ± SE) of burn classes at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. Nests indicate the number detected on plots within burn classes.

	Time Since Burn			
	0 years	1 - 2 years	3 - 4 years	5+ years
Nests	102	58	49	50
Nests / ha	$2.15 \pm 0.43_{a}$	$1.49 \pm 0.31_{a,b}$	$1.30 \pm 0.25_{a,b}$	$0.914 \pm 0.18_{b}$
Territories / ha	$2.03 \pm 0.23_{a}$	$1.76 \pm 0.19_{a,b}$	$1.53 \pm 0.20_{a,b}$	$1.34 \pm 0.14_{b}$
Eggs / ha	$8.66 \pm 1.27_{a}$	$5.60 \pm 1.10_{a,b}$	$5.09 \pm 0.84_{b}$	$3.55 \pm 0.75_{b}$
Fledglings / ha	$3.08 \pm 0.54_{a}$	$2.22 \pm 0.54_{a,b}$	$2.24 \pm 0.42_{a,b}$	$1.11 \pm 0.31_{b}$

(Burn classes with the same letter do not differ, $P > 0.05$)

Table 8. Seaside Sparrow nest and territory density (mean ± SE) within each fire management unit at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. Nests detected are the number of nests detected on plots within each unit.

	Unit				
	2	3	4	5	7
Nests	36	85	16	33	89
Nests / ha	$0.955 \pm 0.18_{a,b}$	$2.25 \pm 0.44_{c}$	$0.610 \pm 0.23_{a}$	$1.20 \pm 0.55_{a,c}$	$2.02 \pm 0.21_{b,c}$
Territories / ha	$1.45 \pm 0.19_{a,b}$	$2.23 \pm 0.19_{c}$	$1.03 \pm 0.19_{a}$	$1.42 \pm 0.26_{a,d}$	$1.96 \pm 0.14_{b,c,d}$

(Units with the same letter do not differ, $P > 0.05$)

Table 9. Model-selection results for the top 10 logistic-exposure models of daily nest survival for Seaside Sparrows at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. Forty-four candidate models were ranked based on Akaike's Information Criterion (AIC), which uses log likelihood (*L*), the number of model parameters (*K*) and Akaike weights (w_i).

Model	$\log_e(L)$	K	AIC_c	ΔAIC_c	w_i
Burn[a] + Unit[b] + Year + Burn*Unit interaction	-469.13	20	978.59	0.00	0.782
Burn + Unit + *Spartina alterniflora* + Burn*Unit interaction	-470.55	20	981.44	2.85	0.188
Burn + Unit + Nest height + Burn*Unit interaction	-472.85	20	986.04	7.45	0.019
Year	-491.79	2	987.59	9.01	0.009
Unit + Year	-489.94	6	991.90	13.32	0.001
Burn + Year	-491.02	5	992.06	13.47	0.001
Burn + Unit + VOR + Burn*Unit interaction	-478.12	20	996.57	17.99	0.000
Burn + Unit + Year	-489.30	9	996.68	18.09	0.000
Burn + Unit + Burn*Unit interaction	-480.42	19	999.15	20.56	0.000
Burn + Unit + *Schoenoplectus americanus* + Burn*Unit interaction	-479.52	20	999.37	20.78	0.000

[a] – time since burn class
[b] – management unit

Table 10. Parameter estimates, standard errors and odds ratios with 95% confidence intervals of the best-supported logistic-exposure model of Seaside Sparrow nest survival at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. The parameters include all levels of burn class, unit, year and burn class x unit interaction. Interactions involving Unit 2 are not listed because Unit 2 was designated as a reference group (all interactions have value 0.00 ± 0.00).

Parameter	Estimate	SE	Odds Ratio	95% CI
0 YSB class	0.00	0.00	1.00	1.00 - 1.00
1 - 2 YSB class	-0.46	0.48	0.63	0.25 - 1.60
3 - 4 YSB class	0.28	0.45	1.32	0.55 - 3.18
5+ YSB class	-0.18	0.56	0.84	0.28 - 2.48
Unit 2	0.00	0.00	1.00	1.00 - 1.00
Unit 3	0.07	0.33	1.08	0.57 - 2.04
Unit 4	0.20	0.59	1.22	0.38 - 3.90
Unit 5	0.21	0.39	1.24	0.58 - 2.63
Unit 7	0.69	0.42	2.00	0.87 - 4.58
Year 2007	0.00	0.00	1.00	1.00 - 1.00
Year 2008	-0.93*	0.29	0.39	0.22 - 0.70
Year 2009	-1.38*	0.30	0.25	0.14 - 0.45
Burn 0 x Unit 3	0.00	0.00	1.00	1.00 - 1.00
Burn 1 x Unit 3	0.49	0.62	1.63	0.48 - 5.53
Burn 3 x Unit 3	-0.46	0.60	0.63	0.19 - 2.05
Burn 5 x Unit 3	0.14	0.70	1.16	0.29 - 4.53
Burn 0 x Unit 4	0.00	0.00	1.00	1.00 - 1.00
Burn 1 x Unit 4	1.42	0.83	4.15	0.81 - 21.35
Burn 5 x Unit 4	-17.32	885.07	3.00×10^{-8}	0.00 - 1717.43
Burn 0 x Unit 5	0.00	0.00	1.00	1.00 - 1.00
Burn 1 x Unit 5	15.66	625.06	6.31×10^{6}	0.00 - 1240.65
Burn 3 x Unit 5	0.42	0.90	1.53	0.26 - 8.95
Burn 5 x Unit 5	-0.32	0.75	0.73	0.17 - 3.13
Burn 0 x Unit 7	0.00	0.00	1.00	1.00 - 1.00
Burn 1 x Unit 7	-0.96	0.63	0.38	0.11 - 1.33
Burn 3 x Unit 7	-0.88	0.64	0.42	0.12 - 1.47
Burn 5 x Unit 7	-0.48	0.68	0.62	0.16 - 2.37

* - $P \leq 0.01$

Table 11. Seaside Sparrow daily nest survival (±95% confidence intervals) and period nest survival for units and burn classes (YSB = years since burn) within units at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD) 2007 - 2009.

		Unit				
		2	3	4	5	7
Nests		65	98	25	37	98
Daily Nest Survival (95% CI)		0.913 (0.883 - 0.936)	0.934 (0.915 - 0.949)	0.943 (0.904 - 0.967)	0.933 (0.900 - 0.955)	0.934 (0.915 - 0.950)
Period Nest Survival		0.093	0.169	0.218	0.163	0.171
0 YSB	Nests	25	52	7	21	26
	Daily Nest Survival (95% CI)	0.919 (0.871 - 0.950)	0.932 (0.905 - 0.951)	0.935 (0.838 - 0.976)	0.927 (0.881 - 0.956)	0.966 (0.937 - 0.981)
	Period Nest Survival	0.111	0.158	0.176	0.141	0.402
1 - 2 YSB	Nests	12	18	14	3	22
	Daily Nest Survival (95% CI)	0.875 (0.775 - 0.934)	0.950 (0.902 - 0.975)	0.969 (0.927 - 0.987)	1.00 (1.00 - 1.00)	0.786 (0.678 - 0.865)
	Period Nest Survival	0.031	0.262	0.440	1.00	0.002
3 - 4 YSB	Nests	18	14	0	5	23
	Daily Nest Survival (95% CI)	0.938 (0.884 - 0.968)	0.911 (0.841 - 0.952)	n/a*	0.967 (0.879 - 0.992)	0.961 (0.929 - 0.979)
	Period Nest Survival	0.189	0.089	n/a*	0.423	0.357
5+ YSB	Nests	10	14	4	8	27
	Daily Nest Survival (95% CI)	0.865 (0.721 - 0.941)	0.942 (0.887 - 0.971)	0.00 (0.00 - 0.00)	0.852 (0.709 - 0.931)	0.914 (0.861 - 0.948)
	Period Nest Survival	0.023	0.210	0.00	0.015	0.097

*- Unit 4 did not contain a 3 - 4 YSB class.

Table 12. Seaside Sparrow daily nest survival (± 95% confidence intervals) and period nest survival by year at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD). Nest survival for 2007 is from Blackwater NWR only.

	Year		
	2007	2008	2009
Nests	62	137	124
Daily Nest Survival	0.971	0.938	0.881
95% CI	0.956 - 0.981	0.923 - 0.950	0.854 - 0.903
Period Nest Survival	0.469	0.190	0.037

Table 13. Dominant vegetation cover (mean ± SE) for random points (n = 570) and Seaside Sparrow nests (n = 365) within each burn class at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009.

	Time Since Burn							
	0 years		1 - 2 years		3 - 4 years		5+ years	
Vegetation Covariate	Nest	Random	Nest	Random	Nest	Random	Nest	Random
Thatch depth (cm)	8.47 ± 0.86	8.01 ± 0.76	18.60 ± 1.22	16.53 ± 0.96	11.49 ± 1.11	10.59 ± 0.98	16.51 ± 1.25	16.93 ± 1.20
Visual obstruction reading	3.34 ± 0.10	3.14 ± 0.14	3.25 ± 0.10	3.34 ± 0.18	2.74 ± 0.11	3.18 ± 0.22	3.21 ± 0.12	2.81 ± 0.18
Percent cover of *Distichlis spicata*	1.57 ± 0.29_a	2.57 ± 0.43_b	0.25 ± 0.07	0.42 ± 0.09	0.22 ± 0.08	0.54 ± 0.14	0.44 ± 0.20_a	0.99 ± 0.17_b
Percent cover of *Schoenoplectus americanus*	1.50 ± 0.33_a	3.15 ± 0.38_b	1.35 ± 0.28_a	3.46 ± 0.37_b	1.35 ± 0.32_a	2.87 ± 0.43_b	1.16 ± 0.30	1.56 ± 0.24
Percent cover of *Spartina alterniflora*	8.25 ± 0.50_a	4.00 ± 0.41_b	6.48 ± 0.67_a	3.05 ± 0.36_b	8.57 ± 0.98_a	4.74 ± 0.54_b	8.33 ± 0.84_a	4.47 ± 0.42_b
Percent cover of *Spartina patens**	20.49 ± 1.34_a	13.18 ± 1.15_b	22.50 ± 4.06_a	11.56 ± 1.58_b	14.05 ± 1.92	11.55 ± 1.42	12.96 ± 1.76	13.94 ± 1.47
Other (dead vegetation, bare ground, standing water)*	67.71 ± 1.40_a	75.25 ± 1.25_b	69.13 ± 3.97_a	80.92 ± 1.45_b	75.33 ± 1.88	78.83 ± 1.37	76.83 ± 1.67	77.90 ± 1.39

* - indicates a significant interaction term, $P < 0.05$; subscripts within a burn class indicate that nest and random points differ, $P < 0.05$.

Chapter 2

EFFECT OF PRESCRIBED FIRE ON FOUR SECRETIVE MARSH BIRDS IN THE CHESAPEAKE BAY

INTRODUCTION

Tidal marshes are highly stressful and productive habitats with a global extent of about 45,000 km^2 (Mitsch and Gosselink 2000, Greenberg 2006). They support a small suite of highly specialized species adapted to extremes of tide, temperature and salinity (Greenberg et al. 2006). Over 50% of all coastal marshes in the continental United States were lost between the 1950’s and the 1970’s due to dredging/filling for agriculture, channelization and pollution (Tiner 1984, Dahl 1990). Despite conservation efforts, intertidal wetlands declined by 0.5% from 1998 – 2004 and they continue to be threatened by development, degradation and sea level rise (Dahl 2006). Not surprisingly, endemic marsh birds have declined and many are considered to be of conservation concern (Wilson et al. 2007).

Prescribed burning has been used to manage tidal marshes on the Gulf and Atlantic coasts of the United States since at least the 1930’s (Mitchell et al. 2006). Resource managers use burning to improve waterfowl and furbearer habitat, facilitate invasive species removal and reduce wildfire risk (Griffith 1940, Hoffpauir 1961, Givens 1962, Nyman and Chabreck 1995). However, the historic fire frequency of tidal marshes is not well-understood (Mitchell et al. 2006). Some research indicates that natural fire has always played an important role in tidal marsh ecology (e.g. (Lynch 1941, Givens 1962, Frost 1995, Nyman and Chabreck 1995)), but it is likely that fire frequency varied regionally. In marshes on the mid-Atlantic coast, fires are thought to have occurred every 4 – 6 years in the centuries prior to European colonization (Frost 1998, Baily et al. 2007). The Chesapeake Bay contains approximately 41% of all tidal marshes on the Atlantic coast (Wilson et al. 2007) and prescribed burning is used as a management tool on about 2,000 – 5,000 acres (809.4 – 2023.4 ha) annually (Mitchell et al. 2006, W. Giese, USFWS, personal communication). Within the Chesapeake Bay, breeding tidal marsh birds have declined, but little is known about specific population trends or the effects of prescribed burning on these species (Mitchell et al. 2006, Wilson et al. 2007).

To evaluate the effects of prescribed burning on breeding tidal marsh birds, I surveyed birds in the Chesapeake Bay on the eastern shore of Maryland. The objectives of this research were to evaluate single- and multi-season occupancy of Least Bittern (*Ixobrychus exilis*), Virginia Rail (*Rallus limicola*), Saltmarsh Sparrow (*Ammodramus caudacutus*) and Coastal Plain Swamp Sparrow (*Melospiza georgiana nigrescens*) in relation to short-term (2007 – 2009) and long-term (1986 – 2009) prescribed fire. I hypothesized that either fire management or landscape context of the study sites most-strongly influenced occupancy of the target species.

METHODS

Study Area

I studied breeding birds at Blackwater National Wildlife Refuge (NWR) (38° 24′ N, 76° 0′ W) and Fishing Bay Wildlife Management Area (WMA) (38° 23′ N, 76° 59′ W) in Dorchester County, Maryland (Figure 4). Fishing Bay WMA contained 25,000 acres (10,117 ha) of tidal marsh and abutted the eastern border of Blackwater NWR, which contained 9,700 acres (3926 ha) of tidal marsh (U.S. Fish and Wildlife Service 2006, G. Schenck, Maryland DNR, personal communication). The primary marsh type was brackish high marsh, which is characterized by intermediate salinity levels (0.5-30 ppt) and a relatively diverse vegetation community, including eastern baccharis (*Baccharis halimifolia*), spikegrass (*Distichlis spicata*), Jesuit's bark (*Iva frutescens*), chairmaker's bullrush (*Schoenoplectus americanus*), smooth cordgrass (*Spartina alterniflora*), big cordgrass (*Spartina cynosuroides*), and meadow cordgrass (*Spartina patens*) (Frost 1995, U.S. Fish and Wildlife Service 2006).

The study area included 5 fire management units (Table 14) established from 1998 – 2003 for prescribed burn research. These units contained replicate fire treatments, but differed in their landscape context (Table 14). Unit 2, which borders Blackwater Lake, had a very high proportion (93%) of its perimeter adjacent to channel (water). Units 4 and 7 were closest to the marsh edge and about one-third of their perimeter bordered upland (forest) or road.

I established one study plot within each of the fire treatments within each unit, for a total of 20 plots (Figures 5 and 6). Plots ranged in size from 3 – 4 ha and were delineated in a 25 m^2 grid pattern with red wire stake flags. I was interested in comparing the effects of short-term history (2007 – 2009) and long-term history (1986

– 2009) on marsh bird occupancy, so I placed each plot in a short-term and a long-term burn class (Table 14). Total area sampled for each short-term burn class ranged from 10 – 42 ha while the total area sampled for each long-term burn class ranged from 24 – 45 ha (Table 15).

Prescribed burns were conducted on a predetermined schedule, conditions permitting, between January and March by the Blackwater NWR Fire Program. Fire was applied when several centimeters of water were present over the marsh surface, creating a cover burn. Cover burns remove dead standing vegetation, but do not damage roots or peat, allowing the vegetation to rapidly re-grow in the subsequent growing season (Lynch 1941, Nyman and Chabreck 1995). Specifically, prescribed burns on Blackwater NWR and Fishing Bay WMA were intended to remove 70% of the above-ground biomass and leave 5 – 10 cm of stubble (U.S. Fish and Wildlife Service 2010).

Occupancy

The goal of occupancy modeling is to determine the proportion of sites occupied (or the probability that a site is occupied, ψ) given imperfect detection of the target species (MacKenzie et al. 2002, Donovan and Hines 2007). Estimating the proportion of sites (or more broadly, the proportion of sampled area) occupied by a species is useful for large-scale monitoring and can inform our understanding of metapopulation dynamics (MacKenzie et al. 2002). A naïve occupancy estimate, which fails to account for imperfect detection, often underestimates true occupancy because species present may go undetected during some surveys (MacKenzie et al.

2006). Detection probability (p) can be influenced by many factors, including observer, weather and time of survey.

Single-season occupancy modeling is a combination of two probabilities: 1) the probability that a target species occupies the sampling site (ψ) and 2) the conditional probability, given an occupied site, that the observer will detect the target species (p). It is based on repeated visits to a number of sites within a single survey season. Multi-season occupancy is based on repeated visits to a number of sites over $\geq$ 2 survey seasons. Multi-season occupancy, therefore, is able to estimate 2 additional probabilities: 1) the probability that a previously-unoccupied site becomes occupied between survey seasons (local colonization, γ) and 2) the probability that a previously occupied site becomes unoccupied between survey seasons (local extinction, ε) (MacKenzie et al. 2002).

Single-season Occupancy

I conducted callback surveys in June 2007 and from May to July in 2009 to detect secretive birds by eliciting vocalizations in response to recordings (Conway 2008). In 2007, I had one visit to 12 plots in Units 2, 3 and 7. In 2009, I had 3 visits to 20 plots in Units 2, 3, 4, 5, and 7. Visits occurred between 0545 and 1045 and replicate surveys were separated by at least 2 weeks. Each survey began with a 5 minute passive listening period to focus on detection of tidal marsh sparrows (Saltmarsh Sparrow; Seaside Sparrow, *Ammodramus maritimus*; and Coastal Plain Swamp Sparrow), followed by recordings of 8 other species (Black Rail, *Laterallus jamaicensis*; Least Bittern; Virginia Rail; King Rail, *Rallus elegans*; Clapper Rail, *Rallus longirostris*; American Bittern, *Botaurus lentiginosus*; Common Moorhen, *Gallinula chloropus*; Pied-billed Grebe, *Podilymbus podiceps*). Each recording was 30 seconds in length, separated by 30 seconds of silence (Conway 2008).

Multi-season Occupancy

I conducted spot-map surveying in 2007 – 2009. I visited each study plot between 10 – 15 times per year, from mid-May to mid-August. During each survey, I walked through the plot and recorded the location and activity (i.e. flying, calling) of all secretive marsh bird species (sparrows, rails, bitterns and moorhen). Visits occurred between 0545 and 1230 and were completed in one hour or less (International Bird Census Committee 1969, Verner and Milne 1990).

Data Analyses

Occupancy estimates from callback and spot-map surveys were analyzed independently, due to differences in number of sampling occasions and methodology. I used single-season occupancy models to analyze callback data, treating each plot in each year as a unique sampling site with either one (2007) or three (2009) visits. I used multi-season models to estimate occupancy and local extinction probability on the spot-mapping data (2007 – 2009).

Many of my target species were detected infrequently ($\leq$ 5 detections/season), so I focused my analysis on 4 species (Least Bittern, Saltmarsh Sparrow, Coastal Plain Swamp Sparrow and Virginia Rail) detected in sufficient numbers to provide meaningful estimates of occupancy rates and patterns (MacKenzie et al. 2002). I modeled occupancy of my target species using Program PRESENCE

(Hines 2006). Program PRESENCE can estimate occupancy (ψ), detection (p), local colonization (γ) and local extinction (ε) as a function of site and/or survey covariates, and does not discriminate against missing observations (MacKenzie et al. 2006). I began by determining which survey covariate(s) had the greatest influence on detection probability for each species (Rush et al. 2009). Survey covariates included: date (coded as days since first survey of the year), start time, temperature, wind speed, cloud cover, and precipitation. I then developed occupancy models for each species based on a priori hypotheses, incorporating the most important detection covariate(s) (Rush et al. 2009).

For each species, I evaluated 2 hypotheses related to occupancy (and local extinction, for multi-season models). The fire management hypothesis predicted that occupancy (and local extinction) was most influenced by conditions resulting from various times since fire. The unit hypothesis predicted that occupancy (and local extinction) was most influenced by landscape context, such as proximity to upland or open water.

For the single-season models, I modeled occupancy as a function of the site covariates Short-term Burn, Long-term Burn, and Unit. For the multi-season models, occupancy and local extinction were modeled as functions of Short-term Burn, Long-term Burn, and Unit. Local colonization was held constant. Short-term burn was coded with 3 categories based on the number of times the plot was burned from 2007 – 2009 (0 = not burned, 1 = burned once, 2 = burned two or three times). Long-term burn was coded with 2 categories to reflect the number of times the plot was burned from 1986 – 2009 (0 = burned 6 – 15 times, 1 = burned 16 – 24 times).

Unit was coded as a categorical covariate. For both single- and multi-season occupancy, I also evaluated constant occupancy and detection models, and global models, which incorporated all site covariates (Short-term Burn, Long-term Burn, and Unit) and all survey covariates (date, time, temperature, wind speed, cloud cover, and precipitation). I evaluated model fit using Akaike's Information Criterion (AIC), the number of parameters (K) and the deviance (Dev). I ranked candidate models using ΔAIC and AIC weights (w_i), and considered models that had ΔAIC $\leq$ 2 to be well-supported (Burnham and Anderson 2002).

RESULTS

Single-season Occupancy

The fire management hypothesis was supported only for Least Bittern (Table 16). Naive Least Bittern occupancy was 0.19, but occupancy calculated from the best model ranged from 0.15 – 0.96 and increased with short-term burn frequency (Table 17). Detection probability for Least Bittern was negatively related to survey time (Table 16). The unit hypothesis was supported for Saltmarsh Sparrow and Swamp Sparrow (Table 16). Saltmarsh Sparrow naive occupancy was 0.53 and modeled occupancy ranged from 0.31 – 1.00 (Table 17). Detection was negatively related to date and positively related to cloud cover (Table 16). Swamp Sparrows were only detected on Units 4 and 5, and detection decreased with date and increased with time of day (Tables 3 and 4). The constant occupancy model was the best-supported for Virginia Rail (Table 16). Naïve Virginia Rail occupancy (0.89) was high compared to the other species and occupancy estimated from the constant model was 0.96 (Table 17). Detection of Virginia Rails was most influenced by survey temperature, cloud cover, survey time, wind, and precipitation (Table 16).

Multi-season Occupancy and Local Extinction

The fire management hypothesis was again supported for Least Bittern (Table 16). Occupancy estimates were 1.0 for all burn types (Table 18), while naive occupancy was 0.45. Local extinction probabilities were also great (1.0) and were positively related to burning (Table 19). Least Bittern detection probability was negatively related to cloud cover, while precipitation negatively impacted detection of Saltmarsh Sparrow, Swamp Sparrow and Virginia Rail (Table 16). Saltmarsh Sparrow occupancy and local extinction had 3 best models: Short-term Burn, Long-term Burn, and Global (Table 16). Occupancy was estimated to be 1.0 from both the Short-term Burn and the Long-term Burn models (Table 18). However, more frequent Short-term burning negatively influenced occupancy, while more frequent Long-term burning positively influenced occupancy (Table 18). Local extinction probabilities were low (0.0 – 0.04) and were also negatively influenced by Short- and Long-term burning (Table 19). These results indicate that there may be a lag-time in the Saltmarsh Sparrow response to fire.

The unit hypothesis was again supported for Swamp Sparrow, and only Units 4 and 5 were occupied (Tables 16 and 18). Local extinction probability was low in Units 4 and 5 (0.1) and high in Units 2, 3 and 7 (0.8 – 1.0, Table 19). Virginia Rail occupancy and local extinction had 3 best models: Global, Short-term Burn and Long-term Burn (Table 16). Occupancy estimates from the best models were high (0.7 – 1.0) (Table 18). Local extinction probabilities were negatively influenced by Short- and Long-term burning, indicating that Virginia Rails are more likely to persist from year to year on more-frequently burned areas (Table 19).

DISCUSSION

Prescribed burning had a positive effect on Least Bittern occupancy and local extinction. The impact of fire on Least Bitterns is not well-understood, but 2 studies in Florida did not find a dramatic response to fires (Kushlan 1973, Frederick 1990). Kushlan (1973) observed high densities of Least Bitterns adjacent to the burned areas and speculated that they may provide foraging sites. Frederick (1990) found that burning did not greatly affect Least Bittern abundance. In my study area, more frequently burned sites were more likely to be occupied, but were also more likely to go extinct from year to year. This turnover may indicate that Least Bitterns are not strongly-dependent on fire or it may be a result of insufficient detections.

Multi-season models estimated greater occupancy for Least Bitterns than single-season models, probably due to differences in model input. Visual surveys are thought to be more effective for detecting Least Bitterns than call-back surveys because Least Bitterns do not always respond to conspecific vocalizations (Manci and Rusch 1988, Tozer et al. 2007). My results support this conclusion and show that using only call-back surveys may result in underestimation of Least Bittern occupancy.

Saltmarsh Sparrows are entirely restricted to the Atlantic coast of the United States and are listed as “Vulnerable” on the International Union of Conservation of Nature (IUCN) Red List (Greenlaw and Woolfenden 2007, IUCN 2008). No previous studies have investigated the effect of fire on breeding Saltmarsh Sparrows. I found that burning provided the best explanation of occupancy and local extinction in multi-season models, but that landscape context was most important in single-season models. Occupancy was negatively impacted by more frequent short-term burning, but positively impacted by more frequent long-term burning. Saltmarsh Sparrows appear to have a delayed response to prescribed burning. Immediately following a fire, burned areas were less suitable, but conditions improved over time so that the overall impact of fire was positive. This finding illustrates the importance of long-term monitoring of management actions.

Spot-map surveys estimated higher occupancy than callback surveys for Saltmarsh Sparrows. These birds are known for their soft vocalizations and secretive habits, such as walking or hopping through vegetation, and flying short distances (Greenlaw and Rising 1994). Given these behavioral characteristics, it is not surprising that spot-map surveys, which allow the moving observer to record birds flushed from the vegetation, estimated higher occupancy than callback surveys.

Swamp Sparrows were strongly associated with Units 4 and 5 on Fishing Bay. The majority of the population of the Coastal Plain subspecies of Swamp Sparrow (*A. g. nigrescens*) is restricted to areas of shrubs adjacent to high marsh within the Chesapeake and Delaware Bays (Beadell et al. 2003). Units 4 and 5 were the only areas that contained this specific habitat. Prescribed burning may decrease habitat suitability for this species, given that one of its objectives is to reduce woody shrub cover (Givens 1962). Coastal Plain Swamp Sparrows in the Chesapeake Bay have suffered large declines and additional research to inform conservation is needed (Beadell et al. 2003, Wilson et al. 2007).

Virginia Rails were distributed almost uniformly across the study sites. Both single-season and multi-season models estimated high occupancy probability. Callback surveys are widely used to detect Virginia Rails, but my results indicate that spot-map surveys provide comparable occupancy estimates, at least in areas where the birds are relatively abundant. Prescribed burning has been recommended as a management tool for improving Virginia Rail habitat by reducing dead vegetation and high stem densities, which impede rail movement (Conway and Eddleman 1994). My results indicate that burning promotes Virginia Rail occupancy and reduces the likelihood that Virginia Rails will leave occupied sites.

Management Implications

In mid-Atlantic tidal marshes, prescribed marsh burning promotes occupancy of Least Bitterns, Saltmarsh Sparrows and Virginia Rails, but has little impact on Coastal Plain Swamp Sparrow occupancy. Land managers employing prescribed burning should monitor bird populations pre- and post-treatment to ensure that the desired management goals are being accomplished. Least Bitterns and Saltmarsh Sparrows can be most effectively monitored through spot-map surveys (or a similar type of transect survey), while Swamp Sparrows and Virginia Rails can be monitored by either spot-map or callback surveys. Additional research is needed to determine the effect of burning on reproductive success of these species. For nests detected during the course of this study, see Appendix A.

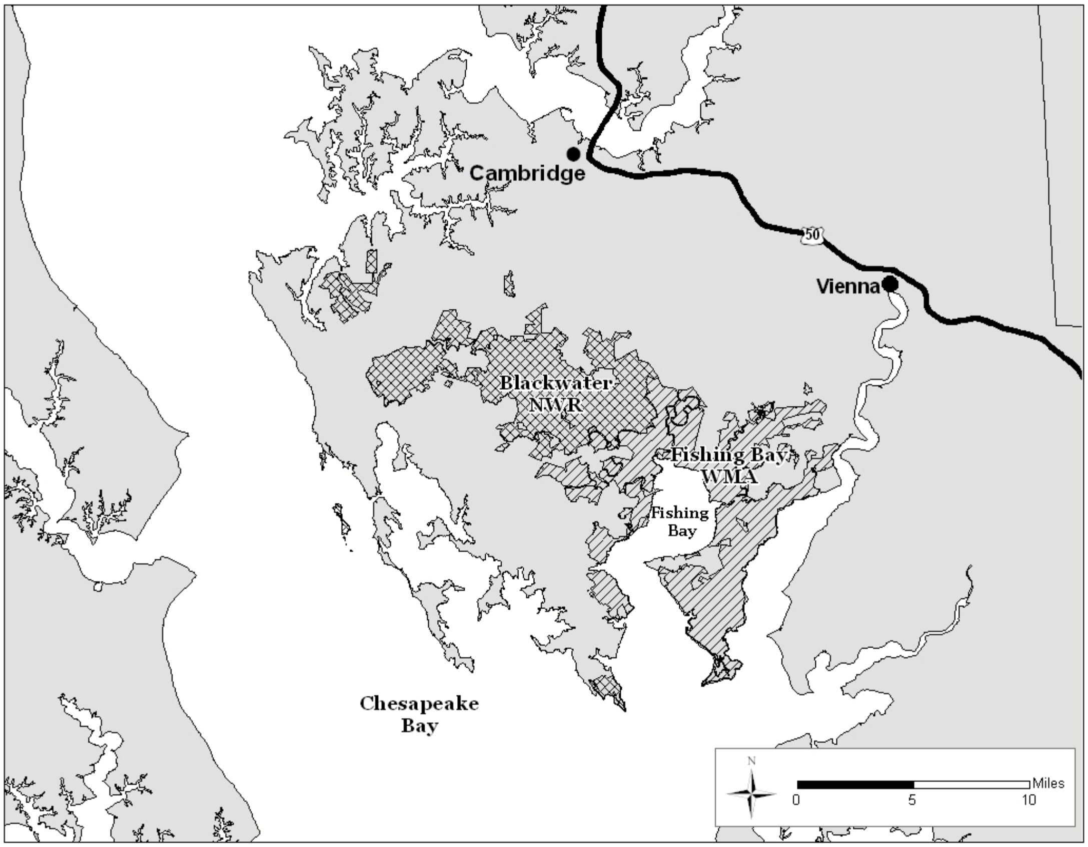

Figure 4. **Map of Blackwater National Wildlife Refuge (NWR) and Fishing Bay Wildlife Management Area (WMA), Dorchester County, MD.**

Table 14. Fire management units at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD) from 2007 - 2009.

Plot Location	Unit	% Perimeter Adjacent to: Marsh	Upland/Road	Channel	Plot ID	Plot Area (ha)	Lat.	Long.	# Burns 2007 - 2009[a]	# Burns 1986 - 2009[b]
Blackwater NWR	2	7.4	0.0	92.6	2A	2.88	38.4130	76.0803	3	24
					2B	2.94	38.4080	76.0685	1	15
					2C	3.13	38.4139	76.0697	0	9 - 10
					2D	3.66	38.4062	76.0821	0	6 - 13
	3	37.0	0.0	63.0	3A	2.99	38.3860	76.0779	3	19 - 23
					3B	2.98	38.3908	76.0744	1	7 - 10
					3C	3.14	38.3945	76.0731	0	6 - 10
					3D	4.33	38.3909	76.0813	0	4 - 11
	7	27.2	29.4	43.4	7A	3.26	38.3898	76.0719	2	20 - 21
					7B	4.23	38.3958	76.0723	0	16 - 19
					7C	3.14	38.3983	76.0814	0	13 - 16*
					7D	4.27	38.4008	76.0676	0	6 - 16*
Fishing Bay WMA	4	41.7	33.8	24.5	4A	3.74	38.4112	75.9931	2	18
					4B	3.11	38.4078	76.0028	0	12
					4C	3.27	38.4114	76.0096	0	8 - 10
					4D	3.28	38.4121	76.0116	0	8 - 10
	5	58.0	0.0	42.0	5A	3.27	38.3781	76.0111	2	20
					5B	3.33	38.3813	76.0109	1	13
					5C	3.33	38.3802	76.0016	0	8 - 10
					5D	4.27	38.3896	75.9978	0	6 - 9

[a] – Coded as Short-term Burn Class for occupancy models (0 = no burns, 1 = 1 burn, 2 = 2 to 3 burns)

Table 14. Continued.

[b] – Coded as Long-term Burn Class for occupancy models (0 = 6 – 15 burns, 1 = 16 – 24 burns)

* – 7C more than half of the plot had been burned 16 times, so it was placed in class 1. 7D more than three-quarters of the plot had been burned 12 times, so it was placed in class 0.

Figure 5. Study plots (in yellow) within Units 2, 3 and 7 at Blackwater NWR (Dorchester County, MD), 2007 - 2009.

Figure 6. **Study plots (in yellow) in Units 4 and 5 at Fishing Bay WMA (Dorchester County, MD), 2008 - 2009.**

Table 15. Area of each burn class sampled at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009.

Short-term Burn Class	Area (ha)
No burn	42.26
1 burn	10.15
2 - 3 burns	16.14
Long-term Burn Class	Area (ha)
6 - 15 burns	45.40
16 - 24 burns	23.51

Table 16. Model selection results for occupancy (Ψ), local extinction (ε) and detection probability (p) from single-season (A) and multi-season (B) analyses at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. In multi-season models, local colonization (γ) was held constant.

	Species	Ψ (ε)	p	AIC	ΔAIC	w_i[3]	K[4]	Dev[5]
	Least Bittern	Short-term burn	Time	38.98	0.00	0.72	4	30.98
		Long-term burn	Time	41.87	2.89	0.17	4	33.87
		Unit	Time	43.54	4.56	0.07	7	29.54
		Constant	Time	45.30	6.32	0.03	2	41.30
		Global	Time	47.86	8.88	0.01	14	19.86
	Saltmarsh	Unit	Date + Cloud	84.27	0.00	0.88	8	68.27
	Sparrow	Short-term burn	Date + Cloud	90.09	5.82	0.05	5	80.09
		Long-term burn	Date + Cloud	90.43	6.16	0.04	5	80.43
A[1]		Global	Date + Cloud	91.10	6.83	0.03	14	63.10
		Constant	Date + Cloud	98.47	14.20	0.00	2	94.47
	Swamp	Unit	Date + Time	37.66	0.00	0.65	8	21.66
	Sparrow	Global	Date + Time	38.91	1.25	0.35	14	10.91
		Long-term burn	Date + Time	63.02	25.36	0.00	5	53.02
		Short-term burn	Date + Time	63.19	25.53	0.00	5	53.19
		Constant	Date + Time	64.49	26.83	0.00	2	60.49
	Virginia Rail	Constant	Temp + Cloud + Time + Wind + Precip	78.22	0.00	0.89	2	74.22

Table 16. Continued.

	Species	Ψ (ε)	p	AIC	ΔAIC	w_i[3]	K[4]	Dev[5]
A[1]	Virginia Rail (cont'd)	Short-term burn	Temp + Cloud + Time + Wind + Precip	83.85	5.63	0.05	8	67.85
		Long-term burn	Temp + Cloud + Time + Wind + Precip	83.89	5.67	0.05	8	67.89
		Unit	Temp + Cloud + Time + Wind + Precip	87.58	9.36	0.01	11	65.58
		Global	Temp + Cloud + Time + Wind + Precip	92.47	14.25	0.00	14	64.47
B[2]	Least Bittern	Short-term burn	Cloud	113.34	0.00	0.50	7	99.34
		Long-term burn	Cloud	113.34	0.00	0.50	7	99.34
		Unit	Cloud	126.91	13.57	0.00	13	100.91
		Global	Cloud	135.34	22.00	0.00	22	91.34
		Constant	Cloud	153.69	40.35	0.00	4	145.69
	Saltmarsh Sparrow	Short-term burn	Precip	792.23	0.00	0.43	7	778.23
		Long-term burn	Precip	792.39	0.16	0.40	7	778.39
		Global	Precip	794.13	1.90	0.17	22	750.13
		Unit	Precip	801.84	9.61	0.00	13	775.84
		Constant	Precip	866.94	74.71	0.00	4	858.94
	Swamp Sparrow	Unit	Temp + Precip	190.29	0.00	0.96	14	162.29
		Long-term burn	Temp + Precip	197.87	7.58	0.02	8	181.87

Table 16. Continued.

	Species	Ψ (ε)	p	AIC	ΔAIC	w_i[3]	K[4]	Dev[5]
	Swamp	Short-term burn	Temp + Precip	198.51	8.22	0.02	8	182.51
	Sparrow	Global	Temp + Precip	201.54	11.25	0.00	22	157.54
	(cont'd)	Constant	Temp + Precip	216.13	25.84	0.00	4	208.13
B[2]	Virginia Rail	Global	Precip	683.47	0.00	0.41	22	639.47
		Short-term burn	Precip	683.95	0.48	0.32	7	669.95
		Long-term burn	Precip	684.26	0.79	0.27	7	670.26
		Unit	Precip	693.03	9.56	0.00	13	667.03
		Constant	Precip	764.94	81.47	0.00	4	756.94

[1] - Only Ψ was estimated for these models.
[2] - Ψ and ε were estimated for these models.
[3] - AIC weight or relative support of evidence for the model.
[4] - Number of parameters.
[5] - Log likelihood times - 2.

Table 17. Untransformed parameter estimates and occupancy probability estimates from top single-season models for Least Bittern, Saltmarsh Sparrow, Swamp Sparrow and Virginia Rail at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009.

Species	Model	Parameter	Parameter Estimate	SE[1]	Occupancy Probability (95% CI)
Least Bittern	Short-term burn	Intercept	-1.72	1.31	
		No burn	2.51	1.97	0.15 (0.01 - 0.70)
		One burn			0.69 (0.03 - 0.99)
		Two - three burns			0.96 (0.01 - 1.00)
Saltmarsh Sparrow	Unit	Intercept	-	-	
		Unit 2	-0.22	1.04	0.45 (0.10 - 0.86)
		Unit 3	-0.82	0.88	0.31 (0.07 - 0.71)
		Unit 4	28.78	9.25×10^5	1.00 (0.00 - 1.00)
		Unit 5	28.78	8.86×10^5	1.00 (0.00 - 1.00)
		Unit 7	25.90	2.13×10^5	1.00 (0.00 - 1.00)
Swamp Sparrow	Unit	Intercept	-	-	
		Unit 2	-29.62	1.07×10^6	0.00 (0.00 - 0.00)
		Unit 3	-28.52	6.09×10^5	0.00 (0.00 - 0.00)
		Unit 4	29.56	1.28×10^6	1.00 (0.00 - 1.00)
		Unit 5	29.56	1.26×10^6	1.00 (0.00 - 1.00)
		Unit 7	-28.19	5.10×10^5	0.00 (0.00 - 0.00)
Virginia Rail	Constant	Intercept	2.99	1.11	
		Constant	1.48	0.33	0.96 (0.69 - 0.99)

[1] - Standard error of 0 can occur when occupancy approaches 0 or 1.

Table 18. Untransformed parameter estimates and occupancy probability estimates from top multi-season models for Least Bittern, Saltmarsh Sparrow, Swamp Sparrow and Virginia Rail at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD).

Species	Model	Parameter	Parameter Estimate	SE[1]	Occupancy Probability (95% CI)
Least Bittern	Short-term burn	Intercept	35.73	3.16×10^{10}	
		No burn	10.65	3.16×10^{10}	1.00 (0.00 - 1.00)
		One burn			1.00 (0.00 - 1.00)
		Two - three burns			1.00 (0.00 - 1.00)
	Long-term burn	Intercept	42.96	3.16×10^{10}	
		6 - 15 burns	8.75	3.16×10^{10}	1.00 (0.00 - 1.00)
		16 - 24 burns			1.00 (0.00 - 1.00)
Saltmarsh Sparrow	Short-term burn	Intercept	44.15	6.59×10^{10}	
		No burn	-10.03	3.18×10^{10}	1.00 (0.00 - 1.00)
		One burn			1.00 (0.00 - 1.00)
		Two - three burns			1.00 (0.00 - 1.00)
	Long-term burn	Intercept	25.57	1.34×10^{5}	
		6 - 15 burns	4.02	3.60×10^{10}	1.00 (0.00 - 1.00)
		16 - 24 burns			1.00 (0.00 - 1.00)
	Global	Intercept	-	-	
		Unit 2	56.18	0	1.00 (1.00 - 1.00)
		Unit 3	50.94	1.00×10^{-6}	1.00 (1.00 - 1.00)
		Unit 4	7.95	0	1.00 (1.00 - 1.00)
		Unit 5	7.95	0	1.00 (1.00 - 1.00)
		Unit 7	44.12	1.20×10^{-5}	1.00 (1.00 - 1.00)

Table 18. Continued.

Species	Model	Parameter	Parameter Estimate	SE[1]	Occupancy Probability (95% CI)
Saltmarsh Sparrow (cont'd)	Global (cont'd)	Recent burn	-11.46	2.40×10^{-6}	0.00 (0.00 - 0.00)
		24-year burn	1.48	1.30×10^{-6}	0.81 (0.00 - 1.00)
Swamp Sparrow	Unit	Intercept	-	-	
		Unit 2	-35.35	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 3	-36.02	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 4	45.56	3.16×10^{10}	1.00 (0.00 - 1.00)
		Unit 5	1.10	1.16	0.75 (0.24 - 0.97)
		Unit 7	-36.10	3.16×10^{10}	0.00 (0.00 - 0.00)
Virginia Rail	Global	Intercept	-	-	
		Unit 2	78.61	3.16×10^{10}	1.00 (0.00 - 1.00)
		Unit 3	78.61	3.16×10^{10}	1.00 (0.00 - 1.00)
		Unit 4	116.58	3.16×10^{10}	1.00 (0.00 - 1.00)
		Unit 5	0.69	1.23	0.67 (0.15 - 0.96)
		Unit 7	67.96	3.16×10^{10}	1.00 (0.00 - 1.00)
		Recent burn	4.86	1.97×10^{5}	0.99 (0.00 - 1.00)
		24-year burn	13.60	4.21×10^{5}	1.00 (0.00 - 1.00)
	Short-term burn	Intercept	35.90	3.16×10^{10}	
		No burn	12.81	3.16×10^{10}	1.00 (0.00 - 1.00)
		One burn			1.00 (0.00 - 1.00)
		Two - three burns			1.00 (0.00 - 1.00)
	Long-term burn	Intercept	20.93	0.00	
		6 - 15 burns	15.93	0.00	1.00 (0.00 - 1.00)
		16 - 24 burns			1.00 (0.00 - 1.00)

[1] - Standard error of 0 can occur when occupancy approaches 0 or 1.

Table 19. Untransformed parameter estimates and local extinction probability estimates from top multi-season models for Least Bittern, Saltmarsh Sparrow, Swamp Sparrow and Virginia Rail at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD).

Species	Model	Parameter	Parameter Estimate	SE[1]	Local Extinction Probability (95% CI)
Least Bittern	Short-term burn	Intercept	29.22	8.45×10^{5}	
		No burn	10.83	3.16×10^{10}	1.00 (0.00 - 1.00)
		One burn			1.00 (0.00 - 1.00)
		Two - three burns			1.00 (0.00 - 1.00)
	Long-term burn	Intercept	37.75	3.16×10^{10}	
		6 - 15 burns	9.25	3.16×10^{10}	1.00 (0.00 - 1.00)
		16 - 24 burns			1.00 (0.00 - 1.00)
Saltmarsh Sparrow	Short-term burn	Intercept	-3.17	1.12	
		No burn	-56.46	3.16×10^{10}	0.04 (0.00 - 0.27)
		One burn			0.00 (0.00 - 1.00)
		Two - three burns			0.00 (0.00 - 1.00)
	Long-term burn	Intercept	-3.27	1.28	
		6 - 15 burns	-39.78	3.16×10^{10}	0.04 (0.00 - 0.32)
		16 - 24 burns			0.00 (0.00 - 1.00)
	Global	Intercept	-	-	
		Unit 2	-0.70	0.82	0.33 (0.09 - 0.71)
		Unit 3	-48.47	0.00	0.00 (0.00 - 0.00)
		Unit 4	-55.38	0.00	0.00 (0.00 - 0.00)
		Unit 5	-55.38	0.00	0.00 (0.00 - 0.00)
		Unit 7	-46.42	0.00	0.00 (0.00 - 0.00)

Table 19. Continued.

Species	Model	Parameter	Parameter Estimate	SE[1]	Local Extinction Probability (95% CI)
Saltmarsh Sparrow (cont'd)	Global (cont'd)	Short-term burn	-31.12	1.00×10^{-5}	0.00 (0.00 - 0.00)
		Long-term burn	12.69	0.00	1.00 (0.00 - 1.00)
Swamp Sparrow	Unit	Intercept	-	-	
		Unit 2	13.44	3.16×10^{10}	1.00 (0.00 - 1.00)
		Unit 3	4.18	3.16×10^{10}	0.98 (0.00 - 1.00)
		Unit 4	-2.23	1.39	0.10 (0.01 - 0.62)
		Unit 5	-2.21	1.89	0.10 (0.00 - 0.82)
		Unit 7	1.49	3.16×10^{10}	0.82 (0.00 - 1.00)
Virginia Rail	Global	Intercept	-	-	
		Unit 2	-79.46	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 3	-79.46	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 4	-88.17	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 5	-80.42	3.16×10^{10}	0.00 (0.00 - 0.00)
		Unit 7	-0.08	1.49	0.48 (0.05 - 0.94)
		Recent burn	19.31	3.16×10^{10}	1.00 (0.00 - 1.00)
		24-year burn	-77.06	3.16×10^{10}	0.00 (0.00 - 0.00)
	Short-term burn	Intercept	-2.48	0.82	
		No burn	-21.48	6.47×10^{4}	0.08 (0.02 - 0.30)
		One burn			0.00 (0.00 - 0.00)
		Two - three burns			0.00 (0.00 - 0.00)
	Long-term burn	Intercept	-2.58	1.21	
		6 - 15 burns	-20.82	3.10×10^{-5}	0.07 (0.01 - 0.45)
		16 - 24 burns			0.00 (0.00 - 0.00)

[1] - Standard error of 0 can occur when occupancy approaches 0 or 1

Appendix A. Nests detected at Blackwater NWR and Fishing Bay WMA (Dorchester County, MD), 2007 - 2009. Seaside Sparrow nests are excluded

		Nests by Unit					Nests by Years Since Burn							
Species	# Nests	Unit 2	Unit 3	Unit 4	Unit 5	Unit 7	0 YSB	1-2 YSB	3-4 YSB	5+ YSB	S[1]	F[2]	U[3]	Apparent Survival
Virginia Rail	40	10	10	8	2	10	9	11	7	13	16	3	21	0.84
Saltmarsh Sparrow	30	5	4	1	16	4	15	7	5	3	9	15	6	0.38
Eastern Meadowlark	8	0	0	5	3	0	3	1	0	4	3	4	1	0.43
Swamp Sparrow	4	0	0	1	3	0	0	0	2	2	2	2	0	0.50
American Black Duck	4	1	0	0	3	0	1	1	0	2	0	1	3	0.00
Willet	3	0	0	2	1	0	3	0	0	0	0	0	3	n/a[4]
Least Bittern	2	1	1	0	0	0	2	0	0	0	2	0	0	1.00
Common Moorhen	1	0	0	0	0	1	1	0	0	0	1	0	0	1.00
Common Yellowthroat	1	0	0	1	0	0	0	1	0	0	0	1	0	0.00

[1] – Successful nests
[2] – Failed nests
[3] – Nests with uncertain fate
[4] – Unable to determine

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